BEFORE THE NATIONAL GREEN TRIBUNAL
PRINCIPAL BENCH, NEW DELHI
I.A. NO. OF 2025
IN
ORIGINAL APPLICATION No.1004/2024

IN THE MATTER OF:

PRAHLAD ROY GOENKA & ORS …APPLICANTS

VERSUS

UNION OF INDIA & ORS …RESPONDENTS

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REPLY BY THE WAY OF AFFIDAVIT ON BEHALF OF

RESPONDENT NO. 6

I LAXMI PRASAD JOSHI, S/o Lt. Sh. VIDHYA DUTT JOSHI aged about 58 years, presently posted as EXECUTIVE DIRECTOR presently at TEHRI do hereby solemnly affirm and state on oath as under:

1. That I have gone through the contents of this Affidavit and have properly understood the same. The Deponent is in its capacity as aforesaid is well conversant with the facts and circumstances of the instant case which is derived from official records and the deponent is duly Authorized officer and as such competent to swear this Affidavit on behalf of the Respondent herein.

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2. I have gone through the contents of the Petition under reply and list of dates, I have understood the same.

3. That at the outset it is humbly submitted that the petitioner has disclosed true and correct facts pertaining to the subject matter at hand. Therefore, the answering respondent craves the leave of this Hon'ble Court to supplement the same by way of the foregoing preliminary submissions.

4. This Hon'ble Tribunal *vide* order dated 19.11.2024, issued notice to the respondents granting liberty to the Ld. Counsels for submitting their replies by way of affidavit.

5. It is submitted that the present Original Application (OA) pertains to the alleged decline in the population of the Golden/Himalayan Mahseer fish within India's aquatic ecosystem, particularly in the Central and Western Himalayan regions. The Applicants have relied upon various publications, annexed with the OA, to substantiate their claim regarding the rapid decline in the number, scale, and quality of the Golden Mahseer, and have accordingly sought urgent intervention from this Hon'ble Tribunal.

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A. PRELIMINARY SUBMISSIONS

6. That Respondent No. 6, THDC India Limited, is a leading power sector and profit-making Public Sector Undertaking and was registered as a Public Limited Company in July 1988

under the Companies Act 1956.That Respondent No. 6 was conferred Mini Ratna Category-I status by the Government of India in October, 2009 and was upgraded to Schedule 'A' PSU in July, 2010.

7. That the case of the Applicants is that the Golden Mahseer is on the verge of extinction, *inter alia,* owing to following factors:

7.1. Urbanization, deforestation, and widespread dam/barrage construction have led to the degradation andfragmentation of Golden Mahseer's natural habitats/ecosystem, impacting their ability to migrate and reproduce;

7.2. Industrial and human pollution. Water pollution from agricultural runoff, industrial discharges, and other sources have negatively impacted Golden Mahseer populations, affecting their health and reproductive success;

7.3. Unsustainable fishing practices, both legal and illegal, have exerted excessive pressure on Mahseer populations, leading to a decline in their numbers;

7.4. Changes in water temperature and flow patterns due to climate change can disrupt Golden Mahseer's breeding and migration patterns, further impacting their survival.

THDCIL is associated with the Tehri Hydro Power Complex (HPC), a multipurpose scheme situated on the River Bhagirathi, a tributary of the River Ganges. The Tehri HPC comprises three distinct projects, namely the Tehri Hydro Power Plant (Tehri HPP), the Koteshwar Hydro Electric Project (Koteshwar HEP), and the Tehri Pumped Storage Plant (Tehri PSP). These projects serve multiple purposes, including electricity generation, irrigation, drinking water supply, and flood mitigation, thereby contributing significantly to the nation's development.

10. That the aforementioned projects are engineered and constructed to impound excess river flow of River Bhagirathi during monsoon season and subsequently releasing the said stored water to meet irrigation and potable water requirements of the populace residing in the Gangetic plains of the States of Uttarakhand and Uttar Pradesh during non-monsoon periods, while concurrently generating 2400MW of peak electrical power.

11. The Tehri reservoir fulfils manifold functions beyond hydroelectric generation, specifically providing irrigation facilities to an additional agricultural area measuring 270,000 hectares and sustaining the existing irrigated area of 604,000 hectares. Furthermore, the said reservoir ensures potable

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water supply to approximately 4 million residents of Delhi and 3 million inhabitants of Uttar Pradesh and Uttarakhand.

12. It is submitted that the Tehri Hydroelectric Power Project constitutes a significant national infrastructure asset and a source of national prestige. After its commissioning, the said project has demonstrably achieved excellence in multiple operational aspects, inter alia: supply of essential drinking and irrigation water to the designated area, meeting critical peak power requirements for the Northern Grid, and achieving significant flood control during heavy rainfall events in the years 2010, 2011, and 2013.

13. It is further submitted that reservoirs created by impoundments provide significant aquatic habitats with stable water sources and consistent temperatures, creating protected environments suitable for fish reproduction, juvenile development, and growth, free from ecological stress caused by overcrowding. These reservoirs enable regulated water level management, reducing the adverse effects of water flow variations that could otherwise disrupt fish breeding cycles.

14. Furthermore, the creation of reservoir ecosystems increases nutritional resources for fish populations through the growth of aquatic plants and invertebrate species. As evidenced by correspondence dated 04.02.2025 from the Department of

Fisheries, Government of Uttarakhand, both the Tehri and Koteshwar reservoirs serve as key conservation habitats for Mahseer species, where these species show a notably high population density. The aforementioned correspondence is annexed herewith and marked as **[Annexure- R1]** for the kind perusal of this Hon'ble Tribunal.

15. The answering respondent, being a responsible corporate entity, hereby affirms its unwavering commitment to the protection and preservation of the environment and ecological systems. It is respectfully submitted that the hydroelectric power project in question does not generate any polluting emissions or discharges during its operational phase, while the associated reservoir functions solely to accumulate water from its designated catchment area. In furtherance of its environmental obligations, the answering respondent conducts regular and systematic monitoring of various environmental parameters pertaining to water quality in both the upstream and downstream regions of the Tehri reservoir. Upon analysis, all such parameters have consistently been found to remain within the permissible limits as prescribed by the applicable regulatory framework.

16. That in accordance with the recommendations of the Hanumanta Rao Committee constituted by the Government of

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India, a *"Post-Impoundment Faunal Survey and Analysis of Tehri Dam Environs"* was conducted by H.N.B. Garhwal University (a Central University), Srinagar, during the period 2009–2011. The study included a comparative analysis of pre- and post-impoundment statuses of freshwater invertebrates, fish, Rhopalocera, amphibians, reptiles, avian species, and mammals, among others. Key observations from the report are as follows:

16.1. **Freshwater Invertebrates Diversity**: An increase in the annual mean density of zooplankton attributable to the impoundment.

16.2. **Fish Diversity**:

a. The proportion of *Schizothorax spp.* has increased from 57.9% to 58.1%.

b. The proportion of *Schizothoraichthysprogastus* has increased from 6.3% to 8.5% of the total fish composition.

c. Mahseer production has shown an increase from 9.1% to 12.8%.

d. The newly introduced *Cyprinuscarpio* now contributes 3.5% to the fish composition, a species absent in the pre-impoundment scenario. This increase is likely due to the expansion of freshwater

habitat dimensions and the introduction of fish seeds into the reservoir.

16.3. **Amphibian Diversity**: No significant adverse impact of the impoundment of the Bhagirathi and Bhilangana rivers on amphibian diversity has been observed. However, the creation of the reservoir has led to a considerable increase in the population of these species in the periphery of the reservoir.

The study indicates that Mahseer production has demonstrated an increase from 9.1% to 12.8%. A copy of the Post-Impoundment Study Report is annexed hereto and marked as **Annexure-R 2** for the kind perusal of this Hon'ble Tribunal.

17. It is hereby submitted that a comprehensive Thermal and Water Quality Modelling study of the Tehri Reservoir was conducted in 1992 by IIT Roorkee (formerly designated as University of Roorkee). The aforesaid study conclusively established that the water released from the reservoir has higher temperatures compared to the incoming water. The maximum temperature difference is around 7°C, mainly occurring during winter months, while in other periods of the year, this difference is significantly reduced. THDCIL's assessment confirms that the warmer water released from

Tehri, after flowing approximately 40 kilometers, mixes with the Alaknanda River at Deoprayag, leading to minimal temperature differences between the incoming and outgoing waters downstream of Deoprayag.

18. That the thermal range of Tehri discharge fluctuates between 12°C and 20°C, which remains entirely suitable for domestic and recreational utilization. Moreover, a scholarly literature review regarding piscine ecology indicates that the elevated water temperatures in discharges from Tehri reservoir extending to Deoprayag will not adversely impact pisciculture. The aforementioned report further confirms that the dissolved oxygen levels in water released from the Tehri reservoir meet the required standards for various water uses, ensuring no harmful effects on aquatic life or downstream activities. A copy of the THDCIL assessment report, accompanied by the IITR report, is annexed herewith and marked as **Annexure- R [3]** for the kind perusal of this Hon'ble Tribunal.

19. As recommended by the Zoological Survey of India ('ZSI'), an action plan for the potential mitigation of Mahseer fish was formulated through M/s Tropical Fisheries Consultants Ltd. and subsequently submitted to the Ministry of Environment and Forests ('MOEF') in 1994. The said Action Plan for

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Mahseer fish was implemented in consultation with the Director, National Research Centre on Cold Water Fisheries Station, Indian Council of Agricultural Research (ICAR), Bhimtal. A Mahseer fish hatchery and fish farm site has been established near the Koteshwar Dam, located 20 kilometres downstream of the Tehri Dam.

20. In light of the technical expertise of the State Fisheries Department in seed production and its designation as the holder of "fisheries and aquaculture rights" for the development of fisheries in water bodies within Uttarakhand, the Mahseer hatchery was transferred to the Department of Fisheries, Uttarakhand, on lease through a Memorandum of Understanding (MoU) dated 26.01.2015. It is pertinent to note that, in compliance with the requirements of the Ministry of Environment and Forests (MOEF), a study was conducted by the Zoological Survey of India (ZSI) to evaluate the impact of the reservoir on the local fauna. The report was submitted to the MOEF in 1993.A copy of the Zoological Survey of India report is annexed hereto and marked as **Annexure-R [4]** for the kind perusal of this Hon'ble Tribunal.

21. It is submitted that M/s Tropical Fisheries Consultants Ltd. observed that detailed studies on Mahseer indicate that, as a species, they exhibit remarkable adaptability and can thrive in

diverse environmental conditions across the country. While it was previously understood that Mahseer is predominantly a riverine fish, recent findings demonstrate that Mahseer has also successfully adapted to reservoir ecosystems. Given its omnivorous feeding habits, Mahseer plays a significant role in controlling aquatic weeds, epiphyton, crabs, molluscs, and forage fish within reservoirs.

22. Mahseer has been successfully established in various reservoirs, including Walwhan, Shirwta, Mulshi, and Shivajisagar in Maharashtra; Sukta, Barna, Harsi, Halali, and Gandhisagar in Madhya Pradesh; and Pong and Govindsagar in Himachal Pradesh. Additionally, Mahseer is forming a viable fishery in the lakes of Kumaon. Consequently, it is reasonably presumed that Mahseer could also be established as a fishery in the Tehri and Koteshwar reservoirs, which would serve as new habitats for Mahseer in the Garhwal Himalayas. The report prepared by M/s Tropical Fisheries Consultants Ltd. is annexed hereto and marked as **Annexure-R [5]** for the kind perusal of this Hon'ble Tribunal.

23. To examine the hydrodynamics of the Tehri Reservoir, Mathematical Model Studies were conducted by the Central Water and Power Research Station ('CWPRS'), Pune, a national hydraulic research institute operating under the

Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation ('MoJS', 'DoWR', 'RD&GR'), New Delhi. The findings of the study were submitted in September 2001. The study concluded that the Tehri Reservoir undergoes a complete cycle of storage replenishment on an annual basis. The study further revealed that during the monsoon season, the inflow volume of water, approximately equivalent to the storage below the Minimum Draw Down Level (MDDL), is added to the reservoir within a span of 17 days, thereby replenishing the entire storage below the MDDL within this period. Additionally, the gross storage volume is fully replenished within 67 days of active monsoon. Consequently, the Tehri Reservoir completes its annual cycle of storage replenishment within this timeframe. The report of the study is annexed hereto and marked as **Annexure-R [6]** for the kind perusal of this Hon'ble Tribunal.

24. It is most respectfully submitted that a study titled *"Self-Purification Capacity of River Bhagirathi: Impact of Tehri Dam"* was conducted by the National Environmental Engineering Research Institute (NEERI), Nagpur, over a period of two years (2002-2004). The study concluded that the Tehri Dam does not adversely affect the water quality or the self-purification properties of the Bhagirathi/Ganga River.

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The reservoir functions akin to a static container, creating conditions conducive to maintaining water quality. A copy of the report is annexed hereto and marked as **Annexure-R [7]** for the kind perusal of this Hon'ble Tribunal.

25. Additionally, a *"Water Quality Study of Bhagirathi/Ganga River in the Himalayan Region"* was conducted by NEERI, Nagpur, over a period of three years, with the final report submitted in July 2011. The study concluded that the unique characteristic of the Bhagirathi/Ganga River lies in its sediment content, which is more radioactive compared to sediments from other rivers and lakes. These sediments facilitate the proliferation of coliphages under static conditions, which in turn reduce and ultimately eliminate coliforms from the overlying water column. Thus, the Tehri Dam does not impair the water quality or self-purification properties of the Bhagirathi/Ganga River, as the reservoir mimics a static container that supports conditions essential for maintaining water quality. Suspended particles play a significant role in the self-purification of Ganga water. With an average annual flow of 258 cubic meters per second (with suspended sediment concentration of 29.5 mg/l) in the Bhagirathi River and 467 cubic meters per second (with suspended sediment concentration of 32.2 mg/l) in the

Alaknanda River, there is a substantial contribution of sediments from the Alaknanda River downstream of Deoprayag. The study further indicated that the particulate matter in the Alaknanda River possesses antibacterial properties identical to those of the Bhagirathi River. A copy of the report is annexed hereto and marked as **Annexure-R [8]** for your kind perusal.

26. It is submitted that the daily release of water from the Tehri Hydro Power Complex (HPC) is regulated through the Koteshwar Dam to ensure the mandated environmental flow (e-flow) in the downstream areas of the Tehri HPC throughout the year, in compliance with the Gazette of India Notification dated 09.10.2018, issued by the Ministry of Water Resources, River Development & Ganga Rejuvenation ('MoWRRD&GR'). Adherence to the prescribed e-flow requirements is monitored and reported to the regional office of the Central Water Commission (CWC) on a daily basis. A copy of the Gazette Notification is annexed hereto and marked as **Annexure-R [9]** for your kind perusal.

27. That Mahseer seeds have been periodically collected and stored for the conservation and promotion of Mahseer fish. Over the past five years, Mahseer seeds have been accumulated in various rivers and tributaries, as detailed

below:

Year	2020		2021		2022		2023		2024	
District	Population in Lakhs	Water Stream/ River Name	Population in Lakhs	Water Stream/ River Name	Population in Lakhs	Water Stream/ River Name	Population in Lakhs	Water Stream/ River Name	Population in Lakhs	Water Stream/ River Name
Tehri Garhwal	1.50	Bhagirathi	1.0	Bhilangna	2.0	Kotigad	0.15	Kotigad	1.90	Bhagirathi

28. Fisheries, being a state subject, are regulated by the State Fisheries Department. In recognition of the technical expertise of the State Fisheries Department in seed production and its authority as the holder of "fisheries and aquaculture rights" for the development of fisheries in water bodies located within Uttarakhand, the Mahseer hatchery was transferred to the Department of Fisheries, Uttarakhand, on lease through a Memorandum of Understanding (MoU) dated 26.01.2015.

29. It is submitted that the answering respondent herein has secured the Consolidated Consent to Operate and Authorization from the Uttarakhand Pollution Control Board in compliance with the Water (Prevention and Control of Pollution) Act, 1974, for the Tehri and Koteshwar Hydroelectric Projects, and adheres to the stipulated conditions accordingly. A copy of the Consolidated Consent to Operate and Authorization is annexed hereto and marked

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as **Annexure-R [10]** for the kind perusal of this Hon'ble Tribunal.

30. It is most respectfully submitted that the answering respondent, THDC India Limited (THDCIL), has consistently adhered to all statutory and regulatory requirements in the development, operation, and maintenance of the Tehri Hydro Power Complex (HPC), including the Tehri Hydro Power Plant (Tehri HPP), Koteshwar Hydro Electric Project (Koteshwar HEP), and Tehri Pumped Storage Plant (Tehri PSP). The projects have been designed and implemented with due regard to environmental sustainability, ecological balance, and the conservation of aquatic biodiversity, including the Golden/Himalayan Mahseer.

31. The answering respondent reiterates its commitment to environmental protection and sustainable development, as evidenced by the various studies, reports, and compliance measures undertaken, including but not limited to:

31.1. Regular monitoring and maintenance of water quality parameters within permissible limits;

31.2. Implementation of environmental flow (e-flow) requirements in compliance with the Gazette of India Notification dated 09.10.2018;

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31.3. Establishment of a Mahseer fish hatchery and fish farm near Koteshwar Dam for the conservation and promotion of Mahseer species;

31.4. Conducting comprehensive studies, including post-impoundment faunal surveys, water quality assessments, and hydrodynamic modelling, to ensure minimal ecological impact;

31.5. Collaboration with reputed institutions such as the Zoological Survey of India (ZSI), National Environmental Engineering Research Institute (NEERI), and Central Water and Power Research Station (CWPRS) to address environmental concerns.

32. The answering respondent respectfully submits that the allegations regarding the decline of the Golden/Himalayan Mahseer population, even if correct, cannot be attributed to the operations of the Tehri HPC. On the contrary, the reservoir ecosystems created by the projects have provided conducive habitats for Mahseer and other aquatic species, as demonstrated by the increase in Mahseer production and the establishment of viable fisheries in the Tehri and Koteshwar reservoirs.

33. The answering respondent further submits that the hydropower projects under its purview serve critical national

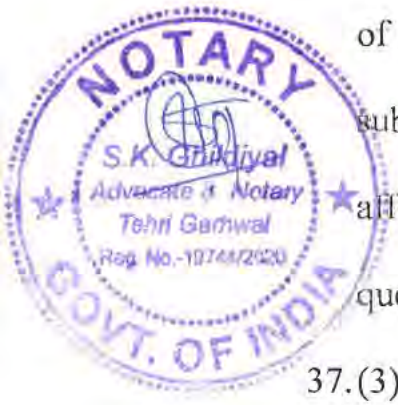
interests, including electricity generation, irrigation, drinking water supply, and flood mitigation, while simultaneously contributing to regional economic development and employment generation.

34. In light of the foregoing submissions, the answering respondent respectfully craves the leave of this Hon'ble Tribunal to take on record the detailed submissions and annexures filed herein.

B. PARAWISE REPLY

35. (1) The contents of the corresponding paragraph are a matter of record and merit no response. It is, however, respectfully submitted that the Appellant herein is not directly related to the Hydroelectric projects of THDCIL that are questioned in the OA.

36. (2) The contents of the corresponding paragraph are a matter of record and merit no response. It is, however, respectfully submitted that the Appellant herein is in no manner directly affected by the Hydroelectric projects of THDCIL that are questioned in the OA.



37. (3) The contents of the corresponding paragraph are a matter of record and merit no response.

38. (4) The contents of the corresponding paragraph are a matter of record and merit no response.

39. (5) The contents of the corresponding paragraph are a matter of record and merit no response.

40. (6) The contents of the corresponding paragraph are a matter of record and merit no response.

41. (7) The contents of the corresponding paragraph are a matter of record and merit no response.

42. (8) The contents of the corresponding paragraph are a matter of record and merit no response.

43. (9) It is submitted that the answering respondent has implemented appropriate measures for the conservation of fish populations in the reservoirs of its hydroelectric projects, in compliance with the clearances granted by the erstwhile Ministry of Forests (now: Ministry of Environment, Forest and Climate Change), which is the nodal ministry responsible for granting statutory environmental clearances required for hydroelectric projects.

44. (10) The contents of the corresponding paragraph are a matter of record and merit no response.

45. (11) The contents of the corresponding paragraph are a matter of record and merit no response.

46. (12) The contents of the corresponding paragraph are a matter of record and merit no response.

47. (13) The contents of the corresponding paragraph are a matter of record and merit no response.

48. (14) The contents of the corresponding paragraph are a matter of record and merit no response.

49. (15) The contents of the corresponding paragraph are a matter of record and merit no response.

50. (16) The contents of the corresponding paragraph are a matter of record and merit no response.

51. (17) The contents of the corresponding paragraph are a matter of record and merit no response.

52. (18) The contents of the corresponding paragraph are denied as being incorrect and misleading. A detailed point wise reply is given below:

52.1. (h) The contents of the corresponding paragraph are denied as being incorrect and misleading. It is submitted that hydropower projects are vital to address India's energy needs, supporting power supply, irrigation, and drinking water, while fostering employment and regional development. THDC India Limited (THDCIL) develops and operates the Tehri Hydro Power Complex (HPC) on the River Bhagirathi, comprising the Tehri HPP, Koteshwar HEP, and Tehri PSP. These projects provide electricity, irrigation,

drinking water, and flood control, benefiting national development. The Tehri reservoir stores monsoon flow, releasing it in non-monsoon periods to meet irrigation and drinking water needs in Uttarakhand and Uttar Pradesh, while generating 2400 MW of peak power. It irrigates 270,000 additional hectares, sustains 604,000 hectares of existing land, and supplies drinking water to 7 million residents. The project has excelled in flood mitigation during extreme rainfall in 2010, 2011, and 2013. Reservoirs create stable aquatic habitats, supporting fish reproduction and growth. Regulated water levels mitigate adverse impacts on breeding cycles, while enhanced aquatic flora and fauna provide nutritional resources. As per Uttarakhand Fisheries Department correspondence dated 04.02.2025, the Tehri and Koteshwar reservoirs are key Mahseer conservation habitats, with significant population density. The correspondence is annexed as **Annexure-R [1].** A study was conducted by H.N.B. Garhwal University (a Central University), Srinagar, during the period 2009 2011. The study included a comparative analysis of pre- and post-impoundment statuses of freshwater invertebrates, fish, Rhopalocera,

amphibians, reptiles, avian species, and mammals, among others. The study indicates that Mahseerproduction has demonstrated an increase from 9.1% to 12.8%. A copy of the Post-Impoundment Study Report is annexed hereto and marked as **Annexure - R [2]** for the kind perusal of this Hon'ble Tribunal.

52.2. (i) The contents of the corresponding paragraph are denied as being incorrect and misleading. The answering respondent, being a responsible corporate entity, hereby affirms its unwavering commitment to the protection and preservation of the environment and ecological systems. It is respectfully submitted that the hydroelectric power project in question does not generate any polluting emissions or discharges during its operational phase, while the associated reservoir functions solely to accumulate water from its designated catchment area. In furtherance of its environmental obligations, the answering respondent conducts regular and systematic monitoring of various environmental parameters pertaining to water quality in both the upstream and downstream regions of the Tehri reservoir. Upon analysis, all such parameters have consistently been found to remain within the

permissible limits as prescribed by the applicable regulatory framework.

52.3. (j) The contents of the corresponding paragraph fall outside the purview of THDCIL.

52.4. (k) The contents of the corresponding paragraph are denied for want of knowledge. It is submitted that a comprehensive Thermal and Water Quality Modelling study of the Tehri Reservoir was conducted by IIT Roorkee in 1992. The study established that water released from the reservoir is warmer than incoming water, with a maximum temperature difference of 7°C, primarily in winter, and significantly reduced in other periods. THDCIL's assessment confirms that the warmer water, after flowing 40 kilometers, mixes with the Alaknanda River at Deoprayag, resulting in minimal temperature differences downstream. The discharge temperature ranges between 12°C and 20°C, suitable for domestic and recreational use. Scholarly literature confirms that elevated temperatures do not adversely impact fish ecology. The report also affirms that dissolved oxygen levels in the released water meet required standards, ensuring no harm to aquatic life or

downstream activities. The THDCIL assessment and IITR report are annexed as **Annexure-R [3].**

52.5. (l) The contents of the corresponding paragraph are denied as being incorrect and misleading. As evidenced by correspondence dated 04.02.2025 from the Department of Fisheries, Government of Uttarakhand, both the Tehri and Koteshwar reservoirs serve as key conservation habitats for Mahseer species, where these species show a notably high population density. The aforementioned correspondence is annexed herewith and marked as **Annexure- R [1]**. A study was conducted by H.N.B. Garhwal University (a Central University), Srinagar, during the period 2009–2011, indicating that Mahseer production has increased from 9.1% to 12.8%. A copy of the Post-Impoundment Study Report is annexed hereto and marked as **Annexure-R [2]**.

52.6. (m) The contents of the corresponding paragraph are denied as incorrect and misleading. It is submitted hereinunder:

52.6.1. The Mahseer hatchery was transferred to the Uttarakhand Department of Fisheries on lease via an MoU dated 26.01.2015, recognizing its

expertise in seed production and fisheries development. A ZSI study submitted to MOEF in 1993 assessed the reservoir's impact on local fauna. The ZSI report is annexed as **Annexure-R [4].**

52.6.2. M/s Tropical Fisheries Consultants Ltd. observed that Mahseer is highly adaptable, thriving in diverse environments, including reservoirs. Its omnivorous diet controls aquatic weeds, epiphyton, crabs, molluscs, and forage fish.

52.6.3. Mahseer has been established in reservoirs like Walwhan, Shirwta, Mulshi, Shivajisagar (Maharashtra); Sukta, Barna, Harsi, Halali, Gandhisagar (Madhya Pradesh); and Pong, Govindsagar (Himachal Pradesh), as well as Kumaon lakes. It is presumed Mahseer can establish fisheries in Tehri and Koteshwar reservoirs. The report is annexed as **Annexure-R [5].**

52.6.4. CWPRS, Pune, conducted Mathematical Model Studies on Tehri Reservoir's hydrodynamics. The 2001 study found that the reservoir replenishes annually, with storage below MDDL restored in

17 days during monsoon season and gross storage in 67 days. The report is annexed as **Annexure-R [6].**

52.6.5. A 2002–2004 NEERI study concluded the Tehri Dam does not impair water quality or self-purification, functioning as a static container. The report is annexed as **Annexure-R [7].**

52.6.6. A 2011 NEERI study highlighted Bhagirathi/Ganga's unique radioactive sediments, promoting coliphages that reduce coliforms. The dam does not hinder water quality or self-purification, with significant sediment contributions from the Alaknanda River downstream of Deoprayag. The report is annexed as **Annexure-R [8].**

52.6.7. As evidenced by correspondence dated 04.02.2025 from the Department of Fisheries, Government of Uttarakhand, both the Tehri and Koteshwar reservoirs serve as key conservation habitats for Mahseer species, where these species show a notably high population density. The aforementioned correspondence is annexed herewith and marked as **Annexure- R [1].**

52.7. (n) The statement made in the corresponding paragraph does not pertain to THDCIL. It is, however, submitted that the Department of Fisheries, Uttarakhand, which holds the fisheries and aquaculture rights in the state, has informed vide their letter dated 04.02.2025 that warnings have been issued to prohibit the use of any chemicals and explosives in the reservoirs. A copy of the letter is annexed hereto and marked as **Annexure-R [1]** for reference.

53. (19) The contents of the corresponding paragraph are a matter of record and merit no response.

54. (20) The contents of the corresponding paragraph are a matter of record and merit no response.

55. (21) The contents of the corresponding paragraph fall outside the purview of THDCIL.

56. (22) The contents of the corresponding paragraph are denied as incorrect and misleading. In light of the technical expertise of the State Fisheries Department in seed production and its designation as the holder of "fisheries and aquaculture rights" for the development of fisheries in water bodies within Uttarakhand, the Mahseer hatchery was transferred to the Department of Fisheries, Uttarakhand, on lease through a Memorandum of Understanding (MoU) dated 26.01.2015. It

is pertinent to note that, in compliance with the requirements of the Ministry of Environment and Forests (MOEF), a study was conducted by the Zoological Survey of India (ZSI) to evaluate the impact of the reservoir on the local fauna. The report was submitted to the MOEF in 1993. A copy of the Zoological Survey of India report is annexed hereto and marked as **Annexure-R [4].** As evidenced by correspondence dated 04.02.2025 from the Department of Fisheries, Government of Uttarakhand, both the Tehri and Koteshwar reservoirs serve as key conservation habitats for Mahseer species, where these species show a notably high population density. The aforementioned correspondence is annexed herewith and marked as **Annexure- R [1].** A study was conducted by H.N.B. Garhwal University (a Central University), Srinagar, during the period 2009–2011, indicating that Mahseer production has increased from 9.1% to 12.8%. A copy of the Post-Impoundment Study Report is annexed hereto and marked as **Annexure-R [2].**

57. (23) The contents of the corresponding paragraph are denied as incorrect and misleading for the reasons mentioned above. The same is not repeated herein for the sake of brevity.

58. (24) The contents of the corresponding paragraph are denied as incorrect and misleading.

58.1. (i) The contents of the corresponding paragraph fall outside the purview of THDCIL.

58.2. (ii) The contents of the corresponding paragraph fall outside the purview of THDCIL.

58.3. (iii) It is submitted that The Ministry of Environment, Forest and Climate Change (MoEF&CC) grants Environmental Clearance (EC) for projects, a mandatory requirement for most developmental projects, including hydroelectric projects. The EC process necessitates the project proponent to conduct an Environmental Impact Assessment (EIA) to demonstrate that the proposed project will not cause significant environmental harm and to outline mitigation measures for potential adverse impacts. While granting clearance for the Tehri project, the Ministry of Environment and Forests, vide letter dated 19.07.1990, imposed specific conditions requiring certain studies to be conducted. Based on their findings, action plans were to be formulated and implemented concurrently with the project's construction.

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58.4. As per MOEF stipulations, a study by the Zoological Survey of India (ZSI) assessed reservoir impact on

fauna, with the report submitted in 1993. Based on ZSI's recommendations, an action plan for Mahseer fish mitigation was prepared by M/s Tropical Fisheries Consultants Ltd. and submitted to MOEF in 1994. Implementation was undertaken in consultation with the Director, National Research Centre on Cold Water Fisheries Station, ICAR, Bhimtal. A Mahseer fish hatchery and farm were established near Koteshwar Dam (20 km downstream of Tehri Dam).

58.5. Owing to the State Fisheries Department's expertise in seed production and its fisheries and aquaculture rights in Uttarakhand, the Mahseer hatchery was transferred to it on lease via an MoU dated 26.01.2015.

58.6. Biodiversity, a key indicator of ecosystem health, was assessed through a post-impoundment faunal survey conducted by H.N.B. Garhwal University (2009–2011) as per the Hanumanta Rao Committee's (1998) recommendations. The study compared pre- and post-impoundment statuses of freshwater invertebrates, fish, Rhopalocera, amphibians, reptiles, avian species, and mammals. Key findings include:

- Increased zooplankton density due to impoundment.

- Rise in *Schizothorax spp.* (57.9% to 58.1%) and *Schizothoraichthysprogastus* (6.3% to 8.5%).

- Mahseer production increased from 9.1% to 12.8%.

- *Cyprinuscarpio*, newly introduced, now contributes 3.5% to fish composition.

- No adverse impact on amphibian diversity; populations increased near the reservoir.

The Post-Impoundment Study Report is annexed as **Annexure-R [2].** The Department of Fisheries, Uttarakhand, in its letter dated 04.02.2025, confirmed that Tehri and Koteshwar reservoirs are primary Mahseer conservation sites, with abundant populations. The letter is annexed as **Annexure-R [1]**

58.7. (iv) The contents of the corresponding paragraph are denied as incorrect and misleading for the reasons mentioned above. The same is not repeated herein for the sake of brevity.

58.8. (v) The contents of the corresponding paragraph fall outside the purview of THDCIL.

58.9. (vi) The contents of the corresponding paragraph fall outside the purview of THDCIL.

58.10. (vii) The contents of the corresponding paragraph fall outside the purview of THDCIL.

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58.11.(viii) The contents of the corresponding paragraph fall outside the purview of THDCIL.

59. (25) The contents of the corresponding paragraph are a matter of record and merit no response.

60. (26) The contents of the corresponding paragraph are denied in toto as incorrect and misleading for the reasons stated in Paras 58.3, 58.4, 58.5 and 58.6 of this reply affidavit. The same is not repeated herein for the sake of brevity.

61. (27) The contents of the corresponding paragraph are denied as incorrect and misleading for the reasons mentioned above. The same is not repeated herein for the sake of brevity.

62. (28) The contents of the corresponding paragraph are denied as incorrect and misleading. It is submitted that the daily release of water from the Tehri Hydro Power Complex (HPC) is regulated through the Koteshwar Dam to ensure the mandated environmental flow (e-flow) in the downstream areas of the Tehri HPC throughout the year, in compliance with the Gazette of India Notification dated 09.10.2018, issued by the Ministry of Water Resources, River Development & Ganga Rejuvenation ('MoWRRD&GR'). Adherence to the prescribed e-flow requirements is monitored and reported to the regional

office of the Central Water Commission (CWC) on a daily basis. A copy of the Gazette Notification is annexed hereto and marked as **Annexure-R [9]**; and for reasons mentioned in Para 52.5 of this reply affidavit. The same is not repeated herein for the sake of brevity.

63. (29) The contents of the corresponding paragraph fall outside the purview of THDCIL.

64. (30) The contents of the corresponding paragraph are denied in toto as incorrect and misleading for the reasons stated in Paras 52.1, 52.6, 58.3, 58.4, 58.5 and 58.6 of this reply affidavit. The same is not repeated herein for the sake of brevity.

65. (31) The contents of the corresponding paragraph are a matter of record and merit no response.

66. (32) The contents of the corresponding paragraph are denied in toto as incorrect and misleading for the reasons stated in Paras 52.5 of this reply affidavit. The same is not repeated herein for the sake of brevity.

67. (33) The contents of the corresponding paragraph are a matter of record and merit no response.

68. (34) The contents of the corresponding paragraph are a matter of record and merit no response.

69. (35) The contents of the corresponding paragraph are a matter of record and merit no response.

70. (36) The contents of the corresponding paragraph are denied in toto as incorrect and misleading for the reasons stated in Paras 52.1, 52.6, 58.3, 58.4, 58.5 and 58.6 of this reply affidavit. The same is not repeated herein for the sake of brevity.

71. (37) The contents of the corresponding paragraph are a matter of record and merit no response.

72. (38) The contents of the corresponding paragraph are a matter of record and merit no response.

73. (39) The contents of the corresponding paragraph are denied for want of knowledge. A detailed reply is stated in Paras 52.1, 52.6, 58.3, 58.4, 58.5 and 58.6 of this reply affidavit. The same is not repeated herein for the sake of brevity.

74. (40) The contents of the corresponding paragraph are denied for want of knowledge. A detailed reply is stated in Paras 52.1, 52.6, 58.3, 58.4, 58.5 and 58.6 of this reply affidavit. The same is not repeated herein for the sake of brevity.

75. (41) The contents of the corresponding paragraph fall outside the purview of THDCIL.

76. (42) The contents of the corresponding paragraph are a matter of record and merit no response.

77. (43) The contents of the corresponding paragraph are a matter of record and merit no response.

78. (44) The contents of the corresponding paragraph are a matter of record and merit no response.

79. (45) The contents of the corresponding paragraph are a matter of record and merit no response.

80. (46) (l) The contents of the corresponding paragraph fall outside the purview of THDCIL.

81. (46) (m) It is submitted by the answering respondent that for reasons already specified in, but not limited to, Para 56 of this reply affidavit. Mahseer seeds have been periodically collected and stored for the conservation and promotion of Mahseer fish. Over the past five years, Mahseer seeds have been accumulated in various rivers and tributaries, as detailed below:

Year	2020		2021		2022		2023		2024	
District	Population in Lakhs	Water Stream/ River Name	Population in Lakhs	Water Stream/ River Name	Population in Lakhs	Water Stream/ River Name	Population in Lakhs	Water Stream/ River Name	Population in Lakhs	Water Stream/ River Name
Tehri Garhwal	1.50	Bhagirathi	1.0	Bhilangna	2.0	Kotigad	0.15	Kotigad	1.90	Bhagirathi

82. (46) (n) It is submitted that the daily release of water from the Tehri Hydro Power Complex (HPC) is regulated through the Koteshwar Dam to ensure the mandated environmental flow (e-flow) in the downstream areas of the Tehri HPC

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throughout the year, in compliance with the Gazette of India Notification dated 09.10.2018, issued by the Ministry of Water Resources, River Development & Ganga Rejuvenation ('MoWRRD&GR'). Adherence to the prescribed e-flow requirements is monitored and reported to the regional office of the Central Water Commission (CWC) on a daily basis. A copy of the Gazette Notification is annexed hereto and marked as **Annexure-R [9].**

83. (46) (o) The contents of the corresponding paragraph fall outside the purview of THDCIL.

84. (46) (p) The contents of the corresponding paragraph fall outside the purview of THDCIL.

85. (46) (q) It is submitted that the Department of Fisheries, Uttarakhand, is undertaking necessary activities for the promotion and conservation of fisheries. In this regard, a copy of the letter from the Department of Fisheries, Uttarakhand, is annexed hereto and marked as **Annexure-R [1]** for reference.

86. (46) (r) It is submitted that the answering respondent is in no way tampering with the ecological processes of natural waters for reasons mentioned in Paras 52.6, 58.3, 58.4, 58.5 and 58.6 of this reply affidavit. The same is not repeated herein for the sake of brevity.

87. (46) (s) It is submitted that the Department of Fisheries, Uttarakhand, is undertaking necessary activities to create awareness and foster a sense of responsibility towards the protection of Mahseer. In this regard, a copy of the letter from the Department of Fisheries, Uttarakhand, is annexed hereto and marked as **Annexure-R [1]** for reference.

88. (46) (t) The contents of the corresponding paragraph fall outside the purview of THDCIL.

89. (46) (u) The contents of the corresponding paragraph are wholly denied. The appellants' submissions for the removal of all dams/barrages are vehemently denied in their entirety. THDCIL operates its projects in strict compliance with all applicable laws and regulations. Prior to initiating any project, THDCIL obtains all necessary clearances and permissions from relevant authorities, including the Central Electricity Authority (CEA), the Central Water Commission (CWC), and various departments of the Central and State Governments. Importantly, THDCIL secures environmental clearance from the Ministry of Environment, Forest and Climate Change (MoEF&CC), which involves comprehensive environmental impact assessments and mitigation plans. As per MOEF stipulations, a study was conducted by the Zoological Survey of India (ZSI) to assess

the impact of the reservoir on fauna. The report was submitted to MOEF in 1993 and is annexed hereto as **Annexure-R [4]** for reference. Additionally, for reasons mentioned in Para 52.6 of this reply affidavit, the answering respondent denies the corresponding paragraph as incorrect and misleading. The same has not been repeated for the sake of brevity.

90. (46) (v) The contents of the corresponding paragraph fall outside the purview of THDCIL.

91. (47) (i) It is submitted that Fisheries, being a state subject, are regulated by the State Fisheries Department. In recognition of the technical expertise of the State Fisheries Department in seed production and its authority as the holder of "fisheries and aquaculture rights" for the development of fisheries in water bodies located within Uttarakhand, the Mahseerhatchery was transferred to the Department of Fisheries, Uttarakhand, on lease through a Memorandum of Understanding (MoU) dated 26.01.2015. It is clarified that no specific laws have been violated, as this matter does not pertain to the answering Respondent, THDCIL.

92. (47) (ii) It is submitted that for reasons mentioned in Para 91, the answering respondent is not in breach of any law. The same is not repeated herein for the sake of brevity.

93. (47) (iii) The contents of the corresponding paragraph fall outside the purview of THDCIL.

94. (47) (iv) THDCIL has secured the Consolidated Consent to Operate and Authorization from the Uttarakhand Pollution Control Board under the Water (Prevention and Control of Pollution) Act, 1974, for the Tehri and Koteshwar Hydroelectric Projects and is in compliance with the stipulated conditions. A copy of the Consolidated Consent to Operate and Authorization is annexed hereto and marked as **Annexure-R [10]** for reference.

C. REPLY TO SUBSTANTIAL QUESTIONS OF ENVIRONMENT

95. (A) It is submitted that the answering respondent has implemented appropriate measures to conserve fish populations in the reservoirs of its hydroelectric projects, in compliance with the clearances granted by the Ministry of Environment, Forest and Climate Change (MoEF&CC), the nodal ministry responsible for granting statutory environmental clearances for hydroelectric projects. The implementation of the Action Plan for Mahseer fish was

undertaken in consultation with the Director, National Research Centre on Cold Water Fisheries Station, ICAR, Bhimtal. A Mahseer fish hatchery and fish farm were established near Koteshwar Dam, located 20 kilometers downstream of the Tehri Dam. In light of the technical expertise of the State Fisheries Department in seed production and its authority as the holder of "fisheries and aquaculture rights" for the development of fisheries in water bodies within Uttarakhand, the Mahseer hatchery was transferred to the Department of Fisheries, Uttarakhand, on lease through a Memorandum of Understanding (MoU) dated 26.01.2015. The answering respondent has obtained all requisite statutory clearances from the relevant authorities for the implementation of the project. Additionally, measures to support aquatic ecology in the reservoir, including various studies conducted through expert agencies, have been implemented.

96. (B) It is submitted that the question in the corresponding paragraph holds no water for the reasons mentioned in Para 95 of this reply affidavit. The same is not repeated herein for the sake of brevity.

97. (C) The contents of the corresponding paragraph fall outside the purview of THDCIL.

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98. (D) The contents of the corresponding paragraph fall outside the purview of THDCIL.

99. (E) The contents of the corresponding paragraph fall outside the purview of THDCIL.

D. REPLY TO GROUNDS

100. (A) The contents of the corresponding ground are denied as incorrect. As evidenced by correspondence dated 04.02.2025 from the Department of Fisheries, Government of Uttarakhand, both the Tehri and Koteshwar reservoirs serve as key conservation habitats for Mahseer species, where these species show a notably high population density. The aforementioned correspondence is annexed herewith and marked as **Annexure- R [1]**. A study was conducted by H.N.B. Garhwal University (a Central University), Srinagar, during the period 2009–2011, indicating that Mahseer production has increased from 9.1% to 12.8%. A copy of the Post-Impoundment Study Report is annexed hereto and marked as **Annexure-R [2]**.

101. (B) The contents of the corresponding ground are denied as incorrect. A systematic and precautionary approach has been adopted since the inception of the Tehri and Koteshwar projects. Accordingly, a Mahseer fish hatchery was constructed and made operational, which is currently

managed by the Department of Fisheries, Uttarakhand, following its transfer under a Memorandum of Understanding (MoU) dated 26.01.2015. With the necessary interventions, Mahseer continues to thrive in THDCIL's project area, as evidenced by **Annexure – R[1]** and **Annexure – R[2],** annexed with this reply affidavit.

102. (C) The contents of the corresponding paragraph fall outside the purview of THDCIL.

103. (D) The contents of the corresponding ground are denied as incorrect. It is submitted that the Ministry of Environment and Forests (MoEF), Government of India, granted Environmental Clearance to the Tehri Dam Project vide letter dated 19th July 1990. In compliance with MoEF stipulations, various studies, including assessments of potential impacts on flora and fauna, were conducted through the Botanical Survey of India (BSI) and Zoological Survey of India (ZSI), respectively. As recommended by ZSI, an action plan for mitigating the impact on Mahseer fish was prepared by M/s Tropical Fisheries Consultants Ltd. and submitted to MoEF in 1994. The consultants suggested that, given the impracticality of fish ladders/passes for Mahseer, the optimal approach is to establish fish seed farms for breeding, raising stock, and

releasing them into natural streams, rivers, and reservoirs. The report of M/s Tropical Fisheries Consultants Ltd. is annexed hereto as **Annexure - R[5].** Additionally, for reasons mentioned in, but not limited to, Para 52.5 in the reply affidavit, the contents of the corresponding ground are denied in toto. The same is not repeated herein for the sake of brevity.

104. (E) The contents of the corresponding paragraph fall outside the purview of THDCIL.

105. (F) The contents of the corresponding ground are denied as incorrect for reasons already mentioned in, but not limited to, Para 82 of this reply affidavit. The same is not repeated herein for the sake of brevity. In its April 1994 report on the action plan for mitigating the potential impact on Mahseer fishery due to the construction of the Tehri Dam, M/s Tropical Fisheries Consultancy Services stated that while dam construction reduces downstream river flow, leading to a decline in riverine capture fishery, the benefits from fish production facilities in reservoirs, ponds, and tanks more than compensate for this loss. M/s Tropical Fisheries Consultants Ltd. observed that Mahseer, as a species, exhibits remarkable adaptability and can thrive in diverse environments across the country. Furthermore, during the

adaptation process, Mahseer may have explored new feeding and spawning grounds in the tributaries and streams joining the main river downstream of the Tehri Dam.

106. (G) The contents of the corresponding paragraph fall outside the purview of THDCIL.

107. (H) The contents of the corresponding ground are denied as incorrect for reasons already mentioned in, but not limited to, Para 52.5 of this reply affidavit. The same is not repeated herein for the sake of brevity.M/s Tropical Fisheries Consultants Ltd. observed that detailed studies on Mahseer indicate that, as a species, they are highly adaptable and can thrive in diverse environments across the country. Apart from the Bhagirathi River, the Tehri reservoir is fed by major tributaries such as the Bhilangana, Jalkur, and Balganga rivers. These tributaries provide ample silt-free, stony substratum, facilitating upstream migration of Mahseer through rapids.

108. (I) The contents of the corresponding ground are denied as incorrect for reasons already mentioned in, but not limited to, Paras 52.1 and 58.6 of this reply affidavit. The same is not repeated herein for the sake of brevity.

109. (J) The contents of the corresponding paragraph are a matter of record and merit no response.

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110. (K) The contents of the corresponding paragraph fall outside the purview of THDCIL.

111. (L) The contents of the corresponding paragraph fall outside the purview of THDCIL.

112. (M) The contents of the corresponding paragraph fall outside the purview of THDCIL.

113. (N) The contents of the corresponding ground are denied as incorrect for reasons already mentioned in, but not limited to, Paras 52.6.1, 52.6.2 and 52.6.3 of this reply affidavit. The same is not repeated herein for the sake of brevity.

114. That in the view of the above submissions made, the present petition is, therefore, liable to be dismissed.

115. That the deponent craves leave of this Hon'ble Court to file further affidavits/documents/applications as and when required.

DEPONENT

L. P. JOSHI
Executive Director (TC)
THDC India Ltd Tehri

NOTARY
S.K. Dhiddiwal
Advocate & Notary
Tehri Garhwal
Reg. No. 19744/2020
GOVT. OF INDIA

VERIFICATION

I, the above-named Deponent, do hereby verify that the contents of para 1 to are true to my knowledge and the rest of the paras are true to my knowledge being based on official record. No part of it is false and nothing material has been concealed therefrom.

Verified at New Tehri on this, the 31 day of May 2025

Identified By Me

वरिष्ठ प्रबन्धक (पर्यावरण)
Senior Manager (Environment)
टीएचडीसी इण्डिया लिमिटेड,टिहरी
THDC India Limited, Tehri

NOTARY
S.K. Ghildiyal
Advocate & Notary
Tehri Garhwal
Regd. No. 10142/2020
GOVT. OF INDIA

L. P. JOSHI
Executive Director (TC)
THDC India Ltd Tehri

Sworn Solemnly Affirmed by the Deponent Sh. Laxmi Prasad Joshi, presently as Executive Director, LTIC T.H.D.C India, Ltd, Tehri S/o Late Sh. Vidhya Dutt Joshi Identified by Sh. Jagdish Singh Rawat Sr. Manager Environment T.H.D.C. B. Puram on dt. 31/5/25

(S.K. Ghildiyal)
Advocate & Notary
Court Compound, New Tehri
Tehri Garhwal
31/5/25

THDC INDIA LIMITED

(Schedule - 'A' Mini Ratna Goverment PSU)

Bhagirathipuram, Tehri Garhwal, Uttarakhand

ID Cad No. : 1154
Name : **Laxmi Prasad Joshi**
Designation : **Executive Director (T.C.)**
Employee No. : **2293676**
Validity : **28-Feb-2027**

Signs as :-

THDC INDIA LIMITED

Issuing Authority

Date of Birth : 28-Feb-1967 | **Blood Group : B+**

L. P. JOSHI
Executive Director (TC)
THDC India Ltd Tehri

Address : Executive Director Residence, Bhagirathipuam, Tehri Garhwal- 249124 (U.K.)
Phone No. : 9411109427

- This card is the property of THDC India Limited to whom it must be **returned on** retirement, resignation, transfer of leaving the job for any reason whatsoever.
- If the card is lost, employee must immediaely lodge a First information Report with Police and intimate P&A Department, THDC India Limited in Writing with copy of FIR Duplicate card will be issued on payment of Rs. 500.00
- If this card is found, kindly return it to **P&A** Department, **THDC India Limited**, Bhagirathipuram, Tehri Garhwal, Uttarakhand. **Tel** : 01378-231341

NOTARY S.K. Ghildiyal Advocate & Notary Tehri Garhwal Reg. No.-19744/2020 GOVT. OF INDIA

ATTESTED
(S.K. Ghildiyal)
Advocate & Notary
Court Compound, New Tehri
Reg. No.-19744/2020
31/5/25

948

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Annexure R/1

प्रेषक,

सहायक निदेशक मत्स्य
टिहरी गढ़वाल।

सेवा में,

उप महाप्रबन्धक
बांध एवं पर्यावरण विभाग
टीएचडीसी इण्डिया लिमिटेड, टिहरी गढ़वाल।

पत्रांक 411 /कोटे0 हैचरी/2024–25 दिनांक 04/02/2025

विषय :– NGT के आदेश (Application N. 1004 के सम्बन्ध में।

महोदय,

उपरोक्त विषयक आपके कार्यालय पत्र संख्या 105/टीएचडीसीइंलि/टिहरी/पर्या0/2024/एफ–59 दिनांक 20/12/2024 का सन्दर्भ ग्रहण करने का कष्ट करें, उक्त सन्दर्भित पत्र के क्रम में अवगत कराना है कि मत्स्य विभाग, टिहरी गढ़वाल के अन्तर्गत NGT के आदेश पर बिन्दुवार सूचना तैयार कर पत्र के साथ संलग्न कर सूचनार्थ सादर प्रेषित है।

संलग्नक– उपरोक्तानुसार

भवदीय

(उपेन्द्र प्रताप सिंह)
सहायक निदेशक मत्स्य
टिहरी गढ़वाल

महाशीर मछली के संरक्षण हेतु जनपद टिहरी द्वारा किये गये कार्य/उपाय

महांशीर मछली उत्तराखण्ड की राज्य मछली है, इसके संरक्षण एवं संवर्द्धन हेतु निम्न कार्य किये गये तथा किये जा रहे है।

1. **उत्तरांचल (उत्तराखण्ड) मत्स्य अधिनियम, 2003** के अन्तर्गत जनपद टिहरी गढ़वाल की मुख्य नदियों एवं सहायक नदियों में महाशीर क्षेत्रों का चिन्हांकन करते हुये उसके संरक्षण को बढावा दिया जा रहा है। उक्त अधिनियम के अन्तर्गत कुल 135 कि0मी0 नदियों/सहायक नदियो को महाशीर जोन के रूप में चिन्हित किया गया है। इन जोनों में अवैध रूप में शिकारमाही रोकने, प्रजनन काल में पूर्णतः शिकारमाही रोकने की व्यवस्था की गयी है, जिससे कि महाशीर मछली का संरक्षण किया जा सके। नदी एवं सहायकवार विवरण निम्नवत है :–

जनपद का नाम	नदी एवं सहायक नदी का नाम	महाशीर जोन कि0मी0 में
टिहरी	भागीरथी	80
	भिलंगना	20 (भागीरथी संगम से ऊपर)

2. **महाशीर मछली के संरक्षण एवं संवर्द्धन हेतु महाशीर मत्स्य बीज संचय** – महाशीर मछली के संरक्षण एवं संवर्द्धन हेतु समय–समय पर महाशीर मत्स्य बीज संचय किये गये है। विगत 05 वर्षो में विभिन्न नदियो एवं सहायक नदियों में महाशीर मत्स्य बीज संचित किये गये, जिसका विवरण निम्नवत है–

वर्ष	2020		2021		2022		2023		2024	
जनपद	संख्या लाख में	जल धारा /नदी का नाम	संख्या लाख में	जल धारा /नदी का नाम	संख्या लाख में	जल धारा /नदी का नाम	संख्या लाख में	जल धारा /नदी का नाम	संख्या लाख में	जल धारा /नदी का नाम
टिहरी गढ़वाल	1.50	भागीरथी	1.00	भिलंगना	2.00	कोटीगाड	0.15	कोटीगाड़	1.90	भागीरथी

3. **महांशीर मछली के संरक्षण एवं संवर्द्धन तथा शिकारमाही के रोकथाम हेतु की गयी गतिविधियॉ–** महांशीर मछली के संरक्षण एवं संवर्द्धन तथा शिकारमाही के रोकथाम हेतु जनपद/विकासखण्ड स्तर पर विभिन्न प्रकार की गष्ठियां/जन जागरूकता/प्रशिक्षण निम्नलिखित कार्यकम आयोजित किये जाते है–

मत्स्य निरीक्षक
कार्यालय सहायक निदेशक मत्स्य
टिहरी गढ़वाल

सहायक निदेशक मत्स्य
टिहरी गढ़वाल।

1. जनपद में प्रचार प्रसार व गोष्ठियों के माध्यम से महाशीर संरक्षण हेतु जनजागरूकता अभियान चलाये गये।
2. समस्त विकास खण्डो में अवैध शिकारमाही रोकथाम हेतु ग्राम स्तर पर अभियान चलाये गये।
3. टिहरी जलाशय में महाशीर मछली के संरक्षण हेतु महाशीर के बच्चों को प्रतिवर्ष छोटी–छोटी सहायक जल स्रोत/नदियों से एकत्रित कर संचय किया गया।
4. कोटेश्वर जलाशय में महाशीर मछली के संवर्द्धन एवं संरक्षण हेतु राजकीय मत्स्य प्रक्षेत्र प्रभारी के माध्यम से महाशीर मत्स्य संरक्षण एंव संवर्द्धन को बढावा दिया जा रहा है साथ ही कोटेश्वर जलाशय में अवैध शिकारमाही को रोकने के प्रयास किये जा रहे है।
5. जनपद टिहरी जलाशय प्रभारी द्वारा प्रतिवर्ष अवैध शिकार माही व भागीरथी तथा भिलगना नदी के तटीय क्षेत्रो में अवैध मत्स्य शिकारमाही की निगरानी की जा रही है।
6. टिहरी जलाशय व कोटेश्वर जलाशय महाशीर मछली के संरक्षण का एक मुख्य स्त्रोत है जिसमें कि महाशीर मछली की अधिकता पायी जाती है।
7. महाशीर मछली के संरक्षण एवं संवर्द्धन हेतु टिहरी जलाशय व कोटेश्वर जलाशय के तटबन्धीय ग्रामों में महाशीर संरक्षण एवं संवर्द्धन हेतु सक्रिय अभियान चलाये गये। जिसमें ग्रामीणों को महाशीर मछली के संरक्षण के महत्व को बताया गया।
8. जलाशयों में किसी भी प्रकार के रसायन व विस्फोटक को रोके जाने हेतु चेतावनी निर्गत की गयी।
9. अवैध शिकारमाही को रोके जाने हेतु ग्राम स्तर पर जागरूकता की जा रही है।
10. महाशीर संवर्द्धन एवं संरक्षण हेतु जनपद में वर्ष 2020 से 2024 तक कुल 23 गोष्ठियां एवं 3 प्रशिक्षण कराये गये है।

4. **जल विद्युत परियोजनों के निर्माण से पूर्व से महाशी संरक्षण हेतु मात्स्यिकी संवर्द्धन कार्यो को बढावा देना– जनपद** में विभिन्न नदियों/सहायक नदियों में निर्मित/निर्माणाधीन जल विद्युत परियोजनों में महाशीर मछली के सवंर्द्धन एवं संरक्षण हेतु हैचरियों का निर्माण/फिश लैडर के निर्माण हेतु दिशा–निर्देश समय–समय पर निर्गत किये जाते रहे है।

मत्स्य निरीक्षक
कार्यालय सहायक निदेशक मत्स्य
टिहरी गढ़वाल

सहायक निदेशक मत्स्य
टिहरी गढ़वाल।

Annexure R/2

ENVIRONMENTAL IMPACT ASSESSMENT

REPORT

POST-IMPOUNDMENT

FAUNAL SURVEY AND ANALYSIS

OF

TEHRI DAM ENVIRONS

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R. C. Sharma

PROF. RAMESH C. SHARMA
HOD, Environmental Sciences

CONTENTS

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Chapter- 01

INTRODUCTION

Human started building dams on the rivers a long time ago, and this way they have influenced natural flow regime. In 2,600 B.C., the first large dam was built in Sadd el Kafara in Egypt in the Garasi ravine facing Memphis. Kautilya's Arthshastra (450 B.C.) has references about the constructions of dams and canals for irrigation in India. European rivers have been subjected to modifications relatively early in the history of the continent. Roman engineers riveted rivers, constructed channels and harnessed water power as early as 100A.D. Hydropower, with rich water resources; and dam construction for generation of power and irrigation has been one of the oldest engineering practices of the country. Thousands of small and medium dams of varying heights in the past have contributed considerably to the agricultural economy of the country in addition to power for promoting economic developments

Hydroelectric power has an important role to play in meeting the Government of India's (GOI) ambitious goal to install an additional 100,000MW of generating capacity 2012. The bulk of India's undeveloped hydropower capacity is located in mountain states, one of which is Uttarakhand (Mac Donald, 2009). The Uttarakhand is newly carved out hill state of the country. It has vast potential for hydropower generation. But the vulnerability of the mountain ecosystem has warranted us for sustainable development of hydroenergy without causing much harm to the environment.

The Tehri Dam construction was planned in post independent era for giving boost to the development in terms of providing power, irrigation facilities, drinking water and tourism. The Tehri Dam, a multipurpose, rock and earth fill dam is located on the Bhagirathi River, about 1.5 km downstream its confluence with Bhilangana at Ganesh

Prayag, Tehri, Uttarakhand (Longitude 30º 22' 54'' N; Latitude 78º 29' 3'' E) at an altitude of 640 m above m.s.l. It is the highest (260.5 m above m.s.l) dam in Asia. The Tehri Dam Project encompasses two stages. The stage I comprised of Tehri Hydropower Plant (1,000 MW), which is commissioned in 2006 under the authority of Tehri Hydro Development Coorporation (THDC) India Ltd. The stage II comprised of Koteswar Dam (400MW) and Pumping Storage Plant (1,000 MW). Koteswar Dam has also been commisioned. The Tehri Dam construction has transformed the fluvial system of Bhagirathi and Bhilangana into a big reservoir (2.62 X 10^9 m^3). The extent of the reservoir at FSL is 42 km^2 with 44 km up Bhagirathi near Dharasu Bridge and 25 km up Bhilangana near Ghansali.

As a consequence of impoundment, major transformations in the fluvial morphology of Bhagirathi and Bhilangana rivers have been resulted. Biodiversity of the area has also been influenced. As, the biodiversity is one of the essential characteristics of any ecosystem for assessing its health, stability, and resilience, the initiative taken by the THDC India Ltd. under the direction of MoEF, Govt. of India for implementing the recommendations of Hanumanta Rao committee for getting the post impoundment study of the faunal survey for two annual cycles done is in the direction of suggesting measures for minimizing the impact of the Tehri Dam Project on the ecosystem and its biodiversity.

The Garhwal Himalayas present a unique ecosystem in the Indian subcontinent and drained by the major rivers Bhagirathi, Alaknanda, Bhilangana, Mandakini, Nandakini, Dhauliganga, Rishiganga, Nayar, Balganga, Asiganga,Pindar, Birahiganga, Tons and Yamuna. The climate ranges from hot, dry sub-tropical in the river valley to cool, moist temperate in the higher hills. The Garhwal Himalayas, due to its varied physiographic, temperature gradients and climate conditions, possesses very rich floral and faunal diversity. The Zoological Survey of India (Northern Regional Station, Dehradun) reported the assemblage of 2,200 vertebrates and invertebrates species from eight districts (Dehradun, Tehri, Pauri, Uttarkashi, Chamoli, Nainital, Almora and Pithoraghar) of Uttarakhand. A total of 340 faunal species including 260 invertebrate species and 80 species of vertebrates were reported from the Tehri Garhwal district (ZSI, 1995).

PRE-SUBMERGENCE SCENARIO

The Tehri Dam environs before submergence was in the form of a Valley drained by two major rivers-Bhagirathi and Bhilangana and many tributaries The Tehri town was located close to the confluence of these two rivers. The fluvial system of Bhagirathi and Bhilangana rivers was the metarhithronic zone (Sharma 1989).The zone was characterized by alternation of pools and riffles. Riffles were characterized by rapids ,cascades and low gradient riffles at many places .Bottom substrates consisted of small

boulders, gravel, pebbles and cobbles sized particles .Pools of the metarhithronic zone had various types of habitats(back water pools ,tench pools and dammed pools).A vast tract of land(42.5km^2) covering 91 villages with 22 villages along with the township of Tehri was fully submerged and 69 villages went under partial submergence due to creation of Tehri Dam Reservoir. The vegetation of the pre-submerge area was dominantly degraded secondary scrub (Uniyal *et al* 1995).Agriculture was the major occupation of inhabitants. The major crops of the area were wheat (*Triticum aestivum*), Paddy (*Oryza sativa*), Arhar (*Cajanus cajan*), Jhangora (*Echinochloa fumentacea*), Onion (*Allium cepa*) and Til (*Seasamum indicum*) under two major cropping seasons – Kharif and Rabi (BSI 2011).

Keeping in view, the importance of environmental protection and survival of flora and fauna, the Northern Regional Station, Dehradun of Zoological Society of India, was asked to undertake a faunal survey under the Environmental Impact Assessment study during a period of six months(May-October 1992) under five extensive faunistic surveys each of 10 days duration. A total of 282 faunal species including 159 species of invertebrates and 123 species of vertebrates were reported from the pre-impoundment area. There are few contributions available on the faunal survey in the pre-impoundment area of Tehri Dam environs. Sharma(1984) reported fish fauna form the Bhagirathi River. He reported 23 fish species of 11 genera and 4 families. *Culpisoma garua* Hora was reported for the first time from the Bhagirathi River. Singh *et al* (1987) reported geographical distribution of ichthyofauna of Garhwal Himalaya form various rivers.Sharma(1992) reported on the impact of ecological changes on fishes of Ganga Basin in Garhwal Himalaya.

Bhattacharya and Goel(1992) reported 462 plants under 99 families from the area of Tehri Dam before impoundment. They reported 378 dicots (under 86 families), 73monocots (under 13 families),4 gymnosperms and 7 pteridophytes. Botanical Survey of India(Northen Regional Centre,Dehradun) undertook floristic survey of the submergible area during August-October 1992 and April 1993,which was published by MoEF, Govt. of India under the title" Plant Diversity in the Tehri Dam Submersible Area" in 1999

The Hamumanta Rao Committee (HRC) in 1998 recommended a comprehensive multidisplinary study (covering Botany ,Zoology, Water Quality, Micro-climate and their Inter-relationship) to identify in detail the impact of the Tehri Dam Project on the faunae, florae biodiversity of the region for atleast two complete annual cycles, so that recommendations can be made for minimizing the adverse impact of impoundment on the faunal and floral diversity.

OBJECTIVES:

Keeping in view the compliance of the recommendations of the Hanumanta Rao Committee's recommendations, the present work on the "Post impoundment Faunal Survey and Analysis of Tehri Dam Environs" was undertaken for a period of more than two annual cycles so that recommendations can be made for minimizing the adverse impact of impoundment on faunal diversity. The major objectives of the present study are given below:

- Documentation of current status of faunal diversity in Tehri Dam environs after in-depth survey in various seasons for two annual cycles.
- Assessment of post –impoundment faunal changes and faunal composition caused due to conversion of lotic environment into lentic and semi lentic environment.
- Impact on fauna (depletion in abundance or loss) due to developmental and construction activities.
- Assessment of the impact of Tehri Dam Project on the ecosystem function and habitat loss.
- Comparison of pre-impoundment and post impoundment faunal composition of the Tehri Dam environs.
- Identifying the activities which are detrimental to faunal diversity.
- Assessment of corrective measures taken and further need for minimizing the impact of impoundment on ecosystem function and faunal diversity.
- Recommendations for conservation and management of faunal diversity of Tehri Dam environs.

Chapter: 02
THE STUDY AREA

The study area is located in Tehri-Garhwal district of Uttarakhand state (Fig. 2.1). It includes the reservoir (42.5 km^2 area) created by the construction of Tehri Dam and covers a significant portion of Bhagirathi and Bhilangana Valley. Its northern limit in Bhagirathi Valley ends at Dharasu, where as in the Bhilangana Valley, it is extended upto Ghansali, close to the confluence of Balganga with the Bhilangana River. The downstream area of Tehri Dam of Bhagirathi Valley upto Koteshwar Dam in south is also a part of the study area. The Bhagirathi and Bhilangana were the two major watersheds comprising 13 sub-watersheds before impoundments. Tehri Dam was constructed at an elevation of 640 m above m.s.l. at the river bed. Thus, the reservoir area is extended upto 835 m above m.s.l including the maximum reservoir level. The study area is surrounded by mountains as high as 1,000 – 2,000 m m.s.l on three sides.

GEOLOGY:

Geologically, Tehri Dam area is located in the lesser Garhwal Himalayas. The geological map of the area has been presented in the Fig. 2.2. The mountains of this region are of recent geological origin. The terrain of the area is undulating rocky with moderate slopes. The Bhagirathi Valley represents a thick succession of quartzite, slate and limestone. The Bhilangana Valley comprises low to medium-grained, metaphoric like gneiss, quartzite, kind of schists, phyllite, marble's lenticular band, ephidiorite and amphibolites owing to its typical rock types,it is categorized as Bhilangana Formation between Panwali Thrust and Thayeli Thrust, with the general composition of streaky porphyroblastic gneisis quartzite ,schists, crystalline limestone, marbles, amphibolites and carbonaceous phyllite. The Calc-zone mainly between Pratapnagar and Tehri in Bhagirathi Valley falls in Kotga Banali Group which represents a thick succession of quartizite,slate and limestone. The

dam area is bounded on the south by South Almora Thrust (SAT) and north in Bhilangana Valley by Bhatwari Thrust and Bhagirathi Valley by Munsiari Thrust (MCT),while North Almora Thrust(NAT) passes in between SAT and MCT. The major lithunits of this area are Krol Nappe, Almora Nappe and Inner Lesser Himalaya unit. The hills above the dam site are also constituted by highly deformed and soft rocks. The Tehri Dam is seated on a single such tectonic block.

CLIMATE:

The Bhagirathi and Bhilangana Valley has sub-tropical climate with four major seasons- Autumn (September-October), Winter (November-February), Summer (March-June), Monsoon (July-August).Summer temperatures vary with altitude from a minimum of 10^0C to a maximum of 35^0C.However, the average day temperature remains between 20^0C -30^0C. Temperatures fall rapidly during the night. Winter temperature ranges from 3^0C to 15^0C during day time. However, night temperatures during winters are extremely low. Snowfall is common at the higher reaches only during winters.

VEGETATION:

The Tehri Dam environs was described by Atkinson(1882) as "A very hot place devoid of trees and surrounded by bare hills". High temperature and water scavenging Pine at the top has created dry habitat with open slopes under the rein of scrub jungle and scattered occurrence of trees. General vegetation with dominance of weeds, abundance of sub-tropical scrubby elements and absence of endemics. The entire Valley of Bhagirathi and Bhilangana presents common sight with pine at top, scrub jungles on mid-slopes and Reservoir slopes dotted with scattered villages and cultivated terraces along gads (rivulets). Forests of Chir(*Pinus roxburghii*) form the signature forests type throughout the Valley. Vertically extended from upper reservoir level to hill top. Occasional exposed gaps in the canopy are occupied by shrubs. The floor of the forest is usually grassy covered with thick mat of pine needles with sporadic ground flora (BSI 2011)

FRESHWATER HABITAT ENVIRONMENT:

Freshwater habitats in the Tehri Dam environs have two major watersheds of Bhagirathi and Bhilangana with 13 sub-watersheds of snow fed and spring fed rivers, streams and rivulets. These upland freshwater habitats are fragile and vulnerable to any anthropogenic and natural pressure.

Freshwater environments are sensitive to environmental stresses. Extremes of temperatures discharge with related changes in depth or velocity, turbidity affecting light penetration and deposition of materials, low or high dissolved oxygen concentration and

movement of unstable substrate, all contribute to the environmental stresses of life in freshwater (Hellawell, 1986).

The Tehri Dam is ubiquitous structure on flowing waters of Bhagirathi and Bhilangana that has altered flow regimes, temperature, hydraulics, stability and composition of bottom substrates, channel morphology, riparian vegetation, sediment load and as a consequence, the structure of benthic macro-invertebrate and fish communities. The Tehri Dam construction has converted the lotic ecosystem of Bhagirathi River upstream 44 km and Bhilangana River upstream 24 km into a big reservoir.

The mean seasonal variations in physico-chemical environmental valuables of the pre-impoundment and post-impoundment freshwater habitat environments has been presented in Table 2.1 and Table 2.2.A drastic change in the geomorphology of the fluvial system of Bhagirathi and Bhilangana was recorded due to impoundment. Structure of rapids, runs, riffles, cascades, was converted into a deep stagnant and semi-stagnant pool of reservoir. Upstream extreme of reservoir was having the characteristics of a hill stream at Dharasu in Bhagirathi, and Sarans in Balganga River. Water velocity of these rivers was drastically reduced and the hydromedian depth (HMD) was abnormally increased. The downstream stretch of Bhagirathi ecosystem between Tehri Dam and Koteshwar Dam is also degraded due to Tehri Dam construction.

Table 2.1. Mean seasonal variations in the physico-chemical environmental variables in the pre-impoundment freshwater habitats of Tehri Dam area (Sharma 1991)

Environmental Variables	Autumn (Sep-Oct)	Winter (Nov-Feb)	Summer (March-Jun)	Monsoon (Jul-Aug)
Air temperature (^{0}C)	23.7 ± 3.5	15.9 ± 1.4	23.7 ± 3.8	27.9 ± 0.5
Water temperature (^{0}C)	15.4 ± 1.2	11.3 ± 0.5	17.5 ± 2.0	16.9 ± 0.3
Water current (m sec^{-1})	2.44 ± 0.29	1.64 ± 0.72	1.66 ± 0.89	3.22 ± 0.10
HMD (m)	1.53 ± 0.13	0.65 ± 0.19	1.02 ± 0.52	2.37 ± 0.38
Turbidity (NTU)	12.25 ± 8.13	7.13 ± 4.15	84.50 ± 82.24	633.25 ± 189.15
Transparency (m)	0.40 ± 0.39	0.62 ± 0.15	0.20 ± 0.11	0.04 ± 0.03
Conductivity (μ S cm^{-1})	0.14 ± 0.03	0.13 ± 0.05	0.15 ± 0.04	0.05 ± 0.03
TDS (mg l^{-1})	20.50 ± 2.12	8.25 ± 3.71	33.25 ± 21.75	87.00 ± 2.83
Dissolved Oxygen (mgl^{-1})	10.24 ± 0.36	11.17 ± 0.72	10.54 ± 0.79	9.66 ± 0.23
Free CO_2 (mg l^{-1})	2.09 ± 0.16	1.63 ± 0.40	1.79 ± 0.25	2.50 ± 0.01
pH	7.50 ± 0.04	7.33 ± 0.10	7.56 ± 0.10	7.79 ± 0.06
Hardness (mg l^{-1})	63.25 ± 20.15	72.0 ± 7.0	57.25 ± 4.62	37.50 ± 3.54
Alkalinity (mg l^{-1})	45.75 ± 8.84	52.50 ± 2.86	51.63 ± 4.48	44.00 ± 5.66
Chlorides (mg l^{-1})	2.88 ± 0.28	2.24 ± 0.25	2.38 ± 0.12	3.54 ± 0.22
Nitrates (mg 1^{-1})	0.46 ± 0.04	0.18 ± 0.14	0.41 ± 0.16	0.79 ± 0.04
Phosphates (mg l^{-1})	0.09 ± 0.12	0.10 ± 0.09	0.33 ± 0.49	0.56 ± 0.30

Table 2.2 Mean seasonal variations in the physico-chemical environmental variables in the post-impoundment freshwater habitats of Tehri Dam Environs

Environmental Variables	Autumn (Sep-Oct)	Winter (Nov-Feb)	Summer (March-Jun)	Monsoon (Jul-Aug)
Air temperature (^{0}C)	23.9 ± 3.3	16.2 ± 1.2	23.7 ± 3.8	28.0 ± 0.7
Water temperature (^{0}C)	15.5 ± 1.1	12.1 ± 1.1	17.8 ± 2.1	17.1 ± 0.2
Water current (m sec^{-1})	2.56 ± 0.44	0.97 ± 0.41	2.53 ± 1.05	4.20 ± 0.21
HMD (m)	1.62 ± 0.26	0.55 ± 0.19	0.97 ± 0.42	2.19 ± 0.28
Turbidity (NTU)	53.25 ± 23.69	41.21 ± 32.52	96.38 ± 89.15	663.25 ± 215.31
Transparency (m)	0.13 ± 0.01	0.14 ± 0.08	0.18 ± 0.12	0.01 ± 0.01
Conductivity (μ S cm^{-1})	0.14 ± 0.04	0.15 ± 0.03	0.16 ± 0.05	0.07 ± 0.02
TDS (mg l^{-1})	37.50 ± 3.54	25.42 ± 2.79	38.50 ± 20.29	100.0 ± 18.38
Dissolved Oxygen (mgl^{-1})	9.00 ± 0.32	10.18 ± 0.52	8.90 ± 0.36	7.23 ± 0.13
Free CO_2 (mg l^{-1})	3.97 ± 0.31	3.35 ± 0.41	3.73 ± 0.57	4.52 ± 0.16
pH	7.73 ± 0.11	7.45 ± 0.08	7.62 ± 0.08	7.84 ± 0.01
Hardness (mg l^{-1})	71.00 ± 16.97	75.25 ± 12.42	61.25 ± 7.64	45.75 ± 1.77
Alkalinity (mg l^{-1})	53.75 ± 5.30	55.17 ± 4.18	56.25 ± 5.66	45.50 ± 4.24
Chlorides (mg l^{-1})	3.24 ± 0.30	2.66 ± 0.49	3.08 ± 0.40	4.24 ± 0.05
Nitrates (mg 1^{-1})	0.40 ± 0.32	0.27 ± 0.09	0.51 ± 0.08	0.85 ± 0.08
Phosphates (mg l^{-1})	0.20 ± 0.08	0.18 ± 0.09	0.54 ± 0.61	0.84 0.11

- Water velocity (m.sec^{-1}) was drastically reduced in the Reservoir
- HMD (m) has increased many folds in the Reservoir (0.65 m to 185 m)

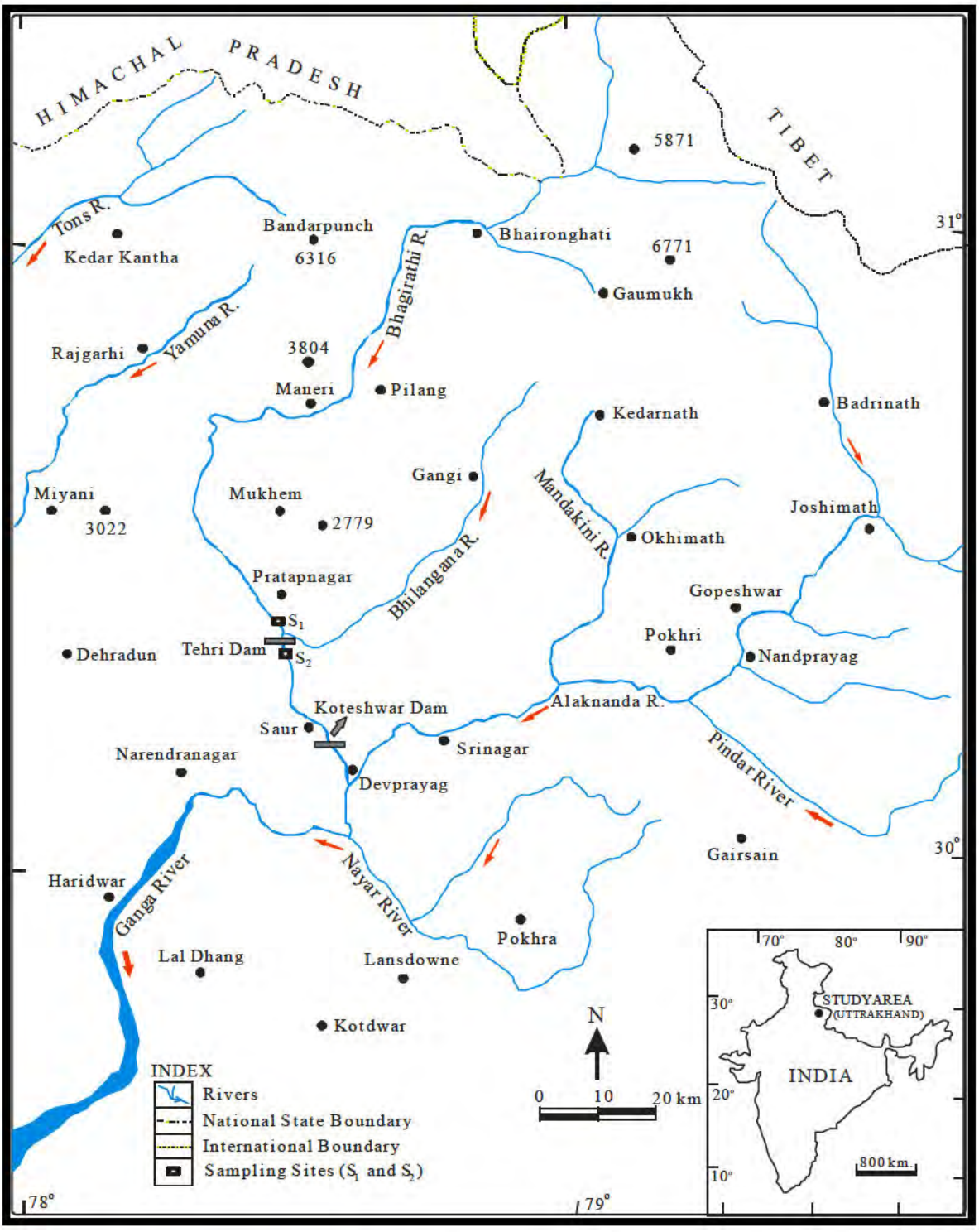


Fig. 2.1. Location map of the study area showing the location of the Tehri Dam

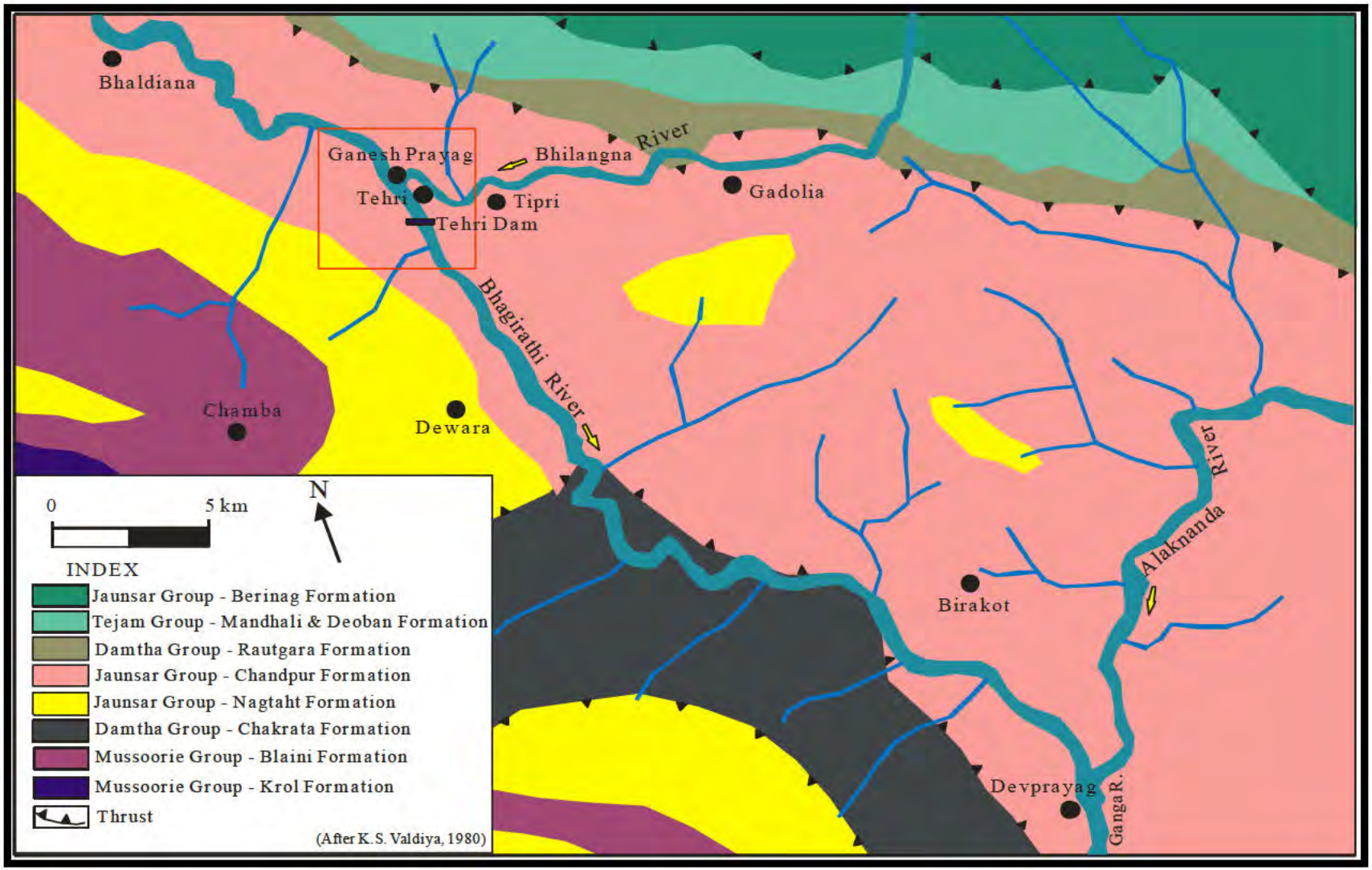


Fig. 2.2. Geological map of the area of Tehri Dam Project

Chapter - 03
METHODOLOGY

The present study on the post-impoundment faunal survey of Tehri Dam environs was undertaken for two annual cycles (2009-2011). Complying the implementation of the recommendations of Hanumanta Rao Committee, an extensive seasonal faunistic survey of the entire Tehri Dam environs was undertaken. Four major seasons Autumn (September-October), Winter (November-February), Summer (March-June), Monsoon (July-August) prevalent in the area were identified for the study.

3.1 SAMPLING SITES:

A total of six sampling sites (SA_1-SA_6) were identified for the survey of freshwater faunal diversity in the study area for covering the every kind of freshwater habitat of the Tehri Dam environs (Table 3.1). However, a total of eight sampling sites (ST_1-ST_8) were identified for collection of data related with terrestrial biodiversity (Invertebrates, Amphibians, Reptiles, Birds and Mammals) inhabiting the terrestrial habitats including the newly developed forest patches and Botanical Garden in the Tehri Dam environs. The details of transect sites, their geographical locations, altitude and the type of habitats, and vegetation cover are given in the Table 3.2

3.2 COLLECTION OF FRESHWATER FAUNA:

Freshwater faunal diversity of Tehri Dam environs is represented by zooplankton, aquatic insects and fish. Collection and analysis of freshwater faunal diversity was made following the methods outlined in Wetzel and Likens (1991) and APHA (1998).

For collection of zooplankton, a ring type terricot net (24 mesh/mm^2) filled with mouthed bottle (500 ml) was kept in the flowing water for an hour to enable the water

to flow through it. Few drops of formalin were added to preserve the contents. The contents were centrifuged at 1500 rpm for 10 minutes period. The sediment of the centrifuge tube was made to concentrate and was used for enumeration of population. A plankton chamber of 0.5 ml capacity was used for counting of plankton under the Inverted Compound Microscope.

The freshwater insects and other freshwater benthic animal life were collected by enclosing one square meter of river bottom with square meshed cloth. The bottom stones, gravel, and sand were upturned to dislodge the aquatic life. Each animal was then brush picked and preserved in 4% formalin.

For the collection of fishes, cast net of mesh size 0.5cm with heavy sinkers and scoop net (mesh size 0.25mm) were employed. The cast net was operated 20-25 times at a time at each sampling site, drag net were also used to enclose the sampling area. Similarly the scoop net was also fixed in the shallow zone of the river/reservoir for an hour. Representative fishes were collected in the field after preserving them in 10% formalin. Experimental fishing was also undertaken in diverse habitats for assessing the fish composition after impoundment, for comparing with the reference studies undertaken by Sharma (1991).

For the identification of freshwater faunal components, the standard references like Day (1889), Smith (1950), Pennack (1978), Ward and Whipple (1992), and APHA(1998), were consulted.

Geographical locations (longitude ,latitude), altitude (m.s.l.) of the sampling sites were determined with the help of Megellan Trail Blazer XL GPS system.The ecological status of the faunal species was carried out according to International Union for the Conservation of Nature and Natural Resources (IUCN Red List 2011).

3.3 COLLECTION OF BUTTERFLIES AND OTHER TERRESTRIAL INSECTS:

The specimens of butterflies were collected with the help of insect collection net(circumference 93cm,handle length 87cm,bag depth 77cm) by sweeping method during day time. Adults collected were killed in a killing bottle by using liquid Ethyl acetate carbon tetrachloride. All the specimens collected from various localities were pinned with different sizes of entomological pins (38mm×0.40mm; 38mm×0.55mm) and stretching in spreading board boxes (40cm×30cm×10cm).The specimens were identified with the help of published literature.

3.4 SURVEY OF AVIFAUNA:

Survey of avifauna was conducted during different seasons for two annual cycles. Keeping in the view the comparatively large size of the study area, Stratified Random Sampling Technique was followed for studying the birds of Post-impoundment Tehri Dam environs, which involved the division of sites into different strata, based on vegetation type and habitats. Birds were observed with aid of 10 × 50 super Zenith prismatic field binoculars. Field identifications were carried out with the help of various field guides (Ali and Ripley 1983; Grimmett et.al. 1999; Kazmierczak 2000). The data recorded in each survey from different habitat types was kept separate and analyzed for relative abundance on the basis of relative frequency scale of occurrence depending upon the number of sightings, as followed by Mc Kinnon and Philips (1993) as: very common – sighted more than 10 times; common – sighted more seven to nine times; uncommon – sighted more three to six times; and rare – sighted once or twice.

Residential status of birds was also worked out and different status categories like resident, summer visitor and summer influx were assigned on the basis of presence or absence of birds in Tehri Dam environs. The bird that showed irregular trend of sighting and population fluctuations (non-seasonal) was placed under residents with local movement category.

3.5 COLLECTION OF AMPHIBIANS:

Collection of amphibians was made from different habitats – pools, streams, river banks, periphery of the reservoir, under big bolulders, stones, under decaying logs, vicinity of shaded mountain streams, open fields, cultivated paddy fields, stagnant water of reservoir and grasslands. They were photographed and were fixed in 8% formaldehyde solution. After fixation for two-three days, the specimen were washed in water thoroughly and were preserved 90% alcohol.

3.6 SURVEY OF REPTILES AND MAMMALS:

Mammals were observed with the help of 10×50 Super Zeinth prismatic field binoculars. The signs of pellets, claw marks, pug marks were also used for collecting data. Informations were also collected by interacting with the people of the area.

Reptiles were also surveyed by visiting diverse habitats, and these were photographed. Identification for the same was made with the help of the standard references.

Table 3.1 : Sampling sites and their physical attributes for collection of data related with freshwater faunal diversity

Site	Name of Transect	Name of Site	Altitude in m (above m.s.l.)	Longitude	Latitude	Bottom substrate type	Habitat Types
SA_1	Balganga Valley	Sarans upper limit of Reservoir	840	30^0 26′ 49″ N	78^0 38′ 24″E	Boulder, cobbles, gravels	Rapids, pools, runs, riffles
SA_2	Bhilangana Valley	Pilakhi	625	30^0 41′ 10″N	78^0 52′ 18″E	Sand silt, pebbles	Deep pools, semi-stagnant water
SA_3	Bhagirathi Valley	Dharasu Bridge Upper limit of Reservoir	830	30^0 61′ 38″N	78^0 31′ 28″E	Boulders, cobbles, pebbles ,gravels, sand	Runs, rapids, riffles, shallow pools
SA_4	Bhagirathi valley	Dobra village	805	30^0 44′ 12″N	78^0 43′ 18″E	Silt, pebbles, sand	Deep pools , stagnant, semi-Stagnant water
SA_5	Bhagirathi Valley (Down stream to Tehri Dam)	Zero bridge	589	30^0 12′ 10″N	78^0 35′ 49″E	Boulder, stones, pebbles, gravel	Runs, riffles, rapids
SA_6	Bhagirathi Valley (Down stream to Tehri Dam)	Koteshwar	525	30^0 26′ 05″N	78^0 49″38′ E	Pebbles, sand, gravels	Deep pools, rapids, riffles

Table 3.2 : Sampling sites and their physical attributes for collection of data related with the terrestrial faunal diversity

Site No.	Name of Transect	Name of site	Altitude in m (above m.s.l.)	Longitude	Latitude	Habitat types Vegetation
ST_1	Balganga Valley	Sarans village	858	30^0 26′ 36" N	78^0 38′ 16" E	Scattered forest patch, wide Balganga valley
ST_2	Bhilangana Valley	Pilakhi	838	30^0 24′ 58" N	78^0 38′ 11" E	Cultivated fields, forest, scrub at the higher reaches
ST_3	Bhilangana Bhagirathi Valley	Tippari	900	30^0 22′ 42" N	78^0 33′ 37" E	Dense forest, pine trees
ST_4	Bhagirathi Valley	Dharasu	848	30^0 36′ 59" N	78^0 18′ 38" E	Wide valley with scattered vegetation ,spring fed streams
ST_5	Bhagirathi Valley	Kamand village	845	30^0 28′ 2" N	78^0 22′ 03" E	Patch of pine trees, good forest cover
ST_6	Bhagirathi Valley	Botanical Garden	900	30^0 26′ 12" N	78^0 39′ 15" E	Newly created vegetation, new plantations
ST_7	Bhagirathi Valley (Down stream to Tehri Dam)	Kyari Village	590	30^0 30′ 10" N	78^0 48′ 02" E	Fair uniform vegetation
ST_8	Bhagirathi Valley (Down stream to Koteshwar Dam)	Sain Village	615	30^0 25′ 03" N	78^0 50′ 07" E	Forest patch at the higher reaches

Collection of samples near Koteshwar

Collection of freshwater inveretebrates

Interaction with the people

Collection of samples from the Tehri Dam Reservoir

Weighing of fish samples

Experimental fishing

Chapter 04
FRESH WATER INVERTEBRATE DIVERSITY

Fresh water invertebrate diversity of Tehri Dam environs is represented by zooplankton (Protozoa, Rotifera, Copepoda and Cladocera) macrozoobenthos (Aquatic insects, Annelida and Mollusca). These faunal components are present at different trophic levels of the freshwater ecosystem.The zooplankton and macroinvertebrates (macrozoobenthos) represent the second trophic level in the Bhagirathi and Bhilangana rivers(pre impoundment environs).The freshwater fluvial ecosystem of Bhagirathi and Bhilangana provides a rich habitats in terms of rapids, riffles and runs for benthic organisims, as stones,gravels,pebbles and boulders of various sizes offer favourable substrata for these organisims.However, stray specimens of zooplankton were present in the pre-impounment rapids and riffles of Tehri Dam environs, while a rich populations of zooplankton were present in pools and side water and back waters.

A considerable work has been done on the impact of impoundments on freshwater faunal diversity. Some of the important contributions on the faunal diversity of freshwater of pre-impoundment habitats of Tehri Dam Environs are also available (Sharma and Singh 1980, Sharma 1984, Sharma 1986,Sharma 1991,1995,2005). However, for comparison, with the post impoundment study, the pre impoundment study of Sharma (1991) was taken as reference.

ZOOPLANKTON:

Zooplanktons are the important constituent of the food chain in aquatic ecosystem. Zooplanktons feed on the phytoplankton, bacteria, aggregates of detritus and micro-organisms as well as other zooplankton species. Almost all freshwater fish feed on zooplankton at some stage in their life history. Zooplankton species succession and

tolerances to various abiotic and biotic factors.Despite the fact that the factors such as predation and compeletion may alternately induce changes in zooplankton communities favouring one species over another. The seasonal fluctuations of zooplankton population are a well known phenomenon.

The zooplanktons are the important constituent of the Tehri Dam environs. The major components of zooplankton of Tehri Dam environs are the members of Protozoa, Rotifera, Cladocera and Copepoda. Considerable increase in the population of zooplankton in newly formed reservoir was recorded than the zooplankton present in pre-impoundment environment. A comparative mean seasonal qualitative distribution and abundance of zooplankton in pre-impoundment and post-impoundment environments have been presented Table 4.1.Seasonal variations of zooplankton have revealed that the maximum density was recorded during winter season and minimum during monsoon season

PROTOZOA

An in-depth study on the diversity of zooplankton of the reservoir for two- annual cycles revealed that a total of 19 genera of Protozoa were recorded. Protozoan constituted the major zooplankton diversity (Table 4.1). The protozoans were observed dominantly during the months of February to May and September to January. They abode in the side pools, having stones, pebbles of variable size, low water current, pebbles of variable size, low water current and high transparency. Amongst Protozoans, majority of these were Rhizopods, which crawl on stones with the help of temporary walking organs, the pseudopodia. Only few celliates have been observed in the Tehri Dam environs. They are either free living or attach themselves to the stones.

Abundance of Protozoans was very poor in rapids and riffles of pre-impoundment habitats of Bhagirathi and Bhilangana, as these Protozoans cannot withstand the fast water current.

The specific role of Protozoan plankton in the freshwater ecosystem is poorly understood. It is considered that temperature, dissolved Oxygen and the characteristics of the substratum influence the distribution and productivity of Protozoans. Most of the Rhizopods need slimy substrate.Cilliate Protozoans are important in the metabolisim of dissolved and particular organic matter of sewage treatment facilities and organically polluted streams (Cairns 1974). Most of the common Rhizopods like *Diffugia limnetica* increases in their abundance in early summer and attain maximum density in late summer. These Rhizopods undergo encystment and on the return of favourable conditions, they reappear.

Normally, the ciliate Protozoans do not dominate the freshwaters specially hillstreams, because of fast current and the absence of influsoria, the food of these free living

cilliates. As a consequence of impoundments of the Bhagirathi and Bhiangana rivers. Some mild pollution has been caused due to submergence of organic matter and the nearby human habitations in periphery of Reservoir which are dumping domestic wastes and the faecal matters of domestic cattle.

A considerable increase in the density of zooplankton (50.50 ± 7.78 units l^{-1}) in the post-impoundment habitat of Tehri Dam environs was recorded than the density recorded (35.0 ± 4.24 units l^{-1}) in the pre impoundment environment. The Protozoans increased from 18.50± 0.71units l^{-1} to 21.0 ± 1.41 units l^{-1}.

ROTIFERA

Another important component of zooplankton is Rotifera. Overall 12 genera of Rotifera have been recorded from the diverse habitats of Tehri Dam environs. Out of twelve genera of Rotifera, *Keretella spp; Brachionus spp. and Asplanchna* spp. were common in most of the freshwater habitats .The abundance of Rotifera has been recorded during summer season (March-June). The present study has indicated that the temperature, food quality and quantity are dominant factors in the regulation of rotifera population, reproduction rate and population succession. The abundance of Rotifera in post impoundment environs increased from 5.50± 0.71units l^{-1} to 10.0 ± 2.3 Units l^{-1} from pre-impoundment.

CLADOCERA

Six genera of Cladocera have been reported from all the diverse habitats of Tehri Dam environs. The most common Cladoceran was *Daphnia* spp. *Monia* spp. was also common in the area. The populations of Cladocerans were abundant during summers and winters. However, minimum abundance and absence of Cladocera was recorded in monsoon season (July –August and upto September). The annual mean density of Cladocera increased from 2.2 ± 0.34Units l^{-1} to 11.50 ± 3.54 Units l^{-1} after impoundment.

COPEPODA

Only three genera of Copepoda have been found to inhabit Tehri Dam environs. The species of *Cyclops* were common in the diverse habitats of Tehri Dam environs. *Diaptomus spp.* was also recorded in most of the sampling sites. The populations of Copepoda increased considerably after impoundment. It may be due to warmer climate and deposition of organic matter in the Reservoir having stagnant or semi stagnant water.

The populations of Copepoda is also interrupted by diapauses that persists from one to several months.There are various periods of diapauses, either at egg stage or in the copepod stages with or without encyctment upon sediments (Wierzbicks 1996)

Adult copepods frequently predominate in stagnant or semi stagnant water of the Tehri Dam Reservoir. Adults feed heavily on rotifers and in absence of rotifers,they feed on their own naupli during winter season.Further, the populations of *Cyclops spp*. and *Diaptomus spp.* have inter relationships with each other , as adult *Cyclops* spp. prey heavily on Naupli of this species. Hence, *Cyclops spp*. could not occur in abundance in the Tehri Dam environs.

MACROZOOBENTHOS

Macrozoobenthos are the most important valued ecosystem component of the freshwater ecosystem of Bhagirathi and Bhilangna rivers. These important biotic components are bottom dwellers and are secondary producers. These are present at the second trophic level. These were represented by the taxa of Stoneflies (Plecoptera), May flies (Ephemeroptera), Dragonfiles (Odonata), Caddisflies (Trichoptera), two winged flies (Diptera), bugs (Hemiptera) and beetles (Coleoptera) dwelling at the bottom substrates. In addition to these aquatic insects, few members of Annelida and Molllusca were also present under macrozobenthos.

The abundance of aquatic insects is related to the presence of organic matter, bottom substrates and macrophytes. Cummins and Meritt(1996) divided the aquatic insects into five braod categories on the basis of trophic mechanisims and food types mainly shredders (Plecoptera, Trichoptera), collectors (Ephemeroptera, Trichoptera, Hemiptera) and scrappers (Ephemeroptera, Trichoptera, Hemiptera) predators (Odonata, Plecoptera, Trichoptera ,Hemiptera) and macrophytes piercers (Trichoptera).

Annual mean density (ind.m^{-2}) of macrozoobenthos was significantly reduced in the post impoundment habitats from the annual mean pre impoundment density (Sharma 1991) of macrozoobenthos (Fig. 4.2).

EPHEMEROPTERA (May flies)

Twenty genera of Ephemeroptera (May flies) were reported from the study area. The larvae and nymphs of Ephemeroptera were common in the pre-impoundment habitats of Bhagirathi and Bhilangana. Ephemeropterans were represented by the taxa of *Heptagenia, Leptophlebia , Caenis , Cloeon, Baetis, Centroptilum, Ephemerella, Ecdynurus, Siphlonurida, Rhithrogenea, Hexagenia, Ephoron, Paraleptophlebia, Isonychia, Potaminthus, Cinygmula, Cinygma, Ametropus, Chroterpes* and *Stenonema.* However, few taxa were missing in the modified habitat of main reservoir. *Ecdynurus*

and *Siphalonurus* were disappeared from the post – impoundment area. However, these were present at the extreme upper limit of the reservoir in the Bhagirathi, Bhilangana and Balganga rivers. The density of the members of Ephemeroptera was drastically influenced by impoundment. It reduced from 1,525 ind.m^{-2} to 325 ind.m^{-2} after impoundment.The density /abundance of Ephemeroptera was found to be maximum in Febraury and minimum in August during the period of observations for two annual cycles. Seasonally , it was found to be maximum in winter (574.87 m^{-2} in pre impoundment habitats,193.74 m^{-2} in post impoundment habitats) and minimum (37.5 m^{-2} in pre impoundment and 6.25 m^{-2} in post impoundment habitats).

TRICHOPTERA (Caddis flies)

Trichoptera was found to be the second most abundant component among all the benthic insects in the Tehri Dam environs. Trichoptera was represented by 11 genera. The important genera representing Trichoptera were *Hydropsyche, Rhyacophila, Glossosoma, Hydroptila, Limnephilus, Brachycentrus, Philopotamus, Polycentrophus and Trianoedis*. However, few species of *Hydropsyche* and *Glossosoma* disappeared from few of the sampling sites of post impoundment habitats of Tehri Dam environs. The density of Trichoptera reduced from 350 m^{-2} to 100 m^{-2} during the period of observations of two annual cycles. Seasonally, it was maximum (115.62 ind.m^{-2}during pre impoundment and 38.37 ind.m^{-2} in post impoundment habitats) in winter and very few or completely absent Trichoptera were there at few sampling sites in monsoon season.

DIPTERA (Two-winged flies)

Diptera was represented by 5 taxa (*Psychoda, Antocha, Culex, Symbiocladius, Pentaneura, Tendipes* and *Tabanus*) from the Tehri Dam environs. Density of Diptera reduced from 325 ind.m^{-2} to 100 ind.m^{-2} in post impoundments habitats .Seasonally it was found to be maximum (81.25 ind.m^2 in pre impoundments and 68.75 ind.m^{-2} in post impoundments) in winter and minimum in monsoon season.

COLEOPTERA (Beetles)

Coleoptera was represented by 11 genera(*Ochihebius, Dineutus, Amphizoa, Agabinus, Peltodytes, Gyrinus, Hydrophilus, Hydracna, Prephynus, Psephanus and Stenolophus*) in the Tehri Dam environs. A drastic change in the population of few species (*Dineutus, Amphizoa, Peltodytes*) were recorded after impoundment. Density of Coleopteran reduced from175 ind.m^{-2} to 50 ind.m^{-2} during the period of observations. Seasonally, it was found to be maximum in summer and few individuals of coleoptera were found in monsoon and autumn seasons.\

PLECOPTERA (Stoneflies)

Plecoptera (Stoneflies) was represented by nymphs and larvae of seven genera of *Brachyptera, Acroneuria, Isoperla, Perla, Atoperta, Nemoura and Perinella* in the Tehri Dam environs. Density of Plecoptera reduced from 75 ind.m^{-2} to 25 ind. m^{-2} after impoundment. Seasonally, it was found to be maximum in winters and it was very few individuals or completely absent in most of the sites during monsoon and summers.

HEMIPTERA (Bugs)

Hemiptera was represented by 6 genera (*Corexa, Hesperocorixa , Ranetis, Belostoma and Micronecta)* in the Tehri Dam environs. Density of Hemiptera was found to be maximum (100 ind. m^{-2}) in April and totally absent in July- August. Seasonally, it was found to be maximum in winter and minimum or even absent in monsoon seasons.

ODONATA (Dragon flies)

Odonata was represented by 5 genera (*Hagenius* , M*acromia, Agrion , Argea and Ischmura*). Seasonally, it was found to be maximum in winters and minimum or complete absent in most of the sampling sites during other seasons.

ANNELIDA

Only one genus (*Glossaphonia*) was commonly present in the Tehri Dam environs representing the Annelida.

MOLLUSCA

Mollusca was mainly represented by Gastropoda. 3 genera (*Lymnea , Parathelpusa, Limax*) represented the Mollusca from the Tehri Dam environs. The Mollusca reduced drastically from 50 ind. m^{-2} to 25 ind m^{-2} after impoundment.

IMPACT OF IMPOUNDMENT ON THE PROFILE OF FRESHWATER BIODIVERSITY

An overall impact of impoundment on the profile of freshwater biodiversity on the Tehri Dam environs has been presented in Fig 4.3. Pre-impoundment study (Sharma, 1991) was taken as reference. Periphyton, phytoplankton and zooplankton percentage increased in the post-impoundment from pre-impoundment habitats. A substantive depression in the population of zoobenthos was recorded from the population recorded in the pre-impoundment study. It reduced from 51% to 30 % (Fig. 4.3).

Aquatic macrozoobenthos are extremely diverse group of animals. Macrozoobenthos species are differently sensitive to any biotic and abiotic factors in their environment.

They have been used as an indicator of the condition of an aquatic ecosystem. They play a major role in herbivory and the deposition of organic nutrient, and therefore, affect nutrient availability. They have relatively long life cycles compared to zooplankton.

Nymphs of may flies (Ephemeroptera), larvae of caddis flies (Tricoptera), and larva of stone flies (Pleccoptera) can survive only in the swift, cool, and well oxygenated water. Thus, these components reduced drastically in their population in the post-impoundment habitat of the reservoir. The structure and composition of bottom substrata are one of the main factors controlling the composition of macro-invertebrates. The bottom substrates in the pre impoundment rivers ranged from small pebbles to big boulders. The post impoundment habitats were silted. Cobble habitat without silt generally supports higher taxonomic diversity than do silted areas (Pollard and Reed 2004, Chakraboty and Das 2005). Generally, as the size of the stone increases, the diversity of macroinvertebrates also get increased but these bottom dwelling organisms fail to avail shelter under very big boulders and struggle for their survival due to availability of suitable niche. Therefore, the reduction of density and diversity of macrozoobenthos in the post impoundment habitats may be understandable. The habitat complexity and substrate stability seem to be the important factors in determining the distribution of macrozoobenthos, especially aquatic insects.

Benthic macroinvertebrates offer many advantage as biomonitors (Rosenberg and Resh1993). Firstly, they are ubiquitous, as they are affected by environmental perturbations in aquatic systems. Secondly, the large volume of species offers spectrum of responses to environmental stress. Thirdly, their essentially sedentary nature allows effective spatial analysis of pollutant or disturbance effects. Fourthly, they have long life cycles compared to other groups, which allows detection of temporal changes caused by perturbations. Additionally, different groups of macrozoobenthos have different tolerance to pollution, which means they can serve as useful indicators of water quality.

The presence of fine materials appears to be major factor correlated with the distribution of macroinvertebrates. Mayfly, stonefly, and caddisfly larvae were most adversely affected, because these aquatic insects usually exhibit a relatively great sensitivity to freshwater pollution. Substantive alterations in substrate composition and transportation of fine sediments filling the interstitial space have been noticed in the reservoir due to impoundment. Thus, reduction in the density/abundance of mayfly, stonefly and caddisfly and others in the post-impoundment environs of Tehri Dam is understandable.

Table 4.1. Comparative seasonal qualitative distribution and abundance of zooplankton in pre-impoundment and post-impoundment environments

Sl.No.	Taxon	Autumn (Sept.-Oct)		Winter (Nov. –Feb.)		Summer (March-Jun)		Monsoon (Jul-Aug.)	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
PROTOZOA									
1	*Vorticella*	+	+	++	++	++	++	-	-
2	*Zoothanmniuns*	+	+	+	++	+	-	-	-
3	*Centropyxis*	+	+	++	++	+++	+++	+	-
4	*Campanella*	+	++	++	++	+++	+++	+	-
5	*Carchasium*	+	+	+	-	+	-	-	-
6	*Epistylis*	+	+	+	-	+	-	-	-
7	*Diffugia*	-	+	+	+	+	+	-	-
8	*Arcella*	-	-	+	+	++	++	-	-
9	*Stentor*	-	-	+	+	++	+++	-	-
10	*Colpoda*	+	-	+	-	+	-	-	-
11	*Nebela*	+	++	+	-	+	-	-	-
12	*Thecamoeba*	+	-	+	+	+	-	-	-
13	*Seyangularia*	+	+	+	+	+	-	-	-
14	*Pelomyxa*	+	-	+	+	+	-	-	-
15	*Pontigularia*	+	++	++	++	+++	+++	+	+
16	*Quadrlella*	+	-	+	+	+	-	-	-
17	*Amphizonella*	-	-	+	+	+	-	-	-
18	*Pyxidicula*	+	++	++	++	+++	+++	+	+
19	*Plgiopyxis*	+	-	+	-	+	-	-	-
ROTIFERA									
1	*Ascomorapha*	-	-	+	++	+++	+++	+	-
2	*Asplanchna*	-	-	-	-	+++	+++	+	-
3	*Brachionus*	+	+	+	++	+++	+++	+	-
4	*Keratella*	+	+	+	+	+++	+++	+	-
5	*Lacane*	+	-	+	+	++	++	-	-
6	*Mytilina*	-	-	+	+	++	++	-	-
7	*Philodina*	-	-	-	-	++	++	+	-
8	*Trichocera*	-	-	-	-	++	++	-	-
9	*Filinia*	-	-	-	-	++	++	-	-
10	*Diplois*	-	+	+	++	+	-	-	-
11	*Paracolurella*	-	-	-	-	++	+++	+	-
12	*Manfredium*	-	-	+	++	++	+++	+	-

Table 4.1 Contd.

CLADOCERA									
1	*Ceriodaphnia*	++	+	+	+	+++	+++	+	-
2	*Daphnia*	++	+	+	+	+++	+++	+	-
3	*Moina*	+	-	-	-	++	++	-	-
4	*Pleumonaoxus*	++	++	-	-	+	++	-	-
5	*Bosmina*	++	+	-	-	++	++	+	+
6	*Chydorus*	+	+	+	+	++	+++	+	-
COPEPODA									
1	*Cyclops*	+	+	+	+	++	+++	-	-
2	*Diaptomus*	+	-	-	-	+	+	-	-
3	*Naupli*	+	+	+	+	++	++	-	-

Table 4.2. Comparative seasonal qualitative distribution and abundance of macrobenthos in pre-impoundment and post-impoundment environment

Sl.No.	Taxon	Autumn (Sept.-Oct)		Winter (Nov.– Feb.)		Summer (March-Jun)		Monsoon (Jul-Aug.)	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
Ephemeroptera									
1	*Heptagenia*	+	+	++	+	+++	+	+	_
2	*Leptophlebia*	+	_	++	+	+++	++	+	_
3	*Caenis*	+	+	++	+	+++	++	+	_
4	*Cloeon*	+	-	+	_	++	+	_	_
5	*Bretis*	+	+	++	+	+++	++	+	_
6	*Centroptilum*	+	+	++	_	+++	+	+	_
7	*Ephemerella*	+	_	_	_	+	_	_	_
8	*Ecdynurus*	+	+	+	+	++	+	+	_
9	*Siphlonurida*	+	_	_	_	+	_	_	_
10	*Rhithrognea*	+	+	++	+	++	+	_	_
11	*Hexagenia*	+	+	++	+	+++	++	+	_
12	*Ephoron*	+	_	+	_	++	+	_	_
13	*Paraleptophlebia*	+	+	++	+	+++	++	+	_
14	*Isonychia*	+	+	++	+	+++	+	+	_
15	*Potamenthos*	+	_	_	_	+	_	_	_
16	*Cinygmula*	+	_	+	_	++	+	_	_
17	*Cinygama*	+	+	++	+	+++	++	+	+
18	*Ametropus*	+	+	++	_	+++	++	+	_
19	*Chroterpes*	+	_	+	_	++	_	_	_
20	*Stenonema*	+	_	+	_	++	+	_	_

Table 4.2 Contd.

Tricoptera									
1	*Hydropsyche*	+	+	+++	++	++	+	+	_
2	*Rhyacophila*	+	+	++	+	+	_	_	_
3	*Glossosoma*	+	+	++	+	++	+	_	_
4	*Hydroptila*	_	_	++	+	++	+	+	_
5	*Limnephilus*	+	+	++	+	+	_	_	_
6	*Phrygema*	_	_	++	+	+	_	_	_
7	*Leptocella*	+	+	++	+	+	_	_	_
8	*Brachycentrus*	+	_	+	_	_	_	_	_
9	*Philopotanus*	+	+	++	+	++	+	+	_
10	*Polycentrophus*	+	+	++	+	++	+	_	_
11	*Trianoedis*	+	_	++	+	++	+	_	_
Plecoptera									
1	*Brachyptera*	+	_	+++	++	++	+	+	_
2	*Acroneuria*	+	_	++	+	+	_	_	_
3	*Isoperla*	+	+	+++	++	+	_	_	_
4	*Perla*	+	_	+++	++	+	+	+	_
5	*Atoperla*	+	+	+++	++	+	+	+	_
6	*Nemoura*	+	+	++	+	_	_	_	_
7	*Perinella*	+	_	++	+	+	+	+	_
Diptera									
1	*Psychota*	+	+	++	+	+	+	+	_
2	*Antocha*	+	_	++	+	+	_	_	_
3	*Culex larva*	+	_	+++	++	++	+	+	_
4	*Symbiocladius*	+	+	++	+	+	+	+	_

Table 4.2 Contd.

5	*Pentaneura*	+	+	++	+	+	+	+	_
6	*Terolipes*	+	+	+++	++	+	+	_	_
7	*Tabanus*	+	_	++	+++	++	_	_	_
Coleoptera									
1	*Ochihebius*	+	+	++	+	+++	++	_	_
2	*Dineutus*	+	+	+	_	++	+	_	_
3	*Amphizoa lecontei*	+	_	++	+	+++	++	+	_
4	*Agabinus glabellus*	+	+	++	+	+++	++	+	_
5	*Peltodytes*	+	+	+	_	++	+	+	_
6	*Gyrinus*	+	+	+	_	++	+	_	_
7	*Hydrophilus*	+	_	++	+	++	+	_	_
8	*Hydracna*	+	+	++	+	++	+	_	_
9	*Prephynus*	_	_	++	+	++	+	_	_
10	*Psephanus*	+	+	+	_	++	+	_	_
11	*Stenolophus*	+	+	+	_	++	+	+	_
Hemiptera									
1	*Gerois*	+	+	+	+	+++	++	+	_
2	*Corexia*	+	_	_	_	++	+	+	_
3	*Hesperocorixa*	+	_	+	_	++	+	+	_
4	*Ranatia*	+	+	+	+	++	+	_	_
5	*Belostoma*	+	+	+	+	++	+	_	_
6	*Micronecta*	+	_	_	_	++	+	_	_

Table 4.2 Contd.

Odonata									
1	*Hagenius*	+	_	+	+	++	+	_	_
2	*Macromia*	+	+	+	+	++	+	_	_
3	*Agrion*	+	+	+	_	++	+	+	_
4	*Argia*	_	_	_	_	++	+	_	_
5	*Ischmura*	+	+	+	+	++	+	_	_
Annelida									
1	*Glossiphonia*	+	+	+	_	+	_	_	_
Gastropoda									
1	*Lymnaea*	_	_	+	+	+	+	_	_
2	*Parathelpusa*	+	+	_	_	_	_	_	_
	Limax	+	+	+	+	+	+	_	_

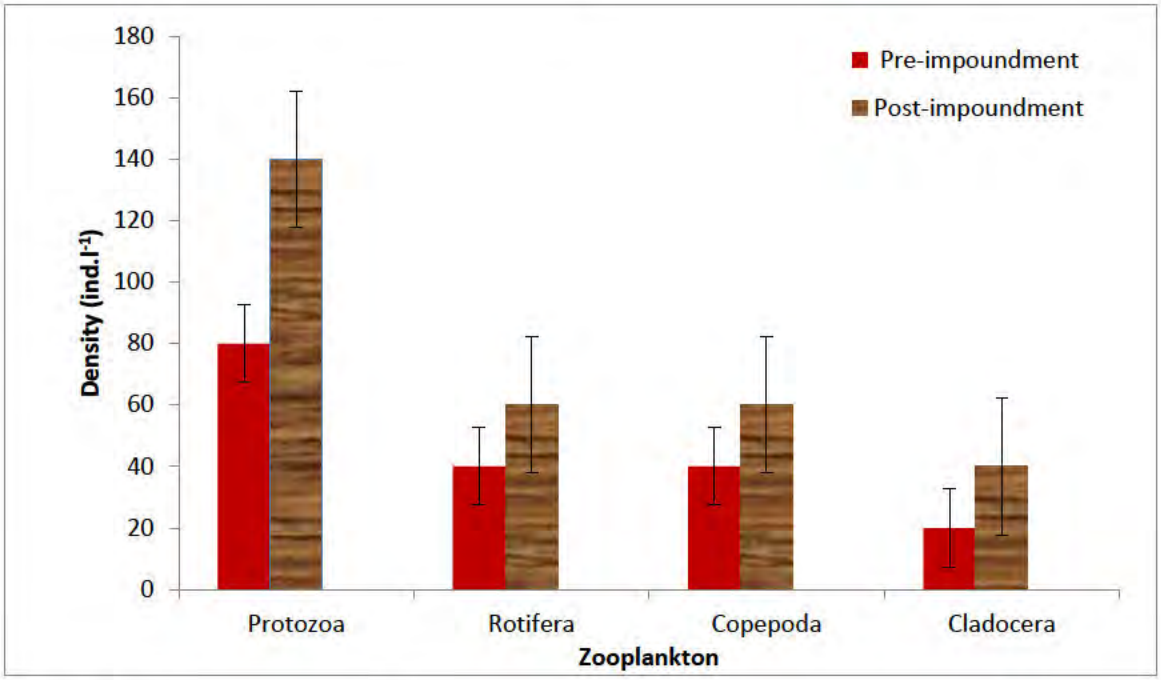


Fig. 4.1 : Increase in annual mean density (ind.l^{-1}) of zooplankton caused by impoundment

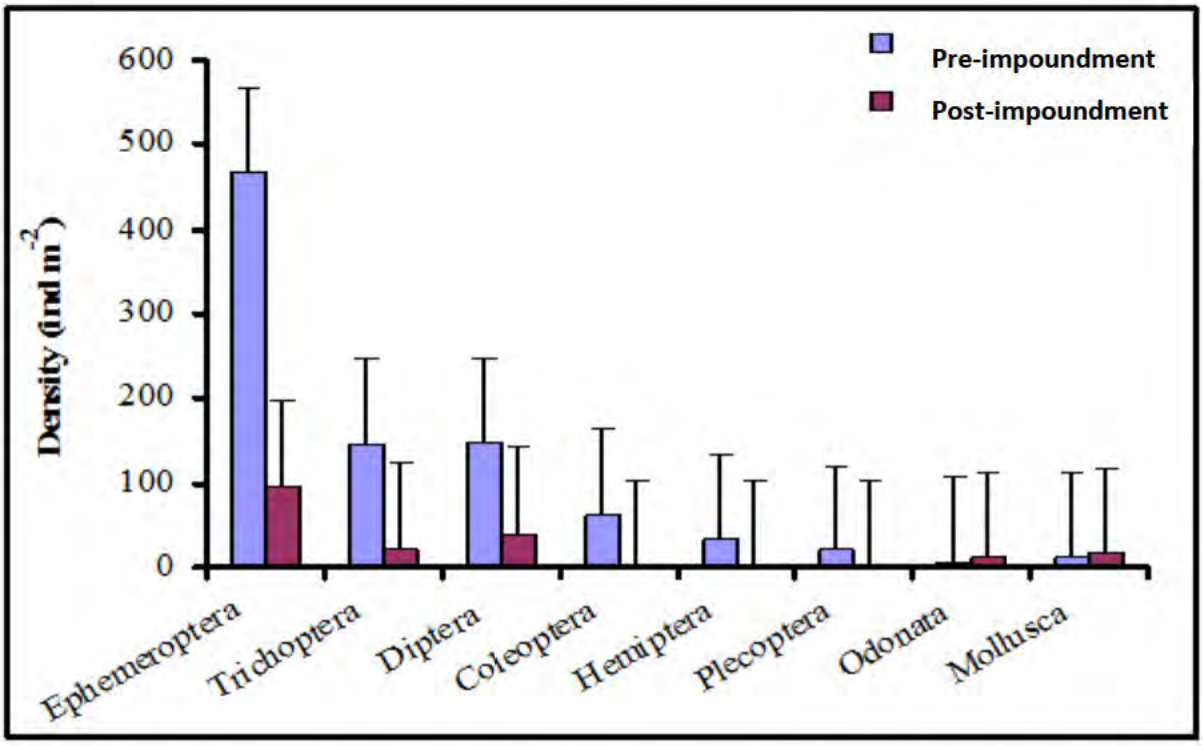
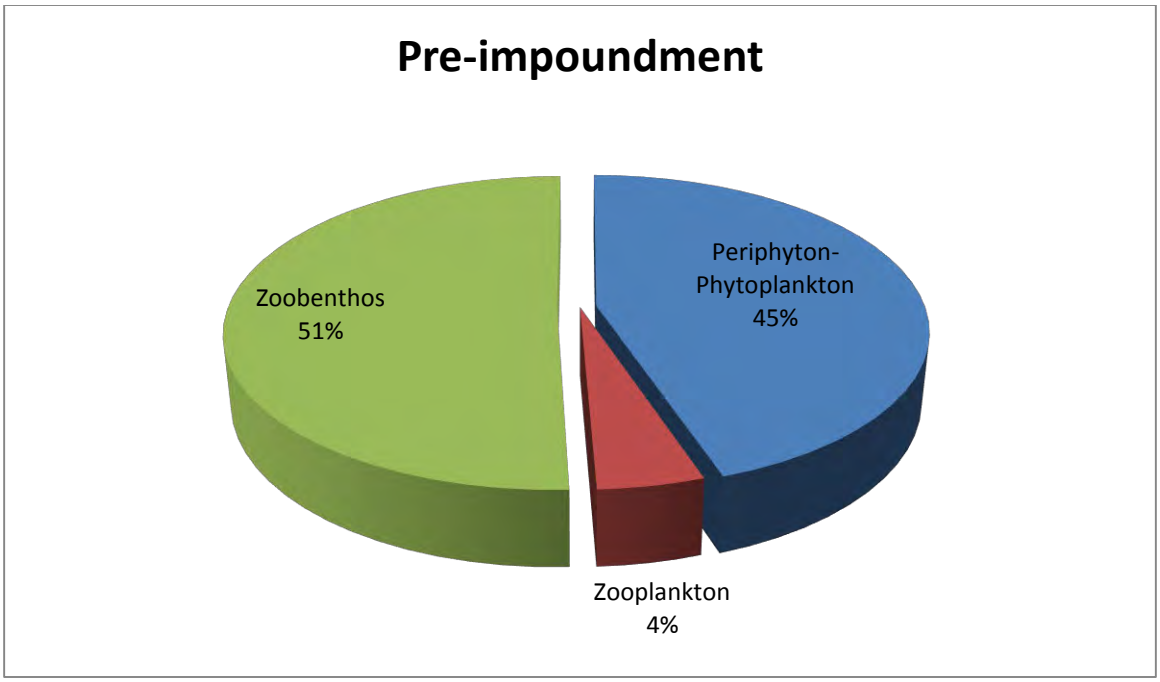


Fig. 4.2 Depression in the annual mean density (ind.m^{-2}) of macroinvertebrates caused by impoundment



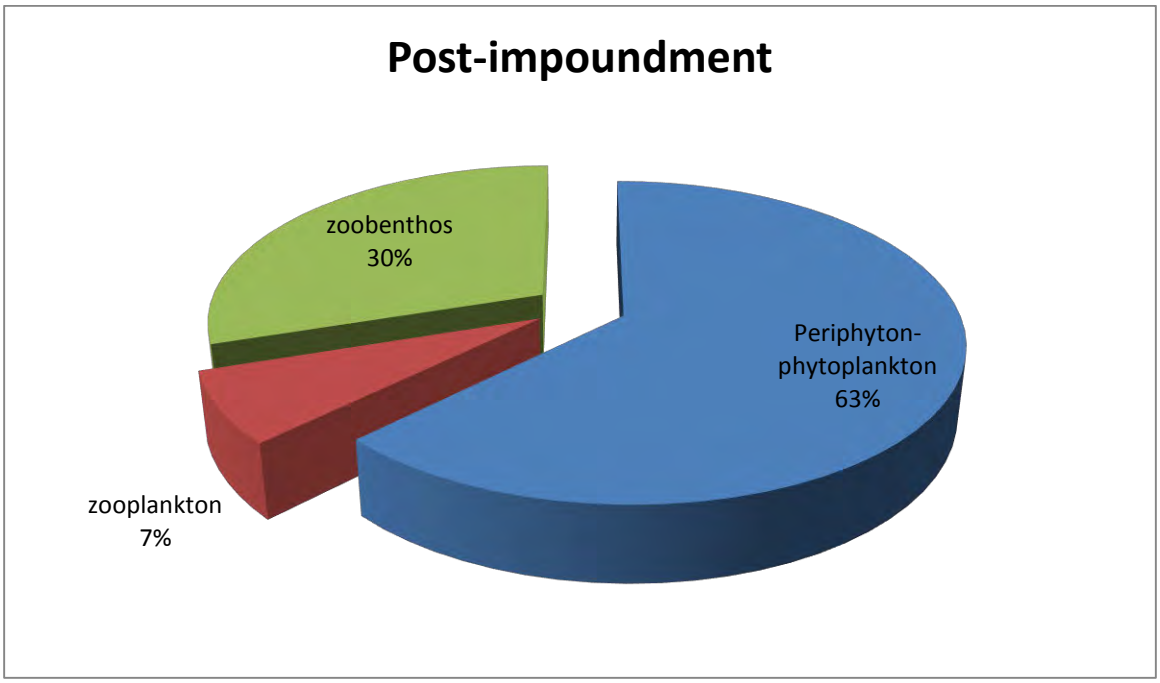


Fig. 4.3: Percentage Composition of Valuable ecosystem components of freshwater biodiversity of Tehri Dam environs under pre-impoundment and post-impoundment conditions

Chapter - 05
FISH DIVERSITY

Fishes are among the earliest vertebrates, going back to the Devonian period – the age of Fishes. About 30,000 species of fishes are known. Over 40% of the fish species live in freshwaters. Inland freshwaters represented by 930 species (Talwar and Jhingran, 1991). Francis Hamilton (1822) in his pioneering work reported 269 species from the Gangetic system. Badola and Pant (1973) reported 18 species from the Uttarakashi District. Badola and Singh (1977) recorded 43 species from Pauri, 28 species from Chamoli and 33 species from Tehri Garhwal districts. Tilak and Baloni (1984) reported 11 fish species from Tehri Garhwal. Sharma (1984) reported 23 species belonging to 11 genera and 4 families from the Bhagirathi River. Singh *et. al.* (1987) have given an account of 64 fish species from Garhwal Himalayas. Singh and Sharma (1998) reported 39 fish species from 15 genera and five families from the Alaknanda River. Sharma (2003) reported a comprehensive account of fish diversity and their ecological status from the protected area of Uttarakhand. A total of 86 species and 36 genera of 11 families have been reported by him from the protected area of Uttarakhand. After the completion of stage I of Tehri Dam Project, in 2006, a large reservoir has been created. No extensive work has been done on the fish diversity of the Tehri Dam Project after impoundment. Therefore, there was an urgent need for providing information on the fish diversity of the Tehri Dam Reservoir and its environs complying the recommendations of the Hannumanta Rao Committee.

PRE- IMPOUNDMENT SCENARIO

The dams are constructed for the welfare of human beings, for irrigation, flood control, navigation and hydropower generation. The generation of power has become necessary for meeting the increasing demand of the country. However, the dams have deleterious effects on the fish resources and their aquatic habitats. Dams interrupt

stream flow and generate hydrological changes along the integrated continuum of river ecosystems that ultimately can be reflected in their associated fisheries.

Taking a serious note of the fact that dams have significant impact on ecosystem not only in immediate environs, but also habitats in far away area downstream, the Government of India asked the North Regional Station of Zoological Survey of India, Dehradun for faunal survey and analysis in the pre-impoundment area of Tehri Dam Environs. ZSI Regional Station, Dehradun undertook five surveys of 10 days duration between May and October 1992 and reported 10 fish species (*Barilius vagra, Tor chelynoides, Tor putitora, Crossocheilus latius, Garra gotyla, Schizothoraichthys progastus, Schizothorax richardsonii, Noemacheilus montanus, Noemacheilus rupecola* and *Glyptothorax pectinopterus*). Eleven more fish species were also reported in this report (Tilak and Baloni, 1984).These fish species were reported from the Tehri Dam Environs and the associated freshwater ecosystems of Tehri Garhwal district. These fish species were *Barilius bendelisis, Tor tor, Labeo dero, Botia dayi, Noemacheilus beavani, Noemacheilus botia, Clupisoma montana, Glyptothorax alaknandi, Glyptothorax cavia, Glyptothorax Garhwali Tilak, Pseudecheneis sulcatus* and *Mastacembelus armetus.*

However, as a result of detailed survey of ichthiyofauna of Bhagirathi, 23 species belonging to 11 genera and 4 families were reported by Sharma (1984).Therefore, this fish faunal survey can be considered as reference study for assessing the impact of Tehri Dam on fish fauna.

POST- IMPOUNDMENT SCENARIO

A total of 24 fish species belonging to 12 genera and 4 families have been reported from Tehri Dam Environs after an in-depth survey for a period of two annual cycles. The detailed account on the ecological status, habitat, feeding habits, breeding and spawning grounds, pre-impoundment and post-impoundment status has been presented in the Table 5.1

Schizothorax:

The genus *Schizothorax* of the the family cyprinidae encompasses three species (*S. richardsonii; S.plagiostomus; S.sinuatus*) in the Tehri Dam Environs, which were present throughout the year. The abundance of *Schizothorax* is possibly due to the presence of coldwater (10^{o}C-20^{o}C). Hence, they are called "snow-trout". The preferred habitat for snow trouts is fast running coldwater specially rapids and are found at bottom under stones and upper reaches of reservoir in Bhagirathi and Bhilangana rivers and near the confluence of Bhilangana and Balganga. Their fry and fingerlings swim at the surface and are found in shoals in the side shallow waters. The mouth of the adults highly modified to suit for scrapping the periphyton attached with the

boulders and big stones. These species feed on algae, diatoms and other plant materials. These species were found to spawn from September to January, as during winter season, the water temperature and the velocity of the water remains quite favourable for the breeding of these species. They breed in shallow running or semi stagnant water on the bank of the river among the gravel and stones.

Schizothoraichthys:

The true snow trout *Schizothoraichthys progastus* is found only in headwaters of Tehri Dam Environs. It is a bottom dwelling fish and takes shelter under stones and rocks due to its pointed snout. This species is omnivores and feeds on insect's nymphs and larvae and green matter. It breeds during September to January in semi stagnant side waters. The species in the pre-impoundment environment was common. Now, it is found occasionally in the post-impounded environs.

Tor:

Two species of *Tor* (*Tor tor; Tor putitora*) were common in the pre -impoundment habitats of Bhagirathi and Bhilangana. These are the biggest fishes of the Himalayan rivers and are commonly known as Mahseer. The preferred habitat for Mahseer's is deep pools. These are also abundant in runs, riffles and rapids. These are omnivorous column feeders. These species are migratory and were common during March to September in the pre-impoundment habitats of Bhagirathi and Bhilangana. These species spawn from April to July, when the water of the fluvial system becomes turbid due to the melting of snow. The Mahseer moves from deep water to upstream region for the purpose of breeding in the backwaters and side waters. The fry and fingerlings Mahseer are planktivorous and surface feeders.

Labeo:

Only one species *Labeo dero* was common in the pre impoundment habitats (deep pools, runs and riffles) during the months of March to June for breeding purposes. This species is migratory in nature. After spawning, they migrate downwards to the Ganga fluvial system. They are bottom feeders. The species is herbivores and detritophagic and feeds on vegetables matter.

Garra:

Garra gotyla and *G.lamta* are the two species of *Garra* in the Tehri Dam environs. These species are strictly bottom living and remain concealed under stones and rocks. The body colour resembles with their background. These species are herbivores, detritophagic.The mouth is well adapted to live in runs, riffles and deep water of the fast current of water. These were common in the fluvial systems of Bhagirathi and

Bhilagana during summer season. After impoundment, the presence of these species has become rare.

Crossocheilus:

Crossocheilus latius latius was quite common in snowfed rivers and streams during summer season .Their preferred habitats are deep pools, runs, riffles. These species migrate from the Ganga river to upwards in snowfed rivers during early summer. They are strictly bottom dwellers. The species is herbivores and feed on green algae. The species is migratory. After impoundment, this species has become rare.

Barilius:

Four species of *Barilius (B.bendelisis; B.barna; B.barila; B.vagra*) were present through out the year in pre impoundment tributaries of fluvial system of Bhagirathi and Bhilagana. They were present in shallow pockets of the marginal water. They live in shoals and swims actively on surface water. These species are omnivores and feed on nymphs and larvae of insects, and algae. They breed during April to June. They lay eggs in shallow pockets of water under stones .These species were found absent or rare in the reservoir area. However, these are present in the spring fed streams of the peripheral mouth habitats of the post impoundment environment.

Noemacheilus:

Four species of *Noemacheilus* (*N.rupecola; N.beavani; N.zonatus; N.multifasciatus*) are commonly called "Gadiyal" by local people, as these are common in streams and rivulets. They were very common in small snowfed streams. These species are well adapted for fast current. These species are omnivorous and feed on insect larvae and nymphs which are found in abundance in hill streams all round the year. These species spawn from July to August in small streams and rivulets. These species were not present in the main reservoir.

Glyptothorax:

Three species of *Glyptothorax (G. madraspatnum, G.pectinopterus, G.cavia)* were present in the Tehri Dam environs. Preferred habitats for these species are rapids of fast current of water. These species are very well adapted to live in swift current of water in snowfed rivers. These species were very common in rainy season in the pre-impoundment habitats of fast current. They prefer to hide under stones and rocks. Adhesive apparatus are well adapted in these species. The species are carnivorous and feed mainly on insects larvae and nymphs. These species breed form April to August. The presence of these species has reduced considerably in Tehri Dam environs after impoundments.

Pseudecheneis:

Pseudecheneis sulcatus was very common in monsoon season in the pre-impoundment habitats. It is a bottom dweller and remains hidden under stones and rocks. This species is carnivorous and feeds mainly on larvae and nymphs of insects.The fish spawns from April to August. The exact spawning ground can'nt be located in the post impoundment habitats. The presence of the species in the post impoundment environs were rare.

Other Species:

One species ,*Clupisoma garua* ,locally known as "Bare" was also reported for the first time from Bhagirathi in pre- impoundment habitats(Sharma 1984).Only one specimen was recorded.it may be possible that Tehri was be the upstream limit for this migratory fish species. Thus, it was not recorded during the present study.

IMPACT OF IMPOUNDMENT:

The most obvious effects from constructing dams on rivers result from formation of new lentic or semi- lentic environments upstream from the dam and tail water environments downstream from the dam in addition to severed adverse impacts on river morphology, physico-chemical degradation of lotic environment and depression of the aquatic biotic components during the dam construction phase. Degradation of the aquatic environment ultimately affects the fish communities in many ways.

The effect of Tehri Dam on Bhagirathi and Bhilangna rivers is more pronounced and has affected the abundance and distribution of fish species in the river by obstructing their longitudinal migration. Construction of dam has considerably reduced surface area of fish habitats to downstream in addition to large destruction of feeding and spawning grounds of fish dwelling Bhagirathi and Bhilangna. As a consequence of the impoundment, the lotic environment of Bhagirathi and Bhilangna has been converted into a large reservoir. Riparian vegetation has been completely submerged upstream after impoundment. The feeding and spawning grounds have been inundated and the migration routes of the fish have been blocked.

For the analysis of the impact of Tehri Dam on fish diversity of the Bhagirathi River, fish species richness and number of species in each community were taken into account. The earlier study on fish diversity made by Sharma (1984) was also taken in account for comparison of distribution of fish in time and space. A total of 23 species were reported form the Bhagirathi River(Sharma 1984).However, Only 19 fish species belonging to 9 genera and 3 families were found in upstream habitats of Tehri Dam environs after impoundments and 12 fish species belonging to 7 genera and 3 families were recorded at the downstream environs of the Tehri Dam. Under the post-

impoundment scenario the entire Tehri Dam Environs can be divided into four main longitudinal zones: Zone A(close to Sarans as reference site);Zone B (Reservoir);Zone C (High Impacted site); just below the dam between Tehri Dam and Koteshwar Dam and Zone D (Downstream/tail race zone between Koteshwar and Devprayag).The data related with the presence of number of species have been presented in Table 5.2.Maximum number (17) of fish species were found in the Zone-D. It may be due to presence of natural habitat as well as connectivity of this zone with the Alaknanda River. Reduction in the diversity in upstream Tehri Dam environs may be due to the fact that longitudinal migration of fishes has been obstructed by the construction of the Tehri Dam.

Experimental fishing in the post-impoundment habitats in different seasons was also undertaken to assess the impact of impoundment on the fish composition. The comparison was made with the reference study undertaken in the pre-impoundment habitats (Sharma, 1991). Initially, there was an adverse impact of Tehri Dam construction on the fish density and its production. The adverse impact reached maximum, when the longitudinal migration of fish was blocked due to conversion of fluvial system into a reservoir in 2006. However, the freshwater habitat was extensively expanded in terms of creation of a reservoir and the fish seeds of Mahseer (*Tor spp.)* and Common Carp (*Cyprinus carpio*) were also introduced in the upper reaches of the reservoir. During the period of 2006-2011, it has recovered considerably and in few cases, it has increased in the percentage composition (Fig5.1).

The *Schizothorax* spp. has increased from 57.9% to 58.1%. However, the *Schizothoraichthys progastus* has increased from 6.3% to 8.5% to the total fish composition. Mahseer production has also shown an increase from 9.1% to 12.8%. Newly introduced *Cyprinus carpio* contribution has reached to 3.5%, which was not available in the pre-impoundment scenario. This may be due to the fact that dimensions of the freshwater habitat has increased manifolds and the fish seeds have been introduced into the reservoir.

A considerable reduction in contribution of *Garra* spp., *Crossochelius* spp., *Barillius* spp., *Noemachelius* spp. *Glyptothorax* and *Pseudechenesis* spp. to the total fish composision has been recorded. As, these fishes used to thrive well in hillstreams of swift and shallow water.

TABLE 5.1: Fish diversity, their ecological status, preferred habitats, feeding habitats, breeding and spawning ground and status of presence in pre-impoundment and post-impoundment environs

S.No	Zoological Name	Local Name	Ecological Status	Preferred Habitat	Feeding Habits	Breeding and Spawning grounds	Pre-impoundment status	Post-impoundment status
Family : **CYPRINIDAE**								
1.	*Schizothorax richardsonii* (Gray)	Maseen	VU	Prefers cold water, torrential water of streams, rivers, riffle, runs and rapids	Herbivorous: feeds on green matter, periphyton, bottom dweller	Breeding period from September January, breeds on gravelled surface	Common	Common in upper reaches
2.	*S.plagiostomus* (Heckel)	Maseen	NE	Prefers fast running water(rapids), bottom dwellers	Herbivorous: feeds on green matter and periphyton,	Breeds during September to January in shallow running and semi stagnant water of 25-30cm depth	Common	Rare
3.	*S. sinuatus* (Heckel)	Maseen	LRnt	Prefers torrential water current (rapids),dwells at the bottom under stones and rocks	Herbivorous:feeds on green matter and periphyton	Breeds during September to January and spawns on the gravelled surface of sediments	Common	Common in upper reaches
4.	*Schizothoraicthys progastus* (McClelland)	Chengu	LRnt	Prefers headwater zone of the coldwater streams	Omnivorus : feeds on insects larve and green matter ,green algae	Breeds during September to January and spawns in the semi-stagnant water on gravelled surface	common	Occasional

Table 5.1: Contd.

5.	*Tor tor* (Hamilton)	Dansulu	EN	Adult prefers deep water pools with rocky bottom, Juveniles: side and semi-stagnant water	Adults are omnivorous: feeds on green matter, insects and their larvae, zoobenthos, column dweller. Juveniles are planktivorous	Spawns from April to June, turbid water due to melting of snow, migratory fish	Rare	Rare
6.	*Tor putitora* (Hamilton)	Dansulu	EN	Adult: prefers deep water pools with rocky bottom, Juveniles prefer side, semi stagnant water	Omnivorous: Green matter,Insects & their larvae column feeder , Juveniles : Planktivorous , surface feeders.	Spawns from April to June in turbid water due to melting of snow, migratory fish	Common	Common, population fragmented
7.	*Labeo dero* (Hamilton)	Dansulu	VU	Prefers deep pools, rapids, torrential water current	Herbivorous, Mid bottom feeder	Spawns from March to June, prefers shallow water migratory fish	Common	Rare
8.	*Crossocheilus latius* (Hamilton)	Sunhara	DD	Prefers runs, riffles with abundant green matter	Herbivorous , bottom feeder	Breeds from April to September , migratory fish	Common	Rare
9.	*Garra gotyla* gotyla(Gray)	Gondal	VU	Prefers deep water pools with runs, riffles with abundant green matter	Herbivorous bottom feeder	Breeds from April to September , migratory fish	Common	Rare
10.	*Garra lamta* (Hamilton)	Gondal	NE	Prefers side water with abundant green matter	Herbivorous bottom feeder	Breeds from April to September, migratory fish	Rare	Absent

Table 5.1: Contd.

11.	*Barilius bendelisis* (Hamilton)	Fulra	LRnt	Prefers small spring fed streams, common in side water	Omnivorous : feeds on nymphs, larvae and algae Surface feeders	Breeds from April to June side stagnant water	Common	Common
12.	*B.barna* (Hamilton)	Fulra	LRnt	Prefers small spring fed streams, common in side waters	Omnivorous : feeds on nymphs, larvae and algae , surface feeders	Shallow pockets of water under stones and macrophytes	Common	Common
13.	*B.vagra* (Hamilton)	Fulra	VU	Prefers small spring fed streams, common in side waters	Omnivorous : feeds on nymphs, larvae and algae , Surface feeders	Shallow pockets of water under stones and macrophytes	Rare	Rare
14.	*B.barila* (Hamilton)	Fulra	VU	Prefers small spring fed streams, common in side water	Omnivorous : feeds on nymphs, larvae and algae, Surface feeders	Shallow pockets of water under stones and macrophytes	Rare	Rare
15.	*Cyprinus carpio cummunis* (Linnaeus)	Commo n carp	NE	Deep water pools and stagnant water	-	Cultured	Absent	Introduced in Reservoir
Family : **BALITORIDAE**								
16.	*Noemacheilus rupecola* (Hamilton)	Gadiyal	LRnt	Prefers to stay in rivulets and streams (bottom gravels under stones)	Omnivorous mainly feeds on nymphs and larvae of insects, algae and diatoms, bottom dwellers	Breeds in July-August , spawns in small streams	Common	Common
17.	*N.beavani* (Gunther)	Gadiyal	DD	Prefers to stay in spring fed rivulets and small streams	Omnivorous : mainly feeds on nymphs and larvae of insects, algae and diatoms, Bottom dweller	Breeds in July-August spawns in small streams	Rare	Very Rare

Table 5.1: Contd.

18.	*N. zonatus* (McClelland)	Gadiyal	NE	Prefers to stay in spring fed rivulets and small streams	Omnivorous : mainly feeds on nymphs and larvae of insects, algae and diatoms, bottom dwellers	Breeds in July-August ,spawns in small streams	Rare	Rare
19.	*N.multifasciatus* (Day)	Gadiyal	EN	Prefers to stay in spring fed rivulets and small streams	Omnivorous : mainly feeds on nymphs and larvae of insects, algae and diatoms, bottom dwellers	Breeds in July-August spawns in small streams	Rare	Rare
	Family: **SISORIDAE**							
20.	*Glyptothorax madraspatmum* (Day)	Nau	Vu	Gets refuge under stones and rocks, common in mansoon	Insectivorous and feeds mainly on insects and nymphs and larvae	Breeds from April to August and spawns in gravelled bottom	Common	Common
21	*G.pectinopterus* (McClelland)	Nau	LRnt	Gets refuge under stones and rocks, common in mansoon	Insectivorous and feeds mainly on insects and nymphs and larvae	Breeds from April to August and spawns in gravelled bottom	Common	Common
22.	*G.cavia* (Hamilton)	Sipliya	EN	Gets refuge under stones and rocks, common in mansoon	Insectivorous and feeds mainly on insects and nymphs and larvae	Breeds from April to August and spawns in gravelled bottom	Rare	Rare

Table 5.1: Contd.

23	*Pseudecheneis sulctus* (Hamilton)	Mungrea	Vu	Bottom dwellers, hidden under stones	Insectivorous / carnivorous and feeds only on insects and their nymphs and adults	Breeds from April to August in gravelled bottom	Common	Rare
	Family: **SCHILBEIDAE**							
24.	*Clupisoma garua* (Hora)	Bare	Vu	Deep water pools and flooded water	Column feeder , omnivorous	Migratory and breeds during monsoon season	Rare	Very Rare

Table 5.2. Distribution of fish species in different zones of Tehri Dam Environs

S.No.	Fish species	Zone A (Reference Site)	Zone B (Reservoir)	Zone C (Impacted Zone)	Zone D (Downstream/ tailrace zone *)
	Family: Cyprinidae				
1.	*Schizothorax richardsonii* (Gray)	+	+	+	+
2.	*S. plagiostomus* (Heckel)	-	-	-	-
3.	*S. sinuatus* (Heckel)	+	+	-	+
4.	*Schizothoraichthys progastus* (McClelland)	-	-	+	+
5.	*Tor tor* (Hamilton)	-	-	+	+
6.	*T. putitora* (Hamilton)	-	-	+	+
7.	*Labeo dero* (Hamilton)	-	-	+	+
8.	*Crossocheilus latius* (Hamilton)	+	-	-	-
9.	*Garra gotyla gotyla* (Gray)	+	+	-	+
10.	*G. lamta* (Hamilton)	+	-	-	-
11.	*Barilius bendelisis* (Hamilton)	+	-	+	+
12.	*B. vagra* (Hamilton)	+	-	+	+
13.	*B. barila* (Hamilton)	+	-	-	+
14.	*B. barna* (Hamilton)	+	-	-	+
15.	*Cyprinus carpio cummnis* (Linnaeus)	-	+	-	-
	Family: Balitoridae				
16.	*N. rupicola* (McClelland)	+	-	+	+
17.	*N. zonatus* (McClelland)	+	-	+	+
18.	*N. beavani* (Gunther)	+	-	-	+
19.	*N. multifasciatus* (Day)	+	-	+	+
	Family: Sisoridae				
20.	*Glyptothorax pectinopterus* (McClelland)	+	+	-	+
21.	*G. madraspatnam* (Day)	-	-	-	-
22.	*G. cavia* (Hamilton)	+	-	-	-
23.	*Pseudechenies sulcatus* (McClelland)	+	-	-	+
	Family: Schilbidae				
24.	*Clupisoma garua* (Hora)	-	-	-	-

*: Zone D is between Koteshwar Dam and Deoprayag

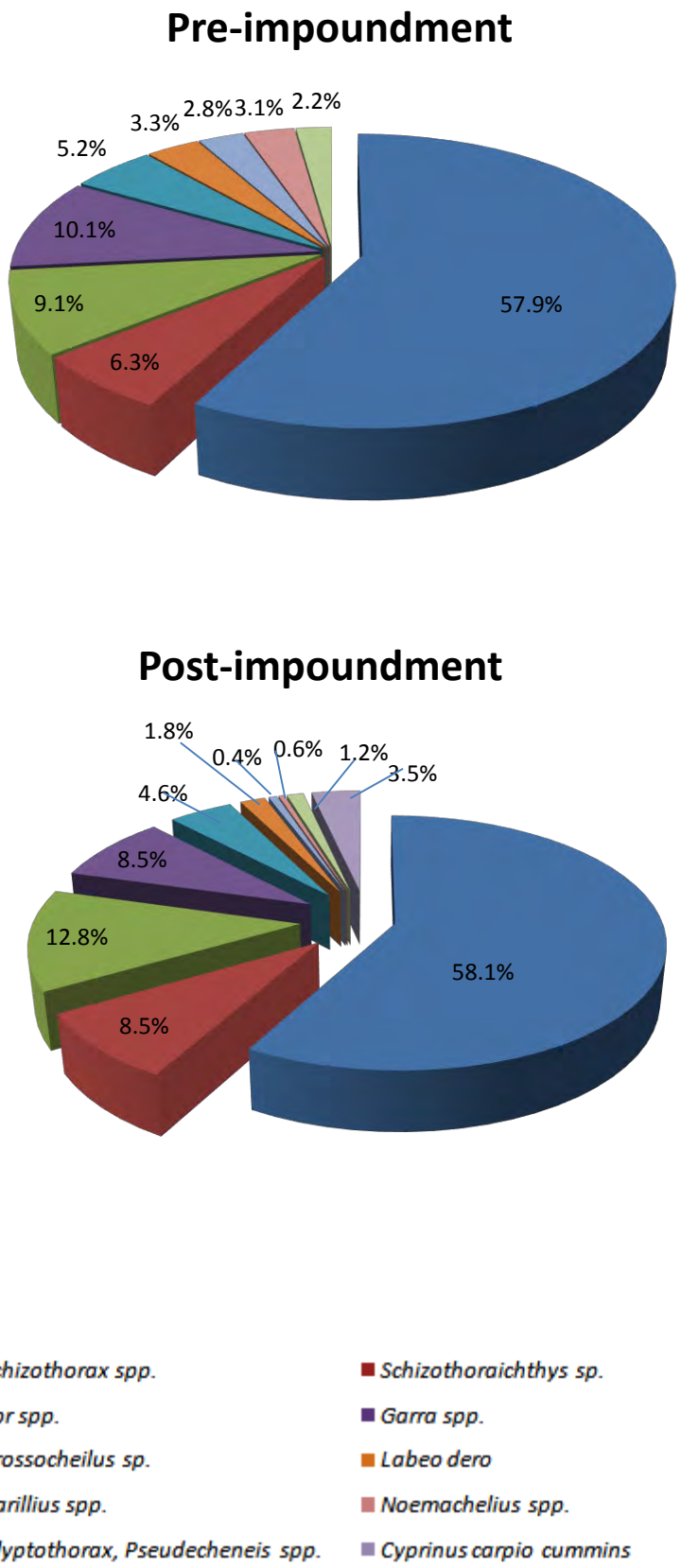


Fig.5.1 : Impact of impoundment on percentage fish composition

FISH DIVERSITY OF TEHRI DAM ENVIRONS

Garra lamta

Schizothoraichthys progastus

Cyprinus carpio communis

Tor putitora

Schizothorax richardsonii

Labeo dero

FISH DIVERSITY OF TEHRI DAM ENVIRONS

Schizothoraichthys progastus

Pseudecheneis sulcatus

Barilius bendelsis

Crossocheilus latius

Garra gotyla gotyla

Studying fish samples at Laboratory

Chapter- 06

RHOPALOCERA (LEPIDOPTERA) DIVERSITY

Lepidoptera, one of the highly specialized orders of class Insecta, includes scale-winged insects of the holometabolous endopterygote series. This includes butterflies and moths that show total metamorphosis and pass through egg, larva, pupa and adult stages. All these stages have characteristic features in structures, habit and habitat so as to readily differentiate butterflies and moths. Lepidoptera, particularly Rhopalocera, or the butterflies is a large and well known with compoliton in distribution. Hamlyn (1969) reported about 1,40,000 species comprising 13,000 butterflies and 1,27,000 moths from the world. Recent estimate of diversity within Lepidoptera from the Indian subregion reveals that the group comprises over 15,000 species distributed over 84 families.

Major contribution on butterflies of Garhwal Himalaya was made by Arora and Mandal (1977), Arora *et.al.*(1995) provided an account on the butterflies of Western Himalayas.

Since the creation of the Tehri Dam Reservoir has submerged a vast area of the terrestrial ecosystem, and created a new habitat in the form of Botanical Gardern and other new plantations, the survey of butterflies in the post impoundment Tehri Dam environs is very important for protection of this vulnerable element of life.

Butterflies play an important role in the food web of the terrestrial ecosystem. The larval stages of butterflies feed on plant-food, mainly foliage and tender shoots. The butterflies are mainly diurnal in habit (mainly fly during day time). Majority of the insectivorous birds feeds on insects and their larvae. However, the animal like lizards,

frogs and toads feed on these butterflies. Thus, butterflies play an important link in the ecological balance of the ecosystem. The butterflies also act as pollinating agents.

PRE-IMPOUNDMENT SCENARIO:

Zoological Survey of India (North Regional Station) reported 81 species of butterflies in the pre-impoundment area. 18 species were reported from the area, upto submergence level, 22 species were reported from the area above submergence levels. A total of 41 species of butterflies common in both the areas, were reported.A total of 81 species belonging to 56 genera and 9 families of butterflies were reported from the pre-impoundment Tehri Dam environs (Table 6.1).

POST-IMPOUNDMENT SCENARIO:

However, an extensive survey of Tehri Dam environs in different seasons for two annual cycles, almost the same number of species of butterflies (80 species) belonging to 51 genera and 9 families of butterflies were collected (Table 6.2). However, 13 species (*Apora agathan caphusa; Aglais cashonirensis\assis; Vagrans sinha; Tarucus extricatus; Enchrysops pandav; Catochrysops strabo; Spindasis vulcanus; Spindasis lohita himalayanus; Badamia exclamationis; Odontoptilium anguleta; Parnara guttatus; Barbo cinnara;* and *Potanthus pseudomooss*) could not be spotted in the Tehri Dam environs of post impoundment. Most of these species were also not recorded from Tehri Garhwal district of Garhwal Himalayas (Arora *et.al.* 1995).

A total of 12 new species (*Delias sanaca sanaca; Pieris brassicae nepalensis; Valeria valeria hippia; Mycalesis francisca sanatana; Neptis mahendra; Vanesa cashmirensis aesis; Cyrestis thyodamas; Kaniska canace himalaya; Symbrenthia hippochus; Zemeros flegyas; Lycaena pavana; and Albulina galathea*) were reported from the post impoundment Tehri Dam environs.

The reason for this may be that the pre impoundment survey was undertaken for a very short period of time (May-October) in 1992. Since most of the species of the butterflies are quite common, depending upon the food being widely distributed, and new habitats (Botanical Garden, New Plantations) have been created, water resources are abundantly available; no adverse impact of post impoundment has been noticed. Even, the population of butterflies has increased considerably.

Post impoundment survey revealed that these species of butterflies are represented by nine families (Papilionidae; Pieridae; Danidae; Acraeidae; Satyridae; Nymphalidae; Erycinidae; Lycaenidae; and Hesperidae). No species of the family Amathusiidae was spotted from the Tehri Dam environs.

A brief characteristic of species of each family reported from the Tehri Dam environs are given below:

PAPILIONIDAE:

Most of the species of Papilionidae visit and feed on flowers. Some of the species sit on damp ground near water bodies and other species love basking in the sun. The flights of the species of this family are variable, rapid and sudden, if disturbed. They are predominantly black or dark brown in colour, which have been reported from the Tehri Dam environs. A total of eight species have been reported under the present study.

PIERIDAE:

A total of 14 species of the butterflies have been spotted from Tehri Dam environs under the present survey for two annual cycles. Most of the species prefer open places. Male butterflies prefer sun-shine, while the females love shaded areas. They prefer to sit on damp ground near reservoir, river and rivulets. Flights are usually very slow and sluggish. Few fast flying species settling on flowers were also reported from the study area.

DANAIDAE:

Most of the species of Danaidae family visit flowers or settle on damp ground including the ground damped with urine (Arora *et.al.* 1995). They also have the habit of settling on flowers, over-ripe fruits or congregate on herbs or shrubs. Flights of these species are usually very slow. A total of six species of this family has been recorded.

ACRAEIDAE:

Only one species of this family has been spotted from the Tehri Dam environs. This species is fond of settling on flowers and leaves. These species exudes foul smelling, repellant to birds and other predators. This species is of tawny yellow in colour.

SATYRIDAE:

A total of 11 species of butterflies of the family Satyridae has been reported from the Tehri Dam environs. These species are predominantly brown in colour. These are weak fliers, with slow, jerky or bouncing movements. They prefer to settle on the litter of dead and fallen leaves. Some of the species prefer open meadows/grasslands. They are also attracted to over-ripe fruits.

ERYCINIDAE:

A total of four species of butterflies of this family has been reported from the Tehri Dam environs. These species visit the areas close to streams, rivers, Reservoir and riparian vegetations. Flights of these species are very fast and do not like to settle on the flowers.

NYMPHALIDAE:

It is the most dominating family of the post-impoundment Tehri Dam Environs. Most of the species visit flowers, bask in the Sun-shine. Flights are very swift. They are also attracted to over-ripe fruits, dung and rotten fruits. These species are the most beautiful amongst butterflies. A maximum number (28 species) of species of this family has been reported from the Tehri Dam environs.

LYCAENIDAE:

These are predominantly blue in colour; however, other colours like brown, yellow, metallic green and white are also not uncommon. Most of the species are found of visiting flowers and are very delicate and slow fliers. They are fond almost everywhere namely open grasslands, shrubs, along road and cleared vegetation. Five species of butterflies of this family have been spotted in post impoundment habitats.

HESPERIDAE:

Predominantly, the species are dark brown with orange, yellow markings or metallic tinge. These are abundantly available in forest patches. Majority of these species are attracted to flowers and feed on them. Only one species was commonly spotted from the post impoundment area. However, other five species reported in pre impoundment report could not be spotted. Arora *et.al*. (1995) also could not spot all these five species from the Tehri Garhwal District.

Post-impoundment survey revealed that all the species of butterflies are common to very common in the entire area. A large number of terrestrial habitats have been submerged due to impoundment. New plantations, development of forest patches and development of Botanical Garden have compensated to the lost habitats. Since, the species of butterflies are quiet common, depending upon the food being widely distributed; the faunal diversity of butterflies is not affected by the Tehri Dam.

Table 6.1 Composition and diversity of butterflies in the pre- impoundment and post - impoundment

Tehri Dam Environs

S.No.	Family	No. of Genera		No. of species	
		Pre-Impoundment	Post-impoundment	Pre-impoundment	Post-impoundment
1.	Papilionidae	03	03	08	08
2.	Pieridae	08	09	12	14
3.	Danaidae	04	04	06	06
4.	Acraeidae	01	01	01	01
5.	Satyridae	06	06	10	11
6.	Nymphalidae	17	19	28	30
7.	Erycinidae	03	03	03	04
8.	Lycaenidae	08	05	07	05
9.	Hesperidae	06	01	06	01
	TOTAL	**56**	**51**	**81**	**80**

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Table 6.2 : Diversity of butterflies and their status of presence in pre-impoundment and post-impoundment Tehri Dam environs

S.No	Zoological Name	Habit and Habitat	Status of Presence	
			Pre-impoundment	Post-impoundment
Family : **PAPILIONIDAE**				
1.	*Chilasa clytia clytia* (Linnaeus)	Settles on flowers, damp ground and near water bodies, Basking in the Sun, flights are rapid and sudden	Common	Common
2.	*Graphium cloanthus* (Westwood)	Settles on flowers, damp ground and near water bodies, Basking in the Sun, flights are rapid and sudden	Near Rare	Near Rare
3.	*G.sarpendon* (Linnaeus)	Settles on flowers, damp ground and new water bodies, Basking in the Sun, flights are rapid and sudden	Common	Common
4.	*Papilio ploytes romulus* (Crammer)	Fond of visiting flowers, Basking in Sun-shine, flights are variable	Very Common	Very Common
5.	*P. protenor protenor* (Crammer)	Fond of visiting flowers, Basking in Sun-shine, flights are variable	Near Rare	Near Rare
6.	*P.polyctor polyctor* (Boisdural)	Fond of visiting flowers, Basking in Sun-shine, flights are variable	Common	Common
7.	*P.demoleus* (Linnaeus)	Fond of visiting flowers, Basking in Sun-shine, flights are variable	Very Common	Very Common
8.	*P.machaon penjabensio* (Eimer)	Fond of visiting flowers, Basking in Sun-shine, flights are variable	Near Rare	Near Rare
Family : **PIERIDAE**				
9.	*Apora agathon caphusa* (Moore)	Prefers open places, males basks in sunshine, females love shaded area, settles on damp ground, flights are slow and sluggish	Reported	Not spotted

Table 6.2 Contd.

10.	*Delias eucharis* (Drury)	Prefers high altitude open places	Common	Common
11.	*A.sanaca sanaca* (Moore)	Prefers high altitude open places	Common	Common
12.	*Artogeia canedia indica* (Evans)	Prefers open places, basks in sunshine, settles on damp ground	Vey Common	Very Common
13.	*Pontia daplidice moorei* (Rober)	Prefers open places, basks in sunshine, settles on damp ground	Common	Common
14.	*Catopsilia crocale* (Cramer)	Prefers open places, basks in sunshine, settles on damp ground	Vey Common	Very Common
15.	*C.pyrantha* (Linnaeus)	Prefers open places, basks in sunshine, settles on damp ground	Vey Common	Very Common
16.	*Gonepteryx rahmani neplensis* (Doubleday)	Prefers open places, basks in sunshine, settles on damp ground	Common	Common
17.	*Eurena lecta lecta* (Boisd)	Settles on damp ground and male basks in sunshine	Vey Common	Very Common
18.	*E.hecabe fimbriata* (Wallace)	Settles on damp ground and male basks in sunshine	Common	Common
19.	*E.brigitta rubella* (Wallace)	Prefers high altitude open places	Vey Common	Very Common
20.	*Colias elcecto fieldi* (Menetries)	Prefers open spaces ,settles on damp ground	Common	Common
21.	*C.erate erate* (Esper)	Prefers open spaces ,settles on damp ground	Common	Common
22.	*Pieris brassicae nepalensis* (Doubleday)	Prefers open spaces ,settles on damp ground	Not reported	Common
23.	*Valeria valenria hippa* (Fabr.)	Prefers open spaces ,settles on damp ground	Not reported	Near Rare

Table 6.2 Contd.

Family : **DANAIDAE**				
24.	*Danaus chrysippus* (Linnaeus)	Settles on damp ground, overripe fruits; flights are slow and sluggish	Vey Common	Very Common
25.	*D.genutia* (Cramer)	Settles on damp ground, overripe fruits; flights are slow and sluggish	Vey Common	Very Common
26.	*Tirumala limniace leopardus* (Butler)	Settles on damp ground, overripe fruits; flights are slow and sluggish	Vey Common	Very Common
27.	*T. hamata septentrionis* (Butler)	Settles on damp ground, overripe fruits; flights are slow and sluggish	Vey Common	Very Common
28.	*Parantica aglea melanoides* (Moore)	Settles on flowers and congregate on herbs	Vey Common	Very Common
29.	*Euploea core* (Cramer)	Settles on flowers and congregate on herbs	Vey Common	Very Common
Family : **ACRAEIDAE**				
30.	*Acrace issoria anomala* Kollar	Settles on flowers and leaves; exudes foul smelling oily fluid	Near Rare	Near Rare
Family : **SATYRIDAE**				
31.	*Mycalesis lepcha lepcha* (Moore)	Prefers to settle on dead leaves, littler, weak flier	Near Rare	Near Rare
32.	*M.francisca sanatana* (Moore)	Prefers to settle on dead leaves, littler, weak fliers	Not reported	Common
33.	*Lethe rohria rohria* (Fabr)	Prefers to settle on dead leaves, littler, weak fliers	Common	Common
34.	*Parage schakra* (Kollar)	Prefers open grasslands, visits flowers, weak fliers	Common	Common
35.	*Callerebia scanda scanda* (Kollar)	Prefers open grasslands, visits flowers, weak fliers	Near Rare	Near Rare
36.	*Ypthima asterope mahratta* (Moore)	Prefers open grasslands, visits flowers, weak fliers	Near Rare	Near Rare

Table 6.2 Contd.

37.	*Ypthima sakra nikea* (Moore)	Prefers open grasslands, visits flowers, weak fliers	Common	Common
38.	*Y.ceylonica kasmira* (Moore)	Prefers open grasslands, visits flowers, weak fliers	Common	Common
39.	*Y. nareda nareda* (Kollar)	Prefers open grasslands, visits flowers, weak fliers	Near Rare	Near Rare
40.	*Y.baldus baldus* (Fabr)	Prefers open grasslands, visits flowers, water fliers	Vey Common	Very Common
41.	*Melanitis leda ismere* (Cramer)	Prefers open grasslands, visits flowers, water fliers	Common	Common
Family **: NYMPHALIDAE**				
42.	*Athyma asura* (Moore)	Mostly visit flowers, fond of basking in sun-shine,swift fliers	Rare	Rare
43.	*A.opalina* (Kollar)	Mostly visit flowers, fond of basking in sun-shine,swift fliers	Common	Common
44.	*A.perius* (Linnaeus)	Mostly visit flowers, fond of basking in sun-shine,swift fliers	Vey Common	Very Common
45.	*Neptis hylas astola* (Moore)	Also settles on flower and attracted to overripe fruits	Vey Common	Very Common
46.	*N.mahendra* (Moore)	Also settles on flower and attracted to overripe fruits		
47.	*N.yerburyz* (Butler)	Also settles on flower and attracted to overripe fruits	Near Rare	Near Rare
48.	*Hypolimnas bolina* (Linn.)	Also settles on flower and attracted to overripe fruits	Common	Common
49.	*H.misippus* (Linn.)	Visits flowers and overripe fruits, swift fliers	Common	Common
50.	*Pseudergolis wedah* (Kollar)	Visits flowers and overripe fruits, swift fliers	Near Rare	Near Rare
51.	*Kallima inachus* (Boisdvral)	Visits flowers and overripe fruits, swift fliers	Near Rare	Near Rare
52.	*Precis hierta* (Fabr.)	Visits flowers and overripe fruits, swift fliers	Vey Common	Very Common

Table 6.2 Contd.

53.	*P.orithya swinhoei* (Buttler)	Visits flowers and overripe fruits, swift fliers	Vey Common	Very Common
54.	*P. lemonias persicaria* (Furhstorfer)	Visits flowers and overripe fruits, swift fliers	Vey Common	Very Common
55.	*P.almana* (Linn.)	Visits flowers and overripe fruits, swift fliers	Vey Common	Very Common
56.	*P.iphita siccata* (Stichel)	Visits flowers and overripe fruits, swift fliers	Vey Common	Very Common
57.	*Cynthia cardui* (Linn.)	Visits flowers and overripe fruits swift fliers	Vey Common	Very Common
58.	*Vanessa indica* (Herbst)	Visits flowers, overripe fruits, swift fliers	Near Rare	Near Rare
59.	V.cashmirensis aesis (Frushtorfer)	Visits flowers and overripe fruits, swift fliers	Not reported	Near Rare
60.	*Argyreus hyperbius* (Linn.)	Visits flowers and overripe fruits, swift fliers	Near Rare	Near Rare
61.	*Cyrestis thyodamas* (Boisduval)	Visits flowers and overripe fruits, swift fliers	Not reported	Common
62.	*Kanishka canace himalaya* (Evans)	Visits flowers and overripe fruits, swift fliers	Not reported	Common
63.	*Childrena childreni sakontala* (Kollar)	Visits flowers and overripe fruits, swift fliers	Near Rare	Near Rare
64.	*Issoria lathonia issoea* (Doubleday)	Visits flowers and overripe fruits, swift fliers	Common	Common
65.	*Phalanta phalantha* (Drury)	Visits flowers and overripe fruits, swift fliers	Common	Common
66.	*Symbrenthia hippoclus* (de.N)	Visits flowers and overripe fruits, swift fliers	Vey Common	Very Common
67.	*Ariadne merione tapsestrina* (Moore)	Visits flowers and overripe fruits, swift fliers	Near Rare	Near Rare
68.	*Cupha erymanthis lotis* (Sulzer)	Visits flowers and overripe fruits, swift fliers	Common	Common
69.	*Diagora persimilis zella* (Butler)	Visits flowers and overripe fruits, swift fliers	Rare	Rare

Table 6.2 Contd.

70.	*Aglais cashminensis assis* (Fruh.)	Visits flowers and overripe fruits, swift fliers	Very Common	Not spotted
71.	*Vagrans sinha* (Cramer)	Visits flowers and overripe fruits swift fliers	Common	Not spotted
Family : **ERYCINIDAE**				
72.	*Libytheca myrrha* (Godart)	Prefers shady hilly forests, visits areas close to reservoir	Common	Common
73.	*L.lepita* (Moore)	Prefers shady hilly forests, visits areas close to reservoir	Common	Common
74.	*Dodona durga* (Kollar)	Prefers shady hilly forests, visits areas close to reservoir	Common	Common
75.	*Zemeros flegyas* (Cramer)	Prefers shady hilly forests, visits areas close to reservoir	Not reported	Near Rare
Family : **LYCAENIDAE**				
76.	*Zizeeria maha* (Kollar)	Found mostly ever where,open grasslands shrubs, along the roads, slow fliers	Common	Common
77.	*Heliophorus sena* (Kollar)	Found mostly ever where,open grasslands shrubs, along the roads, slow fliers	Common	Common
78.	*Celastrina huegelli* (Moore)	Found mostly ever where,open grasslands shrubs, along the roads, slow fliers	Common	Common
79.	*Lycaena pavana* (Kollar)	Found mostly ever where,open grasslands shrubs, along the roads, slow fliers	Not reported	Near Rare
80.	*Tarucus extricatus* (Buttler)	Found mostly ever where,open grasslands shrubs, along the roads, slow fliers	Near Rare	Not spotted
81.	*Euchrysops pandava* (Horsfield)	Found mostly ever where,open grasslands shrubs, along the roads, slow fliers	Common	Common
82.	*Albulina galathea* (Balcharel)	Found mostly ever where,open grasslands shrubs, along the roads, slow fliers	Not reported	Near Rare

Table 6.2 Contd.

83.	*Catochrysops strabo* (Fabr.)	Found mostly ever where,open grasslands shrubs, along the roads, slow fliers	Common	Not spotted
84.	*Spindasis vulcanus* (Fabr.)	Found mostly ever where,open grasslands shrubs, along the roads, slow fliers	Common	Not spotted
85.	*Spindasis lohita himalayanus* (Moore)	Found mostly ever where,open grasslands shrubs, along the roads, slow fliers	Common	Not spotted
Family : HESPERIIDAE				
86.	*Potanthus dara* (Kollar)	Abundant in jungles, attracted to flowers, basking in sunshine, fast fliers	Near Rare	Near Rare
87.	*Badampia* exclamationis (Fabr.)	Abundant in jungles, attracted to flowers, basking in sunshine, fast fliers	Near Rare	Near Rare
88.	*Odontoptilium angulata* (Feldor)	Abundant in jungles, attracted to flowers, basking in sunshine, fast fliers	Near Rare	Near Rare
89.	*Parnara guttatus* (Bremer & Gary)	Abundant in jungles, attracted to flowers, basking in sunshine, fast fliers	Common	Not spotted
90.	*Borbo cinnara* (Wallace)	Abundant in jungles, attracted to flowers, basking in sunshine, fast fliers	Common	Not spotted
91.	*Potanthus psreudomooss*	Abundant in jungles, attracted to flowers, basking in sunshine, fast fliers	Common	Not spotted

RHOPALOCERA DIVERSITY OF THE TEHRI DAM ENVIRONS

Symbrenthia hippoclus

Parantica aglea melanoides

Catopsilia pyranthe

Cynthia cardui

Chilasa clytia clytia

Heliophorus sena

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RHOPALOCERA DIVERSITY OF THE TEHRI DAM ENVIRONS

Pontia daplidice moorei

Ypthima baldus baldus

Hypolimnas bolina

Lethe rohria rohria

Zizeeria maha

Kanishka canace himalaya

Chapter - 07

OTHER IMPORTANT INVERTEBRATE'S DIVERSITY

Faunal diversity in few other important terrestrial invertebrate taxa is also very important to study in the Tehri Dam environs. As, the Tehri Dam environs provide a diversified habitats in terms of terrestrial and aquatic habitats. New habitats in terms of establishment of Botanical Garden and development of new plantations have compensated the lost terrestrial habitats caused by impoundment. The important taxa of Hymenoptera, Arachnida and Myriapoda have been included for providing detailed information of the faunal diversity of Post impoundment Tehri Dam environs.

HYMENOPTERA:

The order Hymenoptera of class Insecta of the phylum Arthopoda evolved during Jurassic period in Mesozoic era, about 155 million years ago. The members of this order exhibits instinctive behavior in its highest state of perfection. These members are economically, medically and biologically important. Hymenopterans are highly specialized, diversified and well adapted to the environment. They are swift fliers and feed mainly on plant food. They form their own colonies leading a complex, social and co-operative life. They are also entomophagous insects-parasites and predators.

A total of 1,20,000 species of Hymenoptera is known globally. However, about 10,000 species of Hymenoptera are found in India, which is about 8.3% of the total species of Hymenoptera in the world. Gupta(1995) presented on account of 200 species of Hymenoptera from eight districts (Dehradun, Tehri ,Pauri, Uttarkashi, Chamoli, Nainital, Almora and Pithoragarh) of Uttarakhand.

Pre Impoundment Scenario:

A total of 24 species of the order Hymenoptera (Class : Insecta) under seven families have been reported by the Northern Regional Station, Zoological Survey of India, Dehradun during a pre-impoundment survey undertaken for a period of six months in 1992.Out of these, 18 species were present above submergence level and 12 species commonly present within submergence area of Tehri Dam environs. Six species of Hymenoptera were common to both the area (within submergence and above submergence level).The study also revealed that the most of the species were common to very common except *Scolia (Discolia) dehraensis* Betrem, which was categorized as Rare. All other species were either widely distributed in India or atleast known to occur in other areas of Western Himalayas and are not threatened.

Post Impoundment Scenario:

An extensive survey of Tehri Dam environs for different seasons for two annual cycles revealed that a total of 46 species of Hymenoptera belonging to 32 genera and nine families were recorded. Largest numbers of 19 species belonging to 12 genera were reported from the family Ichneumonidae of Hymenoptera (Table 7.1 & 7.2). Three species of Pompilidae (*Salivus perplexus,Pompilus bioculatus,P.reflexus*) and one species of Chalcididae (*Brachymaria labus*) were not reported in the pre-impoundment survey. The reason for this may be that the pre-impoundment survey was for a short period of time. Most of the species were common and no threatened species has been recorded .No endemicity of any species has also been recorded for the Tehri Dam environs.

ARACHNIDA:

The members of Arachnida belong to the phylum Arthopoda. The arachnids are generally terrestrial in habit. The order Scorpionida (scorpions) is considered as one of the oldest forms of life. The most striking features of scorpions are large sized pedipalps and abdomen divided into seven segmented pre-abdomen and five segmented post-abdomen or tail- the cauda having a large poison sting. Based on the dwelling habitats, scorpions are grouped into-burrowing (Pelophilous),rock dwelling (lithophilous) and arboreal. Most of the scorpions are solitary and nocturnal. They hide by day under stones, logs, debris, old mattings, crevices, holes and underground in burrows. They are carnivorous and were abundant on the slopes of the hills.

Another order Araneae (spiders) is also very important of the class Arachnida. All spiders are carnivorous. They usually feed on insects and other spiders. The spiders are well known for their webs of different types which help in hunting prey. Cannibalism

is very common among spiders. Most of the spiders have a pair of poison glands which contain venom to kill prey.

Most of the spiders and scorpions collected from the post –impoundment Tehri Dam environs were terrestrial. The scorpions and spiders were found mostly common. None of the species was found endangered or endemic and not threatened by impoundment.

Pre-Impoundment Scenario:

A pre-impoundment survey undertaken by the by the Northern Regional Station, Zoological Survey of India, Dehradun during a short period of six months(May – October) 1992,revealed that two species belonging to the two genera and two families of the order Scorpionida were present in the pre-impoundment Tehri Dam environs.

A total of 21 species belonging to 14 genera and five families of the order Araneae were recorded under the pre-impoundment survey.

Post Impoundment Scenario:

A total of six species belonging to three families of the order Scorpionida has been reported from the post-impoundment Tehri Dam environs; while only two species belonging to two families were reported form the pre impoundment survey.

A total of 19 species belonging to 12 genera and five families of the order Araneae were recorded form the post impoundment Tehri Dam environs(Table 7.3). Almost the same numbers of species were reported under the pre-impoundment survey.

Most of the members of the order Scorpionida and Araneae were common in the study area. None of the species was of threatened category. No endemic species was also reported. Most of the species were also common elsewhere in the Uttarakhand Himalaya. Thus, there was no considerable adverse impact of the impoundment.

MYRIAPODA :

The invertebrates of Super class Myriapoda (Myriads = numberless; pedes = feet) are also important terrestrial arthropods.Myriapods are multisegmented, multilegged and tracheate (air breathing through trachea).The super class Myriapoda into four classes – Chilopoda, Diplopoda, Pairopoda and Symphyla. The Chilopods are commonly known as ‘Centipedes’.The members of Diplopoda are known as millipedes. Though, Myriapoda is a very large group of land arthopods with rich biodiversity, yet no

comprehensive account of species diversity is available in India. The most well worked our group of invertebrates is the order Scolopendromorpha, hence the status report on the biodiversity of Tehri Dam environs is restricted to the order of Scolopendromorpha only.

The Scolopendrid centipedes are known globally by about 600 species,of which India alone supports roughly 15-18% species (Alfred *et. al* 1998).

The centipede is called by various vernacular names- *Kankhajura* in Uttar Pradesh and Uttarakhand , *Kansalva* in Rajasthan , *Kankel* in Punjab, *Kansui* in Maharashtra, *Kennri* in Orissa and *Kannoi* in West Bengal. Considerable work on the diversity of centipedes of Western Himalayas was done by Khanna (1995).The Scolopenrid centipedes are represented by 94 species belonging to seven genera of the family Scolopendridae from India. 20 species of centipedes have been reported from Uttarakhand (Khanna 1998).

Pre-Impoundment Scenario

Pre – impoundment faunal survey undertaken by the Northern Regional Station, Zoological Survey of India, Dehradun during May-October,1992 revealed that the presence of *Rhysida monalii* Khanna & Kumar; and *Otostigmus amballae* Chamberlin from the pre-impoundment habitats was confirmed. However, the possibility of the presence of *Scolopendra moristans* Linnaeus; and *Cormocephalus dentipes* Pocock was also reported. It was also pointed out that these species were neither endemic nor rare and their occurrence would not be affected by the loss of their habitats, following the construction of Tehri Dam.

Post Impoundment Scenario:

An extensive survey of post impoundment of Tehri Dam environs in different seasons for two annual cycles revealed that five species of centipedes belonging to 4 genera and one family were present in the post-impoundment Tehri Dam environs (Table7.4). Most of the species were common and no adverse impact of impoundment was noticed on diversity of centipedes.

Table 7.1 : Diversity composition of Hymenoptera in pre-impoundment and post-impoundment Tehri Dam environs

S.N.	Family	Pre-impoundment		Post-impoundment	
		Genus	Species	Genus	Species
1.	Tiphidae	02	02	01	01
2.	Scolidae	03	08	02	04
3.	Eumenidae	01	01	02	02
4.	Vespidae	02	03	02	03
5.	Pompilidae	Not Reported	Not Reported	02	03
6.	Sphecidae	05	06	09	12
7.	Chaleididae	Not Reported	Not Reported	01	01
8.	Ichneumonidae	03	03	12	19
9.	Apidae	01	01	01	01
	TOTAL	**17**	**24**	**32**	**46**

Table 7.2 : Hymenoptera diversity and their status of presence in pre-impoundment and post-impoundment of Tehri Dam environs.

S.N.	Zoological Name	Status of Presence	
		Pre-impoundment	**Post-impoundment**
Class: **INSECTA**			
Order : **Hymenoptera**			
I.	Family : **Tiphidae**		
1.	*Tiphia (Tiphia) rufofemorata* (Smith)	Common	Common
II.	Family : **Scolidae**		
2.	*Campsomeriella c. collaris* (Fabr.)	Common	Common
3.	*C. annulata* (Fabr.)	Common	Common
4.	*Scolia affins* (Gueria)	Common	Common
5.	*S. dehraensis* (Betrem)	Rare	Rare
III.	Family : **Eumenidae**		
6.	*Eumenses dimidiatipennis* Sauss	Common	Common
7.	*Rhynchium argetatum* (Fabr.)	Not reported	Rare
IV.	Family : **Vespidae**		
8.	*Polistes (Megapolistes) olivaceus* (De Geer)	Common	Common
9.	*P.(Polistella) maculipennis (*Saussure)	Common	Common
10.	*Vespa (Vespa) velutina auraia* (Smith)	Not reported	Common
V.	Family : **Pompilidae**		
11.	*Salivus perplexus* (Smith)	Not reported	Rare
12.	*Pompilus bioculatus* Bingham	Not reported	Uncommon
13.	*P. reflexus* (Smith)	Not reported	Uncommon
VI.	Family : **Sphecidae**		
14.	*Chlorion lobatum* (Fabricius)	Common	Common
15.	*Chalybion bengalense* (Dahlbom)	Common	Common
16.	*Podalonia laeta* (Bingham)	Not reported	Rare
17.	*Ammophila atripes* (Smith)	Common	Common
18.	*A. laeviagata* Smith	Not reported	Uncommon
19.	*A. puncata* (Smith)	Common	Common
20.	*Liris deplanata binghami* (Tsuneki)	Not reported	Uncommon
21.	*Tachysphex bengalensis* (Cameron)	Not reported	Uncommon
22.	*Pison sp*.	Not reported	Rare
23.	*Trypoxylon canaliculatum* (Cameron)	Not reported	Uncommon

Table 7. 2: Contd.

24.	*T. pileatum* Smith	Not reported	Uncommon
25.	*Dasyproctus budhha* (Cameron)	Not reported	Rare
VII.	Family : **Chalcididae**		
26.	*Brachymeria lasus* (Walker)	Not reported	Rare
VIII.	Family : **Ichneumonidae**		
27.	*Neteli virgata* (Fourcroy)	Not reported	Common
28.	*N. orientalis* (Cameron)	Not reported	Common
29.	*N. siva* (Kaur & Jonatham)	Not reported	Rare
30.	*Exetastes nigellus* (Chandra & Gupta)	Not reported	Uncommon
31.	*Campoplex maxmimulus* (Gupta & Maheshwary)	Not reported	Common
32.	*Casinaria formosana bharata*(Maheswary & Gupta)	Not reported	Common
33.	*Urvashia dentipara* (Gupta & Gupta)	Not reported	Rare
34.	*Delopia buddha*(Cameron)	Not reported	Uncommon
35.	*D.lajae* (Gupta & Gupta)	Not reported	Common
36.	*D. simalaensis* (Cameron)	Not reported	Rare
37.	*D.sumptusoa* (Cameron)	Not reported	Common
38.	*D. tipari* (Gupta & Gupta)	Not reported	Uncommon
39.	*Camplotis chloridae* (Uchida)	Not reported	Common
40.	*Xenolytus rugatus* (Townes)	Not reported	Rare
41.	*Charitopes densus* (Townes)	Not reported	Rare
42.	*C.rugatus* (Townes)	Not reported	Uncommon
43.	*Apocryptus garhwalensis* (Gupta & Gupta)	Not reported	Common
44.	*Skeatia maculifrons* (Jonatham & Gupta)	Not reported	Common
45.	*Amblyjoppa annuliatarsis annuliatarsis* (Cameron)	Not reported	Uncommon
IX.	Family : **Apidae**		
46.	*Bomus haemorr hoidelia* (Smith)	Not reported	Common

Table 7.3 : **Arachnida diversity and their status of presence in pre-impoundment and post-impoundment of Tehri Dam environs**

S.N	Zoological Name	Status of Presence	
		Pre-impoundment	**Post-impoundment**
Class :**ARCHNIDA**			
ORDER : **SCORPIONIDA**			
I.	Family : **Buthidae**		
1.	*Mesobutlus tumulus gengeticus* (Pocock)	Common	Common
2.	*Lychas migristernis* (Pocock)	Common	Common
II.	Family : **Chaerilidae**		
3.	*Chearilius granosus* (Pocock)	Common	Common
4.	*C. truncatus* (Karsch)	Common	Common
III.	Family: **Vaejovidae**		
5.	*Scorpiops hardwickii* (Gervais)	Common	Common
6.	*S.montanus* (Karsch)		
ORDER : **ARANEAE**			
IV.	Family : **Argiopidae**		
1.	*Araneus nympha* (Simon)	Common	Common
2.	*Neoscona pavida* (Simon)	Common	Common
3.	*Nephilia maculata* (Fabricius)	Common	Common
4.	*N. clavata* (Koch)	Common	Common
5.	*Leucage decorata (*Blackwall)	Common	Common
6.	*Lycose goleathus* (Pocock)	Common	Common
7.	*L.masteri* (Pocock)	Common	Common
8.	*Pardosa altitudes* (Tikader)	Common	Common
9.	*P.annandelei* (Gravely)	Common	Common
10.	*P.heterothalmus* (Simon)	Common	Common
11.	*P.kukupa* (Tikader)	Common	Common
12.	*P.birmanica* (Simon)	Common	Common
13.	*P.sumatrana* (Thorell)	Common	Common
14.	*Hipoasa creenllae* (Blackwall)	Common	Common
V.	Family : **Telragnathidae**		
15.	*Tetragnatna andamensis* (Tikader)	Common	Common
VI.	Family : **Heteropodidae**		
16.	*Heteropoca phasma (*Simon)	Common	Common
VII.	Family : **Salticidae**		
17.	*Salticus rangitus (*Tikader)	Common	Common
18.	*Stenodophus sarasinorum (*Karsch)	Common	Common
VIII.	Family *:* **Oonooidae**		
19.	*Isnothyraus spp.*	Common	Common

Table 7.4: Myriapoda diversity and their habit and habitats, conservation status and status of presence in pre-impoundment and post-impoundment Tehri Dam environs

S.N.	Zoological Name	Habits and Habitat	Conservation Status	Status of presence	
				Pre-impoundment	Post-impoundment
Class : **CHILOPODA** Order : **SCOLOPENDROMORPHA** Family : **Scolopendridae**					
1.	*Rhysida monalii* (Khanna & Kumar)	Solitary, nocturnal, cannibal, cryptic, takes refuge under stones, cow dung, bark of trees, mosses in the gardens, cultivated land	LC	Common	Common
2.	*R. nuda immarginata* (Porath)	Solitary, nocturnal, inhabits soil of cultivated crops and vegetables and cow dung	LC	Not reported	Common
3.	*Otostigmus amballae* (Chamberlin)	Solitary, nocturnal, takes refuge in the soil of agricultural crops and vegetables	LC	Common	Common
4.	*Scolopendra morsitans* (Linnaeus)	Solitary, nocturnal, takes refuge under cultivated soils	LC	Not reported	Common
5.	*Cormocephalus dentipes* (Pocock)	Solitary, nocturnal, takes refuge under stones, cow dung ,soil of garden and cultivated lands	LC	Not reported	Common

Chapter- 08

AMPHIBIAN DIVERSITY

Amphibians are poikilothermic (cold blooded) vertebrates with smooth skins lending to a bimodal life –life in water as well as land. They may or may not possess limbs and tails. Amphibian's skin is sensitive and devoid of visible scales. Much of the gas exchanges in amphibians occur through their skin. The skin secretion generally protects the skin from desiccation. The fact that the skin has to be moist to be functional restricts the distribution of most amphibians to the largely wet and warm parts of the world (Chanda 1998).

In most amphibians, the life history is organized into eggs, larval, and adult stages. The eggs may be freely deposited inside or near water or carried about by parents. The abundance of amphibians is very uneven in India. The highest concentration of diversity exists in the Northern region and Western Ghats. India harbours 209 species of amphibians out of 5150 species of the world. (Chanda 1998).

The amphibians form an important link in the evolutionary history of vertebrates in India. The amphibians are represented by all the three order- Gymnophiona/Apoda/ Caccillians; Caudata/Urodela; and Salientia/Anura. The anurans, to which frogs and toads belong, are the prominent one.

Uttarakhand embraces almost all types of amphibian habitats. On account of its varied climatic, topographical, altitudinal, and vegetational conditions, the amphibian fauna of Uttarakhand have not been adequately studied. Important contributions on the amphibians of Uttarakhand were made by Anandale (1906,1908), Boulenger (1920),

Waltner (1974), Chopra (1977), Tilak and Ray (1985), Ray (1989, 1995). The construction of Tehri Dam has modified the natural landscape of the area. This has destroyed some of the habitats and some of the entirely new habitats have been created after the formation of new reservoir. Thus, the extensive survey of the area for enlisting amphibians is very relevant and important under the present post impoundment scenario.

An extensive survey and field study of the entire Tehri Dam environs in different seasons for two annual cycles revealed that amphibians were represented by only one order Anura (toads and frogs), belonging to 9 species and 5 genera belonging to 3 families (Table 8.1). Most of the species were common and none is endemic to the area. The same species of amphibians were reported by Zoological Survey of India, North Station, Dehradun in its pre-impoundment survey undertaken in 1992. Thus, there is no tangible adverse impact of impoundment of Bhagirathi and Bhilangana rivers on amphibian diversity. However, creation of big reservoirs, the population of these species has increased considerably in the periphery of the reservoir. The presence of most of the amphibians was common during monsoon season.

Table 8.1 : Amphibians, their habit and habitats, conservation status and status of presence in the pre-impoundment and post-impoundment of habitats of Tehri Dam environs

S.No.	Zoological Name	Common Name	Habit & Habitat	Ecological status	Pre-impoundment status	Post-impoundment status
Order : **ANURA** Family : **RANIDAE**						
1.	*Amolops afghanus* (Gunther)	Gunthu's stream frog	Nocturnal prefers to stay near hill streams ,sometimes found settles on bolulders, voracious feeder	LC	Common	Common
2.	*Rana blanfordii* (Boulenger)	Hill forg	Aquatic species, common June – September, found near reservoir, streams & rivers	DD	Very common	Very common
3.	*Rana cyanophylyctis* (Schneider)	Skipper Frog	Aquatic species, active during day and night, skips over the surface water ,prefer stagnant water of reservoir		Common	Common
4.	*Rana limnocharis* (Boie)	Paddy filed frog	Inhabit mostly in paddy files,near the reservoir edges,Nocturnal	LC	Very common	Very common
5.	*Tomopterna breviceps* (Schneider	Indian Burrowing frog	Terrestiral nocturnal,found under logs and stones; commonly present in June-July(monsoon season),burrows in soil	Not Known	Common	Common

Table 8.1 Contd.

Family : **BUFONIDAE**						
6.	*Bufo himalayanus* (Gunther)	Himalayan Toad	Inhabits higher altitude region near reservoir, throughout the year	DD	Rare	Rare
7.	*Bufo melanostictus* (Scheider)	Common Asian Toad	Nocturnal,found in damp places,indise holes,logs,commonly seen insectivorous during monsoon	LC	Common	Common
8.	*Bufo stomaticus* (Lutken)	Marbled Toad	Inhabit around human habitations,common forest edges,der patches	LC	Present	Present
Family : **MICROPHYLIDAE**						
9.	*Microphyla ornate* Dumeril & Biron	Ornamental Pigmy Frog	Nocturnal,commonly seen in June – August,Prefers leaf litter and moist place covered with grass & herbs,Near Human settlement,well adapted	LC	Common	Common

AMPHIBIAN DIVERSITY OF TEHRI DAM ENVIRONS

Bufo himalayanus
(Himalayan Toad)

Bufo melanostictus
(Common Indian Toad)

Rana cyanophlyctis
(Indian skipping frog)

Bufo stomaticus
(Marbled Toad)

Chapter- 09

REPTILIAN DIVERSITY

Reptiles are cold-blooded vertebrates which breathe by lungs throughout their existence and have the body covered by scales; the skull articulates with the vertebral column by a single median occipital condyle. Reptiles were the dominant group of vertebrates during the Mesozoic period and they reached their maximum and most diversified development at that time. Most of the orders of reptiles were established by the end of Triassic period and some become extinct at that time. Out of the 19 orders of Class Reptilia, the members of 4 orders only survive today. These are Crocodylia (Gharilas and Crocodiles); Testudines (Turtles,Tortoises and Terrapins); Squamata (Lizards and snakes); and Rhynchocephalia which includes a single living speices, the Tuatera (*Sphenodon punctatus*) found only in New Zealand.

The reptilian fauna of India are unique in its diversity, which have the greatest affinity to the Oriental region, and the Indo-Malayan region. Reptiles in India are found in diverse habitats ranging from deserts to the rain forests, from the brackish waters and beaches fringing the coasts of plains, hills and dense jungles. Reptiles are the most important group of predators, the interaction of which maintains the natural balance in the forests, deserts, rivers, lakes, the plains and high mountains of India. A great number of living reptiles are slowly disappearing mainly due to the increasing human interference. Not only reptiles deprived of their habitats but their direct persecution and slaughter are intensified by the rapid growth of industrialization and land exploitation.

The reptilian fauna of Uttarakhand has attracted the attention of various workers during the past. Important contributions are of Bhatnagar (1972); Dwivedi and Mathur (1978); Chopra (1979); Sanyal *et.al.(*1979); Murthy (1985) and Husain and Ray (1995). Waltner (1974) gave a general account of geographical and altitudinal distribution of reptiles in the Himalayas.

The Tehri Dam Project has transformed the ecological set up of the Bhagirathi and Bhilangana Valley. A big area of terrestrial and aquatic habitats has been submerged. A new area of terrestrial habitats in the form of new plantations and Botanical Garden has been established. Therefore, the survey of reptilian fauna in the post-impoundment Tehri Dam Environs is very relevant. The survey is based on extensive visits of the entire area in different seasons for two annual cycles.

Pre-impoundment Scenario:

Zoological Survey of India (Northern Regional Station) reported reptiles comprising lizards and snakes during its surveys in 1992 from various localities within and above the line of submergence of Tehri Dam Project. There was no evidence of the crocodile, turtles, and tortoises from the areas. Four species of lizards belonging to three families (Gekkonidae, Agamidae, Varanidae) were reported from the pre-impoundment area. The species reported from the pre-impoundment were *Crytodactylus fasicolata, Agma tuberculata, Calotes versicolor, and Varanus bengalensis* (Table 9.1).

Six species (*Ramphotyphlops braminus, Amphiesme stolata, Xenochroohis piscator,Elaphe Helena, Ptyas mucosus and Naja naja)* belonging to the order Serpents and four families (Typhlopidae, Natricidae, Colubride, Elapidae) were reported from the pre-impoundment habitats of Tehri Dam environs.

Post-impoundment Scenario:

An in-depth survey of the various habitats of the post-impoundment Tehri Dam Environs for two annual cycles revealed that eight species of lizards (order: Sauria) belonging to four families (Gekkonidae, Agamidae, Varanidae, Scinidae) were present in the area. Four species (*Hamidactylus faviviridis, Hemidactylus brooki, Japulura major and Scincella himalayanum)* of lizards were also reported, which were not reported in the pre-impoundment survey (Table 9.1).

A total of 12 species of snakes (order: Serpentes) belonging to seven families have reported from post impoundment habitats. Six new species of snake (*Phython molurus, Bungarus fasciatus, Vipera ruselli, Boiga multifaciata, Naja oxiana and Oligodon taeniolatus*) have been reported from the post-impoundment Tehri Dam environs.

The reason for the presence of more species may be that the pre-impoundment survey was for a very short period of six months. The present survey was very extensive and intensive for two annual cycles. Creation of huge reservoir has given advantages for providing conducive environment for the propagation of herpetofauna. Abundance of herpetofauna has increased around the periphery of the Reservoir. Thus, the impact of Tehri Dam has a positive impact on the reptilian diversity.

Table 9.1 : Reptiles and their habit and habitats, conservation status and status of presence in the post-impoundment and pre- impoundment Tehri Dam environs

S.No.	Zoological Name	Common Name	Habit & Habitats	Conservation Status	Status of Presence	
					Pre-impoundment	Post-impoundment
Order : SAURIA Family : **Gekkonidae**						
1.	*Crytodactylus fascilotus* (Blyth)	Rock Gecko	Nocturnal, dwells in cervices among rocks, stones, and bushes; non-poisonous	LC	Common	Common
2.	*Hemidactylus faviviridis* (Rupell)	Yellow-bellied House Gecko	Dwells in crevices of rocks, stone walls, holes; feeds on insects, butterflies and other anthropods; basking on stone walls; non-poisonous	LC	Not reported	Very Common
3.	*Hemidactylus brooki* (Gray)	Spotted Indian House Gecko	Nocturnal, inhabits forest patches,human settlements; non-poisonous	LC	Not reported	Common
Family : **Agamidae**						
4.	*Agama tuberculata* (Hardwicke & Gray)	Rock Lizard	Gregarious, inhabits almost throughout the area, non-poisonous	Common	Most Common	Most Common
5.	*Calotes versicolor* (Daudin)	Indian Garden Lizard	Diurnal prefers to live in bushes, shrubs forest areas, road side vegetation, insectivorous, non-poisonous	NT	Common	Common

Table 9.1 Contd.

6.	*Japalura major* (Jerdon)	Garhwal Mountain Lizard	Diurnal, terrestrial, inhabits leaf litters close to rocky mountain streams, uses rock as cover: insectivorus, non-poisonous	LC	Not reported	Common
Family : **Varanidae**						
7.	*Varanus bengalensis* (Daudin)	Monitor lizard	Diurnal, largest lizard, carnivorous, solitary, basking in the morning Sun, Non-venomus	Vu (WPA Schedule I) CITES Appendix I	Common	Common
Family :**Scincidae**						
8.	*Scincella himalayanum* (Gunther)	Himalayan Ground Skink	Diurnal, terrestrial, inhabits moist rotten logs, accumulated leaf and rock piles, insectivorous	LC	Not reported	Common
Order: **SERPENTES** Family : **Typhlopidae**						
9.	*Ramphotyphlops braminus* (Daudin)	Common blind Snake	Inhabits underneath debris, soil, logs, stones, feeds on worms, small insects and their larvae; Non-venomous	NT (WPA Schedule IV)	Common	Common
Family : **Boidae**						
10.	*Phython molurus molurus* Linnaeus	Asiatic Rock Python	Nocturnal, crepuscular, inhabits both primary and degraded forests feeds on rats, jackals, deer, wild boars; Brooding and basking is common, Non-venomous	Vu (WPA Schedule I Appendix II)	Not reported	Rare

Table 9.1 Contd.

Family : **Natricidae**						
11.	*Amphiesma stolata* (Linnaceus)	Stripped Keel-back Snake	Diurnal, inhabits banks of rivers, streams, reservoir, holes, under rocks and branches of trees and bushes, feeds on frogs and toads, Non-Venomous	NT (WPA Schedule IV)	Common	Common
12.	*Xenochrophis piscator* (Scheider)	Checkered Keel-back Snake	Diurnal, frequents streams, rivers, reservoir banks, basking on grass; feeds on fish, frog, toads and tadpoles; Non-venomous	NT (WPA Schedule II)	Common	Common
Family : **Colubridae**						
13.	*Elaphe Helena* (Daudin)	Common Trinket Snake	Diurnal, inhabits leafy trees and bushes, rock holes and crevices, burrows of rodents; Non-venomous	LC	Common	Common
14.	*Ptyas mucous* (Linnaeus)	Rat snake (Dhaman)	Dirunal inhabits rat holes, high grasses paddy / wheat fields, rats as main food, very agile escape in good speed, keeps rats under control; non-venomous	Not assessed (WPA Schedule IV)	Very Common	Very Common
15.	*Oligodon taeniolatus* (Jerden)	Russell's Kukri Snake	Active by day & night found in forest as well as near human habitation, Docile, carnivorous.	DD (WPA Schedule IV)	Not reported	Uncommon

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Table 9.1 Contd.

Family : **Elapinae**						
16.	*Bungarus fasciatus* (Schneider)	Banded Krait	Nocturnal, timid, non aggressive, inhabits variety of habitats, close to water bodies, sandy soils, burrows of rodents; venomous	NT (WPA Schedule IV)	Not reported	Common
17.	*Naja naja* (Linnaeus)	Binocellate Cobra (Nag)	Dirunal, extremely agile, inhabits forests, agriculture fields, hollow trunk of old trees, big holes in the ground, termite moulds, venomous	NT (WPA Schedule II) CITES Appendix II	Common	Common
18.	*Naja oxiana* **(**Eichwald)	Black Cobra	Dirunal, inhabits forest edges at high altitute, eats amphibians, lizards, rodents. Venomous	DD	Not reported	Very Rare
Family : **Viperidae**						
19.	*Vipera russelli* (Shaw)	Russell's Viper	Nocturanl, terrestrial, inhabits cultivated areas, grasses, termite mounds, rat burrows; Venomous	DD	Not reported	Rare
Family : **Homalopsidae**						
20.	*Boiga multifasciata* (Blyth)	Himalayan Cat Snake	Arboreal, nocturnal, inhabits forests, degraded forests, tall grasses, under the bark of trees, mildly Venomous	Not Evaluated (WPA Schedule IV)	Not reported	Uncommon

LIZARDS OF TEHRI DAM ENVIRONS

Varanus bengalensis
(Monitor Lizard)

Calotes versicolor
(Indian garden lizard)

Cyrtodactylus fascilotus
(Rock Gecko)

Hemidactylus brooki
(Spotted Indian House Gecko)

Agama tuberculata
(Rock Lizard)

Hemidactylus faviviridis
(Yellow-bellied House Gecko)

SERPENTS DIVERSITY OF TEHRI DAM ENVIRONS

Dendrelaphis tristis
(Bronze back tree snake)

Ramphotyphlops braminus
(Blind snake)

Bioga multifaciata
Himalayan cat snake

Bungarus fasiatus
Banded Krait

Ptyas musosus
Indian Rat snake

Python molurus molurus
Asiatic Rock Python

SERPENTS DIVERSITY OF TEHRI DAM ENVIRONS

Oligodon taeniolatus
Russell's kukri snake

Naja oxiana
Black cobra

Vipera russelli
Russell's viper

Naja naja
Spectacle cobra

Elephe helena
Trinket snake

Lycodon aulicus
Wolf snake

Chapter- 10

AVIAN DIVERSITY

The Himalayas are the home of thousands of species of birds or avifauna. The avifauna of this mountain chain has been influenced by Palaearctic, South Indian, Malayan, Chinese, Tibetan and Central Asian elements. Amongst the larger birds found in the Himalaya are kites, eagles, vulture, and pheasants. The medium sized birds include fowls, cocks, woodpeckers, and swallows, white tits and warblers are some of the smaller birds of Himalayas.

Class Aves of the phylum Chordata includes the fascinating warm blooded vertebrate creatures, which are known as birds. They are characterized by the presence of feathers which serves many purposes like insulating the body and contributing to the flying apparatus of wings and tail. Birds evolved about 150 million years ago, their diversification of forms were noticeable, sometimes during 60 millions year ago. Since then speciation process continued rapidly and majority of the families and many genera living today have already appeared some 11 millions year ago. By virtue of their flying ability, birds have great mobility and dispersed over every corner of the planet. Many species are gregarious, teaming in flocks of thousands, while other is solitary or moves in pairs and in small group of 5-20. Global diversity of birds enlists 9,026 species living birds under more than 1,800 genera, 182 families and 30 orders

India can boast of having 1,166 species under 405 genera, 78 families and 20 orders. The avifauna abridges Palaearctic, Oriental, Ethiopian, and Australasian zoogeographic regional elements. Distribution of every species is largely dependent on the access to the place, availability of food, nesting grounds, and shelter together with

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other ecological factors. Since, there has been change in various degrees in ecology and overall pattern of geographical features coupled with human activities, there has been a change in distribution pattern of many species of birds

There are ethical, social, and economic relation between man and the birds. Economic relations are many fold. Birds are friends as well as foes to mankind. Some are beneficial being agents for pollination, germination, and for dispersal of seeds of plants. They help in controlling pests, scavenging the carcasses and offering flesh and eggs for the table. On the other hand, destroy crops in the field as well as in ponds by devouring seeds and fishes, spreading disease and also become our enemy. Besides, birds offer themselves as prey species and many other depend directly on bird life. The ecological balance in the nature is also shared by avifauna. Hence, their absence will disturb the cybernatics of the nature.

Many attempts have been made to survey the avian fauna of Uttarakhand area. Hudson (1930) reported birds from Nainital, Briggs (1993) reported birds from Ranikhet, while Bhatnagar and Misra (1971) have reported birds from the Dehradun district. Lavkumar (1956) reported birds from Garhwal. Tak and Kumar (1987) reported birds from Nandadevi, while Lamba (1987) reported birds from Corbett National Park. Kumar (1985) reported birds from Nayar Valley of Pauri-Garhwal district. Tak (1995) summarized the avian diversity of Uttarakhand.

However, no sincere effort has been made on the avian diversity of Tehri Garhwal district except a preliminary report on the birds of pre-impoundment area of Tehri Dam Project (ZSI 1992). The present contribution is aimed at to provide information on the post impoundment survey of avian fauna based on the observations of all types of bird's habitat during various seasons (winter, summer, and monsoon) for two annual cycles.

PRE-IMPOUNDMENT SCENARIO:

Pre-impoundment survey made by Zoological Survey of India, Northern Regional Station, Dehradun for a brief period of six months (May-October 1992) prepared an inventory of birds of Tehri Dam area. During this short survey, reported 73 species, belonging to 63 genera spread over to 31 families and 13 orders. The transect-wise analysis of birds diversity indicated the maximum concentration of birds (36 species) in the Bhilangana Valley, and the minimum (14 species) from the area downstream to Tehri Dam site. 30 species were reported from the Bhagirathi transect along Dehradun Road.

None of the species reported was endemic. However, the Indian Sparrow Hawk being an endangered one included in the Schedule I of the Wildlife Protection Act 1972 and

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the Ring Tailed or Pallas's Fishing Eagle (categorized as IUCN Rare)were reported in the area. In addition to it Red headed Vulture(*Sarcogypus calvus*) and Indian white rumped Vulture (*Gyps bengalensis)* categorized as critically endangered (CR) have also been reported from pre-impoundment habitats.

POST-IMPOUNDMENT SCENARIO:

An extensive and intensive survey of various habitats of post-impoundment Tehri Dam environs resulted in identification of 77 bird's species belonging to 67 genera of 33 families and 15 orders (Table 10.1& 10.2).The dominant order was Passiformes represented by 16 families, 35 genera and 40 species. The dominant family was Musicapidae represented by 13 genera and 14 species followed by Accipitridae represented by 10 species of 9genera of the order Falconiformes.

These are few species which were reported form the impoundment survey,were not found to be present in the Tehri Dam environs. Palla's Fish Eagle (*Haliaectus leucoryphus* Pallas), Indian White rumped Vulture (*Gyps bengalensis* Gemlin*)* were reported under the pre-impoundment report. But, these species were not spotted during the survey of two annual cycles.However, four new species of birds – Large Cormorant (*Phalacrocorax carbosinesis* Shaw), Little Cormorant (*P.niger*), Rudy Shelduck/Brahminy Duck (*Tadorna ferruhines Palla*) and Common Pochard (*Aythya ferina* Linnaeus) all the winter migrants were found in the Post-impoundment Tehri Dam environs. These water birds have landed in the area during winters is due to the creation of big reservoir. Thus, the creation of reservoir will further attract the winter migrant birds in the area. This is the positive impact of Tehri Dam construction. New habitats like Botanical Garden and new plantations in the area have also attracted the birds and the population of the species, dwelling in the Botanical Garden, open parks, and new plantations has increased considerably.

Table 10.1 : Composition and diversity of bird species in the Tehri Dam environs

Order	Family	No. of Genera	No. of Species
Ciconiformes	Ardeidae	01	01
Falconiformes	Accipitridae	09	10
	Falconidae	01	01
Galliformes	Phasianidae	03	04
Charadriformes	Charadridae	01	01
Columbiformes	Columbridae	02	04
Psittaciformes	Psittacidae	01	01
Culculiformes	Cuculidae	02	04
Strigiformes	Strigidae	01	01
Caprimuliformes	Caprimulgidae	01	01
Apdodiformes	Apodidae	01	01
Coraciformes	Alcedinidae	03	03
	Meropidae	01	01
	Upupidae	01	01
Piciformes	Capitonidae	01	01
Passiformes	Hirundinidae	01	01
	Lanidae	01	01
	Oriolidae	01	01
	Sturnidae	02	04
	Dicurridae	01	01
	Corvidae	03	04
	Pycnonotidae	02	03
	Muscicapidae	13	14

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Table 10.1 Contd.

	Cinclidae		01
	Paridae	01	01
	Motacillidae	02	02
	Nectarinidae	01	01
	Zosterpidae	01	01
	Ploceidae	02	02
	Fringillidae	02	02
	Emberizidae	01	01
Pelecaniformes	Pelicanidae	01	02
Anseriformes	Anatidae	01	02
Total: 15	**33**	**67**	**77**

Table 10.2. Avian fauna their habit and habitat, conservation status and status of presence in the pre-impoundment and post impoundment Tehri Dam Environs

S.N	Zoological Name	Common Name	Habit & Habitat	Conservation Status	Status of Presence	
					Pre-impoundment	Post-impoundment
Order: CICONIFORMES Family: Ardeidae						
1.	*Ixobrychus cinnamomeus* (Gmelin)	Chestnut Bittern	Non gregarious, Crepusculer, Voracious Feeder, Carnivorous, Reedy beds of water body, Paddy fields	LC	Resident Local movement, Uncommon	Resident Local movement, Uncommon
Order: FALCONIFORMES Family: Accipitridae						
2.	*Milvus milvus govinda* (Sykeo)	Pariah Kite	Bird of prey, Soaring, glides in search of food, Carnivorous	LC	Resident Common	Resident Common
3.	*Accipiter nisus melachistos* (Hume)	Indian Sparrow Hawk	Smaller bird of prey, hunting behavior	LC	Resident Local migrant, Uncommon	Resident, Local migrant, Uncommon
4.	*Spizaeutus* (cirrhatus) limnectus (Horsefild)	Changeable Hawk-Eagle	Smaller bird of prey, Inhabits forests and wooded land	LC	Resident, Local migrant Uncommon	Resident, Local migrant Uncommon
5.	*Aquila rapax nepalensis* (Hodgson)	Steppe Eagle	Feeds on fresh carion of rodents, small mammals, birds, bird of prey	LC	Resident, Common	Resident, Common
6.	*Haliaeetus leucoryphus* (Pallas)	Ringtailed or Pallas's Fish Eagle	Riverine tract, lakes, reservoir, winter visitor	Vu	Reported	Absent
7.	*Sarcogyps calvus* (Scopoli)	Red headed Vulture	Scavenger, Carion feeder	CR	occasional	occasional
8.	*Gyps himalayensis* (Hume)	Himalayan Griffon Vulture	Inhabits mountain area, feeds mostly, carcasses of animals, soars over	LC	Resident, Common	Resident, Common

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			open areas/mountains, mores in floods grants and hisses at roosts			
9.	*Gyps bengalensis* (Gemlin)	Indian white-rumped Vulture	Common in Gangetic plains, nesting on the trees	CR	Reported	Absent
10.	*Neophron percnopterus ginginianus* (Latham)	Indian Scavenger Vulture/Egyptian Vulture	Scavenger, Carion feeder	EN	Occasional	Occasional
11.	*Spilornis cheela cheela* (Latham)	Crested Serpent Eagle	Inhabits forests and well wooded land perchason leafy trees predator, sharp whistling call at night	LC	Resident Common	Resident Common
Family: Falconidae						
12.	*Falco tinnunculus tinnunculus* (Linnaeus)	European Kestrel	Bird of prey ,swift flier, arboreal, nesting in tree holes	LC	Resident, summer visitor, Uncommon	Resident,Summer Visitor, Uncommon
Order : GALLIFORMES **Family: Phasianidae**						
13.	*Alectoris chukar chukar* (Gray)	Chukar Partridge	Game bird, native range is rocky open hill sides with grasses/scattered scrub	LC	Resident, local movement. common	Resident ,local movement ,common
14.	*Francolinus francolinus asiae* (Bonaparte)	Indian Black Partridge	Inhabits driver, open cultivated land, scrub forests	LC	Resident, Uncommon	Resident, Uncommon
15.	*F.pondicerianus interpositus* (Halert)	North Indian Grey Partridge	Dwells dry grasslands and scub bushes	LC	Resident ,Local migrant,Common	Resident,Local migrant,Common
16.	*Lophura leucomelanos hemiltonii* (Gray)	White Crested Kaleej Pheasant	Inhabits forests edge, Cultivation, Vicinity of Cultivation and streams, lower altitude,emerge to	LC	Resident,Very common	Resident,Very Common

Table 10.2 Contd.

			the road at down and dusk			
Order : CHARADRIFORMES **Family : Charadrridae**						
17.	*Vanellus indicus indicus* (Boddaert)	Red wattled Lapwing	Dwells in open country and arable land near freshwater	LC	Resident, Common	Resident, Common
Order : COLUMBIFORMES **Family : Columbidae**						
18.	*Columba livia intermedia* (Strickland)	Indian Blue Rock Pigeon	Dwells in hilly areas near human habitation	LC	Summer visitor, very common	Summer visitor very , common
19.	*Streptopelia decaocto decaocto* (Frivaldszky)	Indian Ring Dove	Solitory or in pairs, sometimes in flocks, resting on tree tops, feeds in seeds	LC	Resident, Common	Resident, Common
20.	*S. chinensis suratensis* (Gmelin)	Indian Spotted Dove	Resident breeding bird,builts a swaple stick nests	LC	Resident, Summer visitor, Uncommon	Resident, Summer visitor , Uncommon
21.	*S.senegalensis cambayensis* (Gmelin)	Laughing Dove	Dwells near human habitation farm lands and cultivation	LC	Resident, Common	Resident, Common
Order : PSITTACIFORMES **Family : Psittacidae**						
22.	*Psittacula cyanocephala bengalensis* (Forster)	Northern Blossom headed Parakeet	Resident breeding local movement in search of food , bird of forest and open woodland,Nests in holes in trees	LC	Resident, Vey Common	Resident, Very Common
Order: CUCULIFORMES **Family: Cuculidae**						
23.	*Cuculus variaus variaus* (Vahl.)	Common Hawk-Cuckoo/Brainfever Bird	Brood parasite,inhabits graden land arbored	LC	Summer Visitor, Uncommon	Summer Visitor, Uncommon

Table 10.2 Contd.

24.	*Eudynamys scolopacea scolopacea* (Linnaeus)	Indian Koel	Brood parasite, Fruigivorous, Vocal during breeding season, dwells in gorves, large, trees	LC	Resident, Common	Resident, Common
Order : STRIGIFORMES Family: Strigidae						
25.	*Athene brama indica* (Franklin)	Northern Spotted owlet	Nocturnal, arboreal cavities /hollows in large trees	LC	Resident, Common	Resident, Common
Order: CAPRIMULIFORMES Family: Caprimulgidae						
26.	*Caprimulgus macrurus albonotatus* (Tickell)	Indian Long-tailed Night jar	Nocturnal, Insectivorous, nesting on bare ground, dwells in open forests, scrub habitat	LC	Resident , Local migration	Resident, Local migration
Order: APODIFORMES Family: Apodidae						
27.	*Apus affinis affinis* (JE Gray)	Little Swift	Feeds on insects aerial, dwells near tons, flodes noisy at night	LC	Resident Summer Visitor Common	Resident Summer Visitor Common
Order: CORACIFORMES Family: Alcedinidae						
28.	*Ceryle lugubris continentalis* (Hartert)	West Himalayan Pied Kingfisher/ Crested Kingfisher	Solitary, Near water body, Lovers for fish, nesting in tree holes	LC	Resident , Local movement, Uncommon	Resident, Local movement, Uncommon
29.	*Alcedo atthis bengalensis* (Gmelin)	Indian Small Blue Kingfisher	Inhabits close to reservoir, river, solitary, nesting in tree holes	LC	Resident , Local movement, Common	Resident, Local movement, Common
30.	*Halcyon smyrnensis fusca* (Boddaert)	Indian white-throated Kingfisher	Hovers over reservoir/river for eating fish, Solitary nesting in	LC	Resident , Local movement,	Resident, Local movement , Common

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Table 10.2 Contd.

			tree holes		Common	
Family : Meropidae						
31.	*Merops orientalis orientalis* (Latham)	Indian Small Green Bee-eater	Found grassland, scub, forests, insect eater	LC	Resident Uncommon	Resident Uncommon
Family : Upupidae						
32.	*Upupa epops epops* (Linnaeus)	European Hoope	Has a characteristic undulating flight, dells near human settlement and cultivation	LC	Summer visitor, Common	Summer visitor, Common
Order: PICIFORMES Family: Capitonidae						
33.	*Megaliama asiatica aisatica* (Latham)	Blue throated Barbet	Eats fruits ,insects, inhabits forests and wooded areas at lower altitudes	LC	Resident, Common	Resident, Common
Order: PASSIFORMES Family: Hirundinidae						
34.	*Hirundo daurica nepalensis* (Hodgson)	Himalayan Striated Swallow/ Red rumped Swallow	Inhabits hilly area, insectivorous, greganivorous	LC	Summer visitor, Uncommon	Summer visitor, Uncommon
Family: Lanidae						
35.	*Lanius schach erythronotus* (Vigors)	Rufous backed Shrike	Upright shrike attitude, perched on bush feeds on insects, lizards rodents	LC	Summer visitor, Uncommon	Summer visitor, Uncommon
Family: Oriolidae						
36.	*Oriolus oriolus kundoo* (Sykes)	Indian Golden Oriole	Dwells open wooded gardens, plantations	LC	Resident, Common	Resident, Common
Family: Sturnidae						
37.	*Sturnus malabaricus malabaricus* (Gmelin)	Grey headed Myna Chestnut-tailed Starling	Inhabits wooded habitats	LC	Resident, partial migration, Common	Resident, partial migration, Common
38.	*S. pagodarum* (Gmelin)	Black headed Myna/ Brahminy Myna	Pairs/small flocks in open habitats	LC	Resident Common	Resident Common

Table 10.2 Contd.

39.	*Acridotheres tristis tristis* (Linnaeus)	Indian Myna	Omnivorous, open wood bird, Strong terrestrial instinct	LC	Resident Common	Resident Common
40.	*A. fuscus fuscus* (Wagler)	Northern Jungle Myna	Found in forests, Cultivated land	LC	Resident Common	Resident Common
Family: Dicurridae						
41.	*Dicrurus adsimilis albirictus* (Hodgson)	North Indian Black Drongo/ king crow	Common in open agricultural land, Insectivorous, nesting in well	LC	Resident Common	Resident Common
Family: Corvidae						
42.	*Cissa erythrorhycha occipitalis* (Blyth)	Himalayan Red billed Blue Magpie	Inhabits mountains as areas, insectivorous		Resident Very Common	Resident Very Common
43.	*Dendrocitta formosae occidentalis* (Ticehurst)	West Himalayan Tree Pie	Wide distribution along lower altitudes	LC	Resident Common	Resident Common
44.	*Corvus splendens splendens* (Vieillot)	Indian House Crow	Omnivorous, Common near human habitats	LC	Resident Common	Resident Common
45.	*Corvus macrorhynchos intermedius* (Adams)	Himalayan Jungle Crow	Inhabits forests, bushes, of hilly areas, nesting in twigs of trees	LC	Resident Common	Resident Common
Family: Pycnonotidae						
46.	*Pycnonotus leucogenys leucogenys* (Gould)	White Checked Bulbul	Song bird, Inhabits forests, rich gardens, shrubs, roadsides, Insectivorous	LC	Resident Very Common	Resident Very Common
47.	*P. cafer intermedius* (Blyth)	Punjab Red vented Bulbul	Bird of dry scrub, open forests plains, cultivated lands	LC	Resident, Very Common	Resident, Very Common
48.	*Microscelis amaurotis* (Gray)	Brown Eared Bulbul	Bird of open scrub, cultivated lands, gardens	LC	Resident, Common	Resident, Common
Family: Muscicapidae						
49.	*Stachyridopsis pyrrhops* (Blyth)	Black chinned Babbler	Bird of moist low land forests, scrub	LC	Resident, Common	Resident, Common
50.	*Turdoides striatus striatus* (Dumont)	Bengal jungle Babbler	Resident of forests, gardens	LC	Resident, Common	Resident, Common

Table 10.2 Contd.

51.	*Muscicapa thalassina* (Swainson)	Fly Catcher	Found in woodlands, Insectivorous Arboreal		Summer Visitor, Common	Summer Visitor, Common
52.	*Rhipidura albicollis canescens* (Koelz)	Western White throated Fantail Fly Catcher	Found in forests/woodland, Insectivorous Arboreal	LC	Resident, Local migrant, Uncommon	Resident, Local migrant, Uncommon
53.	*Terpsiphone paradisi leucogaster* (Swainson)	West Himalayan Paradise Fly Catcher	Found in mountainous fronts, Insectivorous	LC	Resident, Summer Visitor, Uncommon	Resident, Summer Visitor, Uncommon
54.	*Phylloscopus affinis affinis* (Tickell)	Tickell's Leaf Warbler	Smallest abler, wooded land,Cultivation	LC	Migratory in nature, Common	Migratory in nature, Common
55.	*P. proregulus simalaensis* (Ticehurst)	Western Pallas's Leaf Warbler	Found in hilly region, gardens/parks	LC	Resident, Local movement	Resident, Local movement
56.	*Erithacus (Tarsiger) indicus indicus* (Vieillot)	White Browed Bush Robin	Inhabits forests, bushes of mixed forest	LC	Resident, Common	Resident, Common
57.	*Copsychus saularis saularis* (Linnaeus)	Indian Magpie Robin	National Bird of Bangladesh, dwells gardens/parks hides in rocky niche	LC	Resident, Common	Resident, Common
58.	*Enicurus maculates maculates* (Vigors)	Western Spotted Forktall	Inhabits close to water bodies, rivers, forest water courses	Common	Resident, Common	Resident, Common
59.	*Saxicoloides fulicata cambaiensis* (Latham)	Brown backed Indian Robin	Common in open scub perching in thorny shrubs, rocks	LC	Resident, Common	Resident, Common
60.	*Saxicola caprata bicolor* (Sykes)	Northern Pied Bush Chat	Small passerine bird, Inhabits open scub, grasslands, Insectivorous nests in cavities of stone walls	LC	Resident, Common	Resident, Common
61.	*Monticola solitarius pandoo* (Sykes)	Indian Blue Rock Thrush	Breeds in open mountain area, mostly cliffs omnivorous	Common	Resident, Common	Resident, Common

Table 10.2 Contd.

62.	*Myophonus caeruleus* (Vigors)	Himalayan Whistling Thrush	Mostly seen in hilly area except winter	LC	Resident, Summer Visitor	Resident, Summer Visitor
Family: Cinclidae						
63.	*Cinclus pallasi tenuirostris* (Bonaparte)	Western Himalayan Brown Dipper	Bird of Lower elevation in mountains, dwells new mountain streams and rivers	LC	Resident, Common	Resident, Common
Family: Paridae						
64.	*Parus major nipalensis* (Hodgson)	Nepal Grey Tit	Dwells in open forests and gardens	Common	Resident, Common	Resident, Common
Family: Motacillidae						
65.	*Anthus sylvanus* (Hodgson)	Upland Pipit	Dwells in open habitats short grasslands and cultivation	LC	Resident, Common	Resident, Common
66.	*Motacilla maderaspatensis* (Gamelin)	Large Pred Wagfall	Dwells near water bodies, streams and river banks	LC	Resident, Common	Resident, Common
Family: Nectarinidae						
67.	*Nectarinia asiatica asiatica* (Latham)	Indian Purple Sunbird	Arboreal, feeds on flower nectar, eggs laid in a pouch shaped nest	LC	Resident, Local migrant, common	Resident, Local migrant, common
Family : Zosteropidae						
68.	*Zosterops palpebrosa* palpebrosa (Temminck)	Indian White eye	Arboreal, feeds on flower nectar, eggs laid in a pouch shaped nest suspended to a bravel	LC	Resident, Local migrant, common	Resident, Local migrant, common
Family: Ploceidae						
69.	*Passer domesticus indicus* (Jardine & Sebly)	Indian House Sparrow	Dwells near human settlements	LC	Resident, Common	Resident, Common
70.	*Lonchura striata acuticauda* (Hodgson)	White Backed Munia	Dwells in secondary jungle, grassy areas, Cultivation	Common	Resident, Common	Resident, Common
Family: Fringillidae						
71.	*Carpodacus erythrinus* (Pallas)	Common Rose Finch	Dwells in cultivated lands and forest	LC	Resident, Common	Resident, Common

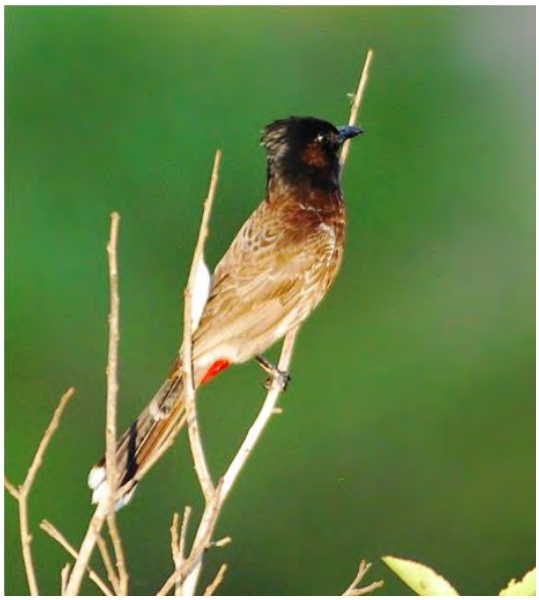
Table 10.2 Contd.

72.	*Pyrrhoplectes epauletta* (Hodgson)	Golden Naped Finch	Dwells in dense forests, scub at higher altitude	LC	Resident, Common	Resident, Common
Family: Emberizidae						
73.	*Melophus lathami* (Gray)	Crested Bunting	Dwells scrubby hillsides, fallow fields	LC	Resident, Common	Resident, Common
Order: PELECANIFORMES **Family: Pelicanidae**						
74.	*Phalacrocorax carbo sinesis* (Shaw)	Large (Great) Cormorant	Gregarious, carnivorous, voracious fish feeder, small groups, breeds from September to February	Common	Not reported	Winter Migrant, Common
75.	*P.niger*	Little Cormorant	Large flocks in reservoir, rivers, hunt on fish	Common	Not reported	Resident, Local migrant from plains
Order: ANSERIFORMES **Family: Anatidae**						
76.	*Tadorna ferrginea* (Pallas)	Rudy Shelduck/ Brahminy Duck	Gregarious, small flocks chiefly carnivorous, open reservoir, large river	Uncommon	Not reported	Winter Migrant
77.	*Aythya ferina* (Linnaeus)	Common Pochard	Frequent open reservoir with deep water, nocturnal, herbivorous, occasionally feeds on insects larvae	Common	Not reported	Winter Migrant, Common

AVIAN DIVERSITY IN TEHRI DAM ENVIRONS

Megalaima asiatica

Phalacrocorax niger



Pycnonotus cafer

Pycnonotus leucogenys

Columba livia intermedia

Lophura jeucomplana

AVIAN DIVERSITY IN TEHRI DAM ENVIRONS

Acridotheres tristis

Pericrocotus ethologus

Eudynamys scolopacea scolopacea

Cissa erythroyncha occipitals

Psittacula krameri

Myophonus caeruleus

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Chapter- 11

MAMMALIAN DIVERSITY

One of the most fascinating features of Indian biodiversity is its mammalian fauna which encompasses species as large as whales, elephants, rhinoceros and tigers and as small as shrews, mice and bats. They are found in all types of the habitat of the country, both terrestrial and aquatic. They may be volant, arboreal, ground dwelling, fossorial or aquatic in habits. Each species has its own unit set of characteristics, enabling to survive it in its particular environment (Alfred *et.al.* 1998).

The term mammals refer to the animal possesses mammary or milk producing glands for nourishing their young ones. Another important feature of the group is possessing of hairs on the body atleast during some period of life cycle.

The mammalian fauna of the world is represented by 4,629 species belonging to 1,135 genera, 136 families and 26 orders (Wilson and Reeder 1993). Of these 390 species belonging to 180 genera, 42 families and 13 orders are found in India. The Indian fauna is heavily influenced by the Indo-Chinese, Malayan, Ethiopian and Palaearctic elements.

The knowledge about the Indian mammals is very old. Descriptions of some mammals are available in the Vedas and even in the Pre-Vedic edicts. There are ethical, social, mythological and economic relationship between man and wild mammals. Some species of mammal are associated with different Hindu gods or goddesses in the Indian mythology and are worshiped.

The mammalian fauna of Uttarakhand has attracted the attention of different workers in the past. Important workers who have studied the mammalian fauna are Prater

(1971), Atkinson (1973), Kumar and Chopra (1977), Upadhayay (1980), Saharia (1982), Osmaston and Sale (1989), Walton (1989) and Sinha (1995),

PREIMPOUNDMENT SCENARIO:

Zoological survey of India (North Regional Station) undertook pre impoundment survey of mammals during May-October 1992.A total of 18 species belonging to 17 genera and 13 families and 6 orders of class Mammalia were reported (Table 11:1, 11.2). It was also reported that 15 species of mammals were common both in area of within submergence level and above submergence level. One species (*Lutra lutra*) was exclusive to the within submergence area. Only two species (*Felis bengalensis* and *Panthera pardus*) which were reported from the preimpoundment were listed in the schedule I of Wildlife Protection Act 1972. None of the mammalian species reported was endemic to the Tehri Dam area.

POSTIMPOUNDMENT SCENARIO:

On the basis of the personal observations, local enquiries and in-depth survey of all the sampling sites for two annual cycles, 29 species of mammals belonging to 26 genera, 13 families and 6 orders were recorded (Table 11.1;11.2)

Eleven species of mammals (*Rousettus leschenalti, Coun alpines, Vivericula indica, Paraoxurus hermaphrodites, Peguma larvat, Panthera tigris, Cervus uniclor, Mus musculus, Mus buguda, Bandicota bengalensis* and *Nesokei indica*) were also spotted in the post impoundmnent Tehri Dam environs. The reason for the presence of more species of mammals under the present study is that the present study was an extensive study for two animal cycles in comparison to pre-impoundment study of a very short period of six months.

Most dominant order was found to be carnivora, which was respresented by 14 species followed by six species of Rodentia(Table 11.1). An abnormally high growth in the population of Wild Boar (*Sus scrola*) and Rhesus Macaque (*Macaca mulata*) was recorded in the post impoundment area. Another interesting fact was the presence of *Panthera tigris* in the area. However, direct evidences could not be collected.

Interaction with the local inhabitants on the issue of presence of Tiger, it was revealed that one to two individuals may be there- one at the higher reaches of Pilakhi in Ghansali Transect and another near the forest patch of Kamand in the Dharasu Transect.

Overall the presence of availability of water resources and food in the post impoundment Tehri Dam environs has given a boost to the growth of wildlife including mammals.

Table 11.1 Composition and diversity of mammals in the pre-impoundment and post-impoundment Tehri Dam environs

ORDER	FAMILY	STATUS OF PRESENCE			
		PRE-IMPOUNDMENT		POST-IMPOUNDMENT	
		GENUS	SPECIES	GENUS	SPECIES
INSECTIVORA	Soricidae	01	01	01	01
CHIROPTERA	Pteropidae	-	-	01	01
	Ceropithecidae	02	02	02	02
CARNIVORA	Canidae	02	02	03	03
	Ursidae	01	01	01	01
	Mustelidae	02	02	02	02
	Vireridae	01	01	04	04
	Felidae	02	03	02	04
ARTIODACTYLA	Suidae	01	01	01	01
	Cervidae	01	01	02	02
	Bovidae	01	01	01	01
LAGOMORPHA	Leporidae	01	01	01	01
RODENTIA	Histricidae	01	01	01	01
	Muridae	01	01	04	05
TOTAL : 06	**14**	**17**	**18**	**26**	**29**

Table 11.2 : Mammals and their habits and habitats, conservation status and status of presence in post-impoundment and pre-impoundment habitats of Tehri Dam environs

S.No	Zoological Name	Common Name	Habit and Habitats	Conservation Status	Status of Presence	
					Pre-impoundment	Post-impoundment
Order : **Insectivora** Family : **SORICIDAE**						
1.	*Suncus murinus* (Linnaeus)	House Shrew	Nocturnal, solitary lives near human settlements, feeds mainly on insects	LC	Common	Common
Order : **Chiroptera** Family : **PTEROPIDAE**						
2.	*Rousettus leschenaltii* Desmerest	Fruit Bat	Arboreal, frugivorous gregarious while roosting	Common	Common	Common
Family : **CERCOPITHECIDAE**						
3.	Macaca mulata (Zimmermann)	Rhesus Macaque	Semi-urban areas, lives in and around human settlements, in summers ascend to higher elevation	LCnt	Common	Common

Table 11.2 Contd.

4.	*Presbytis entellus* (Dufrense)	Hanuman Langur	Forest dweller, move in troops, ascend sub alpine forests in search of food during summers.	Vu	Rare	Rare
Order : **Carnivora** Family :**CANIDAE**						
5.	*Canis aureus* (Linnaeus)	Golden Asiatic Jackal	Dense forests, open areas, shrubs and vicinity of rivers and reservoir, come out at dusk in search of food and returns to their shelter at dawn	LCnt (WPA Schedule II)	Common	Very Common
6.	*Vulpes vulpes* (Linnaeus)	Common Red Fox	Sub-alpine scrub forests, pastures, rocky area, cultivated lands and vicinity of water sources	(WPA Schedule II)	Rare	Rare
7.	*Coun alpines* (Linnaeus)	Indian Wild Dog (Dhol)	Moves in packs of rising rivers, hunts deer,wild goats and occasionally domestic cattle	Vu (WPA Schedule II) CITES Appendix-II	Rare	Rare

Table 11.2 Contd.

Family : **URSIDAE**						
8.	*Selennarctos thibetanus* (Cuvier)	Asiatic Black Bear	Returns to Shelter of Bhagirathi and Bhilangana Valley during winters come out above dusk in search of food. Herbivore and Carnivore	(WPA Schedule I) CITES Appendix-II	Rare	Rare
Family : **MUSTELIDAE**						
9.	*Martes flavigula* (Boddaert)	Yellow-thorated Marten (Chutarale/Khursela)	Lives in forest and hunts alone and avoid areas of human settlements, Peigon rats, mice, hares, lizards, eggs	LC	Common	Very Common
10.	*Lutra lutra* (Linnaeus)	Common Otter (Uad,Ud-bilao)	Was common near the confluence of Bhagirathi and Bhilangana during pre-impoundment, Now, spotted near Ghansali after impoundment	Vu (WPA Schedule I) CITES Appendix-I	Rare	Rare
Family : **VIVERRIDAE**						
11.	*Viverricula indica* (Desmarest)	Small Indian Cat	Found only in the lower reaches, prefers tall grasslands	Rare (WPA Schedule II)	Common	Common

Table 11.2 Contd.

12.	*Paraoxurus* hermaphrodites (Pallus)	Common Palm Civet	Palm and mango trees are favourite shelter near villages and agricultural fields	Rare (WPA Schedule II)	Common	Common
13.	*Paguma larvat* (Hamilton-smith) Masked Palm civet	Masked Palm Civet	Lives in the holes of trees, branches of trees, eats fruits, birds and rodents	Rare (WPA Schedule II)	Common	Common
14.	*Herpestes edwardsi* (Geoffroy)	Indian Grey Mongoose	Lives in open areas scrub land and around cultivated lands	Uncommon (WPA Schedule IV)	Common	Common
Family : **FELIDAE**						
15.	*Felis chaus* (Guldenstacat)	Jungle eat (Ban Birau)	Forest edge, dense Shrubs	LCnt (WPA Schedule II)	Common	Common
16.	*Felis bengalensis* (Kerr)	Leopard Cat (Chita Billi)	Forest edge, dense Shrubs, around human settlements	Vu (WPA Schedule I) CITES Appendix-I	Common	Common
17.	*Panthera pardus* (Linnaeus)	Leopard /Panther (Tenduwa)	Wide distribution, lives both in forests and open rocky areas	Vu	Fairly Common	Fairly Common

Table 11.2 Contd.

18.	*Panthera tigris* (Linnaeus)	Bagh	Hig	EN (WPA Schedule I) CITES Appendix-I	Very Rare (1-2 individuals)	Very Rare (1-2 individuals)
Order**: Artiodactyla** Family**: SUIDAE**						
19.	*Sus scrofa* (Linnaeus)	Wild Boar (Jungali Suer)	Prefers to live in scrubland and grasslands,often raids cultivated fields, feeds roots, tubers	LCnt	Very Common	Very Common
Family**: CERVIDAE**						
20.	*Muntiacus Muntjak* (Zimmermann)	Barking Deer (kakar, Indian Muntjak)	Forests, scrub, grasslands, solitary, moves in twos/three only, altitudinal migrant, herbivore	LCnt (WPA Schedule III)	Common	Common
21.	*Cervus unicolor* (Keir)	Sambar	Prefers to stay in the forests, open areas near the cultivated fields, feeds on grasses, succulent's shoots &wild fruits. Moves in herds	LCnt (WPA Schedule III)	Rare	Rare

Table 11.2 Contd.

Family**: BOVIDAE**						
22.	*Naemorphedus goral* (Hardwicke)	Goral (Ghwed)	Prefers to live in rocks & steep precipitous slopes, feeds on grasses, leaves, succulents roots, and shoots, spotted in areas of higher reaches during winters only	LCnt (WPA Schedule I) CITES Appendix-I	Rare	Rare
Order:**Lagomorpha** Family: **LEPORIDAE**						
23.	*Lepus nigricolis* (Cuvier)	Indian Hare (Black Napped Hare) (Khargosh)	Lives in the vicinity of the cultivated areas and pastures	LCnt (WPA Schedule IV)	Common	Common
Order**:Rodentia** Family**: HISTRICIDAE**						
24.	*Hystrix indica* (Kerr)	Indian crested Porcupine (Soala/ Sahi)	Lives in forest, rocky hillsides, ejects quills for killing prey and defence mechanism	Vu (WPA Schedule II)	Common	Common
25.	*Rattus rattus* (Linnaeus)	House rat/ Black Rat (Musa/chuha)	Found in and around cultivated fields and human settlements	Lc (WPA schedule V)	Very Common	Very Common
26.	*Mus musculus* (Linnaeus)	House Mouse	Found in and around human settlements, omnivorous	Lc (WPA Schedule V)	Very Common	Very Common

Order:**Lagomorpha** Family**: LEPORIDAE**						
27.	*Mus buguda* (Gray)	Little Indian field mouse	Common in the cultivated fields, pastures and open areas	WPA Schedule V	Very Common	Very Common
28.	*Bandicota bengalensis* (Gray & Hardwicke)	Indian Mole rat	Lives in the vicinity of agricultural fields, burrowing animal	LCnt	Common	Common
29.	*Nesokia indica* (Gray & Hardwicke)	Short tailed Mole Rat	Fossorial, lives in the vicinity of agricultural fields and human settlements. Feeds mainly on earthworms, insects larvae	LC	Common	Common

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MAMMALIAN DIVERSITY IN THE TEHRI DAM ENVIRONS

Panthera pardus

Macaca mulatta

Semnopithecus entellus

Suncus murinus

Martes flavigula

Horpestes edwardsi nyu

MAMMALIAN DIVERSITY IN THE TEHRI DAM ENVIRONS

Felis chaus

Prionailurus bengalensis

Naemorhedus goral

Sus scrofa

Lepus nigricollis

Rattus rattus

Chapter- 12

RECOMMENDATIONS FOR CONSERVATION AND MANAGEMENT OF FAUNAL DIVERSITY

The construction of Tehri Dam has made major geomorphic transformations in the major fluvial system of Bhagirathi and Bhilangana. The metarhithronic stretch of these hillstreams has been converted into a huge reservoir of 2.62 X 10^9 m^3 capacity. The riffles, rapids, runs and cascades of swift water current were converted into deep, stagnant or, semi-stagnant pools. Major terrestrial habitats in terms of forests patches, cultivated and semi-cultivated croplands have been inundated by the construction of the Tehri Dam. Some of the established burrowing habitats and dwellings of wildlife have been wiped out.

Substantial transformations in terms of fragmentation, isolation and destruction of freshwater habitats have been caused. A large scale inundation of spawning and feeding grounds of fishes has been resulted. River edges and riparian corridors were eroded. Migration channels of migratory fish species have been chocked due to impoundment. Thus, there have been several direct and indirect impact of Tehri Dam construction, which resulted in cumulative and synergetic impacts in terms of impairments of ecosystem function, alteration in composition of biodiversity (Fig.12.1).

The major faunal components disturbed by the impoundment were the migratory and endangered fish species, the Mahseer (*Tor tor; Tor putitora*). The migration route of the Mahseer was obstructed due to construction of high dam (260.5m above river bed). Provision of fish ladder in such a high dam was also not an appropriate solution.

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However, the natural flow was completely blocked in October 2005 by the closure of last tunnel. Thus, the migration process of Mahseer was obstructed and the population was fragmented. Fragmented populations of Mahseers are still surviving in the Reservoir.

Another, important aquatic animal, which was disturbed by the Tehri Dam construction was common Otter (*Lutra lutra*). It was commonly present in pre-impoundment habitats. Now, the population has shifted towards Ghansali near the confluence of Balganga and Bhilangana and in the Bhagirathi near Dharasu.

The burrowing terrestrial mammal, the Porcupine (*Hystrix indica*) and other burrowing animals have also lost their established dwellings as a consequence of impoundment. However, the presence of these animals outside the periphery of the reservoir is common. Some of the natural dwellings of the reptiles have also been lost due to impoundments.

Some of the faunal elements like Monkey (*Rhesus macaque*), Wild Boar (*Sus scrofa*) have considerably increased in the Tehri Dam environs after impoundment due to creation of new habitats and availability of food.

A significant addition of aquatic birds to the avian diversity and considerable increase in the population of other terrestrial birds is a positive impact of Tehri Dam construction. Establishment of Botanical Garden and new plantations in the periphery of the reservoir have provided compensatory habitats for the birds and other wildlife.

RECOMMENDATIONS:

For minimizing the adverse impact of impoundment on faunal diversity, following remedial and ameliorative measures have been recommended for the conservation and management of faunal diversity.

***EX-SITU* CONSERVATION:**

Establishment of Mahseer Hatchery:

In compliance with the recommendations of Zoological Survey of India (Northern Regional Station), the THDC India Ltd has constructed a Mahseer hatchery 22 km downstream to Tehri Dam, near Koteswar at an altitude of 630m above m.s.l in 2004 for the rehabilitation and propagation of Mahseer.

The hatchery is having 18 tanks including 10 rearing tanks, 4 fingerlings tanks, 2 adult tanks and 2 brooder's tanks. The hatchery has the capacity of 3.0 lakhs seeds. A total

of 30 brooders were introduced in the hatchery in 2004-05 and these have become 210 in number weighing 1.5 kg to 1.75 kg. Supplementary food is being given to these fishes in the hatchery under expert guidance. More than 45,000 seeds of Mahseers were also introduced in the Reservoir during 2008-09. Growth of the Mahseer in the deep reservoir could not be assessed. However, the presence of Mahseer in the periphery and mouth zones of the reservoir has been recorded.

Thus, Mahseer hatchery is playing an important role in ex-situ conservation of the endangered fish Mahseer.

Establishment of the Botanical Garden:

Botanical garden has also been established by THDC India Ltd complying the recommendations of Botanical Survey of India and commitment for conservation of plant species submerged in the Reservoir. It has been established near Bhagirathipuram in an area of 14.28ha at altitude between 800-1000 m above m.s.l. in 2002. More than 225 species of medicinal and economically important plants are thriving well in this Botanical Garden. In addition to conservation of plant species, this garden is providing a natural habitat for birds and wildlife for their *ex-situ* conservation. Compensating afforestation around the reservoir has also provided additional habitats for terrestrial fauna and playing an important role in ex-situ conservation of faunal diversity. It was noticed that there is lack of water availability in Botanical Garden for wildlife.

Therefore, it is recommended for the construction of atleast 10 traditional khals/chaals (natural water tanks of size 5m×3m×1.5m) for storing rainwater in the entire area of Botanical Garden. It will recharge the dried water springs and provide water to plants, wildlife and birds.

***IN-SITU* CONSERVATION:**

For minimizing the adverse impact of impoundment, some remedial and ameliorative measures have been recommended for *in-situ* conservation of faunal diversity in the Tehri Dam environs.

- **Habitat Restoration:**

Damaged or degraded habitats should be restored based on the principle of integrated hydrology, geomorphology and ecology of the entire watershed. Aquatic habitat enhancement should be undertaken integrating the natural channel design techniques,

aquatic vegetation restoration, and more traditional hydraulic and channel design engineering practices.

- **Functional Habitat Recovery:**

'Functional habitat' is a tool for evaluating the heterogeneity of existing aquatic habitats. It is a core biotope in a freshwater ecosystem. "Functional habitat" recovery in the post impoundment habitats is possible by physical reconstruction in terms of widths, depths, velocities and habitat edges based on the geomorphological principles for maintaining the habitat diversity. Thus, the action on functional habit recovery is recommended.

- **Restoration of Riparian Corridor:**

Riparian vegetation, stream bank geomorphology, overgrazing vegetation, undercut banks and hill slope vegetation of Bhagirathi and Bhilangana rivers (pre-impoundment) have been drastically altered by the construction of Tehri Dam. Riparian vegetation moderates water temperature, provide habitat cover, and helps in stability embankments. Afforestation of hillslopes of the periphery of reservoir will be instrumental for reducing the capacity of weathering and erosion. Thus, the restoration of the riparian corridor is strongly recommended.

- **Principle of Minimum Environmental Flows:**

Defining minimum environmental flows requirements downstream to dams presents one of the problems of aquatic biodiversity and their management almost all over the world. Therefore, THDC India Ltd. should ensures release of optimum environmental flows for sustenance of the freshwater faunal diversity of the downstream habitats of Tehri Dam.

- **Mitigation of Erosion and Sedimentation in the Reservoir:**

Accumulation of debris/ sediments at the base of the reservoir affects not only the storage capacity but also many biological processes. Some water level management practices can minimize erosion and sediment deposition in the Tehri Dam Reservoir during known periods of high sediments. Thus, these practices of water level management are recommended for mitigation of erosion and sedimentation in the reservoir.

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- **Destratification of Deep Water:**

Tehri Dam Reservoir has a big water column (> 185 m) making stratification in terms of reducing temperature and dissolved Oxygen through depth. Hypolimnetic discharges, air bubbling and mechanical pumping between the hypolimnion to generate water movement and the various methods are recommended to prevent stratification in the deep water column. Aeration of the hypolimnion through oxygen can also be tried.

- **Facilitation of Downstream Movement of Fish:**

The Tehri Dam is also a barrier to downstream passage of juveniles and adults that have spawned in upstream areas or that are on their downstream spawning migrations. A variety of downstream physical screening devices has been used to prevent fish from passing through the turbines. Thus, installing these devices are recommended for facilitation of downstream movement of fish.

- **Control of Eutrophication:**

There is strong evidence that, in time, Tehri Dam reservoir will develop an excessive growth of aquatic weeds in the periphery, which will adversely affects freshwater faunal diversity. To cope with this problem, introduction of herbivorous native fish species (*Schizothorax richardsonii*, *Garra gotyla gotyla* , *Crossocheilus latius)* and few exotic species (*Ctenopharyngodon idella*) and silver carp (*Hypophthalmicthys molitrix*) has been recommended in the Reservoir for biological control of eutrophication.

- **Lower River/Stream Habitat Enhancement Programme:**

Downstream habitat enhancement programmes can also be promoted through construction of check dams, weirs, logs, rock/cross veins, flow constrictors, and boulders, clusters for providing habitat diversity.

- **Development of Landing Islands for Migratory Birds:**

Many migratory birds have attracted due to creation of a big water body for their winter stay. An effort should be made to develop landing islands at the appropriate sites for the migratory birds for their winter stay.

- **Promotion of Public Awareness:**

Promotion of public awareness among the masses is of paramount importance for the conservation and management of faunal diversity. Therefore, public awareness campaigns should be launched.

- **Integrated Efforts for Conservation and Management :**

Integrated efforts involving every stakeholder- THDC India Ltd., public administration, local inhabitants, policy makers, environmental biologists, freshwater biologist, geologists, policy makers, government and non-government functionaries should be undertaken for conserving and managing the faunal diversity of the Tehri Dam environs.

- **Adoption of Adaptive Management:**

Strategy of adaptive management should be promoted for effective conservation and management of faunal diversity with the regular monitoring of changes in ecosystem function and faunal diversity of Tehri Dam environs.

- **Faunal Survey after Every Five Years:**

The last, but not the least, it is strongly recommended that the THDC India Ltd. should carry out a detailed faunal survey to assess the faunal and ecosystem changes in the Tehri Dam environs after every five years. This is necessary for opting the strategy of adaptive management. Future strategies can accordingly be planned based on the results indicating improvement or degradation of ecosystem functions and enrichment or loss in faunal diversity of the Tehri Dam environs.

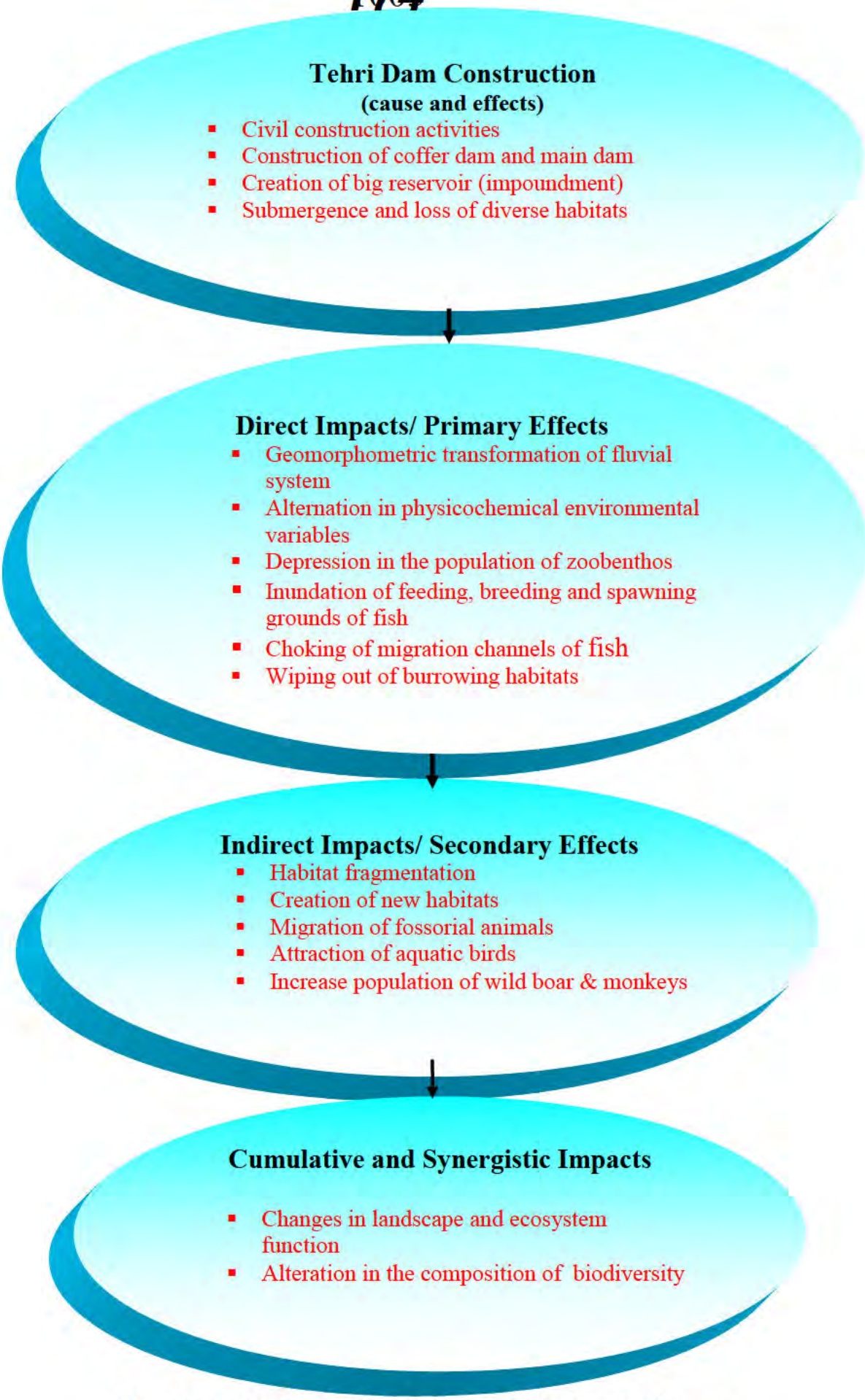

Fig. 12.1 Cumulative Impact of Impoundment

Ex-situ Conservation of Faunal Diversity

Mahseer Hachery at Koteshwar

Inspection of Mahseer hatchery

Botanical Garden

New habitats for Wildlife at Botanical Garden

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REFERENCES

Alfred,J.R.B., Kumar, A., Tak,P.C. and Sati, S.P. 2001. *Waterbirds of Northern India,* Zoological Survey of India, MoEF, Govt. of India: 1-227.

Ali,S. and Ripley, S.D. 1983. *A Pictorial Guide to the Birds of Indian Sub Continent.* Bombay Natural History Society, Oxford University Press, Delhi: 1-177.

Annandale, N.1906. Notes on the freshwater fauna of India: Some Himalayan Tadpoles. *J.Asiatic Soc.:*289-292.

Annandale, N.1908. Notes on some batrachia recently added to the collection of the Indian Museum. *Rec.Indian Mus.* **2**:304-305.

A.P.H.A. 1998. *Standard Method for the Examination of Water Wastewater*. American Public Health Association, New York.

Arora, G.S. and Mandal, D.K 1977. Butterflies of Garhwal District, U.P. India. *Newsletter Zool. Survey of India* **3**(4): 299-234.

Arora, G.S., Ghosh, S.K., and Choudhary, M. 1995. Lepidoptera: Rhopalocera. In: *Fauna of Western Himalaya*, Zoological Survey of India, Calcutta: 61-73

Atkinson, E.J.1882. *The Himalayan District of North-West Province of India.* Govt. Press, Allahabad.

Atkinson, E.T. 1973. *Himalayan Gazetteer,* Vol II, Cosmos Publ. New Delhi.

Badola, S.P. and Pant,M.C.1973. Fish fauna of the Garhwal Hills Part I. *Ind.J.Zoot.* **14**(1):37:44

Badola, S.P. and Singh,H.R. 1977 a Fish fauna of the Garhwal Hills, Part III (Chamoli district). *Ind.J.Zoot.* **18**(2) : 119-122.

Badola,S.P. and Singh,H.R. 1977 b. Fish fauna of the Garhwal Hills,Part IV.(Tehri district). *Ind.J.Zoot*. **18**(2):115-118

Bhatnagar,R.K. 1972.Reptile fauna of Dehradun district, Uttar Pradesh,Part –I.*Cheetal* 15(4):15-23

Bhatnagar,R.K. and Mishra,P. 1971.Revised synopsis of birds of Dehradun and adjacent hills. *Cheetal,* **14**(2) : 41-56

Bhattacharya,U.C and Goel,A.K 1982. *Studies on the Vegetation of Tehri Dam and Some Rare Plants in Garhwal Himalaya*. Botanical Survey of India, Calcutta.

Bahuguna,N.C and Mallick,J.K. 2010.*Handbook of the Mammals of South Asia.* Natraj Publ., Dehradun: 1-541.

Boulenger,G.A.1920.A monograph of South Asian,Papuan,Melanesian and Suctalian frogs of the genus *Rana*. *Rec.Indian Mus.* **20**:84:221

Briggs,F.S.1931.Birds observed in the neighbourhood of Ranikhet. *J.Bombay Nat. Hist. Soc.* **34**:1072-1079

B.S.I. 2011. *Post impoundment Floristic Survey and Analysis of Tehri Dam Environs*. Botanical Survey of India,Dehradun.

Cairns.J.Jr.1974.Protozoans (Protozoa) In : Hart,CW and Fuller,L.H.(eds) *Pollution Ecology of Freshwater Invertebrates.* Academic Press, New York.

Chakraborty, D. and Das,S.K. 2005. Alteration of macroinvertebrate community in tropical aquatic systems in relation to sediment redox potential and over laying water quality. *Int. J.Env.Sci.Tech.,* **2** (4): 327-334

Chanda,S.K.2002.*Hand Book: Indian Amphibians*. Zoological Survey of India; Calcutta: 1-335

Chopra, R.N. 1977. Amphibian fauna of Corbett National Park. *Newsletter Zool.Surv.India* **3**(4) :215-217

Chopra, R.N. 1979. Fauna of Corbett National Park : Reptiles. *Cheetal* **21**(1) : 30-31

Cummins,K.W and Meritt,R.W.1996.Ecology and distribution of aquatic insects.In: Meritt,R.W. and Cummins.K.W(eds). *An Introduction to the Aqautic Insects of North America*. Hunt Publ.Co. Dobuque Lowe,USA: 78-86.

178

Daniel, J.C. 2002. *The Book of Indian Reptiles and Amphibians.* Bombay Natural History Society, Oxford University Press, Mumbai: 1-238

Day, F. 1889. *The Fauna of British India including Ceylon and Burma: Fishes* Vol I & Vol II. Francis & Taylor, London.

Dwivedi, B.N. and Mathur, R.S. 1978. *Working Plan for Nainital Forest Division, Kumaun Circle, Uttar Pradesh 1978-79 to 1978-88.* , Govt of Uttar Pradesh.

Gupta,S.K.1995.Hymenoptera In: *Fauna of Western Himalaya*. *Zoological Survey of India*,Calcutta:81-89

Grimmett,R.Inskipp,C. and Inskipp,T. (1999) *Pocket Guide to the Birds of the Indian Sub-continet*.Oxford University Press,New Delhi 1-384

Hamilton,B.F.1822. *An Account of the Fishes Found in the River Ganges and its Branches*. Edinburgh & London : 1-405

Hellwell,J.M.1986.*Biological Indicators of Freshwater Pollution and Environmental Management*.Elsevier Applied Science,London :1-546

Hudson,C. 1930.A list of some birds of the seven hills of Nainital, U.P. *J .Bombay Nat.Hist.Soc.*,**34** :821-827

Hussain, A. and Ray, P. 1995. Reptiles. In:Fauna of Western Himalaya. Zoological Survey of India, Dehradun:159-167

Kazmierczak, K. 2000. *Birds of India, Sri lanka, Pakistan, Nepal, Bhutan, Bangladesh and the Maldives.* Om Books International, Noida:1-352.

Khanna, V. 1995. Chilopoda: Scholopendromorpha: Scolopendridae. In: *Fauna of Western Himalaya.* Zoological Survey of India: 111-113

Khanna, V. 1998. Faunal diversity in India: Myriapoda: In: Alfred, J.R.B., Das, A.K. and Sanyal, A.K. (eds). *Faunal Diversity in India*: 343-348

Kumar, G. 1985. *National Resources Data Management System*. Wadia Institute of Himalayan Geology, Dehradun: 97-103

Kumar, K. and Chopra, R.N. 1997. On the rodents of Dehradun and vicinity. *Newsletter Zool. Survey of India* **3**(4):184-186

Lamba,B.S.1987. Fauna of Corbett National Park: Fauna of Conservation Area. Zoological Survey of India, Calcutta :82-86

Lavkumar,K.S. 1956.A contribution to the Ornithology of the Rishiganga Valley and the Nanda Devi Sanctuary. *J.Bombay Nat.Hist. Soc.*, **76**(2) : 275-282

Mac Donald M. 2009. *Large-Scale Hydropwer on the Alaknanda River: Cumulative Impact Assessment.*World Bank Reort,Washington D.C,U.S.A.

Mc Kinnon,J. and Philips,K.1993. *A Field Guide to Birds of Sumatra, Java and Bali*. Oxford University Press,Oxford.

Murthy,T.S.N. 1985. Classification and distribution of the Reptiles of India. *The Snake*.17:48-71

Osmaston, B.B. and Sale, J.B. 1989. *Wildlife of Dehradun and Adjacent Hils,* Dehradun: 1-104.

Prater, S.H. 1971. *The Books of Indian Animals*. Bombay

Pennack,R.W 1978.*Freshwater Invertebrates of United States*. John Wiley & Sons,New York.

Pollard,A.I and Reed,T.2004.Benthic invertebrate assemblage change following dam removal in a Wisconsin Stream.*Hydrobiologia*,513:51-58

Sanayal, D.P,Talukar,S.K and Dasguta,G.1979.Two new distibutional records of snakes from the Doon Valley and the Corbett National Park,U.P. *Cheetal* **21**(1):11-12

Saharia,V.B.1982. *Wildlife of India*, New Delhi 1-278

Sharma, R.C. and Singh H.R. 1980. Impact of the Bhagirathi blockade on its riverine ecosystem. *JOSHARD* **4:** 35-38.

Sharma, R.C. 1984. Icthyofauna of the snowfed river Bhagirathi of Garhwal Himalaya. *Uttar Pradesh J. Zool.* **42(2):** 208-212.

Sharma, R.C. 1984. Potamological studies on lotic environment of upland River Bhagirathi, *Env. & Ecol.* **2(4):** 239-242.

Sharma, R.C. 1988. Fish and Fisheries of the snowfed river Bhagirathi of Garhwal Himalayas, *Proc.Nat.Acad.Sci., India,58(B), II:181-192*

Sharma, R.C. 1986. Effect of physic-chemical factors on Benthic fauna of Bhagirathi River, Garhwal Himalaya. *Indian J.Ecol.* 13(1): 133-137.

Sharma, R.C. 1991.*Ecological Impact of Tehri Dam Construction on the Dynamics of Biological Production in the River Bhagirathi of Garhwal Himalaya.* D.Sc. Thesis, H.N.B. Garhwal University, Srinagar-Garhwal, Uttarakhand: 1-118

Sharma, R.C. 1992. Rhithronology of Bhagirathi, Garhwal Himalaya (India). In: Bhatt, S.D. (ed.) *Ecology of Himalayan Waters***.** Gynodaya Publ. Nainital: 125-135.

Sharma, R.C. 1992. Impact of environmental changes on coldwater fisheries of Ganga basin in Garhwal Himalaya. In: Sehgal, K.L. (ed.) *Recent Researches in Coldwater Fisheries***.** Today and Tomorrow Publ., New Delhi:. 79-91.

Sharma, R.C. 1995. Development of food chain models for the Tehri Dam Reservoir (Central Himalaya) India. *Adv. Biosciences:* 479-488.

Sharma, R.C. 2003. Fish diversity and their ecological status in protected areas of Uttaranchal. In: Verma, S.R. (ed). *Protected Habitats and Biodiversity***:** 14-36.

Singh, D. and Sharma, R.C. 1998. Biodiversity, ecological status and conservation priority of the fish of the River Alaknanda, a parent stream of River Ganges(India), *Aquatic Conserv. Mar. Freshw. Ecosyst.* 8: 761-772.

Singh,H.R, Badola,S.P. and Dobriyal,A.K.1987.Geographical distribution list of ichthyofauna of the Garhwal Himalaya with some new records. *J.Bombay Nat. Hist.Soc.* **84** (1):126:132

Smith,G.M. 1950. T*he Freshwater Algae of the United States*. Mc GrawHill,Book Co.New York

Ray, P. 1989 . *Studies on the Amphibian fauna of District Dehradun in Relation to Systematics*. Ph.D. Thesis. University of Garhwal, Srinagar-Garhwal.

Ray, P. 1995. Amphibia: In: *Fauna of Western Himalaya*. Zoological Survey of India: 150-157

Sinha,N.K.1995. Mammalia : *In. Fauna of Western Himalayas.* Zoological Survey of India, Calcutta.201-214

Tak, P.C. and Kumar, G. 1987. Wildlife of Nanda Devi National Park: *Indian J. Forestry* 10(3): 184-190

Tak, P.C. 1995. Aves:In: *Fauna of Western Himalaya,* Zoological Survey of India, Calcutta: 169-199.

Talwar, P.K. and Jhingran, A.G. 1991. *Inland Fishes of India and Adjacent Countries.* Vol I & Vol II, Oxford & IBH Publ. Co. Pvt. Ltd.

Tilak, R. and Ray, P. 1985. Description of new species of the sub-genus *Rana* for Chakrata Hills, District Dehradun, Uttar Pradesh, India. *Zool. Anz. (Jena):* 213-239

Tilak,R. and Baloni,S.P.1984.On the fish fauna of Tehri Garhwal, Uttar Pradesh. *Rec.Zool.Surv.of India*. **81**(3-4):255-271

Uniyal,B.P, Singh.S. and Singh,D.K. 1995.*Plant Diversity in the Tehri Dam Submergence Area*. Botanical Survey of India, Calcutta

Upadhyay, M.1980. *Working Plan of Garhwal Forest Divison, U.P,Allahabad*

Walton, H.G. 1989. *Gazetteer of Garhwal Himalaya*. Dehradun: 1-216

Waltner, R.C. 1974. Geographical and altitudinal distribution of amphibians and reptiles in the Western Himalaya. *Cheetal* 16(1):17-25.

Ward, H.B. and Whipple, G.C. 1992. *Freshwater Biology*. John Wiley & Sons, New York: 1-1248

Wierzbicks, M. 1966. Les resultiats des recherché concernate etat de repose (res stage) desp. *Cydopoidae Veh. Internat. Verein. Limnol.* 16:592-599.

Wilson, D.E. and Reeder,D.M. 1993. *Mammal Species of the World*. Smithsonian Institute Press, Washington D.C, U.S.A

Wetzel, R.G. and Likens, G.E.1991. *Limnological Analyses*. Springer-Verley, New York: 1-391.

Z.S.I. 1995. *Fauna of Western Himalaya.* Zoological Survey of India, Culcutta: 1-228.

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Annexure R/3

D(P)

Design report no. THDC-DE-92/3

TEHRI DAM PROJECT

EFFECT OF IMPOUNDMENT IN TEHRI RESERVOIR ON WATER QUALITY

TEHRI HYDRO DEVELOPMENT CORPORATION LIMITED

RISHIKESH

SEPTEMBER 1992

1083

Design report no. TCHDC-DE-92/3

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SEPTEMBER 1992

EFFECT OF IMPOUNDMENT IN TEHRI RESERVOIR ON WATER QUALITY

C O N T E N T S

WATER QUALITY

INTRODUCTION

Impoundment of river flows in a reservoir changes the quality of water. Water quality changes are generally in the form of reduction in silica content, turbidity, bacterial count, BOD and reducing the variation in dissolved minerals, hardness, PH value, alkalinity, temperature and the dissolved oxygen(Inglos 1957 ; Love 1961). These water quality changes have direct and indirect effects on the aquatic life and other water users in the downstream.

The water quality changes due to impoundment are the functions of river basin characteristics and so each case has to be specifically examined. A review of the available literature reveals that the changes in temperature and dissolved oxygen of water are the primary parameters to assess the impact ~~of impoundment on downstream~~ uses and the aquatic life. These parameters have been quantitatively assessed through mathematical models using finite element technique. These models have also been validated through field observations on existing reservoirs (Loucks 1981, Higgins et.al.1982 Markofsky et.al. 1973, Orlob 1981).

In order to assess the impact of Tehri storage on temperature and the dissolved oxygen of the releases quantitatively using the mathematical modelling techniques, the problem was referred to the Civil Engineering department of University of Roorkee in Jan 1991. The report is appended for reference.

2.0 MODELS

This study has been carried out using mathematical models for the temperature and dissolved oxygen (DO) prediction in the reservoir and the outflow. The Huber and Harleman model modified by Markofsky and Harleman has been used for thermal stratification while Markofsky and Harleman model has been employed for DO studies. The temperature model assumes the reservoir to be two dimensional i.e. the existence of horizontal isotherms. In solving this model it is assumed that the reservoir is initially isothermal at 17^{0} C i.e. the temperature at all depths is same. The boundary condition is that the heat absorbed at the reservoir surface is equal to heat diffused into the reservoir from the water surface.

The DO model assumes that the pollutant (BOD and DO) undergo first order decay. Initially BOD and DO profiles are assumed to be known. The boundary conditions assumed are that the surface is DO saturated and no transfer of BOD across the free surface takes place and the DO at any point in reservoir cannot exceed saturated value. In absence of any reliable information about the values of decay constant, initial BOD and thickness of saturated surface layer, parameterisation studies are conducted to analyse the sensitivity of these parameters., which affected the DO prediction but not the temperature. For solving the models numerically the reservoir has been discretised by a 5 m grid along its depth and the time step is taken as 10 days as inputs are available in terms of 10 day averages. The model was initially run for one year with parameterisation studies but later it was extended for a cycle of four years.

5.0 RESULTS

5.1 Thermal Stratification

The monthly temperature profiles in the reservoir predicted by the model assuming initial isothermal temperature of 17^{o}C in Sept. indicate start of stratification from November. The amount and extent of stratification has been found varying depending on inflows and their temperature and the reservoir operation schedule. The formation of thermocline and hypolimnion regions over the entire depth as predicted by the model is practically the same as obtained in the study of Karnali reservoirs and as observed in Fontana reservoir (Markofsky 1973, Orlob 1981, Karnali Project report). Typically the temperatures vary from 13^{o}C to 17^{o} C over a depth of about 200 m.

The outlet is located at El.720.0 which is found to fall in thermocline region. Thus, the out flow temperature is found to be higher than the inflow throughout the year. The monthly outflow temperatures for a four year cycle vis-a-vis the inflow temperatures are shown in Figure.1. The variation in the outflow temp. in different years for the same month is due to variation in inflows and the reservoir elevations attained in the same month in different years. These results indicate that the outflow from Tehri reservoir would be warmer than the inflow throughout the year. The rise in temperature is about 2 to 3^{o}C in summer months and 6 to 8^{o}C in winters.

.../3/...

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.../3/...

2 DO Study

The variation of DO expressed in PPM with depth has been worked out for different months. These DO profiles have been computed for different combinations of values of decay constant and the initial BOD. The decay constant is varied from .05 to 0.1 and the initial BOD from 0 to 5 ppm. The DO of the outflow for different set of values is given in Fig. 2 and is compared with the inflow DO. It is seen that DO in initial months i.e. from Sept. to Dec. falls rapidly when the initial BOD is assumed 5 ppm which is a high value for Tehri site. The observations (C.W.C.) show that the BOD in this area is around 1 to 2 ppm only. The outflow DO values for different months obtained in a four year cycle are given in Fig.3, under the combination of decay constant as 0.05 and BOD 0.0. The variation in values for different years is due to change in inflows and the reservoir elevation. It is also seen that under this condition of decay constant and BOD the outflow DO dees not change much from the inflow.

4.0 IMPACT ASSESSMENT

With the above quantitative assessment of the expected change in the water quality parameters of temperature and DO an attempt has been made in the following paras to assess their impact on the downstream uses and aquatic life. It is based on the available literature survey, data and the site conditions.

4.1 Temperature

The study has shown that the outflow will be warmer than the inflow (1 to 3°C in summer and 6 to 8°C in winter). The warm Tehri releases after traversing about 40 km meet the unregulated Alakhnanda flows at Deoprayag. Thus, not much difference in temperature of inflows and outflows is expected below Deoprayag. The water of river Ganga is put to industrial, agriculture and domestic use below Rishikesh which is about 70 kms downstream of Deoprayag. Therefore, these water uses are not expected to be affected by the temperature changes in the outflows from Tehri reservoir. It has been reported (Beilinson et.al.) that warm water releases from Nurek dam in USSR when applied to the fields increased the fertility of soil. Thus, Tehri releases may not adversely affect the agriculture production. The range of tempera-

... 4/...

ture of Tehri releases is 12°C to 20°C. It will be quite suitable for domestic and recreational uses.

The effect of warming of outflows from Tehri Reservoir on fish life may be assessed with the help of published literature on the subject. A lot of published research work on this aspect is available in the literature. A literature review reveals that a large number of varieties of fish require warm water while there are certain varieties which need only cold water. The surveys have shown that Trout and Mahesar are the two main species of fish in Tehri region. It is reported (Wright,1967) that for Trout development the most suitable temperature range is 12° to 18°C which is available throughout the year in the thermocline region of the reservoir and in the river downstream of the dam. Besides Trout, there are other species such as salman for which this range of temperature is suitable (Bennet,1962). Due to the thermal stratification (depth wise) of the reservoir a two storey fishery may be developed (Daniel and John,1991). Fish varieties surviving in warm water may be developed in the thermocline region in upper elevations while the varieties surviving in cold water may be developed in the hypolimnion region at lower elevations. This reveals that the somewhat higher temperature of water release from Tehri reservoir upto Deoprayag is not going to affect fish culture adversely.

4.2 Dissolved Oxygen (D.O.)

The level of DO is the indicator of water quality. The various standards for safe DO limit as available in literature are as below :

i) According to IS 2296-1982 the water containing DO more than 4 mg/l is safe for domestic use with conventional treatment followed by disinfection.

ii) According to Central Pollution Control Board, the requirement of DO for propagation of wild life and fisheries is equal to or more than 4 mg/l.

iii) According to Daniel (ASCE 1991) if DO level is below 2 mg/l nuterients, metals, toxins and other constituents may be released with sediment as these are ionized by bacteria seeking oxygen.

iv) No DO limit is fixed for agriculture use of water. However it can not be more stringent than for domestic use.

... 5/...

The spectrum of DO changes on impoundement of river inflows in a deep reservoir. It is reported (Purcell 1939, Biswas 1981) that a stable condition ensuring good quality of water is reached after a few years in the downstream because initial effect of the submarged organic material disappears.

Results of DO study made by UOR for Tehri Reservoir for the two extreme cases of BOD limits of 0.0 and 5.0, the D.O. level is found to range between 4.5 ppm and 8 ppm.

Thus the studies made by Civil Engineering Department of U.O.R.,Roorkee, establish that even for the extreme case of BOD equivalent to 5 ppm the DO level of water released from Tehri Reservoir is higher than the one required for various water uses and is thus not harmful for aquatic life or for other downstream water uses.

REFERENCES

Beilinson, M.E. Kolichko,A.V.,Sharman, S.M.1990 "Nurek Reservoir and The Environment " Gidrotekhnicheskoe Straitelstvo,(Translated) No-11 , Nov 1990 (pp 9-11).

Bennet,G.W.1962,"Management of artificial lakes and ponds". Reinhold Pulishing Corporation, New York.

Biswas, A.K.,1981 "Models for Water Quality Management". Mc GrauHill series in Water Resources and Environmental Engineering.

Bureau of Indian Standards, 1982,"Tolerance Limits for Inland Surface Waters Subject to Pollution" IS - 2296.

Central Pollution Control Board, 1990"Water Quality Statistics of India", Report No- MINARS|3|1989-90 (ENVIS-1).

Daniel, E.I., Gulliver,J,Thene J.R. 1991, " Water Quality Impact Assessment for Hydropower ". J.of Env.Engg.,A.SCE,March 1991 (pp 179-193).

Higgins J.M., Kim B.R. 1982 " DO Models for Discharges from Impoundments ". J. of Env.Engg,ASCE, Feb 1982 (pp.107-122).

Inglos R.S.1957. " Pollution Effects of Hydraulic Power Generation", Sewage and Industrial Wastes 29 (3) (pp. 292-297).

Loucks, D.P. 1981 " Water Quality Models for River System " in Models for Water Quality Management by A.K.Biswas (ed).

Love S.K. 1961 " Relationship of Impoundment to Water Quality " Jour. AWWa 53 : (pp 559-568).

Markofsky, M and Harleman, D.R.F.,1973 , " Prediction of Water Quality in Stratified Reservoirs " J. of Hyd.Div.,ASCE,HY5,May,1973 (pp 729-745).

Orlob,G.T.1981 " Models for Stratified Impoundments " in Models for Water Quality Management by A.K. Biswas (ed).

Purcell, L.T. 1939 " The Aging of Reservoir Water", Jour. of AWWA 31 : 1775 (Oct,1939).

Wright, J.C. 1967 " Effects of Impoundments on Productivity,Water Chemistry and Heat Budgets of Rivers". In Charles.L. lane (Chairman), Reservoir Fishery Resources Symposium,Reservoir Comm, Southern Division Am.Fish.Soc, Univ. of Ga,Athens,GA(569 p).

The Karnali (Chisapani) Multipurpose Project,Annexure'U' "Environmental Impact and Mitigation ". Report prepared by Himalayan Power Consultants,for Govt. of Nepal.

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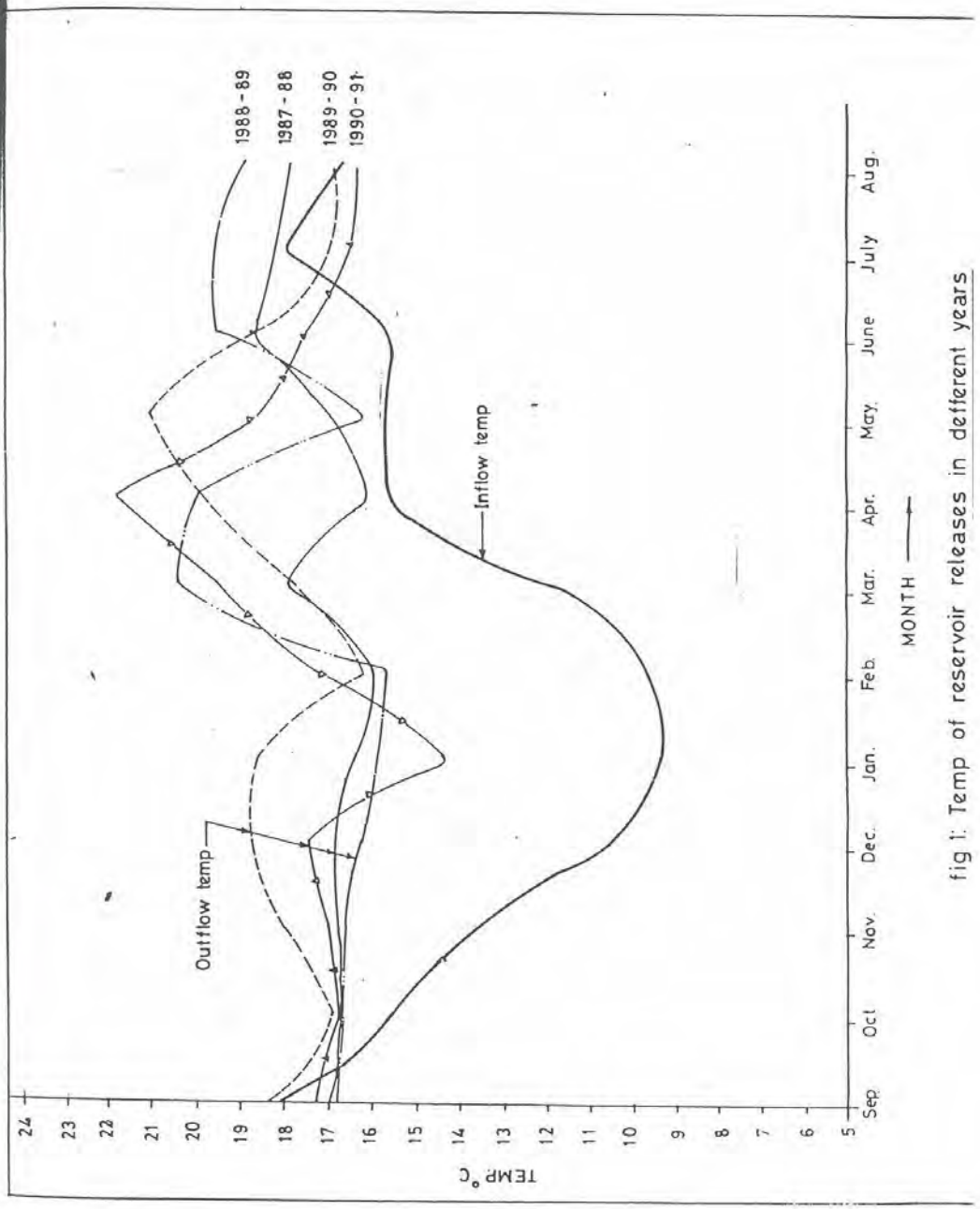

fig 1: Temp of reservoir releases in different years

GATEWAY

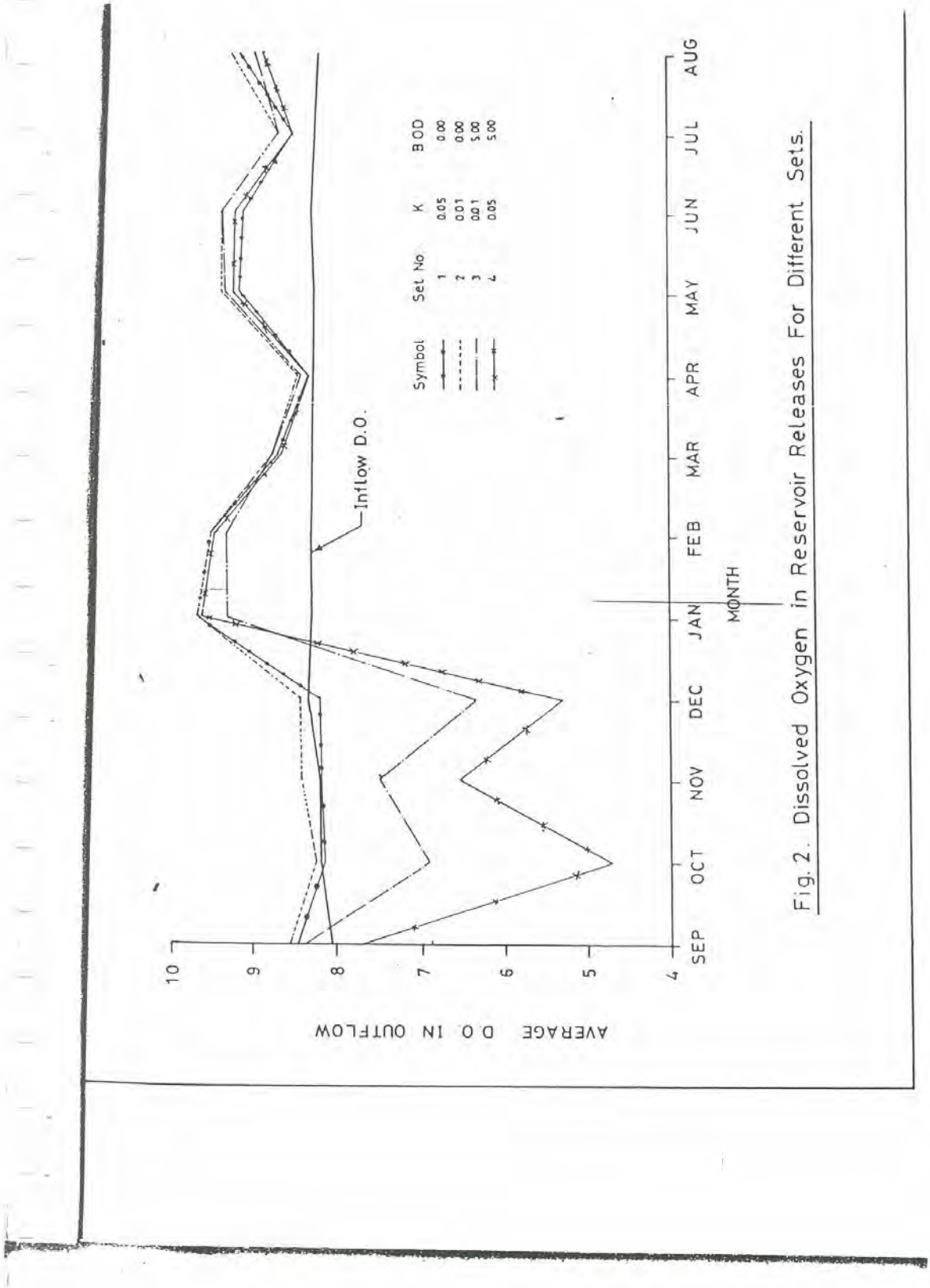

Fig. 2. Dissolved Oxygen in Reservoir Releases For Different Sets.

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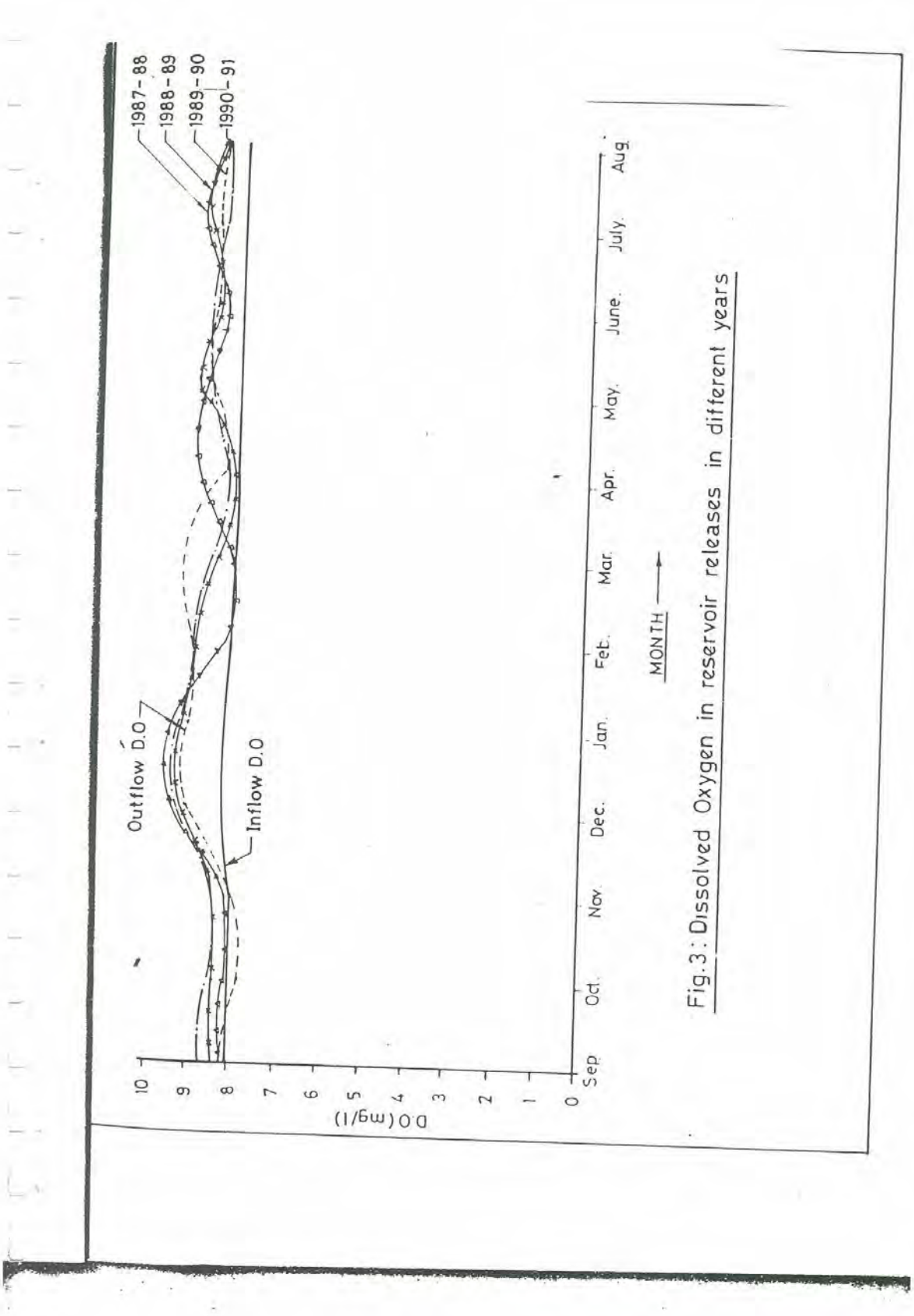

Fig.3: Dissolved Oxygen in reservoir releases in different years

APPENDIX-

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Hydraulic Engineering
Report No. Hyd. 9203

THERMAL AND WATER QUALITY MODELLING OF TEHRI RESERVOIR

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1 INTRODUCTION

The 260.5m high Tehri dam proposed to be constructed on the river Bhagirathi downstream of the Tehri town is an earth and rockfill dam, which will create a reservoir of gross capacity of 3540 million m^3.

The study of the thermal stratification and water quality modelling of this reservoir was entrusted to the Hydraulic Engineering Section of the Civil Engineering Department of the University of Roorkee by the Tehri Hydro Development Corporation Limited vide their letter No.1565/THDC/D-3/T-2 dated January 19,1991. This report describes the methodology employed in the present study and the results obtained therefrom.

The study was carried out using mathematical models for the temperature and dissolved oxygen prediction in the reservoir and in the outflow. The salient features of these models are described in the next section.

2 THE TEMPERATURE AND D.O. PREDICTION MODELS

The model used for temperature prediction was the Huber and Harleman model [1], as modified by Markofsky and Harleman, while the Markofsky and Harleman model was employed for D.O. predictions. A brief description of these is given below.

2.1 The Temperature Model

Assuming the reservoir to be two dimensional, which implies the existence of horizontal isotherms, the governing differential equation for conservation of heat can be written in the simplified form

$$\frac{\partial T}{\partial t} + V\frac{\partial T}{\partial y} = \frac{1}{A}\frac{\partial}{\partial y}\left[A\,(D_M + E)\frac{\partial T}{\partial y}\right] + q_i\left[\frac{T_i - T}{A}\right]$$

$$- \frac{P\phi_m}{\rho c_p A} - \frac{-1}{\rho c_p A}(1-\beta)\phi_o\, e^{-\eta(y_s - y)}\,(-\eta A + \frac{\partial A}{\partial y}) \qquad (1)$$

where T is the temperature, t is the time, V is the vertical convective velocity, y is the vertical distance (elevation), A is the horizontal cross-sectional area of the reservoir, D_M is the thermal diffusivity of mass, E is the turbulent diffusivity of heat, q_l is the inflow rate per unit vertical distance, T_l is the inflow temperature, P is the reservoir perimeter, ρ is the mass density and c_p is the specific heat of water, ϕ_m is the heat flux from heat transfer through the reservoir sides, β is the fraction of solar radiation absorbed at water surface, ϕ_o is the insolation heat flux, y_s is the surface elevation and η is the radiation absorption coefficient.

The above equation is to be solved subject to the following conditions :

Initial condition - Reservoir is isothermal at the beginning i.e.

$$T = T_o \text{ at } t = 0 \text{ for all } y$$

Boundary condition - The heat absorbed at the reservoir surface must equal the amount of heat diffused into the reservoir from the water surface i.e.

$$\rho c_p (D_M + E)\frac{\partial T}{\partial y}\Big|_{y=y_s} = \beta \phi_o + \phi_a - \phi_L \qquad (2)$$

where ϕ_a is the atmospheric radiation flux and ϕ_L is the heat flux from surface heat losses, which is the sum of the evaporative heat flux, the conductive heat flux and heat flux due to long wave radiation from the water surface to the atmosphere.

2.2 The D.O. Model

The governing equations in this model after simplification can written in the following form:

$$\frac{\partial c_1}{\partial t} + V\frac{\partial c_1}{\partial y} = \frac{1}{A(y)}\frac{\partial}{\partial y}\left[D_M A(y)\frac{\partial c_1}{\partial y}\right] - Kc_1 + \frac{\text{sources}_1}{\rho} - \frac{\text{sinks}_1}{\rho} \quad (3)$$

$$\frac{\partial c_2}{\partial t} + V\frac{\partial c_2}{\partial y} = \frac{1}{A(y)}\frac{\partial}{\partial y}\left[D_M A(y)\frac{\partial c_2}{\partial y}\right] - Kc_1 + \frac{\text{sources}_2}{\rho} - \frac{\text{sinks}_2}{\rho} \quad (4)$$

where c_1 and c_2 are the concentrations of two pollutants (B.O.D. and D.O. in this case). K is first order decay constant. It is assumed that the first pollutant is undergoing a first order decay given by the following equation

$$c_1 = c_o\, e^{-K(t-\tau)} \quad (5)$$

where c_o is the B.O.D. at time τ and c_1 is the B.O.D. at time t, and that the second pollutant is also undergoing a first order decay proportional to the amount of first pollutant present. The sources and sinks are due to advection of mass by inflow and outflow velocity distribution and by internal production or consumption not accounted for by the first order decay term.

These equations can be further simplified and written as

$$\frac{\partial c_1}{\partial t} + V\frac{\partial c_1}{\partial y} = -Kc_1 + (U_i c_{1i} - U_i c_1)\frac{B(y)}{A(y)} \quad (6)$$

$$\frac{\partial c_2}{\partial t} + V\frac{\partial c_2}{\partial y} = -Kc_2 + (U_i c_{2i} - U_i c_2)\frac{B(y)}{A(y)} \quad (7)$$

The above equations are solved subject to the following conditions

Initial conditions - B.O.D. and D.O. profiles known at t = 0

Boundary conditions - The surface is D.O. saturated and no transfer of B.O.D. across the free surface i.e.

$$\frac{\partial c_1}{\partial y} = 0 \quad \text{at} \quad y = y_s$$

$$C_2 = C_{sat} \text{ at } y = y_s$$

and no transfer of mass across the bottom boundary i.e.

$$\frac{\partial c_1}{\partial y} = \frac{\partial c_2}{\partial y} = 0 \text{ at } y = y_b$$

An added restriction is that the D.O. value calculated at any point in the reservoir cannot exceed the saturated value for the temperature at that point.

The aforesaid equations for the temperature and D.O. are solved numerically by proper schematisation of the reservoir, determination of suitable velocity fields and accounting for the mixing at reservoir entrance, the lagtime which includes the time for the incoming water to find its own density level and horizontal travel time, the surface instabilities and surface mixing . The computer code comprised of main programme with many sub-routines/function sub-programmes performing different tasks as shown in the schematic diagram.

3. INPUT DATA AND OTHER PARAMETERS

The above models require the following data as input

1. Reservoir Geometry
2. Inflow Temperatures
3. Air Temperatures
4. Relative Humidities
5. Wind Speed
6. Inflow and Outflow Rates

7. Surface Elevations
8. Elevation of Outlet
9. Inflow D.O. and B.O.D.
10 Solar Insolation and Atmospheric Radiation
11 Initial Isothermal Reservoir Temperature
12 Initial D.O. and B.O.D.
13 Decay Rate K
14 Absorption Coefficient η
15 Surface Absorption Fraction β
16 Thickness of Saturated Surface Layer

The values of the parameters at serial numbers 1 to 9 were provided by the project authorities whereas the remaining parameters were either estimated or assumed on the basis of considerations as discussed below:

The reservoir was assumed to have a constant width B(y) at any elevation y, given by

$$B(y) = \frac{A(y)}{L(y)} \qquad (8)$$

where L(y) is the length of the reservoir and A(y) the area at elevation y. This variation of width with depth when plotted on a semi-log graph paper yielded the following expression

$$B = 2.15763\ e^{0.0075y} \qquad (9)$$

here B and y are in m. Equation (9) was used for computations in this programme.

The meteorological data used was that from the Mukhim station of the India Meteorological Department. No measurements of the solar insolation are available at or in the vicinity of the project site and therefore this parameter was estimated on the basis of plots of clear-sky radiation as a function of the latitude as shown in Fig.(1). The insolation was then obtained using the formula

$$\phi_o = \phi_{sc} (1.0 - 0.65\ C^2) \cdot \qquad (10)$$

where ϕ_{sc} is the clear-sky solar radiation and C is the fraction of the sky covered with clouds. The value of C was obtained from the meteorological data.

The surface elevations at different times were computed using the inflow and outflow data alongwith the reservoir elevation capacity curves.

The initial isothermal temperature of the reservoir was assumed to be $17^{\circ}C$, same as that of inflow during July-Aug., which remains nearly constant . This seems reasonable, because the reservoir will get filled in these months in the first year of operation.

Amongst the other parameters which need to be obtained/assumed , β, the average surface absorbed fraction of solar insolation and η the absorption coefficient are best estimated based on actual measurements. However, since no such measurements are possible in this case, these values were chosen based on the values reported in literature (i.e. $\beta = 0.5$ and $\eta = 0.75\ m^{-1}$).

The decay rate K and the initial B.O.D. value also need to be suitably chosen. In the absence of measurements again, it was decided to carry out a sensitivity analysis for the variation of these parameters. It was felt prudent to assume the entire euphotic zone to be D.O. saturated and based on the range of variation of K values available in literature, the model was run for a range of parameters as given below.

Set I : K = 0.05, Initial B.O.D = 0 ppm

Set II : K = 0.01, Initial B.O.D = 0 ppm

Set III : K = 0.01, Initial B.O.D = 5 ppm

Set IV : K = 0.05, Initial B.O.D = 5 ppm

It may also be mentioned that these parametric variations are going to affect only the D.O. prediction, as they do not appear in the temperature model.

The reservoir was discretised by a 5.0 m grid along its depth for these studies and the time step was taken as 10 days. The various inputs were thus in terms 10 daily averages .The model was run for four years, starting in Sept.1987 at which time the initial isothermal reservoir temperature was taken to be 17°C .

4. RESULTS AND DISCUSSIONS

Results obtained on the basis of the present study are as follows:

4.1 Temperature Profiles

Monthly temperature profiles for the Tehri reservoir starting from September 1987 to August 1991 were obtained. Figures 2 to 13 show these temperature profiles for the period from September 1987 to August 1988. As mentioned earlier, it was assumed that the reservoir will get filled in during July-August of first year and will attain an initial isothermal temperature of 17°C. Figures 2 and 3 show the validity of this assumption as the resevoir level during September-October is around 820.0 m and has a nearly constant temperature of 16-17°C except near its surface. The stratification starts from the month of Nov.1987 (See Fig.4) onwards, the extent and the nature of this stratification varies with varying amount of inflows and their temperatures. The temperature profile for the month of Dec.1987 as shown in Fig.5 shows a typical stratification in the reservoir with temperatures varying from 13°C to about 17°C over a depth of water in the reservoir between elevations 600.0 m and 800.0 m.

The nature of variation in the temperature profiles for the three subsequent years i.e. 1988 to 1991 was found to be more or less same as described above. Therefore, these profiles are not shown here, however, to indicate the nature of similarity, the conditions of stratified reservoir for the month of December for these three years are shown in Figs. 14 to 16. Here also the variation in the reservoir temperature is from 13°C to 17°C as was in Dec. 1987 mentioned above.

4.2 D.O. Profiles

D.O. profiles showing the variation in D.O. expressed in ppm with elevation were also obtained for different months for the four years data using the range of various assumed values of K and the initial B.O.D. in the reservoir. The monthly variations in the profiles for the first year i.e. September 87 to Aug. 88 are shown in Figs. 17 to 28. These figures show that the effect of increasing the decay rate, K, is to increase the rate of D.O. consumption within the reservoir, consequently lower values of D.O. are predicted. Further, the effect of K and the initial B.O.D. in the reservoir is limited to only first four months of the year thereafter it reduces significantly. This is to be expected considering the form of the Eq. (5) which governs the decay of initial B.O.D. in the reservoir. In fact it was found after running the model for the entire four year period (1987 to 1991) that from second year onwards these different sets of K and initial B.O.D. values have practically no effect in influencing the predicted D.O. profiles. This aspect can be seen in Figs. 29 to 32 which show typical predicted D.O. profiles for some of the months of second year data. The profiles for subsequent years were showing more or less same trend as such they are not shown here.

On the basis of available data, it was thus seen that the D.O. in the reservoir varies on an average from 8 to 9.0 ppm over most of its depth after about a year from its initial filling.

4.3 Average Temperature of Outflow

On the basis of temperature profiles obtained for different months of the four years period, the average temperatures of the outflow were obtained for different months of each year. Figures 33 to 36 show this variation and for comparison the corresponding inflow temperatures are also shown in these figures. These temperatures are the average temperatures over the thickness of the internal withdrawal layer near the reservoir outlet with its elevation as 720.0 m. In the present study this withdrawal thickness was computed within the programme developed and was found to vary from 15.0 m to 20.0 m.

It can be seen from these figures that in general the outflow temperatures are more than the inflow temperatures. This difference in temperature is more during winter months and decreases during summer months. Such a difference in temperature is expected in these thermally stratified reservoirs where water entering at the upstream end undergoes some initial mixing and enters the resevoir at an elevation corresponding to its own density. This is precisely what happens during winter; the incoming colder water during this period of time will tend to travel towards the lower elevations whereas the withdrawals are from higher elevations.

Results of four years period, show a maximum rise of about 7°C in the outflow temperature.

4.4 Average D.O. in Outflow

The average D.O. in outflow during different months of the year starting from Sept. 1987 to Aug. 1991 alongwith corresponding inflow D.O. values are shown in Figs.37 to 40 for the different set of values of K and the initial B.O.D. in the reservoir as considered in the present model. As mentioned earlier the resulting D.O. predictions are not sensitive to the choice of the

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various combinations of K and initial B.O.D in the reservoir after first year of reservoir operation. In general the average D.O. in outflow is marginally higher than the corresponding inflow D.O. The reduction in water surface elevations in the reservoir during summer months and the effect of surface aeration appear to be the reason for giving these higher outflow D.O. values as in this case outflow water will be drawn from layers close to the reservoir surface. The assumption of entire euphotic zone to be D.O. saturated may also be contributing to higher D.O. predictions. But considering the limitations of any well defined criterion regarding the proper choice of D.O. saturated thickness, the assumption of entire euphotic zone to be saturated appears to be quite reasonable.

From the range of inflow D.O. values available for the present study, it is seen that the average inflow D.O. is around 8 ppm and the average D.O. in outflow is around 8.5 ppm.

5. CONCLUSIONS

On the basis of the present study following salient conclusions are drawn

(i) The Tehri reservoir is expected to get thermally stratified within first year of its filling.

(ii) The temperatures in the stratified reservoir will vary from 15°C to about 17°C between the reservoir elevations 600.0 m and 800.0 m

(iii) The predicted D.O. profiles show the effect of various values of first order decay constant, K, and the initial B.O.D. in the reservoir only in the first year of reservoir operation. Whereas from the second year onwards these D.O. profiles were found to be independent of K and the initial B.O.D. values

iv) The average D.O. in the reservoir is expected to vary from 8.0 ppm to 9.0 ppm over most of its depth.

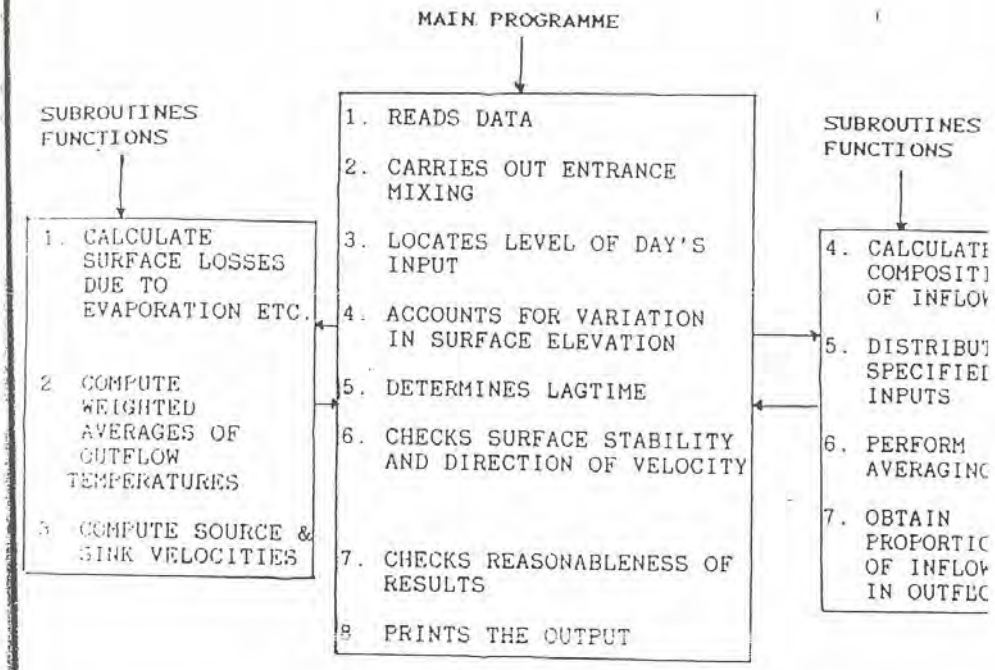
v) The average temperature of the outflow will in general be more than the inflow temperature. The maximum difference is about $7^{\circ}C$ and is limited only during winter months whereas during rest of the months it is expcted to be much smaller.

vi) The average D.O. in outflow is around 8.5 ppm as compared to the average inflow D.O. of 8.0 ppm.

5. REFERENCE

1. Huber, W.C. and Harleman, D.R.F., "Laboratory and Analytical Studies of the Thermal Stratification of Reservoirs", M.I.T. Hydro-dynamics Laboratory Technical Report No.112, October, 1968.

2. Gates, D.M., "Energy Exchange in the Biosphere", New York, Harper and Row, 1962.



SCHEMATIC OF THE COMPUTER PROGRAMME

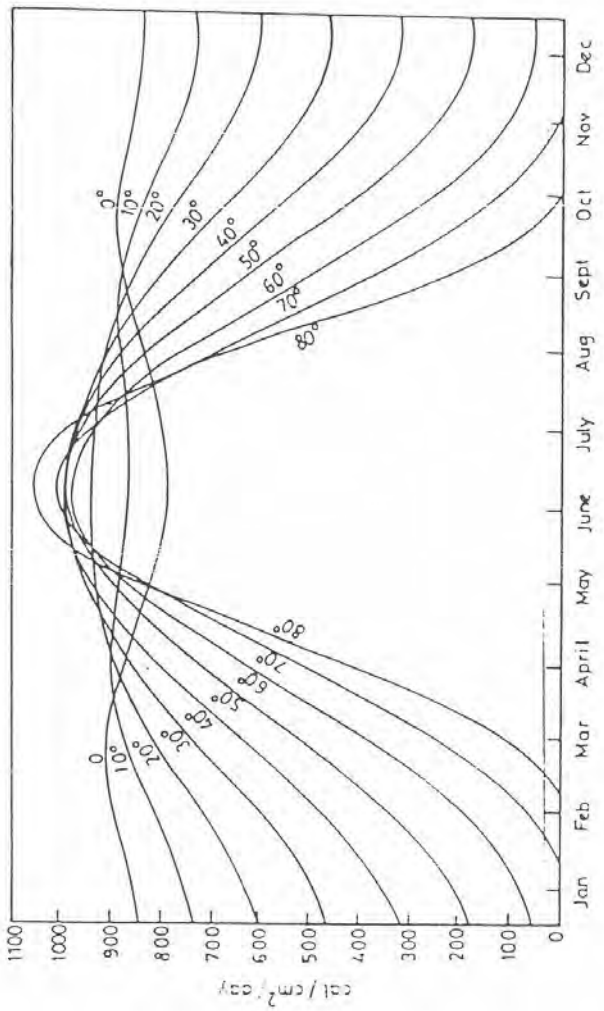


Fig. 1 — Variation of Daily Solar Radiation with Latitude
(Solar Constant Value = 1·94 g cal/cm^2/yr) [2]

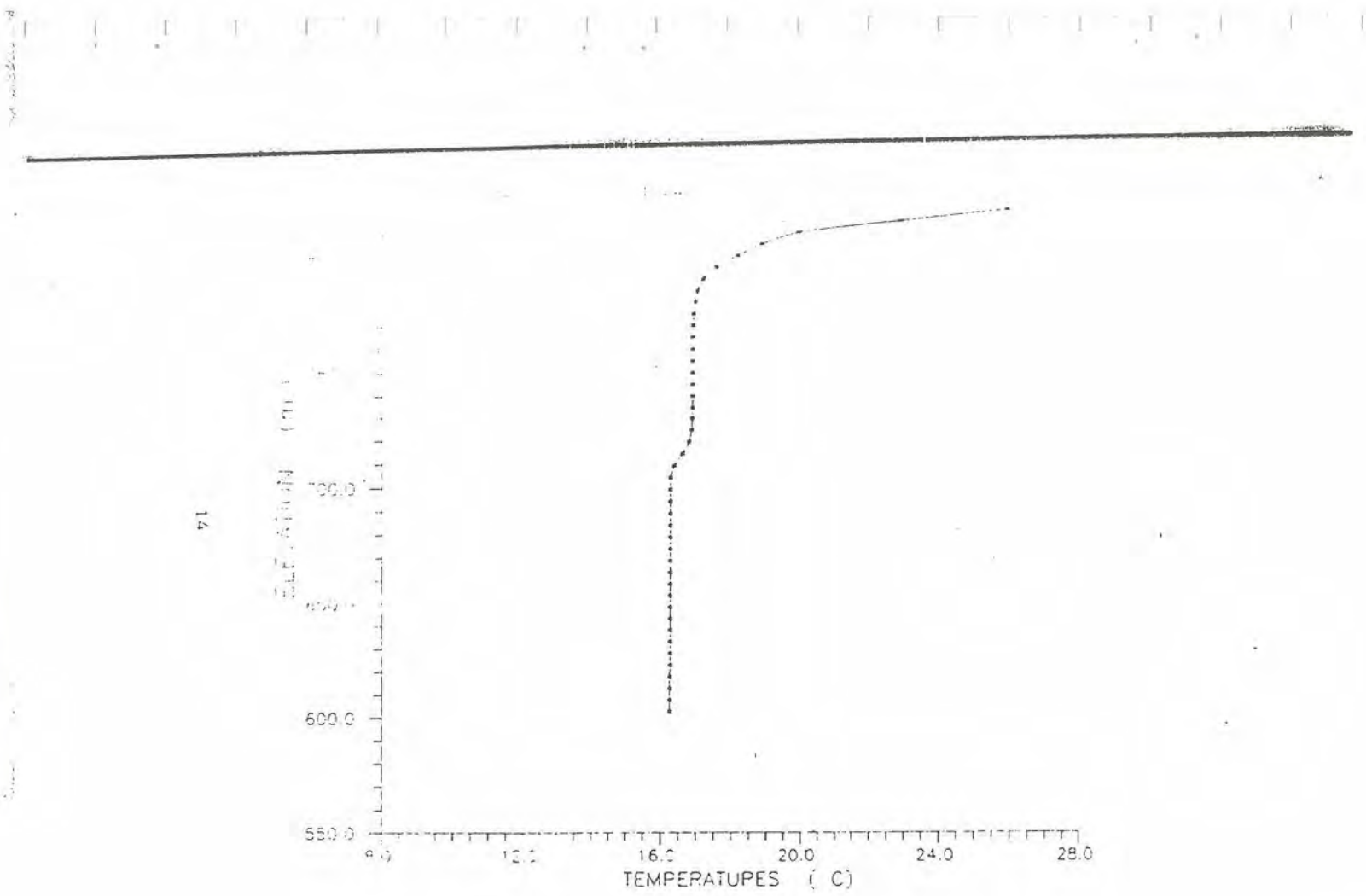


Fig. 2 — Temperature Profile — Tehri Reservoir

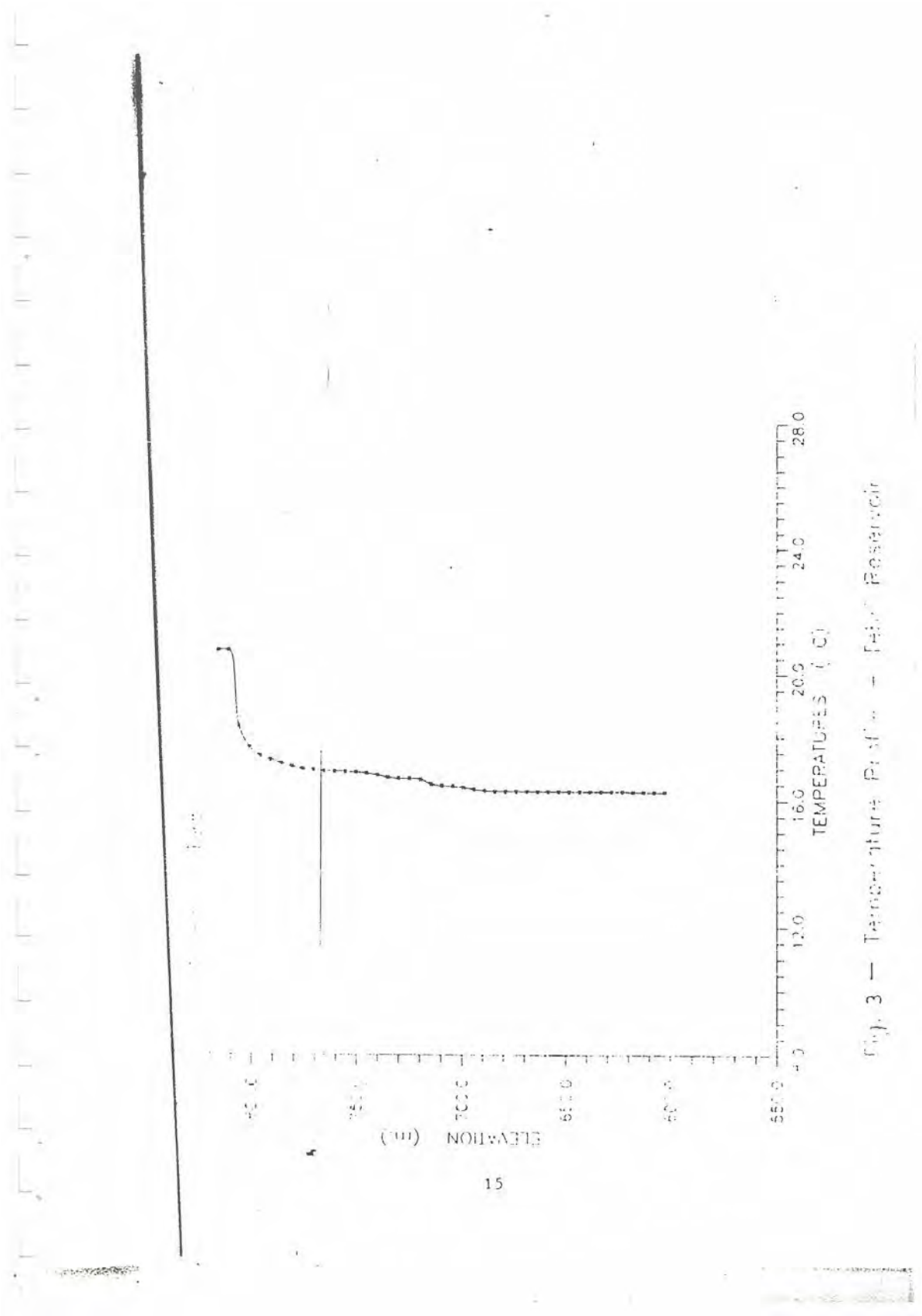


Fig. 3 — Temperature Profile — Feiyi Reservoir

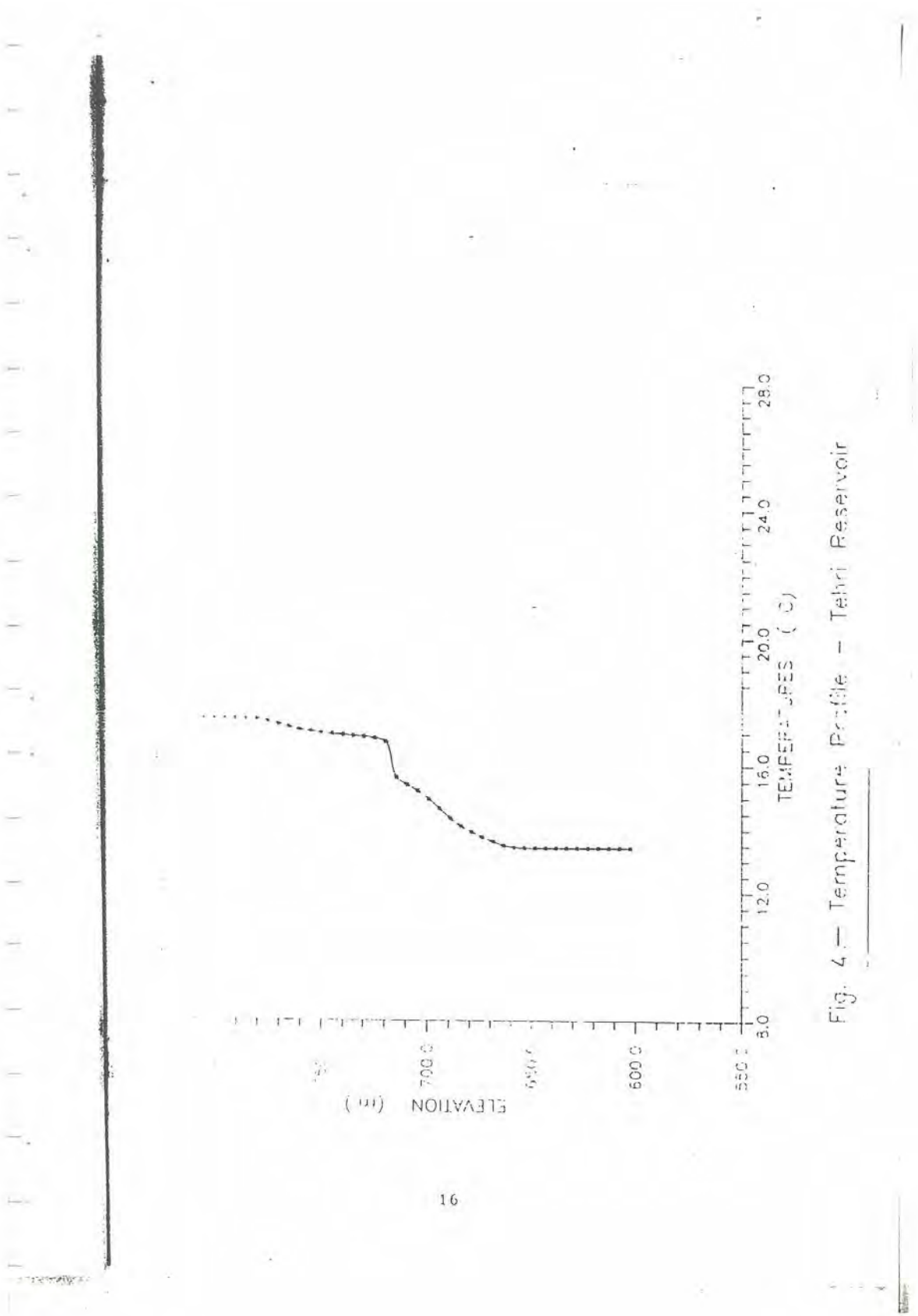


Fig. 4 — Temperature Profile — Tehri Reservoir

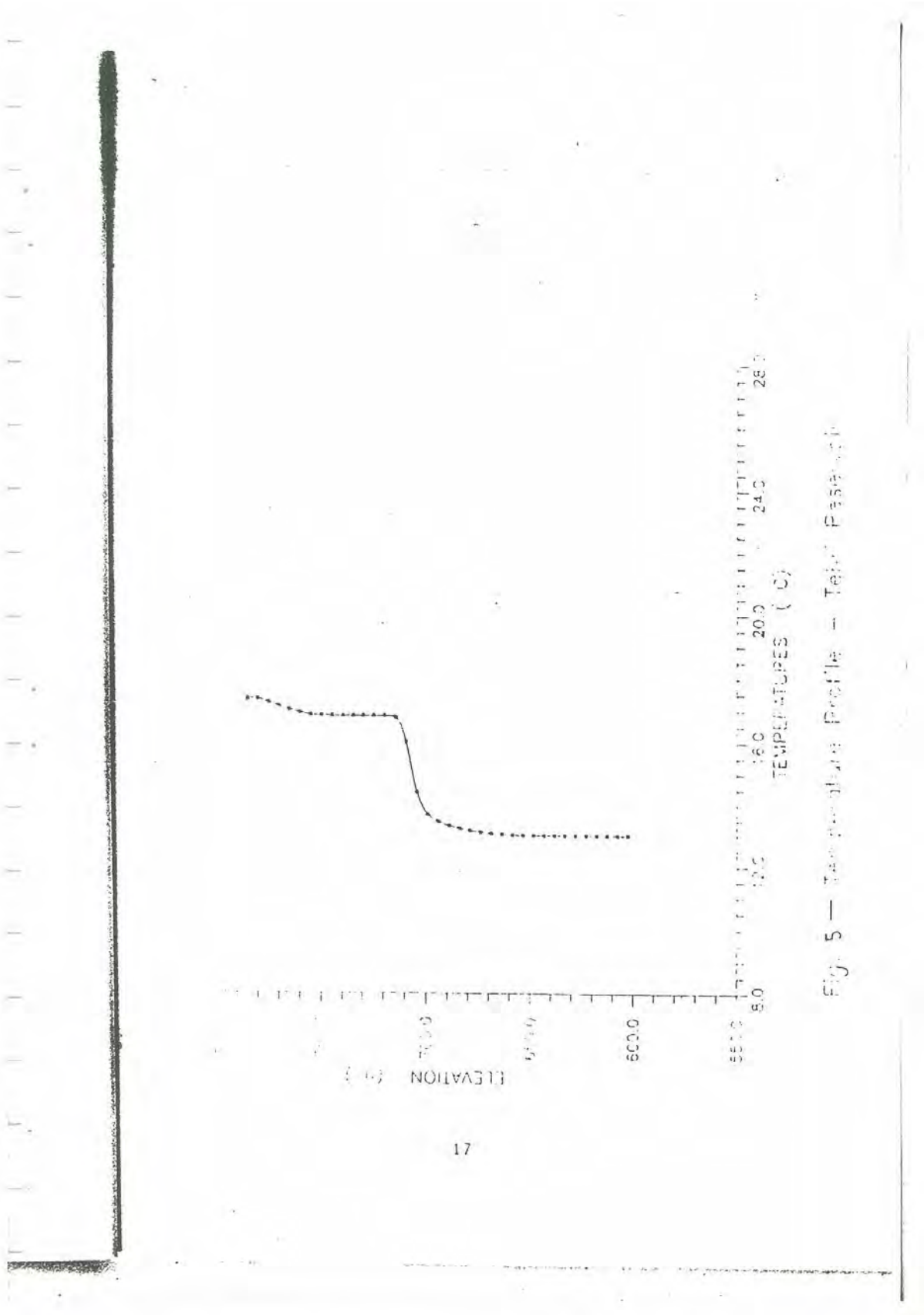


Fig. 5 — Temperature Profile — Tehri Reservoir

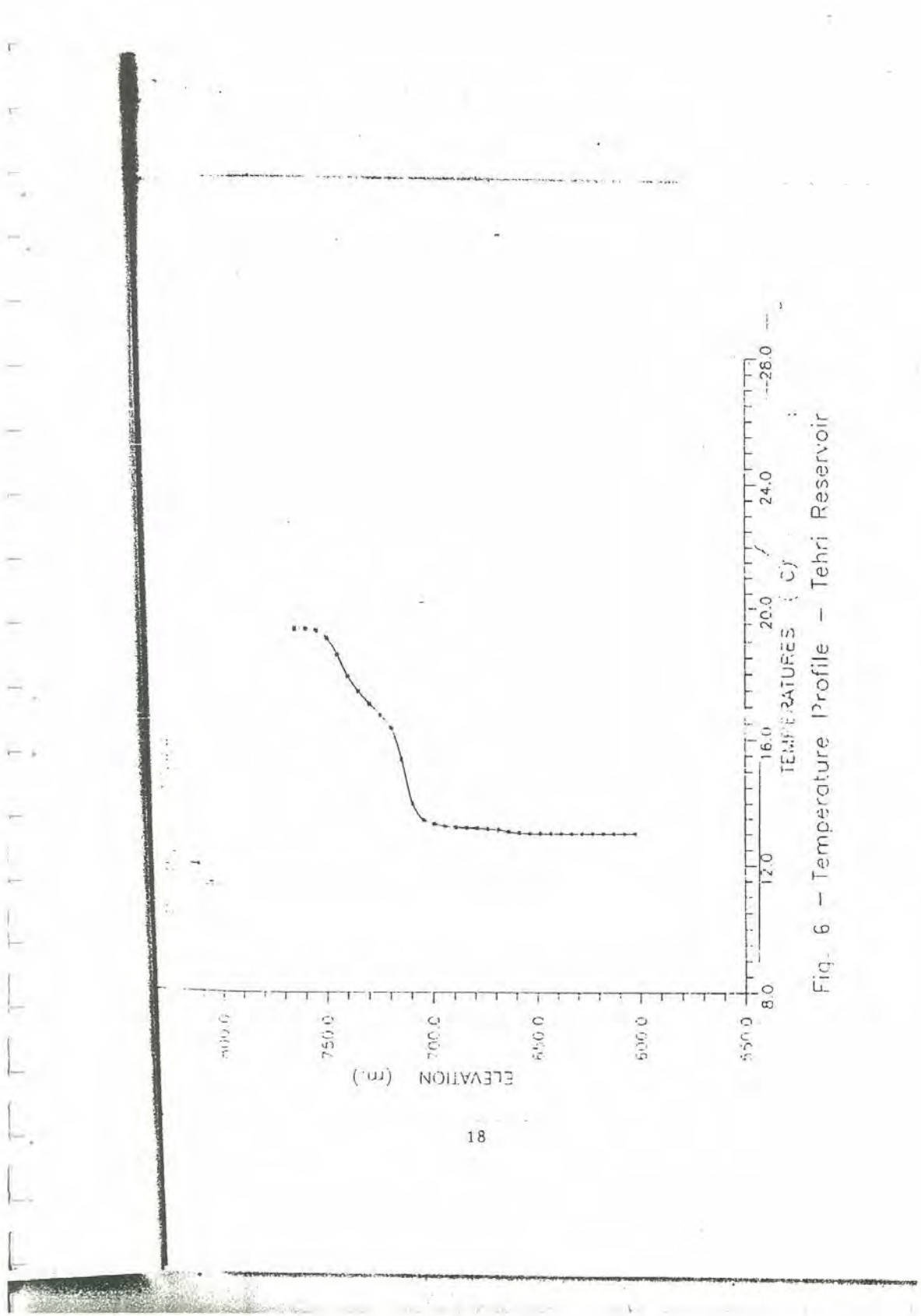
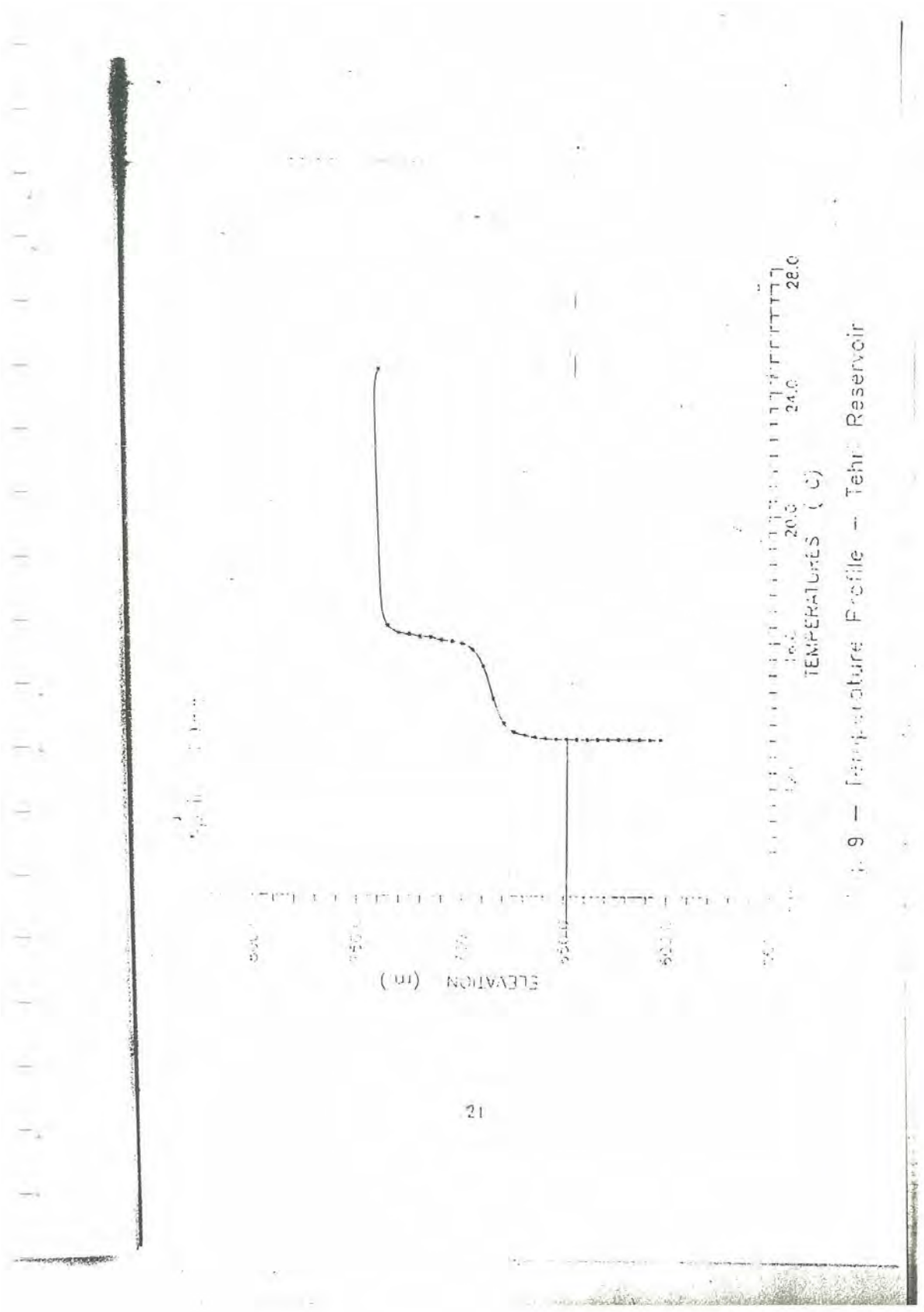


Fig. 6 – Temperature Profile – Tehri Reservoir

Fig. 7 — Temperature Profile — Tehri Reservoir

20



9 — Temperature Profile — Tehri Reservoir

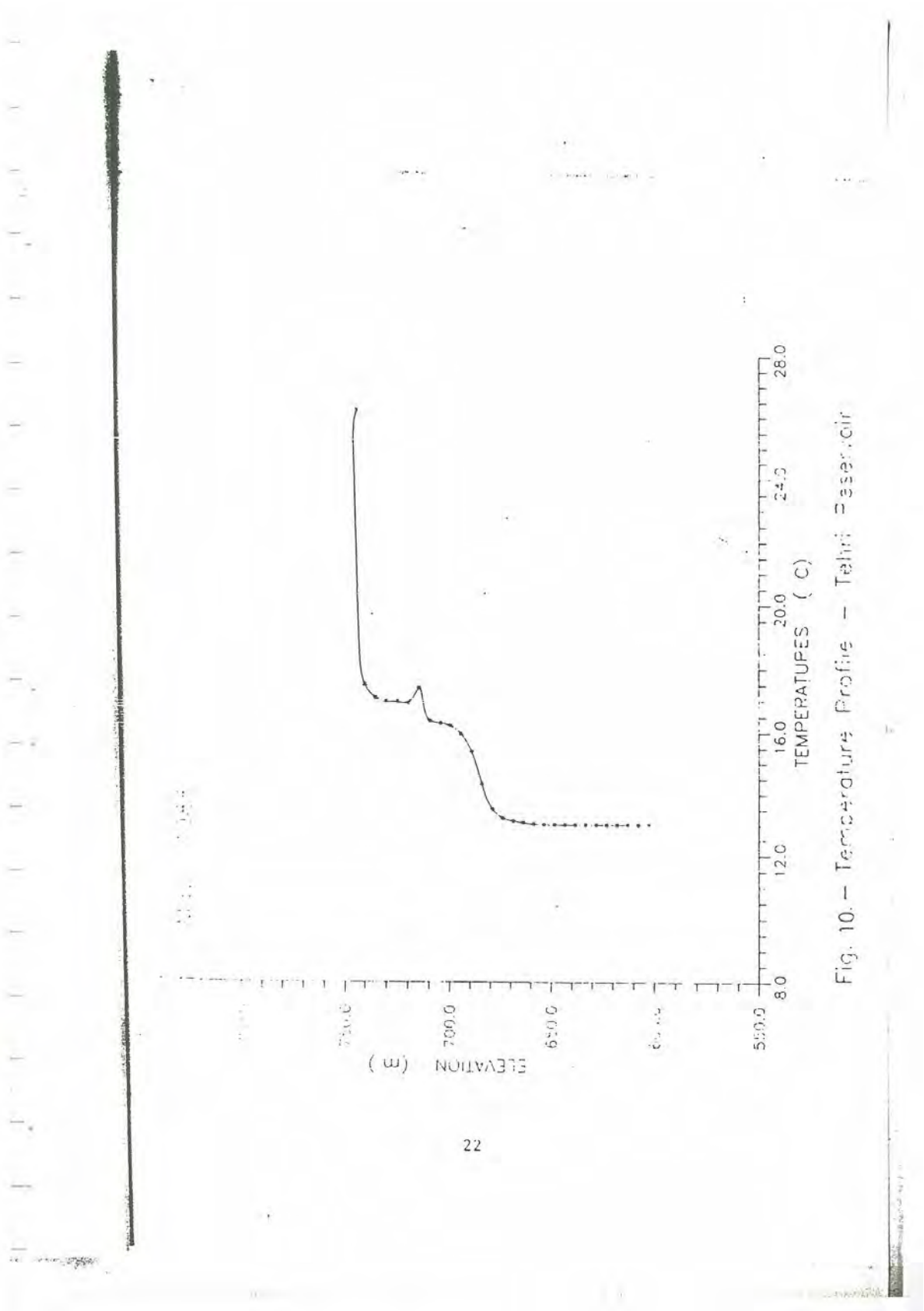


Fig. 10.– Temperature Profile – Tehri Reservoir

Fig. 11 — Temperature Profile — Tehri Reservoir

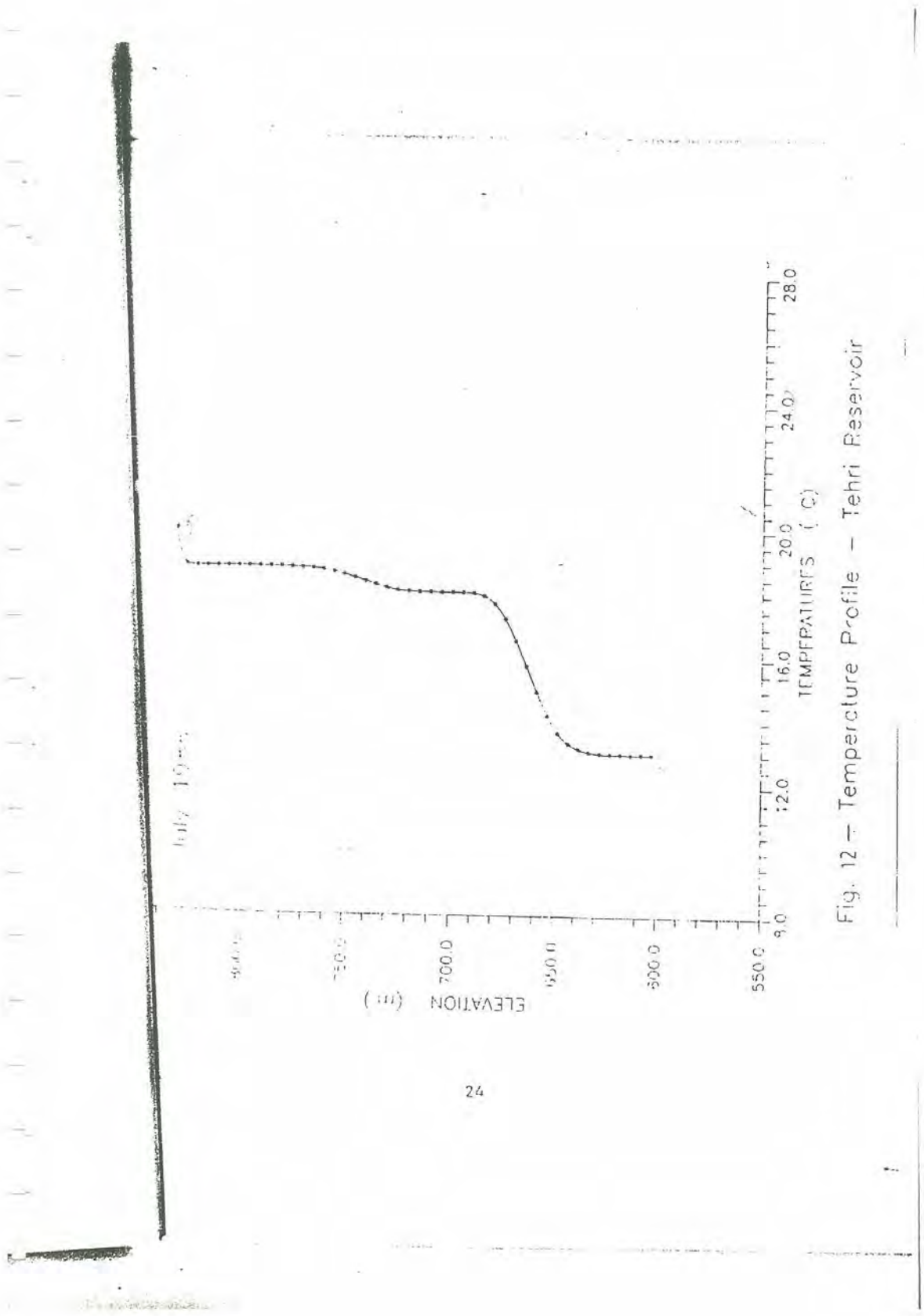
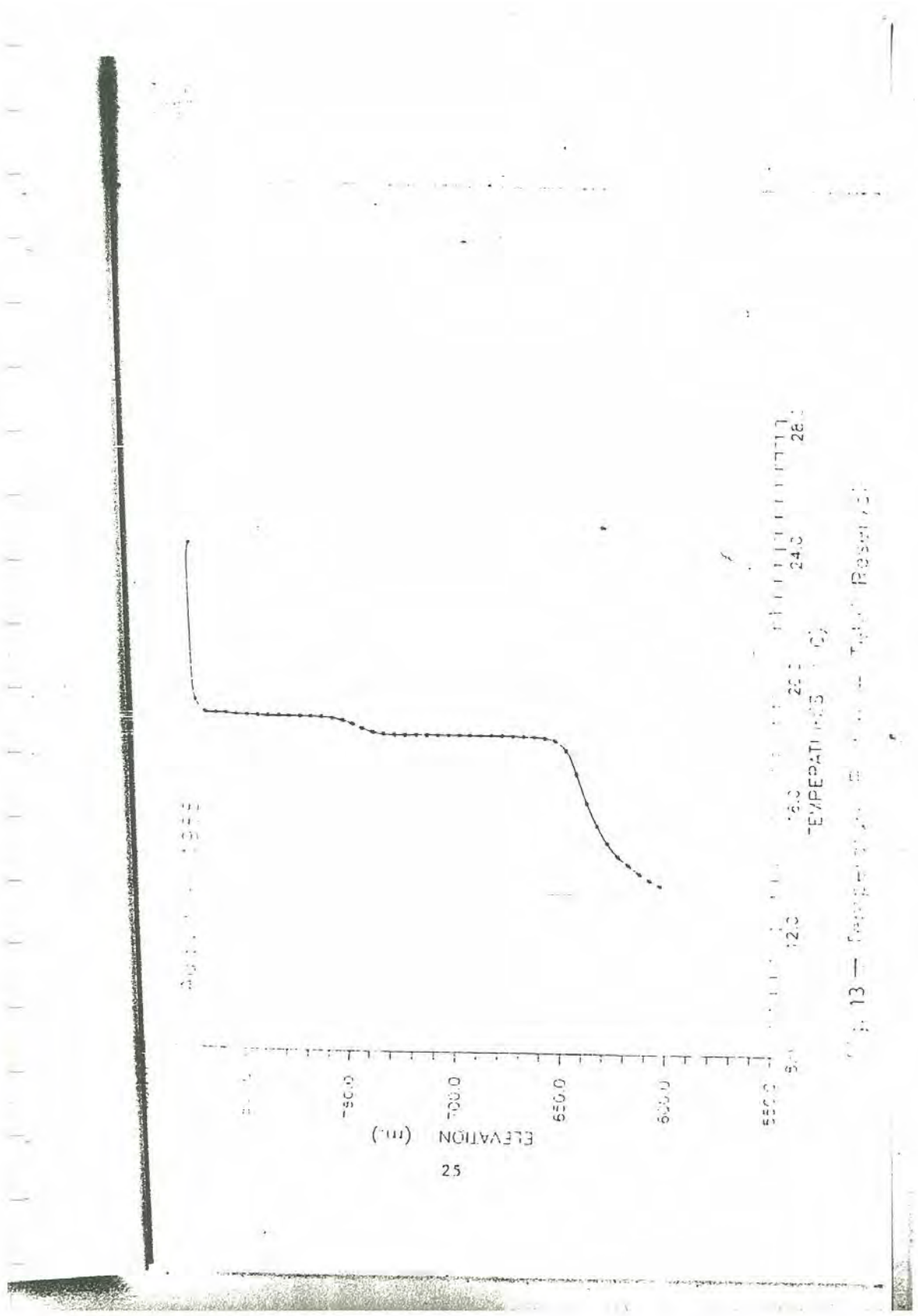


Fig. 12 — Temperature Profile — Tehri Reservoir


ELEVATION (m.)
25

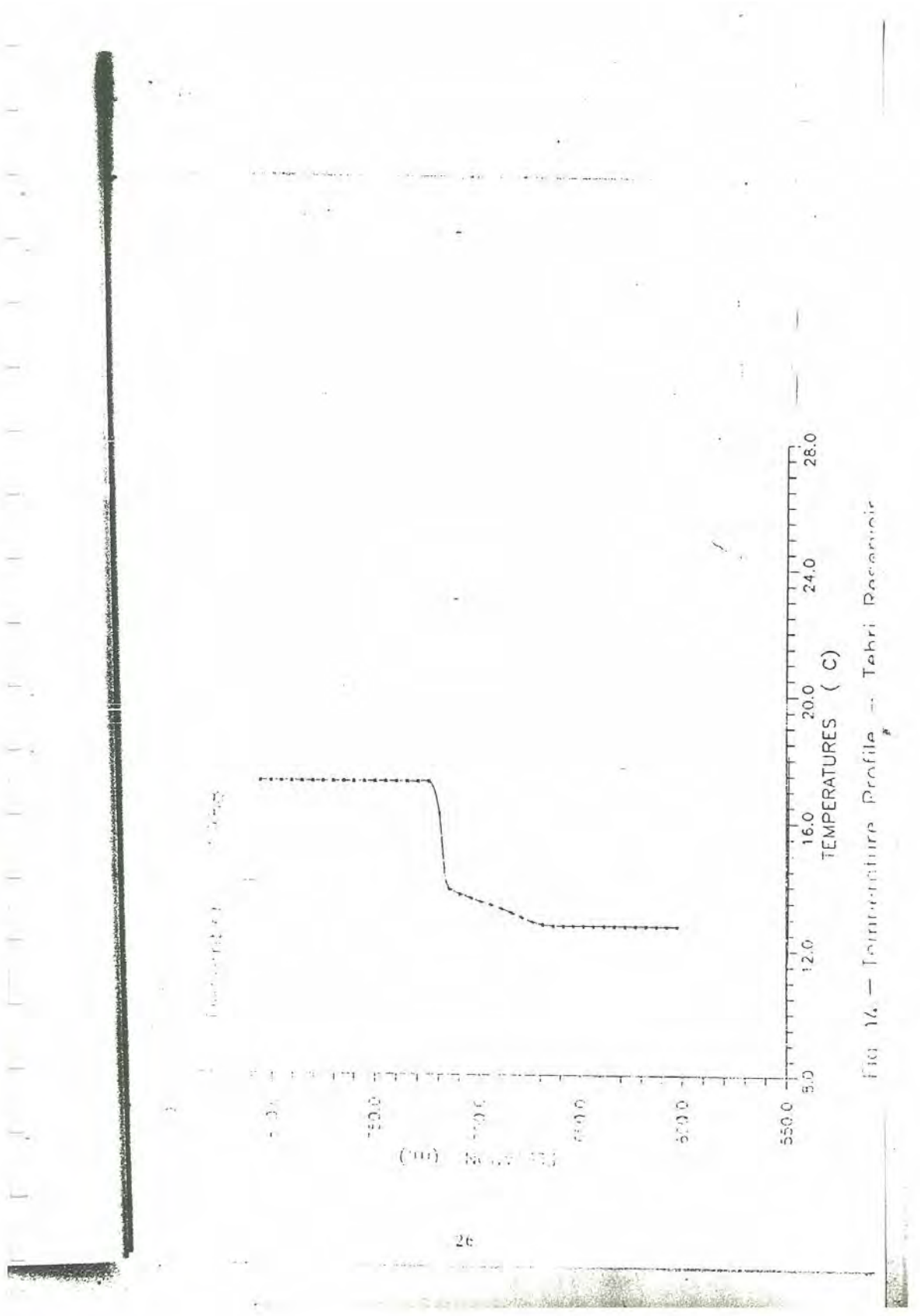


Fig. 14 — Temperature Profile — Tehri Reservoir

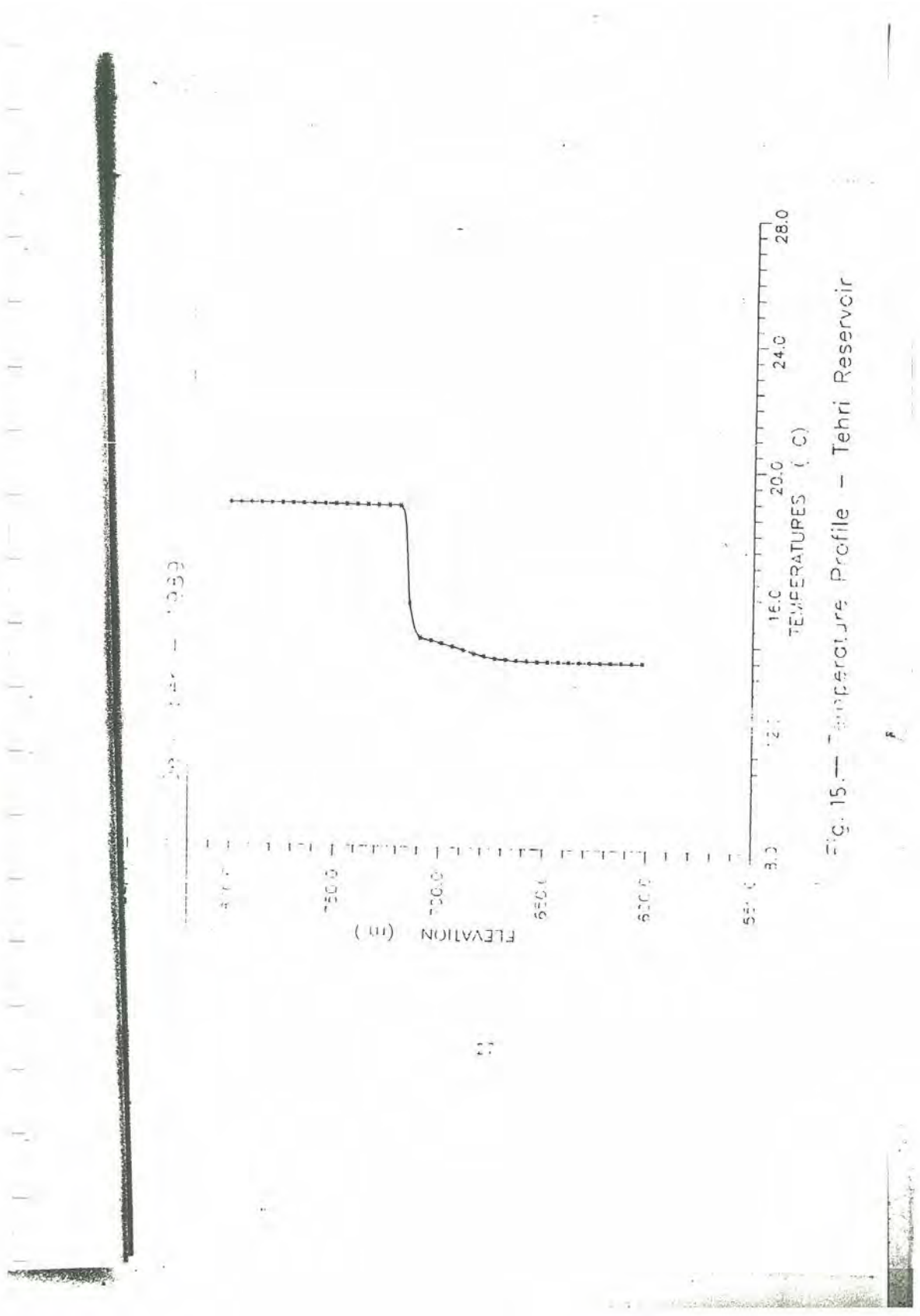


Fig. 15.— Temperature Profile – Tehri Reservoir

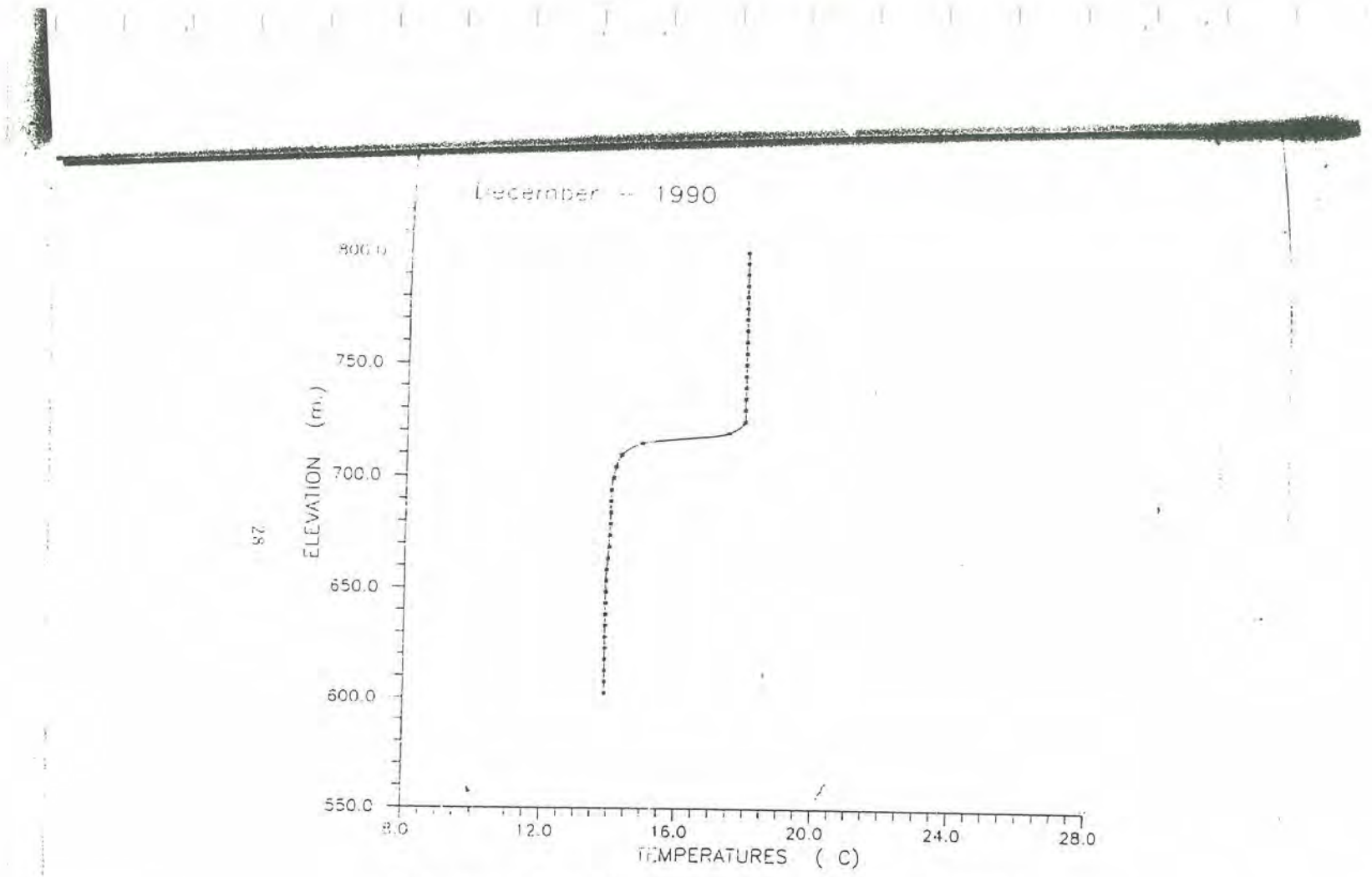


Fig. 16.— Temperature Profile – Tehri Reservoir

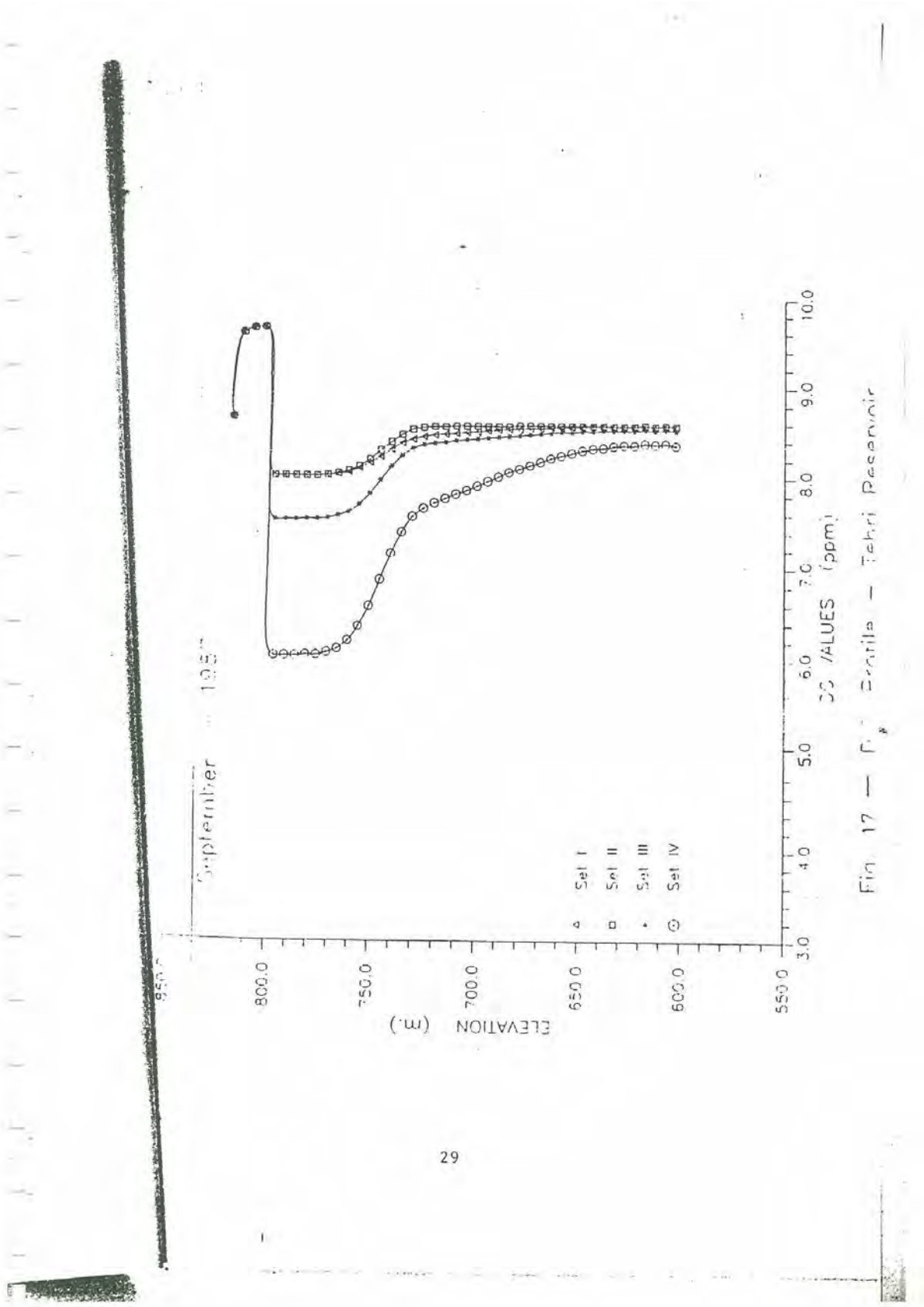


Fig. 17 — [illegible] Erotila — Tehri Reservoir

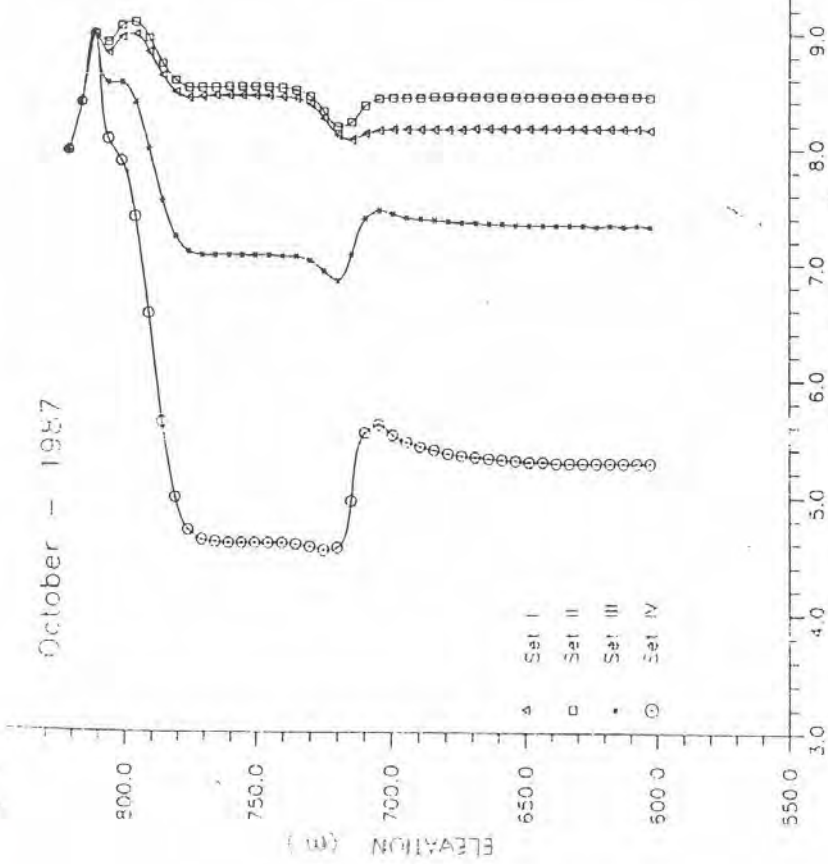


Fig. 18 — D.O Profile — Tehri Reservoir

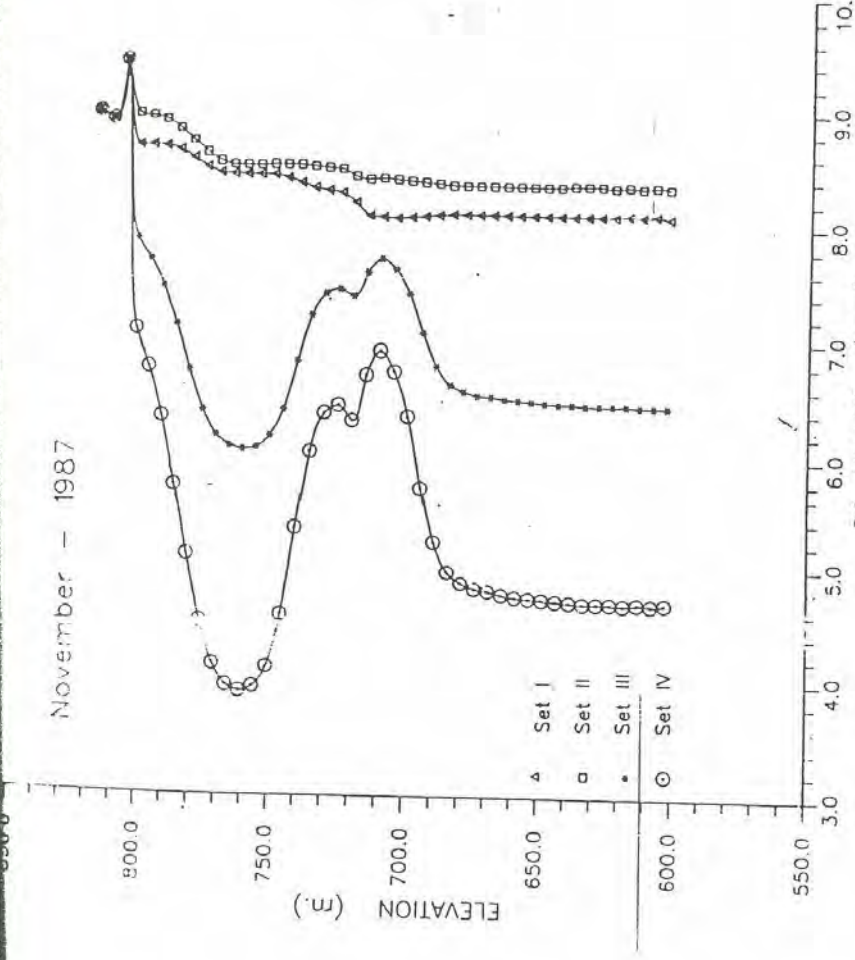


Fig. 19 — D.O. Profile — Tehri Reservoir

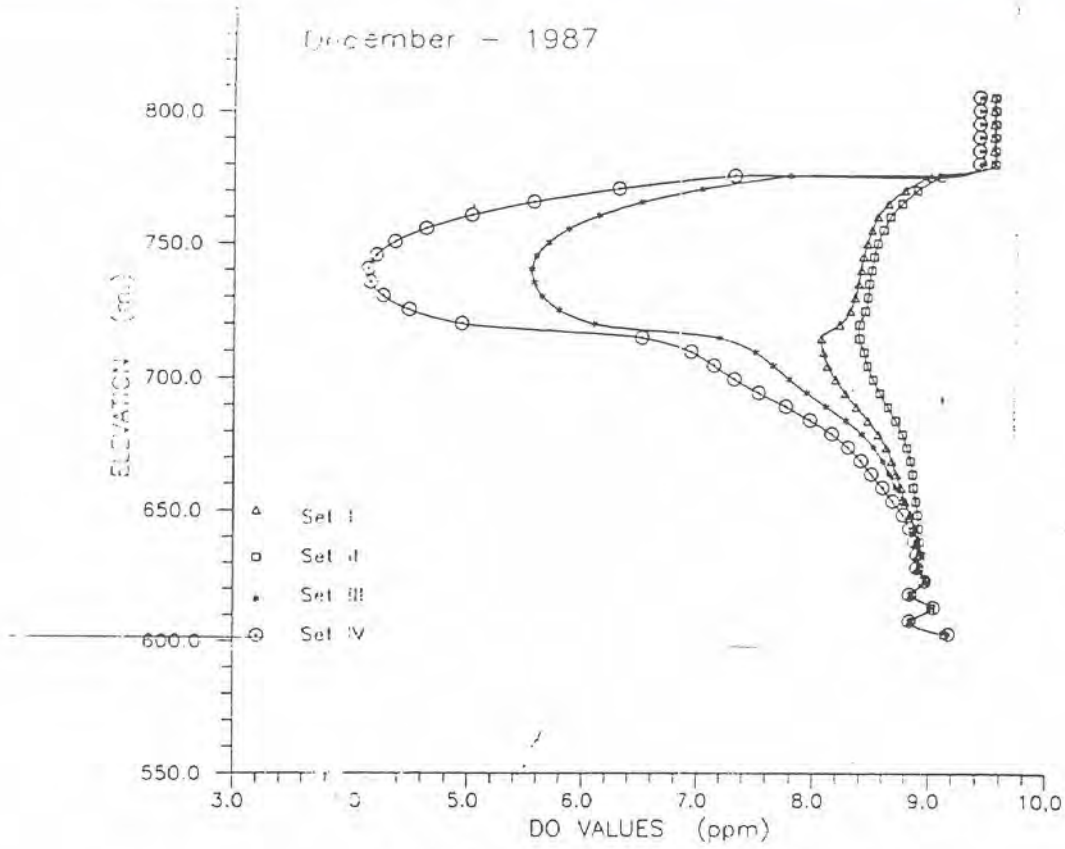


Fig. 20 — D.O. Profile – Tehri Reservoir

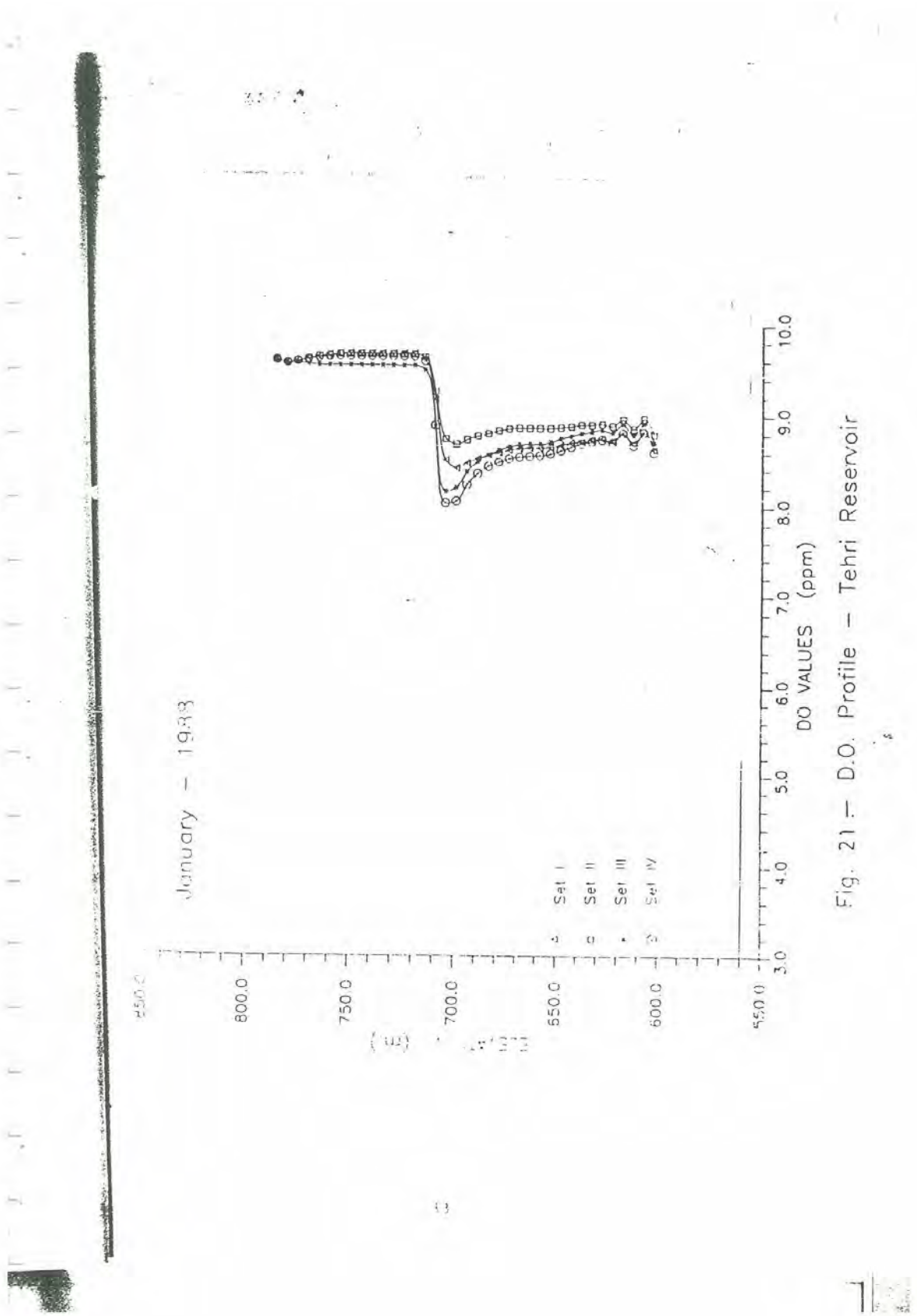


Fig. 21 – D.O. Profile – Tehri Reservoir

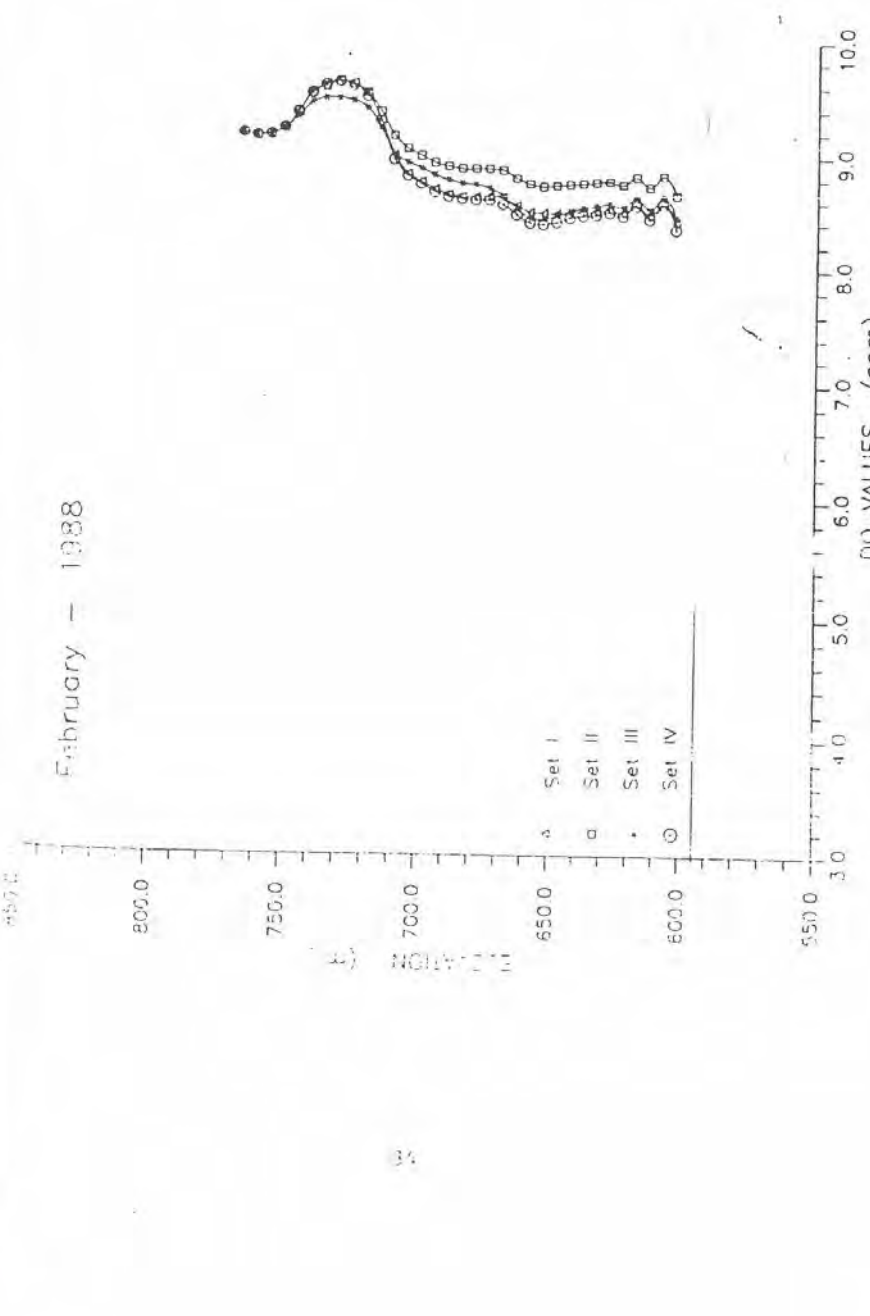


Fig. 22 – D.O. Profile – Tehri Reservoir

Fig. 23 — D.O. Profile — Tehri Reservoir

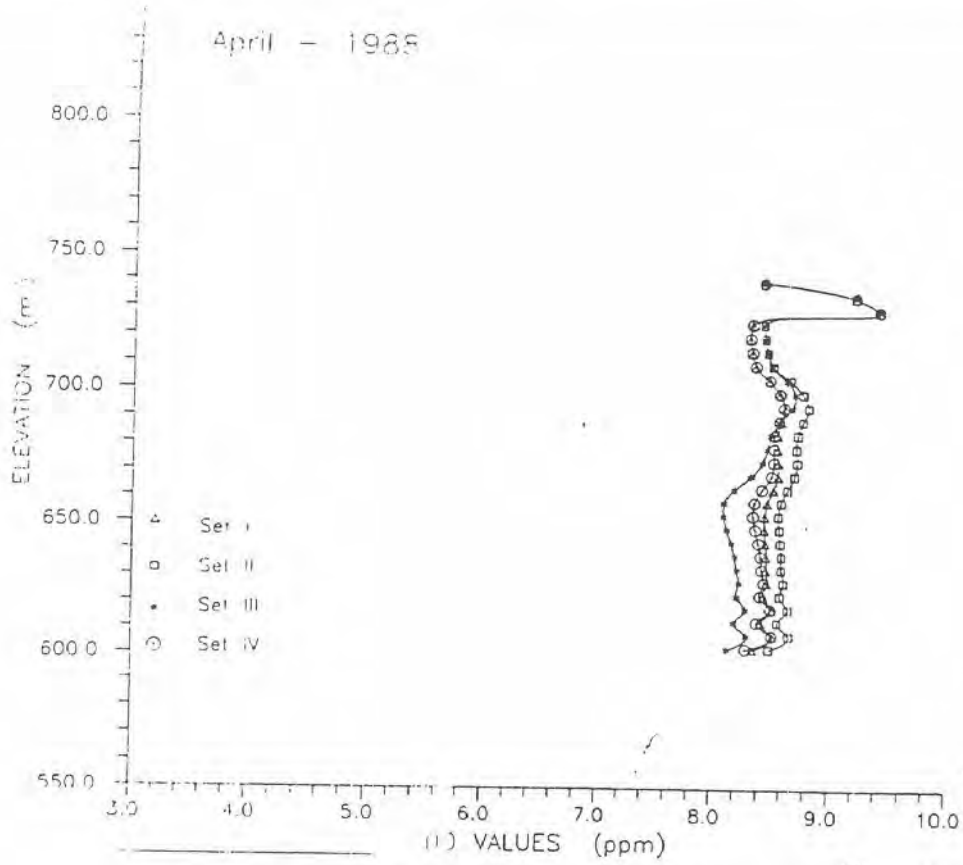


Fig. 24.— D.O. Profile – Tehri Reservoir

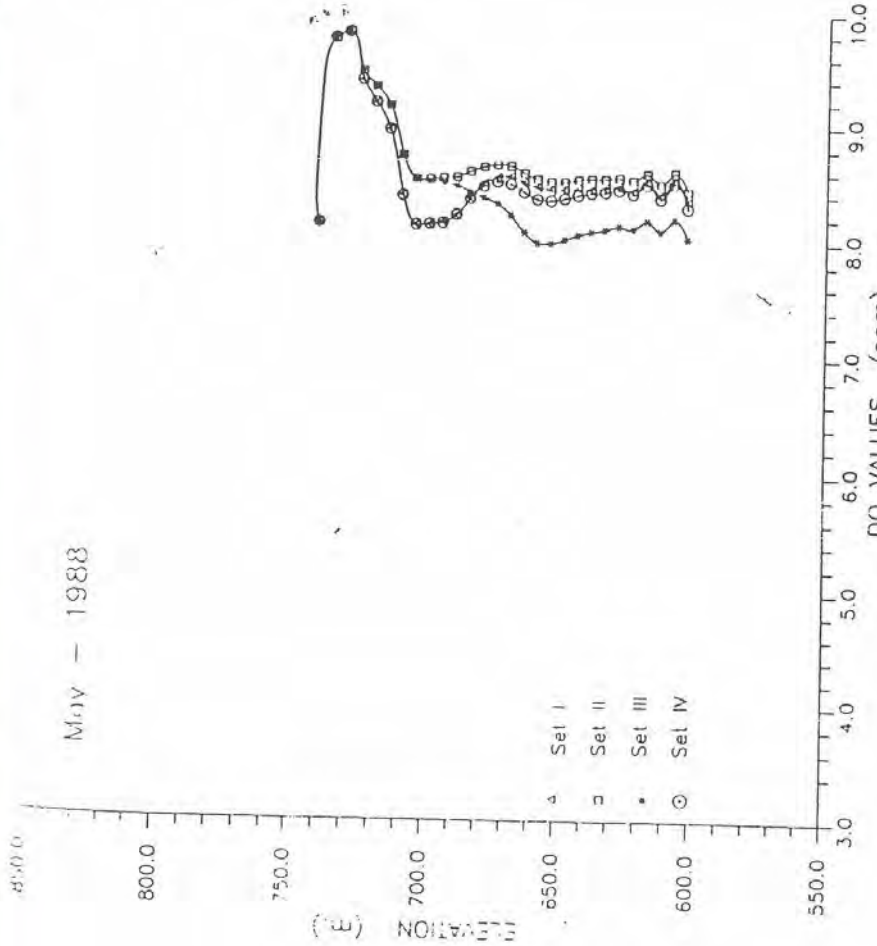


Fig. 25 — D.O. Profile — Tehri Reservoir

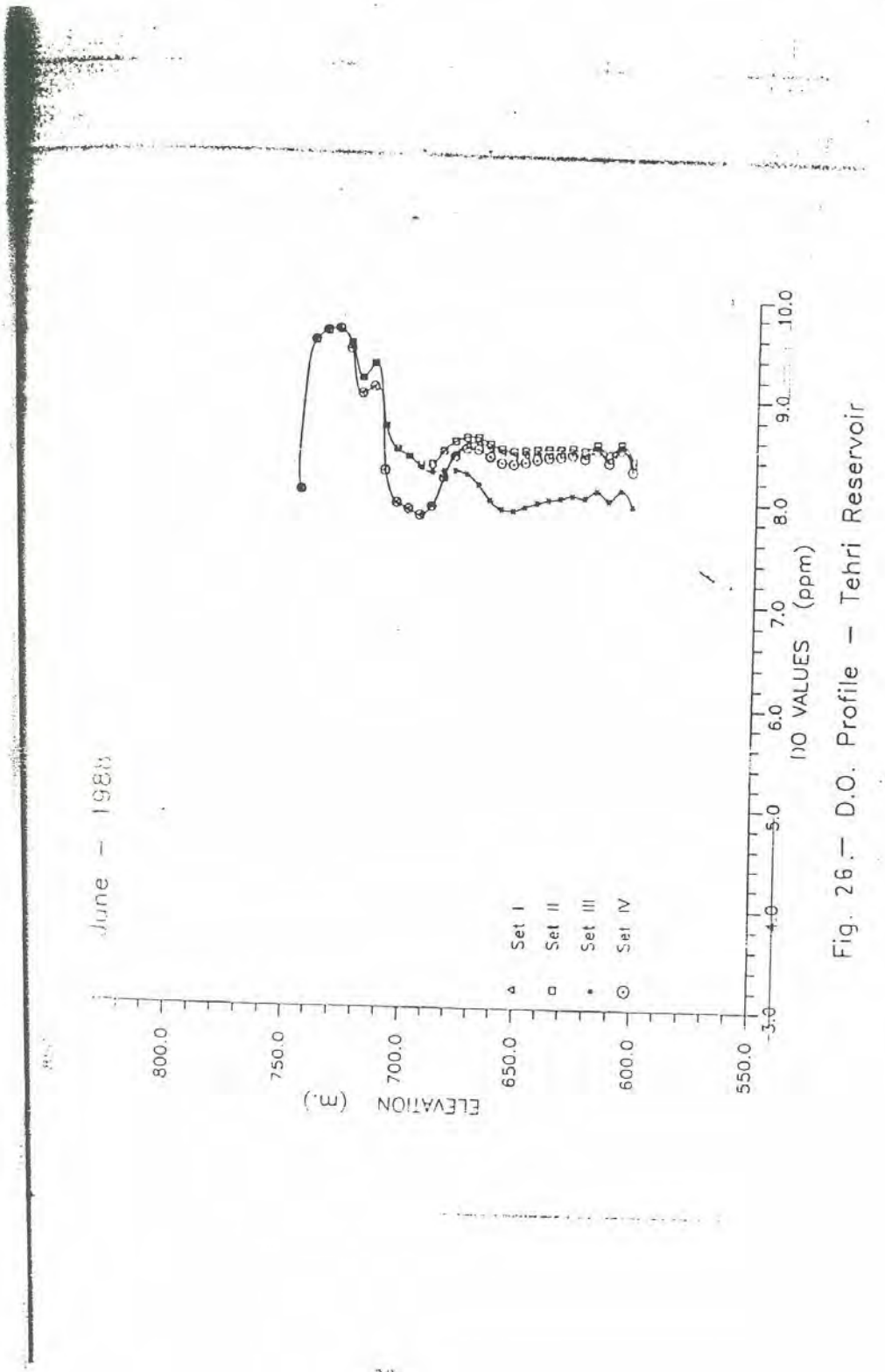


Fig. 26.— D.O. Profile — Tehri Reservoir

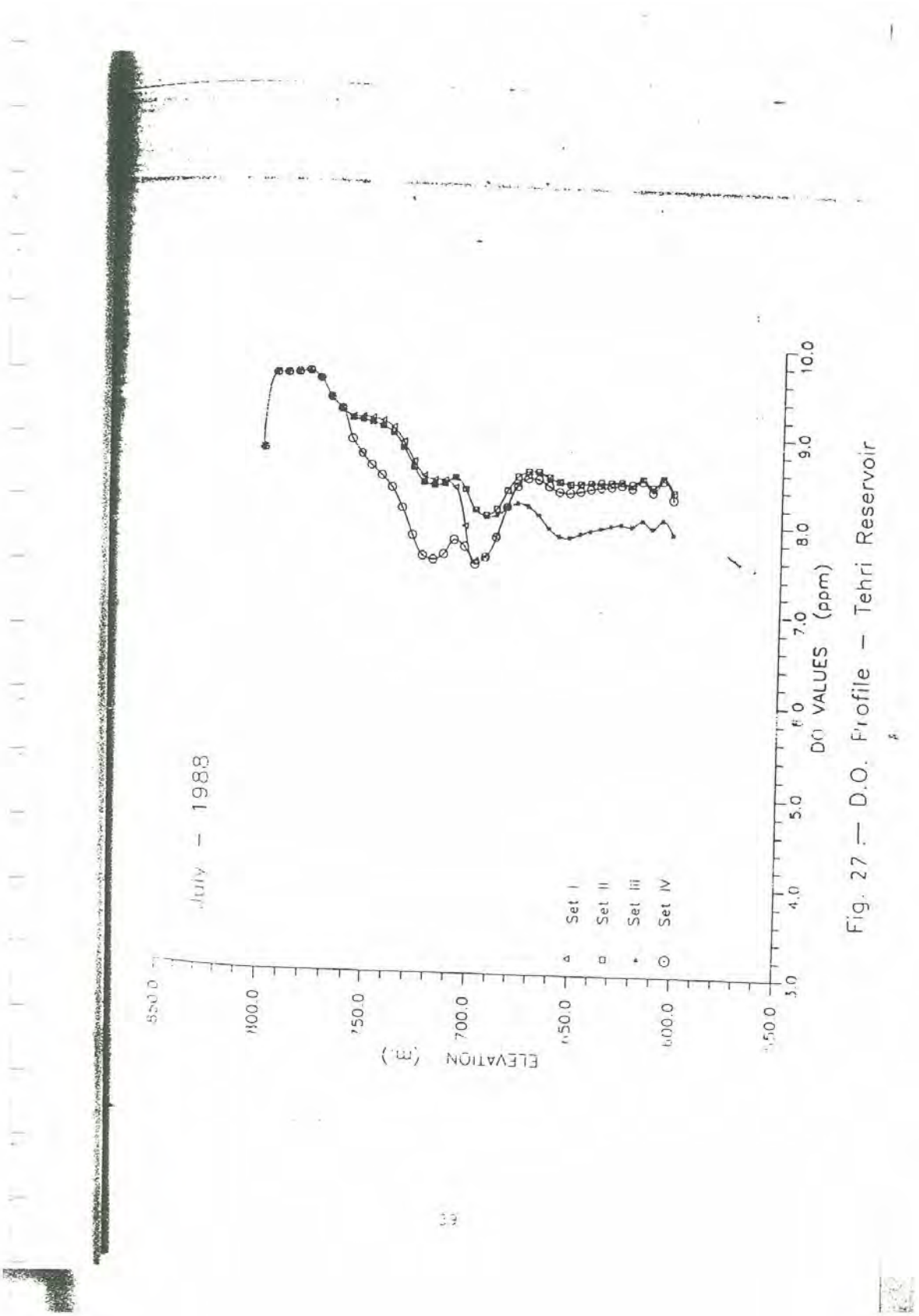


Fig. 27 — D.O. Profile — Tehri Reservoir

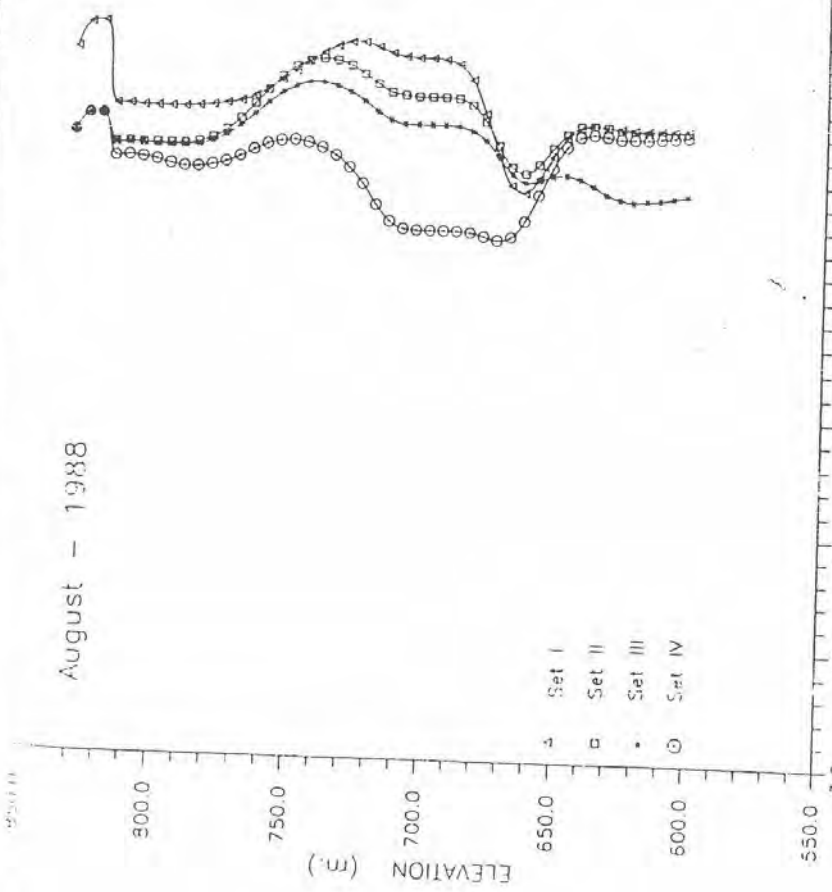


Fig. 28 – D.O. Profile – Tehri Reservoir

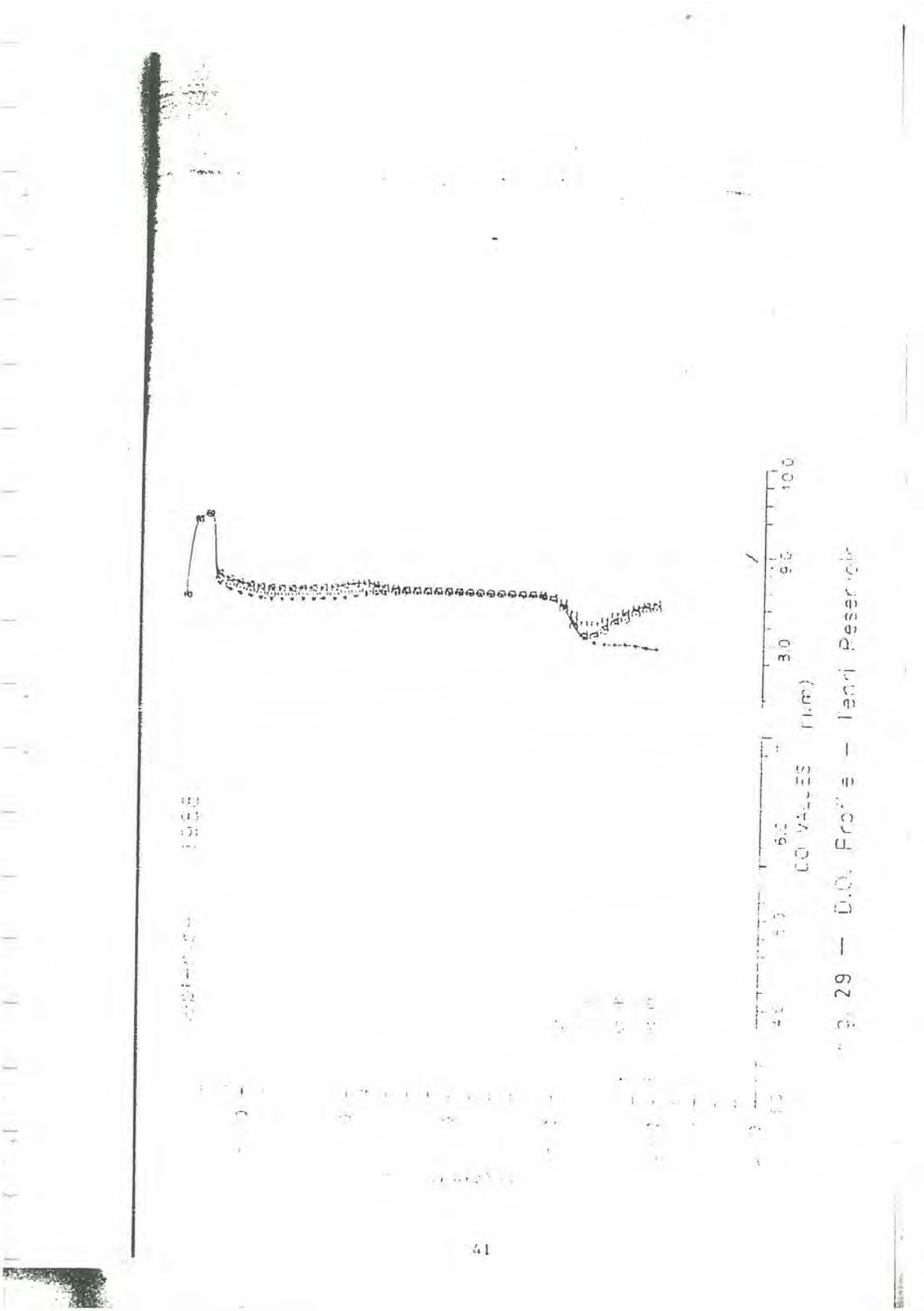


Fig. 29 — D.O. Profile — Tehri Reservoir

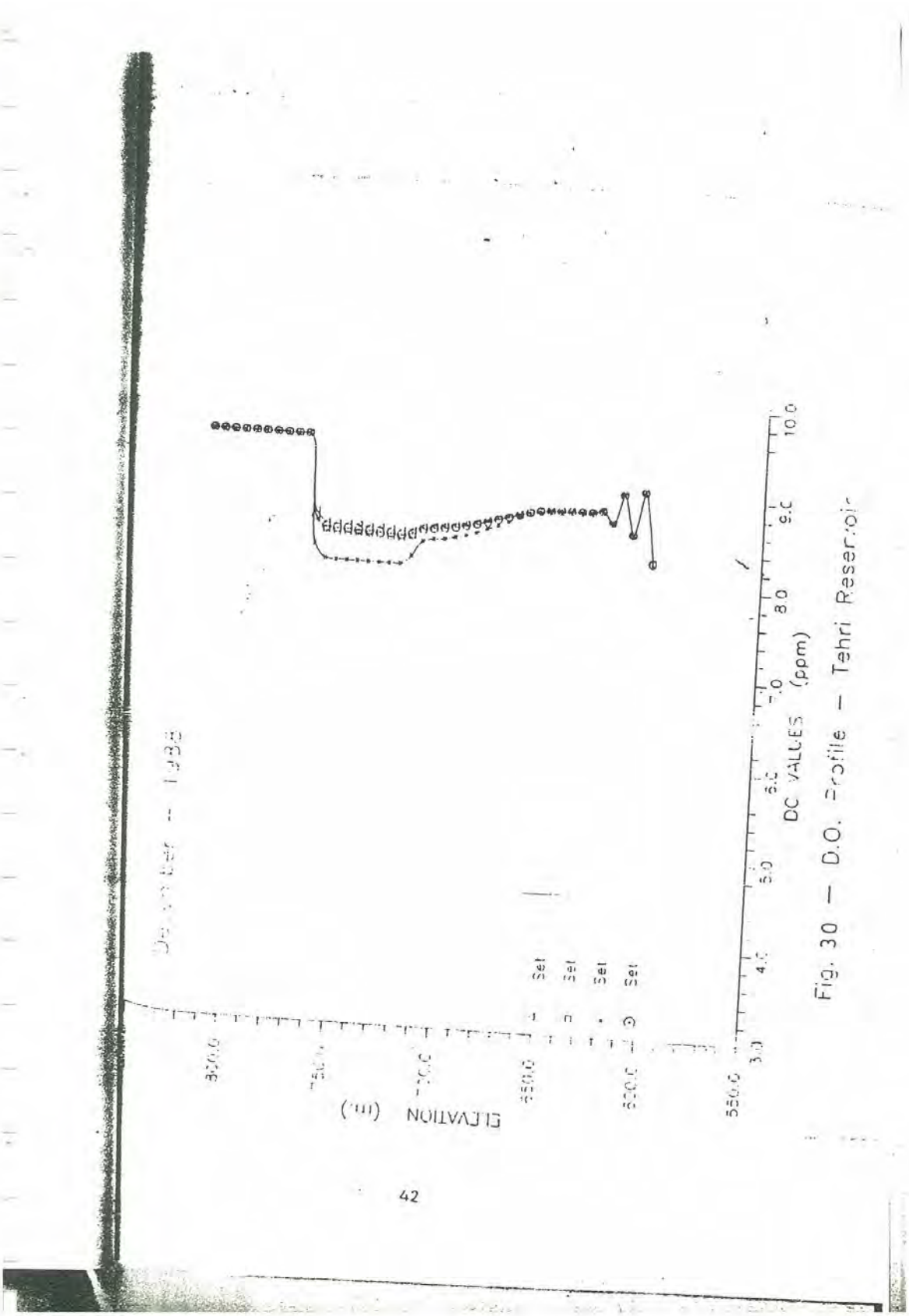


Fig. 30 — D.O. Profile — Tehri Reservoir

Fig. 31 — D.O. Profile - Tenri Reservoir

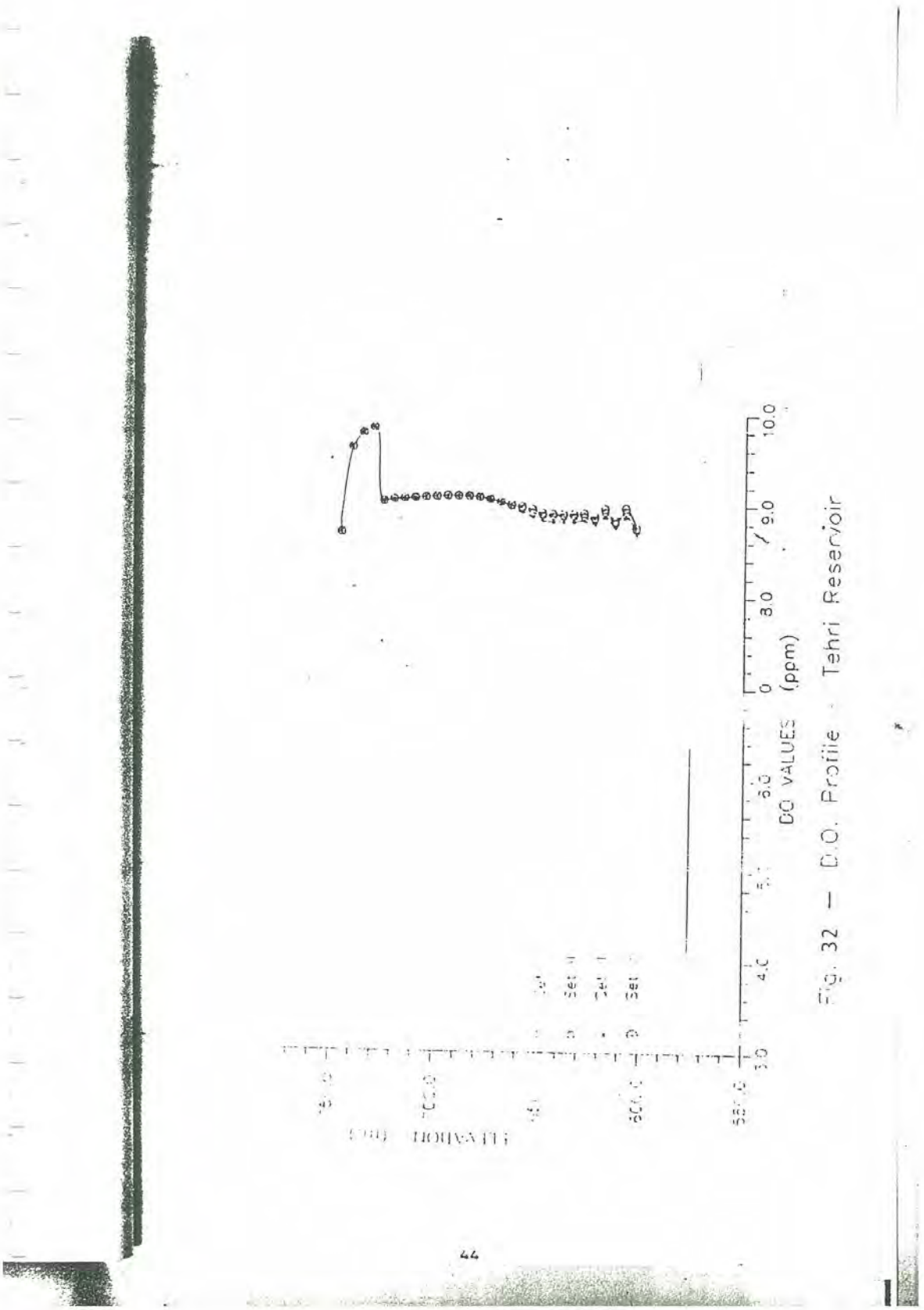


Fig. 32 — D.O. Profile - Tehri Reservoir

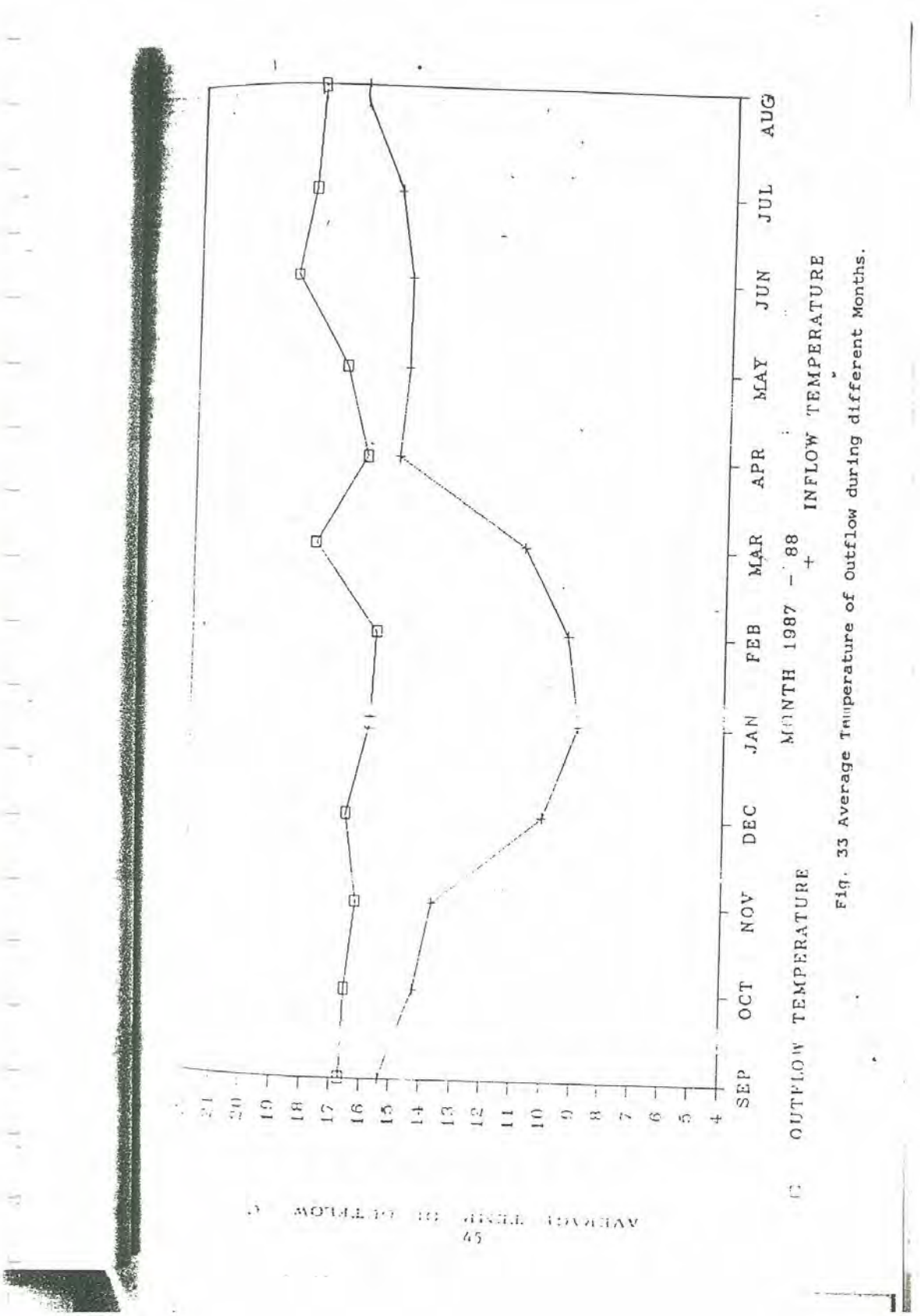


Fig. 33 Average Temperature of Outflow during different Months.

AVERAGE TEMP OF OUTFLOW C
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MONTH 1988 - 89
OUTFLOW TEMPERATURE
INFLOW TEMPERATURE

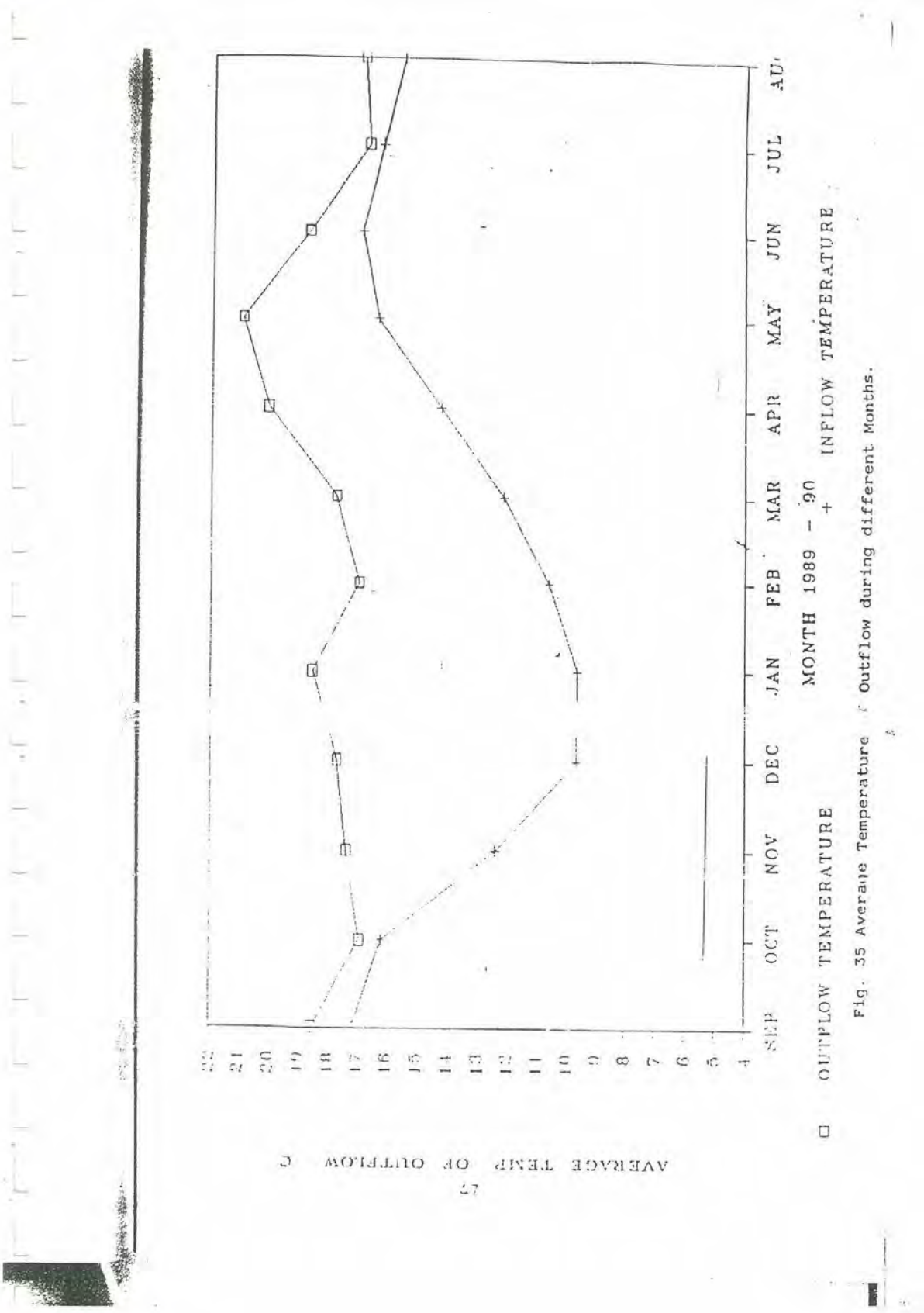
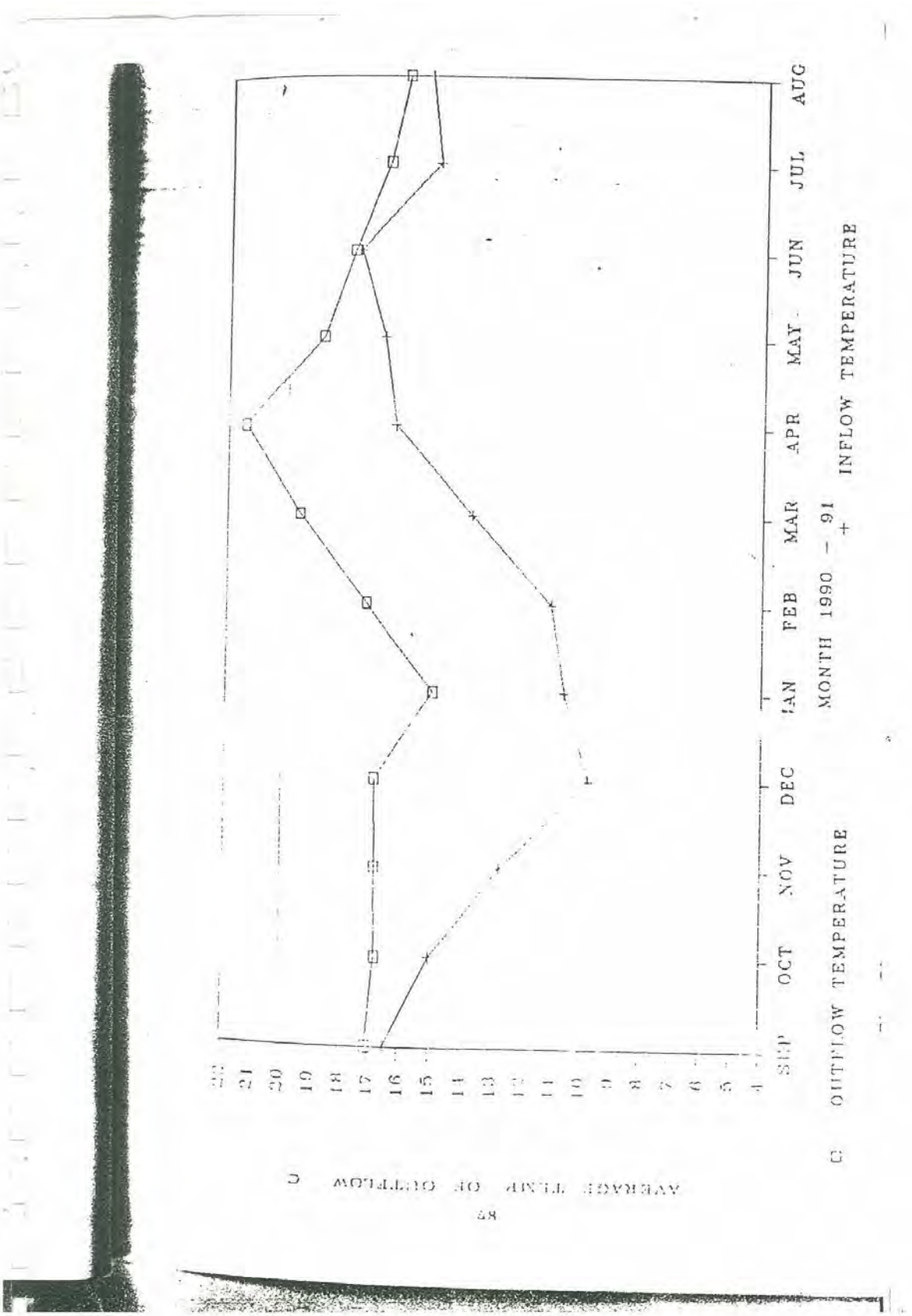


Fig. 35 Average Temperature of Outflow during different Months.


AVERAGE TEMP OF OUTFLOW C
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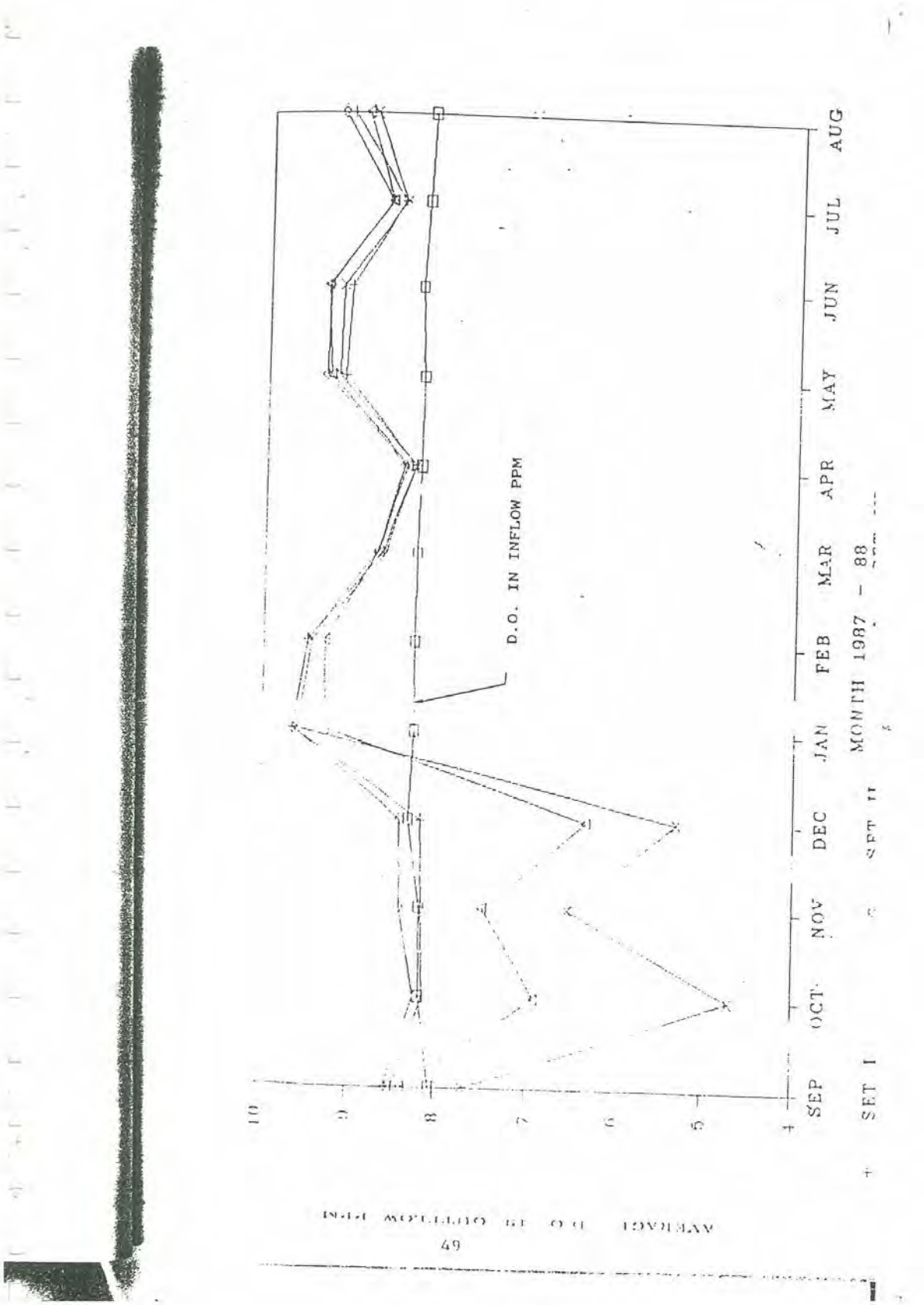
SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG
MONTH 1990 - 91
+ INFLOW TEMPERATURE
□ OUTFLOW TEMPERATURE


D.O. IN INFLOW PPM
JAN FEB MAR APR MAY JUN JUL AUG
SEP OCT NOV DEC
MONTH 1987 - 88
10
9
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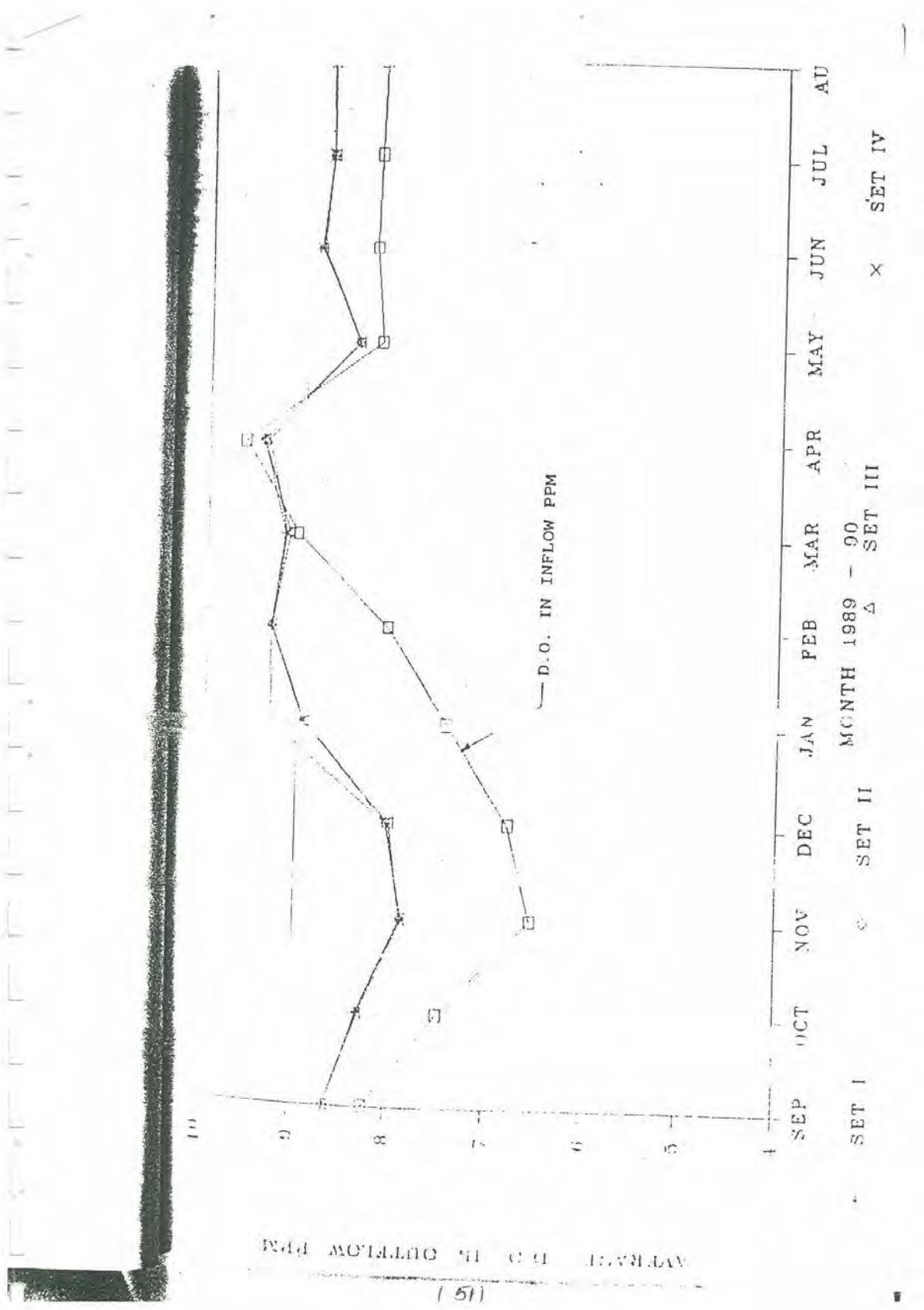
6
5
4

Fig. 38 Average D.O. in Outflow during different Months


D.O. IN INFLOW PPM
SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AU
MONTH 1989 - 90
SET I
SET II
SET III
SET IV

TEHRI DAM HYDEL PROJECT

ENVIRONMENTAL IMPACT ASSESSMENT STUDY

REPORT

ON

FAUNAL ANALYSIS

ZOOLOGICAL SURVEY OF INDIA

Northern Regional Station

Dehra Dun (U.P.)

MARCH, 1993

Table : DISTRIBUTION OF LIZARDS IN PROPOSED TEHRI DAM SITE

Classified List of Species	Transect A		Transect B		Transect C		Transect D
	WSL	ASL	WSL	ASL	WSL	ASL	ASL
Order : Sauria Family: Gekkonidae							
1. Cyrtodactylus fasciolatus (Blyth)	-	+	-	-	-	-	-
Family: Agamidae							
2. Agama tuberculata Hardwicke & Gray	+	+	+	+	+	+	+
3. Calotes versicolor (Daudin)	+	+	+	+	+	+	+
Family : Varanidae							
4. Varanus bengalensis (Daudin)	+	+	+	+	+	+	+
Total number of species under each Transect	3	4	3	3	3	3	3

Note: Distribution based on observation and collections

Pattern of Analysis

I. 1. Total no. of species from the study area .. 4

2. Total no. of species from WSL .. 3

3. Total no. of species from ASL .. 4

4. Total no. of species common to both WSL & ASL .. 3

5. Total no. of species exclusive to WSL .. None

6. Total no. of species exclusive to ASL .. 1

II. 1. Mapping of species diversity along Transect A, B, C & D viz., Ghansali, Dharasu, Koteshwar & N.T.T. roads: Refer Map

2. Total no. of species in WSL along each Transect :

A = 3

B = 3

C = 3

3. Total no. of species in ASL along each Transect :

A = 4

B = 3

C = 3

D = 3

III. Status of schedule/endemic species: Varanus bengalensis in Schedule IW I WL(P)A, 1972.

IV. Status of the group and possible impact of the proposed reservoir :

The species found in the area are likely to shift to the adjoining area and settle there provided sufficient shelter and food are available. Only Bent-toed Banded Gecko is a rare species and needs special attention for its conservation.

II. SNAKES

Order : Serpentes

Family : Typhlopidae

1. Ramphotyphlops braminus (Daudin)

Family : Natricidae

2. Amphiesma stolata (Linnaeus)
3. Xenochrophis piscator (Schneider)

Family : Colubridae

4. Elaphe helena (Dandin)
5. Ptyas mucosus (Linnaeus)

Family : Elapidae

6. Naja naja (Linnaeus)

BRIEF ACCOUNT

1. Ramphotyphlops braminus - Worm Snake, Blind Snake

Local Name: Andha samp

It is widely distributed upto ca 1,000 m elevation and is generally found underneath debris, soil, logs, stones and in ant or termite nests. It comes out of its subsoil burrow when flushed by rain or water. It is a tiny worm-like blackish snake measuring 17 cm in length. It feeds on worms, small insects and their larvae. It lays 5 - 8 eggs during rainy season. It is harmless.

They were observed or collected from some localities (Gadolia on Ghansali road) within the proposed line of submergence and are likely to occur in other localities also. They may move to safer localities in the adjoining areas in case of submergence of their habitats. These snakes are preyed on by other snakes and lizards.

2. Amphiesma stolata - Striped Keelback

Local Name : Hurwa samp

It is a widely distributed snake. It inhabits banks of rivers and streams and marshy areas, holes, under rocks, and branches of trees and bushes. It is a graceful little

Annexure R/4

ENVIRONMENTAL IMPACT ASSESSMENT STUDY

FAUNAL ANALYSIS

Supervised by

Dr G.S.Arora
Scientist SF & Officer-in-Charge

Co-ordinated by

Dr Arun Kumar
Scientist SE

and

Dr Akhlaq Husain
Scientist SD

ZOOLOGICAL SURVEY OF INDIA

Northern Regional Station

DEHRA DUN-248 195

FOREWORD

The Tehri Dam has assumed great importance for various reasons particularly of it being a very large one and among one of the highest in the world; as a result, a large land mass including agricultural land, forests, townships and several villages are likely to be partly or wholly submerged.

As a prerequisite/strategy of Ministry of Environment and Forests, it is obligatory on the part of Tehri Hydro Development Corporation (THDC) for obtaining environmental clearances from various agencies, the Zoological Survey of India being one such nodal agency to provide the base line data. For quite some time THDC had been requesting for Impact Assessment Study of the area, relevant to the fauna, due to the construction of Tehri Dam. The Zoological Survey of India had earlier given its report and mentioned about some of the migratory and resident fishes from the area. In light of the new perspectives, the Ministry of Environment and Forests felt the need to reassess the fauna of THDC area and accordingly a fresh survey programme was drawn out by ZSI team, based at Dehra Dun, for this purpose. The work has now been completed and the results of field study are presented in the present report.

It is hoped that the studies would help to assess the possible impact of the project on the faunal component and formulate appropriate management plan.

DR. A.K. GHOSH
DIRECTOR
Zoological Survey of India

ACKNOWLEDGEMENTS

The present assignment when entrusted to the scientists of Northern Regional Station by the esteemed Director, Zoological Survey of India, looked a very tall order but the team of scientists rose to the occasion and accepted the challenge in real earnest. I am happy that we have been able to complete the task of providing base line data on the faunal analysis of the proposed Tehri Dam Hydel Project areas within the time schedule. It is hoped that the study meets the targets for which the programme was undertaken. The present study would not have been completed but for the constant guidance and encouragement from the Hon'able Director, Dr A.K.Ghosh. I also wish to express my sincere thanks to the authorities of Tehri Hydro Development Corporation, especially, Shri S.P.Singh, Chairman and Managing Director, Shri J.D.Mehtani, Advisor (G.), Shri Y.P.Singh,Advisor (R.& E), Shri Y.Lal, AGM , Shri S.C.Sharma, AGM, and Shri R.K.Sharma, Manager, for their excellent co-operation extended to the field Task Forces. Thanks are also due to Dr M.M. Kanswal, Environment Officer, THDC, Tehri, for having accompanied all the Task Forces of ZSI, Dehra Dun, during field trips.

Last but not the least, I wish to express my sincere thanks to all my colleagues, particularly Dr Arun Kumar, Scientist SE, Dr Akhlaq Husain, Scientist SD, Shri J.P. Sati and Dr P.C.Tak, Asstt. Zoologists, Shri S.K. Gupta and Dr Vinod Khanna, Sr Zool. Assistants and Shri Parmod Kumar, for taking up the job rigorously of the faunal analysis of Tehri Dam Area and for bringing out this report.

I am also thankful to my technical and administrative staff for extending the whole hearted co-operation throughout during the Project.

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CONTENTS

I. INTRODUCTION

The Tehri Dam Project envisages the construction of earth and rock filled dam across the river Bhagirithi at the confluence of R.Bhagirithi and R.Bhilangana,near Tehri town at an altitude of ca. 580 m msl between the 30 15' - 30 45 N and 78 15' - 78 45 E. The height of the dam is proposed to be 216.5 m., with a catchment area of 6921 sq.km. and the submergence area of about 42 sq.km. (Reservoir). The reservoir will extend along the river Bhagirithi to the extent of 45 kms upstream upto village Dharasu, and 25 kms upstream along river Bhilangana upto village Ghansali. Consequently, 112 villages and the existing entire Tehri town will be submerged.

Since the objective of any development project is to contribute to the welfare of the society, it is essential that the impact of that project must be studied in detail to ascertain whether it achieves the stated objective or not. Very often than not, the environmental impact may offset many times over the accepted economic gains of the development project, thereby rendering it destructive rather than constructive in the ultimate analysis.

In the case of river valley projects like Tehri Dam, the creation of reservoir will submerge a vast area, as noted above, the fauna and flora of which is likely to be affected to a greater extent, which will also be extended to the downstream fauna of the prposed reservoir.

In view of the above, the scientists of Zoological Survey of India, Dehra Dun, were assigned to study the Impact Assessment on the fauna of the proposed Tehri Dam w.e.f. May, 1992.

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It may be pertinent to mention here that though Tehri Dam Site was first identified in 1949, the actual investigations for constructing a dam for Hydel Power Generation started in 1961. Tehri Dam Project was first cleared in June, 1972 by the Planning Commission as a State Project for generation of 600 MW. The construction of project began in 1978 by the Govt. of U.P. through its own budget. Subsequently, the capacity was raised to 1000 MW. However, due to paucity of funds, the Govt. of U.P. desired that project may be taken up as a Joint Venture of Govt. of India & Govt. of U.P. Accordingly, with Cabinet approval obtained in Nov.1986, it was decided to implement Tehri Hydro Power Complex comprising of Tehri Dam & Hydro Power Plant (1000 MW), Tehri Pump Storage Plant (1000 MW), Koteshwar Dam & Power Plant (400 MW) and 800 KV/400 KV Associated Transmission System. The Ministry of Environment and Forests accorded Forest clearance in June, 1987. In 1989, THDC formulated the "Environmental Action Plans" for the consideration of Ministry of Environment and Environmental clearance was accorded in July, 1990.

Under the above plan, Zoological Survey of India, Dehradun, submitted a brief inventory of the fauna of THDC area to the concerned authorities, enlisting the sensitive species which are likely to be affected to a larger extent. However, in connection with the implementation of various environmental action plans, a fresh request was received from THDC by Zoological Survey of India, to carry out a detailed study on the fauna, under the following guidelines :

1. The detailed survey and investigation identifying, locationwise, the fauna coming under the submergence of Tehri and Koteshwar reservoirs and spelling out the rare species that needed protection;

2. The Scheme and Action Plan for construction of the rare species;

3. Providing supervision and guidance during implementation of the action plan;

4. Details of adverse effects on the Wildlife habitats in the region; and

5. Studies on the adaptability of the fauna to the new habitat.

In view of the persistent demand of the THDC authorities to submit the report within a very short period of about six months and the present working pattern/expertise available at Zoological Survey of India, Dehra Dun, only the following aspects were committed to be studied :

1. The detailed list of the fauna of the area,including endangered/threatened species, if any;

2.The possible impact of the creation of reservoir on the fauna of the area; and

3. Conservation of the rare and other vulnerable species like Mahaseer.

By the time ZSI was assigned to study the impact on the fauna due to the construction of Tehri Dam, the THDC had already completed the construction of basic infrastructure for bypassing river water during the dam construction, i.e.four diversion tunnels, each of 11 m diameter and length ranging between 1.3 and 1.5 km had been constructed. In addition, the work on the Coffer Dam, which is a part of the main dam, had also been started. The approach roads to the already constructed underground power house and Koteshwar are already completed. Many new roads have already been constructed, besides coming up of a new Tehri Town at an altitude of about 1800 msl., about 16 km from

through the both "Above Submergence Level" (ASL) and "Within Submergence Level" (WSL) catgegory, thus giving six major modes, i.e. A, B, and C for WSL and A, B, and C for ASL; additional seventh code D comprises the localities of Top Terrace (TT) and New Tehri Town (NTT), both falling under ASL category.

For ultimate faunal analysis, all the above Transects, i.e., A, B, C & D were broadly classifed into two categories, e.g., those located above the Submergence Level (ASL) and remaining which fall within the proposed Submergence Level (WSL). This was done to have an assessment of the distributional pattern of the fauna along all the selected four transects within the study area. This would further help in determining the faunal pattern in the "Trauma Zone" i.e. the locations within the study area, which is going to be changed from terrestrial to aquatic biotope.

The fauna, thus collected in the above field surveys, has been brought to the laboratory, duly identified and listed by various specialists of Zoological Survey of India, Dehra Dun. The distributional maps of the major faunal groups, within proposed area of submergence have been prepared individually, thus giving the distributional pattern of various faunal groups. Additionally, the faunal analysis has been made for all the groups studied. Identifying the distributional pattern of the major species, their local as well as general status and also determining/indicating whether any of the identified species is listed in any of the Schedule of the Wildlife (Protection) Act, 1972 or in the IUCN Red Date Book. All these species included in Schedule-I

of Wildlife (Protection) Act, 1972 have been highlighted separately so that these can be taken care of due to construction of Tehri Dam. Species included in the Red Date Book (IUCN) have also been listed.

It may be mentioned here that, while the animals like Birds and Mammals have been observed and their status and distribution recorded for individual species, groups like fishes, Amphibians, Reptiles and all Invertebrate groups have been collected along all "Transects", both WSL and ASL localities.

In each group, whether collected or observed, the analysis has ben made based on whether the animal is occuring exclusively in ASL, WSL localities or common to both the areas. The final analysis shows total no. in each group accordingly.

III. HISTORICAL RESUME (FAUNA)

The Western Himalaya presents an unique ecosystem in the Indian sub-continent. The terrain comprises deeply forked hill ranges, criss-crossed by a large number of major rivers of India like the great river Bhagirathi (Ganga), Yamuna, Ramganga, Kosi, Sharda and Sarju etc. The climate ranges from hot, dry sub-tropical in the river valley to cool, moist, temperate in the higher hills. These hills, because of their varied physiographic and climatic conditions, possess very rich fauna and flora, including many important game animals and fishes. Keeping the above facts in sight, the scientists of Zoological Survey of India, have been engaged for the last many years in undertaking systematic faunistic surveys of each and every districts of Garhwal and Kumaon hills, to collect, identify and prepare an inventory of the fauna present in the area. The information has been compiled in a document entitled "Studies on the Himalayan ecosystem: Fauna of Western Himalaya (Uttar Pradesh: India)". The above document includes more than 2,200 species from eight districts of Garhwal and Kumaon hills. This naturally includes district Tehri, from where a total of 340 species, including 260 forms of invertebrates and 80 of vertebrate have been listed. However, as natural, the aforesaid list included the faunal composition not only from a large number of scattered localities, but also within a great altitudinal variation.

The present assignment demanded a extensive mapping of the species within a short area of about 50 sq. km, within a limited altitudinal variation, physiographic and climatic conditions. Nevertheless, the most important parameter being the occurrence of the faunal components within or above submergence localities of the proposed Tehri Dam Reservoir Area.

Prior to this, a couple of years back, the Zoological Survey of India, Dehra Dun, have given a preliminary list

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Dr.G.S.Arora and Dr. Arun Kumar, Zoological Survey of India, Dehra Dun

of the fauna of the present study area. It identified some species of wild animals and game fishes from the study area. The present study supplements it and gives an exhaustive account of the fauna of the proposed Reservoir area. It is hoped that it serves the purpose for which the study was undertaken.

IV. FAUNAL WEALTH OF THE STUDY AREA

During the present studies, a total of 282 species of the fauna, including 159 species of invertebrates and 123 species of vertebrates have been inventorised from the study area, which includes about 80 localities of the Transects A, B, C & D. Nevertheless, the present list may only be a fragment of the actual fauna that may be occurring.

The major groups dealt with in the present studies are Mammals, Aves (Birds), Reptiles (Snakes and Lizards), Amphibia (Frogs & toads) and Pisces (fresh water fishes) among the vertebrates and the invertebrate groups are generally of insects belonging to Order Lepidoptera (Butterflies), Odonata (Dragonflies), Hymenoptera (Wasps and bees) and other arthropods, namely Arachnida (spiders and scorpions) and Myriapoda (centipedes).

The detailed account of the above mentioned faunal groups is as follows :

MAMMALIA

On the basis of personal observations, local enquiries and Forest Working Plan, as well of the Tehri district (1983-84; 1992-1993), 18 species of Mammals were recorded belonging to 17 genera, 11 families and 6 orders. Of these, 15 were common both to the WSL and ASL; 2 from ASL only; and one species exclusive to the WSL catenory. In transect A, out of 16 species, 14 species were reported from ASL whereas 13 were from WSL areas. In Transect B, out of 17 species, 14 species were reported from ASL whereas 15 were from WSL. On Transect C out of 16 species, 6 were reported from ASL whereas 14 were reported from WSL areas. In trancect D, all the 16 species were reported from ASL areas only.

Out of these 18 species, only two species viz. Felis bengalensis horsefieldi Gray (Leopard Cat) and Panthera pardus Linnaeus (Panther) are listed in the Schedule I of Wildlife (Protection) Act 1992, and they are found both in WSL and ASL localities of proposed dam and also elsewhere in Garhwal Himalayas. None of the Mammalian species reported above is endemic to the region and, therefore, is not threatened by the construction of Dam.

Lutra lutra monticola Hodgson (Common Otter) is the only species found in WSL areas of Transect 'B' and 'C' and is also found elsewhere in the other river systems of Garhwal and as such is not endemic to this area.

However, as suggested elsewhere in this document that since no provision has been made for the "fish ladders" or "fish passes", the dwindling in the population of local fish is bound to occur and as a result, the Otters which thrive mainly on fishes may also have to face starvation and, therefore, depletion in their local population is inevitable. This is specially during the spawning and breeding

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Shri J.P.Sati, Zoological Survey of India, Dehradun

season of the effected species of the fishes.

Hystrix indica Kerr (Indian crested Porcupine) is the only major burrowing species reported from the ASL area only, and would, therefore, have no adverse impact.

The impact of the Dam, however, can be known if the study is continued till its full impoundment and also after post-impoundment.

ANALYSIS OF MAMMALS

(A) Species of Axis A (Ghansali Road) TRANSECT A .. 16

1. Suncus murinus tytleri Blyth
2. Macaca mulatta villosa True
3. Presbytis entellus schistaceus Hodgson
4. Canis aureus Linnaeus
5. Vulpes vulpes montana Pearson
6. Martes flavigula flavigula Boddaert
7. Herpestes edwardsi nyula Hodgson
8. Felis chaus affinis Gray
9. Felis bengalensis horsefieldi Gray
10. Panthera pardus Linnaeus
11. Nemorhaedus goral Hardwicke
12. Muntiacus muntijak vaginalis Boddaert
13. Sus scrofa cristatus Wagner
14. Lepus nigricollis ruficaudatus Geoffroy
15. Rattus rattus gangutrianus Hinton
16. Hystrix indica Kerr

(B) Species of Axis B (Dharasu Road) TRANSECT B .. 17

1. Suncus murinus tytleri Blyth
2. Macaca mulatta villosa True
3. Presbytis entellus schistaceus Hodgson
4. Canis aureus Linnaeus
5. Vulpes vulpes montana Pearson
6. Martes flavigula flavigula Boddaert
7. Lutra lutra monticola Hodgson
8. Herpestes edwardsi nyula Hodgson

9. Felis chaus affinis Gray
10. Felis bengalensis horsefieldi Gray
11. Panthera pardus Linnaeus
12. Nemorhaedus goral Hardwicke
13. Muntiacus muntijak veginalis Boddaert
14. Sus scrofa cristatus Wagner
15. Lepus nigricollis ruficaudatus Geoffroy
16. Rattus rattus gangutrianus Hinton
17. Hystrix indica Kerr

(C) Species of Axis 'C' (Koteshwar Road) TRANSECT 'C' .. 16

1. Suncus murinus tytleri Blyth
2. Macaca mulatta villosa True
3. Presbytis entellus schistaceus Hodgson
4. Canis aureus Linnaeus
5. Vulpes vulpes montana Pearson
6. Martas flavigula flavigula Boddaert
7. Lutra lutra monticola Hodgson
8. Herpestes edwardsi nyula Hodgson
9. Felis chaus affinis Gray
10. Felis bengalensis horsefieldi Gray
11. Panthera pardus Linnaeus
12. Nemorhaedus goral Hardwicke
13. Muntiacus muntijak vaginalis Boddaert
14. Lepus nigricollis ruficaudatus Geoffroy
15. Rattus rattus gangutrianus Hinton
16. Hystrix indica Kerr

(D) Species of Axis 'D' (T.T.N.T.T. Chamba Road) TRANSECT D .. 16

1. Suncus murinus tytleri Blyth
2. Macaca mulatta villosa True
3. Canis aureus Linnaeus
4. Vulpes vulpes montana Pearson

5. Selenarctos thibetanus G. Cuvier

6. Martes flavigula flavigula Boddaert

7. Herpestes edwardsi nyula Hodgson

8. Felis chaus affinis Gray

9. Felis bengalensis horsefieldi Gray

10. Panthera pardus Linnaeus

11. Nemorhaedus goral Hardwicke

1 12. Muntiacus muntijak vaginalis Boddaert

13. Sus scrofa cristatus Wagner

14. Lepus nigricollis ruficaudatus Geoffroy

15. Rattus rattus gangutrianus Hinton

16. Hystrix indica Kerr

2 (A) Total no. of species in ASL & WSL on 'A' Axis (Ghansali Road) .. 14 & 13

(i) S. No. of species of II 1(A):- 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 15, 16 - ASL (14) (11 are common)

(ii) S.No. of species of II 1(A) :- 1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 14, 15 - WSL (13)

(B) Total No. of species in ASL & WSL on 'B' Axis (Dharasu Road) .. 14 & 15

(i) S.No. of species of II 1(B):- 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 16, 17, - ASL (14) (12 are common)

(ii) S.No. of species of II 1(B):- 1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, - WSL .. (15)

(C) Total No. of species in ASL & WSL on 'C' Axis (Koteshwar Road) .. 06 & 14

(i) S.No. of species of II 1(C):- 1, 5, 8, 12, 15, 16, - ASL (06) (04 are common)

(ii) S.No. of species of II 1(C):- 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, - WSL .. (14)

(D) Total No of species in ASL on 'D' Axis (T.T.N.T.T. (Chamba Road) .. 16 only

(i) S.No. of species of II 1(D):- 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, - ASL (16)

III. Felis bengalensis horsefieldi Gray & Panthera pardus Linnaeus have been listed in the Schedule I of Wildlife (Protection) Act, 1972, but they are not endemic to this area only, whereas they are widely distributed in the Garhwal Himalaya and elsewhere in India.

IV. Details on separate sheet - attached.

S.No.	Name of Species	TRANSECT 'A' 1 2 3 4 ASL	5 6 ASL	7 ASL	TRANSECT 'B' 1 2 3 4 5 6 7 8 9 ASL ASL	'C' 1 2 ASL i & ii	3	'D' 1 2 ASL (i) to iv	Status Endangered/ threatened Endemic	Distribution in study area
1.	*§ Suncus murinus tytleri Blyth 1859: House Shrew Local Name: Chhuchhundar	1 - - - -	-	1	- - - 1 - - - - - 1	-	1	-	-	NC
2.	* Macaca mulatta villosa True, 1894: Rhesus Macaque Local Name: Bandar	1 - 1 1	-	1	1 1 1 1 - - - 1	-	1	1	-	VC
3.	*Presbytis entellus schistaceus Hodgson 1840 Hanuman Langur Local Name: Goonj, Langur, Hanuman	- - - 1	-	-	1 - - - - - - 1	-	1	-	-	VC
4.	*Canis aureus Linnaeus, 1758; Asiatic Jackal Local Name: Gidhar	- 1 - -	-	-	- 1 - - - - - - 1	1	-	-	-	C
5.	*Vulpes vulpes montana Pearson, 1836: Common Red Fox Local Name: Lomri	- - 1 -	-	1	- - 1 - - - - 1	1	1	-	-	C

S.No.	Name of Species	TRANSECT 'A' 1 2 3 4 5 6 7 ASL ASL	TRANSECT 'B' 1 2 3 4 5 6 7 8 9 ASL ASL	'C' 1 2 3 ASL i ii	'D' 1 2 ASL i to iv	Status Endangered/ Threatened	Endemic	Distribution in study area
		- - - - - - -	- - - - - - - - - -	- - -	- -	-	-	NC
6.	$Selenarctos thibetanus G.Cuvier, 1828; Himalayan Black Bear Local Name: Bhalu, Reech				1			
7.	*$ Martes flaviqula flaviqula Boddaert, 1785: Yellow Throated Marten Local Name: Chuterala	- - - - 1 - 1	- - 1 - - - 1 - 1 -	- - 1	- -	-	-	NC
8.	Lutra lutra monticola Hodgson, 1939: Common Otter Local Name: Uad; Ud-Bilao	- - - - - - -	- - 1 1 - - - - - -	- - 1	- -	-	-	NC
9.	Herpestes edwardsi nyula Hodgson, 1836: Indian Grey Mongoose Local Name: Nawala	- 1 - - 1 - 1	1 - - - - 1 - - 1 -	1 - 1	1 -	-	-	NC

S.No.	Name of Species	TRANSECT A 1 2 3 4 5 ASL	6 7 ASL ASL	TRANSECT 'B' 1 2 3 4 5 6 7 8 9 ASL ASL	'C' 1 2 ASL i & ii	3	'D' 1 2 ASL i to iv	Status Endangered/ Threatened	Endemic	Distribution in study area
10.	*Felis chaus affinis Gray, 1830: Jungle cat Local Name: Ban Birau	- - 1 1 -	1 -	1 1 - - - - 1 - 1	-	1	- -	-	-	C
11.	*Felis bengalensis horsefieldi Gray, 1842: Leopard Cat Local Name: Sogh; Chita Billi	- - 1 - 1	-	- - 1 1 1 - - - 1	-	1	- -	-	-	NC
12.	*Panthera pardus Linnaeus, 1758: Leopard or Panther Local Name: Chita Bagh Tendwa	- - - 1 -	-	1 1 1 - - - - 1	-	1	1 -	-	-	NC
13.	Camorhedus goral Hardwicke, 1825: Goral Local Name: Ghwed	- 1 - - 1	1	1 - - - 1 1 - - 1	1	1	1 -	-	-	C

17

S. No.	Name of Species	TRANSECT 'A'							TRANSECT 'B'									'C'			'D'		Status Endangered/ Threatened	Endemic	Distribution in study area
		1	2	3 ASL	4	5	6 ASL	7 ASL	1	2	3	4 ASL	5	6	7	8	9 ASL	1 ASL i & ii	2	3	1	2 ASL i to iv			
14.	*$Muntiacus muntijak vaginalis Boddaert, 1785 Barking Deer Local Name: Kakar	-	1	1	-	-	1	1	-	-	1	1	1	-	-	-	1	-	1	-	-	1	-	-	C
15.	$Sus scrofa cristatus Wagner, 1839: Wild Boar Local Name: Jangli Suar	-	-	1 iv	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	NC
16.	*Lepus nigricollis ruficaudatus Geoffroy, 1826: Indian Hare Local Name: Shargosh	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	1	-	1	1	-	-	-	NC
17.	*Rattus rattus gangutrianus Hinton, 1919: House Rat Local Name: Musa, Chuha	1	1	1	-	-	1	1	1	1	1	-	-	1	-	1	1	1	1	1	-	-	-	-	VC

S. No.	Name of species	TRANSECT 'A' 1 2 3 4 5 6 7 ASL ASL	RA SA 1 2 3 4 5 6 7 8 9 ASL	1 2 3 ASL i & ii	1 2 ASL i to iv	Status Endange Threate Endemic Distrit in study area
18.	*Hystrix indica* Kerr,1792: India Crested Porcupine Local Name: Soala, Sahi	- - 1 - - - - 1 - - - - 1 1 - - - - 1 - -	3 5 8 4 5 8 9 2 5 9 9 4 3 4 - 14 6 13 4 8 12			NC

Note: The numbers under localities refer to the serial Nos. of the localities in Transect 'A', 'B', 'C' & 'D' as marked in Chapter 1 - 4 "Locality Classification of THDC Area"

* Observed

$ Local enquiries only

PATTERN OF ANALYSIS: MAMMALIAN FAUNA

I. Species-wise

1. Total no. of species from the study area .. 18
2. Total no. of species Within Submergence Level .. 16
3. Total no. of species Above Submergence Level .. 17
4. Total no. of species common to both WSL & ASL .. 15
5. Total no. of species exclusively to WSL & ASL ..
   (i) WSL .. 01
   (ii) ASL .. 02

II. Transect-wise

A. Ghansali Road : WSL 13; ASL 14; Total = 27
B. Dharasu Road : WSL 15; ASL 14; Total = 29
C. Koteshwar Road: WSL 14; ASL 06; Total = 20
D. Top Terrace & N.T.T: ASL 16 ; Total = 16

AVES

It is an established fact that no Impact Assessment Study on wildlife, in general, and birds, in particular can be completed without relevant field data, collected in all the three major seasons, viz., Winter, Summer and Monsoon, and repeated for 2-3 subsequent years. However, in present case, an attempt was made to prepare the preliminary inventory of the birds of THDC area. During this short field study 73 species, including subspecies of birds, belonging to 63 genera, 31 families and 13 orders were observed (Table 1).

The analysis of the field data revealed that of the 73 species recorded, 54 species were observed at various localities in 'Within Submergence Level' (WSL), while 50 species were sighted in 'Above Submergence Level' (ASL) area and 31 species common to both (WSL & ASL) categories. Further, there were 23 species exclusive to the WSL localities and 19 species exclusive to the ASL localities.

The transect-wise analysis of bird-diversity indicates the maximum concentration along Ghansali Road i.e. Transect A (Table 1). This is applicable to the both i.e. WSL (36 spp.) and ASL (35 spp.) of the transect. The next highly concentrated area was Dharasu Road i.e. Transect B , supporting 30 spp. along WSL and 10 spp. along ASL (Column B under WSL & ASL category, Table 1). Transect C being the poorest in Aves, having only 12 species in WSL and 14 species in ASL (Column C under WSL & ASL category, Table 1).

None of the species recorded from the area is endemic. However, the Indian Sparrow-Hawk, being an endangered one, is included in Schedule I of the Wildlife (Protection) Act, 1972 and the Ringtailed or Pallas's Fishing Eagle categorised as 'Rare' in 1990 IUCN Red List of Threatened Animals .

Dr. P.C.Tak, Zoological Survey of India, Dehra Dun.

Suggestions:

1. Regular updating of the birds of the area for 2 - 3 years is suggested;

2. Simultaneously, for a complete Impact Assessment Study on birds, selection of some 15 - 20 commoner or most sighted birds, as "INDICATOR BIRDS SPECIES" is also suggested. Exercise of working out their relative densities/abundance can be carried out parallely during this 2 - 3 years period;

3. Post Impoundment Study, on the above pattern, is also desirable for final assessment study.

Pattern of analysis : FAUNA OF THHRI DAM AREA : AVES (BIRDS)

I. SPECIES WISE

1. Total number of species from the study area : 73
2. Total number of species from Within Submergence Level (WSL) : 54
3. Total number of species from Above Submergence Level (ASL) : 50
4. Total number of species common to both WSL & ASL : 31
5. Total number of species exclusively to WSL & ASL
   - (i) WSL : 23
   - (ii) ASL : 19

II. TRANSECT WISE

1. Transect - A (Ghansali Road)	:	WSL : 36	;	ASL : 35		Total = 71
2. Transect - B (Dharasu Road)	:	WSL : 30	;	ASL : 10		Total = 40
3. Transect - C (Koteshwar Road)	:	WSL : 12	;	ASL : 14		Total = 26
4. Transect - D (Top Terrace only)	:	ASL : 14				

Table : AVIFAUNA OF THE PROPOSED TEHRI DAM SITE

		WSL				ASL			
	Transect	A	B	C		A	B	C	D
	CLASS : AVES								
	Order : CICONIIFORMES								
	Family : Ardeidae								
1.	Ixobrychus cinnamomeus (Gmelin), Chestnut Bittern.	+	-	-		-	-	-	-
	Order : FALCONIFORMES								
	Family : Accipitridae								
2.	Milvus migrans govinda Sykes, Pariah Kite.	+	-	-		-	-	-	-
3.	Accipiter nisus melaschistos Hume, Indian Sparrow-Hawk.	-	-	+		-	-	-	+
4.	Spizaetus (cirrhatus) limnaeetus (Horsfield), Changeable Hawk-Eagle.	+	-	-			-	-	-
5.	Aquila rapax nipalensis Hodgson, Eastern Steppe Eagle.	-	+	-		+	-	-	-
6.	Haliaeetus leucoryphus (Pallas), Ringtailed or Pallas's Fishing Eagle.	-	+	-		-	-	-	-
7.	Sarcogypus calvus (Scopoli), Black or King Vulture.	-	+	-		-	-	-	-
8.	Gyps himalayensis Hume, Himalayan Griffon Vulture.	+	+	-		-	-	-	-
9.	G. bengalensis (Gmelin), Indian Whitebacked Vulture.	+	-	-		-	-	-	-
10.	Neophron percnopterus ginginianus (Latham), Indian Scavenger Vulture.	-	-	+		-	-	-	-
11.	Spilornis cheela cheela (Latham), Crested Serpent Eagle.	-	+	+		+	-	-	-
	Family : Falconidae								
12.	Falco tinnunculus tinnunculus Linn., European Kestrel.	-	-	+		+	-	-	-
	Order : GALLIFORMES								
	Family : Phasianidae								
13.	Alectoris chukar chukar (J.E.Gray), Chukor Partridge.	+	+	-		+	-	-	-
14.	Francolinus francolinus asiae Bonaparte, Indian Black Partridge								

15.	Francolinus pondicerianus interpositus Haertert, North Indian Grey Partridge.	-	-	-	+	-	-	-
16.	Lophura leucomelana hamiltonii (J.E.Gray), Whitecrested Kaleej Pheasant.	-	-	-	-	+	-	-
	Order : CHARADRIIFORMES							
	Family : Charadriidae							
17.	Vanellus indicus indicus (Boddaert), Redwattled Lapwing.	-	+	-	-	-	-	-
	Order : COLUMBIFORMES							
	Family : Columbidae							
18.	Columba livia intermedia Strickland, Indian Blue Rock Pigeon.	+	+	-	-	-	-	-
19.	Streptopelia decaocto decaocto (Frivaldszky), Indian Ring Dove.	+	+	+	+	+	-	-
20.	S. chinensis suratensis (Gmelin), Indian Spotted Dove.	+	+	-	+	-	-	+
21.	S. senegalensis cambayensis (Gmelin), Indian Little Brown or Senegal Dove.	-	+	+	+	-	-	-
	Order : PSITTACIFORMES							
	Family : Psittacidae							
22.	Psittacula cyanocephala benegalensis (Forster), Northern Blossomheaded Parakeet.	-	-	-	-	+	+	+
	Order : CUCULIFORMES							
	Family : Cuculidae							
23.	Cuculus varius varius Vahl, Common Hawk-Cuckoo or Brainfever Bird.	-	-	-	+	-	-	-
24.	Eudynamys scolopacea scolopacea (Linn.), Indian Koel.	+	-	-	-	-	-	-
	Order : STRIGIFORMES							
	Family : Strigidae							
25.	Athene brama indica (Franklin), Northern Spotted Owlet.	-	-	-	+	-	-	-

	Order : CAPRIMULGIFORMES								
	Family : Caprimulgidae								
26.	Caprimulgus macrurus albonotatus Tickell, Indian Longtailed Nightjar.	-	+	-		-	-	-	-
	Order : APODIFORMES								
	Family : Apodidae								
27.	Apus affinis (J.E.Gray), House Swift.	-	+	-		+	-	-	+
	Order : CORACIIFORMES								
	Family : Alcedinidae								
28.	Ceryle lugubris continentalis Hartert, West Himalayan Pied Kingfisher.	+	+	-		-	+	-	-
29.	Alcedo atthis bengalensis Gmelin, Indian Small Blue Kingfisher.	-	+	-		+	-	-	-
30.	Halcyon smyrnensis fusca (Boddaert), Indian Whitebreasted Kingfisher.	+	+	+		+	+	+	-
	Family : Meropidae								
31.	Merops orientalis orientalis Latham, Indian Small Green Bee-eater.	-	+	+		-	-	-	-
	Family : Upupidae								
32.	Upupa epops epops Linnaeus, European Hoopoe.	+	-	-		-	-	-	-
	Order : PICIFORMES								
	Family : Capitonidae								
33.	Megalaima asiatica asiatica (Latham), Bluethroated Barbet.	+	-	-		+	-	-	-
	Order : PASSERIFORMES								
	Family : Hirundinidae								
34.	Hirundo daurica nipalensis Hodgson, Himalayan Striated Swallow or Redrumped Swallow.	-	-	-		+	-	-	+

	Family : Laniidae							
35.	*Lanius schach erythronotus* (Vigors), Rufousbacked Shrike.	-	-	-	+	-	+	-
	Family : Oriolidae							
36.	*Oriolus oriolus kundoo* Sykes, Indian Golden Oriole.	-	-	-	+	-	-	-
	Family : Dicruridae							
37.	*Dicrurus adsimilis albirictus* (Hodgson), North Indian Black Drongo or King Crow.	+	+	-	+	-	+	-
	Family : Sturnidae							
38.	*Sturnus malabaricus malabaricus* (Gmelin), Greyheaded Myna.	+	-	-	-	-	-	-
39.	*S. pagodarum* (Gmelin), Blackheaded or Brahminy Myna.	+	-	-	-	-	-	-
40.	*Acridotheres tristis tristis* (Linn.), Indian Myna.	+	+	-	+	-	-	-
41.	*A. fuscus fuscus* (Wagler), Northen Jungle Myna.	+	+	-	+	-	-	+
	Family : Corvidae							
42.	*Cissa erythrorhyncha occipitalis* (Blyth), Himalayan Redbilled Blue Magpie.	-	-	+	+	+	-	-
43.	*Dendrocitta formosae occidentalis* Ticehurst, West Himalayan Tree Pie.	+	-	+	+	+	+	-
44.	*Corvus splendens splendens* Vieillot, Indian House Crow.	+	-	-	-	-	-	-
45.	*C. macrorhynchos intermedius* Adams, Himalayan Jungle Crow.	-	-	-	-	+	-	+

	Family : Pycnonotidae							
46.	Pycnonotus leucogenys leucogenys (Gray), Whitecheecked Bulbul.	+	+	-	+	+	-	+
47	P. cafer intermedius Blyth, Punjab Redvented Bulbul.	-	+	-	-	+	+	+
48	Hypsipetes flavalus flavalus (Blyth), Browneared Bulbul.	-	-	+	-	-	-	-
	Family : Muscicapidae							
	Subfamily : Timaliinae							
49.	Stachyris pyrrhops Blyth, Blackchinned Babbler.	+	-	-	-	-	+	-
50.	Turdoides striatus striatus (Dumont), Bengal Jungle Babbler.	-	-	-	+	-	-	-
	Subfamily :Muscicapinae							
51	Muscicapa thalassina thalassina Swainson, Verditer Flycatcher.	-	-	-	+	-	-	-
52.	Rhipidura albicollis canescens (Koelz), Western Whitethroated Faintail Flycatcher.	+	+	-	-	-	+	-
	Subfamily : Monarchinae							
53.	Terpsiphone paradisi leucogaster (Swainson), West Himalayan Paradise Flycatcher.	+	-	-	+	-	+	-
	Subfamily : Sylviinae							
54	Phylloscopus affinis affinis (Tickell), Tickell's Leaf Warbler.	+	-	-	-	-	-	-
55	P. proregulus simlaensis Ticehurst, Western Pallas's Leaf Warbler.	-	-	-	+	-	-	-
	Subfamily : Turdinae							
56.	Erithacus indicus indicus (Vieillot), Whitebrowed Bush Robin.	-	-	-	-	-	+	-
57.	Copsychus saularis saularis (Linn.), Indian Magpie-Robin.	+	+	-	-	-	+	-
58.	Enicurus maculatus maculatus Vigors, Western Spotted Forktail.	-	-	-	+	-	-	-

59.	Saxicola caprata bicolor Sykes, Northern Pied Bush Chat.	-	+	-	+	-	-	+
60.	Saxicoloides fulicata cambaiensis (Latham), Brownbacked Indian Robin.	+	-	-	+	-	-	+
61.	Monticola solitarius pandoo (Sykes), Indian Blue Rock Thrush.	-	-	-	-	-	-	+
62.	Myiophoneus caeruleus temminkii (Vigors), Himalayan Whistling Thrush.	+	+	-	+	-	-	-
	Family : Cinclidae							
63.	Cinclus pallasii tenuirostris Bonaparte, West Himalayan Brown Dipper.	+	-	-	-	-	-	-
	Family : Paridae Subfamily : Parinae							
64.	Parus major nipalensis Hodgson, Nepal Grey Tit.	+	+	-	+	-	-	-
	Family : Motacillidae							
65.	Anthus sylvanus (Hodgson), Upland Pipit.	-	-	-	-	-	+	-
66.	Motacilla maderaspatensis Gmelin, Large Pied Wagtail.	+	-	-	-	-	-	-
	Family : Nectariniidae							
67.	Nectarinia asiatica asiatica (Latham), Indian Purple Sunbird.	+	-	+	+	-	-	-
	Family : Zosteropidae							
68.	Zosterops palpebrosa palpebrosa (Temminck), Indian White-eye.	+	-	-	+	-	-	-

	Family : Ploceidae							
	Subfamily : Passerinae							
69.	Passer domesticus indicus Jardine & Selby, Indian House Sparrow.	-	+	-	+	-	-	+
	Subfamily : Estrildinae							
70.	Lonchura striata acuticauda (Hodgson), Whitebacked Munia.	+	-	-	-	-	-	-
	Family : Fringillidae							
	Subfamily : Carduelinae							
71.	Capodacus erythrinus erythrinus (Pallas), Common Rosefinch or Scarlet Grosbeak.	-	-	-	-	-	+	-
72.	Pyrrhoplectes epauletta (Hodgson), Goldheaded Black Finch.	-	-	-	-	-	+	-
	Family : Emberizidae							
73.	Melophus lathami (Gray), Crested Bunting.	+	+	-	-	-	-	+
		36	30	12	35	10	14	14

Note : 1. WSL = Within Submergence Level
2. ASL = Above Submergence Level
3. Transect A = Ghansali Road
4. Transect B = Dharasu Road
5. Transect C = Koteshwar Road
6. Transect D = Top Terrace Only

REPTILIA

During the recent five surveys, a good number of reptiles comprising lizards and snakes have been observed or collected from various localities within and above the proposed line of submergence, as per the list given below. There is no information on the occurrence of Crocodiles, Turtles or Tortoises in the area. For introducing general awareness on the group brief account (distribution, habitat, body, colouration, size, food, breeding, local occurrence etc.) of each species has been provided. This will help in proper mamagemant of the species in view of the coming up reservoir. If thorough surveys for longer period are conducted, some more species are likely to be added to the list.

I. LIZARDS

Order : Sauria
Family : Gekkonidae

1. Cyrtodactylus fasciolatus (Blyth)

Family : Agamidae

2. Agama tuberculata Hardwicke & Gray
3. Calotes versicolor (Daudin)

Family : Varanidae

4. Varanus bengalensis (Daudin)

BRIEF ACCOUNT

1. Cyrtodactylus fasciolatus - Bent - toed Banded Gecko

Local Name : Jungli chhipkli

It is distributed in Western Himalaya (Uttar Pradesh, Himachal Pradesh). It is nocturnal in habit and usually dwells in crevices among rocks, stone walls and bushes. It is a delicately built and beautifully coloured lizard with 6 - 7 dark brown W-shaped bands above, on body and the tail

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with alternate dark brown and whitish cross bands. Its toes are thin and bent. It feeds largely on insects. Nothing is known about its breeding habits.

During the present study, a specimen was collected at night in the month of May from the crevices in road side stone wall on Tilwara road Ghansali. It may be found in other localities also. Being nocturnal in habit, it is very rarely encountered and hence may be found in other localities. The impoundment of the reservoir may not affect these lizards as they may move to safer sites above and establish there.

The species was earlier known from Shimla and Almora. This being the first record from Garhwal region is being published separately (Husain & Ray, in press).

2. Agama tuberculata - Rock Lizard
   Local Name : Pahari Chhipkli; Chhipara

This is the commonest lizard in western Himalaya . It lives in crevices of rocks, stone walls and holes. It is a medium sized (39 cm) lizard with well built depressed and roughened body and stout tail. It is dark greyish in colour. It feeds on insects, butterflies and other arthropods. The female lays 6 - 9 eggs in a clutch during summer.

During the present surveys, these lizards were seen basking and running on side stone walls around Tehri, Gansali, Dharasu and Koteshwar road sides. A good population was seen around Motibagh and Dam site. With the impoundment of the reservoir, the lizards may shift to the adjoining rocky areas and establish there.

3. Calotes versicolor - Garden Lizard or Blood-sucker
   Local Name : Girgit

It is widely distributed and may be found upto 2,000 m elevation.Being arboreal in habit, it prefers to live on bushes, shrubs, gardens and forest areas. It is commonly known medium sized (40 cm) lizard having oval head

and compressed body with strongly keeled, spine-like dorsal row of scales and long tail. It is sandy grey in colour with more or less distinct dark brown cross bars above and on sides. It feeds primarily on insects; small birds, nestlings, frogs, etc. are also sometimes taken. The female lays 11 - 23 eggs in a clutch in a hole dug on soft soil under bushes during hot season.

These lizards were seen or collected from various localities (Dharasu, Chham, Gadolia, Top Terrace etc.) within and above the proposed line of submergence. The longest specimen measured 29 cm. With the submergence of their habitats, these lizards may shift to the adjoining area where bushes, shrubs and forest vegetation are easily available. To rehabilitate these lizards in the periphery of the reservoir, special care for growing vegetation will be useful.

4. Varanus bengalensis - Monitor Lizard

Local Name : Goh

It is widely distributed lizard and generally inhabits all types of biotopes from evergreen forests to the fringes of desert. It is giant in size, measuring upto 1.75 m in length, with elongated and flattened body, compressed tail and strong limbs. It is olive-grey with sparse black spots. It is carnivorous, feeding on small mammals, birds, lizards, snakes, fish, crustaceans, insects, spiders etc. The female lays 8 - 30 eggs in a clutch in a hole dug by her in debris under bushes during hot season.

During the present work, these lizards were generally encountered while crossing the road or basking in open along the nala side or trying to hide in the rock crevices or under the roadside bushes in all the three transects i.e. Ghansali, Dharasu and Koteshwar road sides. An adult specimen was collected near Siasu. The species is very common in the area. It has been included under Schedule I of Wild Life (Protection) Act, 1972 as it is much sought for the trade of its skin. The lizards may move in the adjoining areas when the reservoir is impounded.

Table : DISTRIBUTION OF LIZARDS IN PROPOSED TEHRI DAM SITE

Classified List of Species	Transect A		Transect B		Transect C		Transect D
	WSL	ASL	WSL	ASL	WSL	ASL	ASL
Order : Sauria							
Family: Gekkonidae							
1. Cyrtodactylus fasciolatus (Blyth)	-	+	-	-	-	-	+
Family: Agamidae							
2. Agama tuberculata Hardwicke & Gray	+	+	+	+	+	+	+
3. Calotes versicolor (Daudin)	+	+	+	+	+	+	+
Family : Varanidae							
4. Varanus bengalensis (Daudin)	+	+	+	+	+	+	+
Total number of species under each Transect	3	4	3	3	3	3	3

Note: Distribution based on observation and collections

Pattern of Analysis

I. 1. Total no. of species from the study area .. 4

2. Total no. of species from WSL .. 3

3. Total no. of species from ASL .. 4

4. Total no. of species common to both WSL & ASL .. 3

5. Total no. of species exclusive to WSL .. None

6. Total no. of species exclusive to ASL .. 1

II. 1. Mapping of species diversity along Transect A, B, C & D viz., Ghansali, Dharasu, Koteshwar & N.T.T. roads: Refer Map

2. Total no. of species in WSL along each Transect :

A = 3

B = 3

C = 3

3. Total no. of species in ASL along each Transect :

A = 4

B = 3

C = 3

D = 3

III. Status of schedule/endemic species: Varanus bengalensis in Schedule IW I WL(P)A,1972.

IV. Status of the group and possible impact of the proposed reservoir :

The species found in the area are likely to shift to the adjoining area and settle there provided sufficient shelter and food are available. Only Bent-toed Banded Gecko is a rare species and needs special attention for its conservation.

II. SNAKES

Order : Serpentes

Family : Typhlopidae

1. Ramphotyphlops braminus (Daudin)

Family : Natricidae

2. Amphiesma stolata (Linnaeus)
3. Xenochrophis piscator (Schneider)

Family : Colubridae

4. Elaphe helena (Dandin)
5. Ptyas mucosus (Linnaeus)

Family : Elapidae

6. Naja naja (Linnaeus)

BRIEF ACCOUNT

1. Ramphotyphlops braminus - Worm Snake, Blind Snake

Local Name: Andha samp

It is widely distributed upto ca 1,000 m elevation and is generally found underneath debris, soil, logs, stones and in ant or termite nests. It comes out of its subsoil burrow when flushed by rain or water. It is a tiny worm-like blackish snake measuring 17 cm in length. It feeds on worms, small insects and their larvae. It lays 5 - 8 eggs during rainy season. It is harmless.

They were observed or collected from some localities (Gadolia on Ghansali road) within the proposed line of submergence and are likely to occur in other localities also. They may move to safer localities in the adjoining areas in case of submergence of their habitats. These snakes are preyed on by other snakes and lizards.

2. Amphiesma stolata - Striped Keelback

Local Name : Hurwa samp

It is a widely distributed snake. It inhabits banks of rivers and streams and marshy areas, holes, under rocks, and branches of trees and bushes. It is a graceful little

snake, measuring upto 90 cm in length, olivaceous-brown with a pair of conspicuous buff stripes and blackish irregular cross bars. It feeds on frogs and toads. The female lays 5 - 10 eggs in a clutch in a convenient underground refuge. It is non-venomous.

During recent surveys, it was found in some localities (Cham, Dharasu road, Nailchami near Ghansali) both within and above the proposed line of submergence. The population of these snakes should not be depleted as with the impoundment of reservoir, as the frog population, which serves as their food, will increase.

3. Xenochrophis piscator - Checkered Keelback water snake

Local Name: Pani-ka-samp

It is widely distributed snake. It frequents streams and rivers and mostly found along their banks, sometimes basking on grass. It is a fairly robust snake, measuring over a metre in length, with strongly keeled scales and characteristic black and white checkered pattern. It feeds mainly on frogs and their tadpoles, fish and occasionally on small rodents and birds. The eggs, numbering upto 91 in a clutch, are laid in a nest hole in the ground near water during summer months. It is nonvenomous.

During the present surveys a few examples measuring upto 58.5 cm from some localities (Balganga near Chamiala and Nakuri nala near village Nakuri on Uttarkashi road) above the proposed line of submergence were collected. Their occurrence in the localities within the line of submergence is very much expected. Its population may rather increase by the impoundment of the reservoir as then it will have plenty of food material - frogs and tadpoles.

4. Elephe helena - Trinket snake

It is widely distributed snake, generally met between 500 - 2,000 m elevation. It inhabits leafy trees and bushes and also termite mounds, rock piles and crevices.

It is a medium-sized slender snake attaining a length of 1.65 m. It is brownish with two prominent dark stripes on the posterior part of body and ocellated cross bands anteriorly. It feeds mainly on rodents and occassionally small birds and their eggs and even snakes. The young ones take insects and small lizards. It breeds almost year round. The female lays 6 - 8 eggs. It is non-venomous.

During the present study, it was found in the bushes along Bhaldiana - Lambgaon road and measured 62 cm in length. It is not very common in the area. The submergence of forest patches and bushes may surely have some depleting effect on its population. It is, therefore, suggested that some vegetation by way of plantation, should be provided along the periphery of the proposed reservoir, so that these snakes easily rehabilitate in the new localities.

5. Ptyas mucosus - Rat snake

Local Name : Dhaman

It is distributed throughout India and has been recorded upto 1,800 m altitude. It inhabits rat holes, termite mounds, high grass, rice and wheat fields etc. It takes readily to water and swims vigorously with the head well above. It is strongly built large snake attaining a length upto 3.5 m. It is olivaceous brown in colour, may be with scales on posterior part of body irregularly margined with black forming reticulate pattern with tendency to form cross bars. Lower jaw with black oblique lines. It feeds mainly on rodents and also on frogs, toads, lizards, birds and even small snakes. The female lays 8 - 16 eggs and young generally appear during summer period. It is sometimes mistaken for Cobra when seen briefly. It is non-venomous.

During the study, these snakes were found near Koti nala, Malideval and the vicinity of Barkot village on Ghansali road i.e. within the proposed submergence line. They are also likely to be found in other localities within and above the submergence line. The occurrence of these snakes in any area depends mostly on the availability of

rodents. Therefore, with the submergence of their habitats, they may move in the adjoining areas in search of rodent food and settle there. As the availability of rodents is associated with food grains, the farming of these crops in the periphery of the reservoir should be encouraged, so that these snakes get the food of their choice in plenty and flourish.

6. Naja naja - Cobra

Local Name : Nag

It is widely distributed upto 1,800 m elevation and is found almost anywhere in forests, agriculture fields, granaries, termite mounds, holes in ground, tangle of roots at the base of trees, hollow of old tree trunks etc. It is usually black or dark brown in colour. The specimens from the area were without the famous spectacled mark on hood. These snakes feed on rats, frogs, toads, lizards, birds, snakes and eggs. The female generally lays 12 - 30 egg in a clutch during summer months. It is the venomous snake of the area.

During the period of study, these snakes were found near Bharpur village, Lambgaon road and Barkot village, Ghansali road i.e. both above and within the line of submergence. With impoundment of the reservoir, these snakes may move towards safer habitats in the periphery, where plenty of rodent or other food is available, specially near agriculture fields.

Table : Distribution of snakes in proposed Tehri Dam Site

Classified list of species	Transect A		Transect B		Transect C		Transect D	General distribution approx. altitude
	WSL	ASL	WSL	ASL	WSL	ASL	ASL	
Order : Serpentes Family: Typhlopidae								
1. Ramphotyphlops braminus (Daudin)	+	-	-	-	-	-	-	Throughout India upto ca. 1000 m.
Family : Natricidae								
2. Amphiesma stolata (Linnaeus)	-	+	+	-	-	-	-	Throughout India upto ca. 2000 m.
3. Xenochrophis piscator (Schneider)	-	+		-	+	-	-	Throughout India upto ca. 2000 m.
Family: Colubridae								
4. Elaphe helena (Daudin)	-	-	-	+	-	-	-	Throughout India common between ca 500-2000 m.
5. Ptyas mucosus (Linnaeus)	-	-	+	-	+	-	-	Throughout India upto ca. 1800 m.
Family : Elapidae								
6. Naja naja (Linnaeus)	-	-	-	+	+	-	-	Throughout India upto ca. 1800 m.

Total no. of species under each transect 1 2 2 2 2 2 2

Note: The occurrence shown under each Transect is based on collection and sight. These snakes are likely to be found all over the site.

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Pattern of Analysis

I. 1. Total no. of species from the study area .. 6

2. Total no. of species from WSL .. 4

3. Total no. of species from ASL .. 4

4. Total no. of species common to both WSL & ASL .. 2

5. Total no. of species exclusive to WSL .. 2

6. Total no. of species exclusive to ASL .. 2

II. Mapping of species diversity along Transects A, B, C & D viz., Ghansali, Dharasu, Koteshwar & NTT. roads .. Refer Map

2. Total no. of species in WSL and ASL areas along each Transect as mentioned above :

A = 1/2
B = 2/3
C = 2/0
D = Nil

III. Status of Schedule/endemic species .. None

IV. Status of the group and possible impact of the proposed reservoir:

The species found in the area are likely to be shifted to the adjoining area and settle there provided sufficient shelter and food are available.

REFERENCE

HUSAIN, A and RAY, P (In press). First record of Cyrtodactylus fasciolatus (Blyth), the Bent-toed banded Gecko (Lacertilia; Gekkonidae; Gekkoninae) from Garhwal hills. J. Bombay nat. Hist. Soc., M.S: 1-3, fig. 1

AMPHIBIA

Field study, as well as detailed examination of the collected samples of amphibians, comprise only the anurans or Toads and frogs. A total number of 82 adults, 45 juveniles and 183 tadpoles, belonging to nine species, five genera and three families were collected. All are very common and none is endemic to the area and are hence not threatened by the construction of dam.

SYSTEMATIC LIST OF AMPHIBIANS

Class : Amphibia
Order : Anura
Family : Bufonidae

1. Bufo himalayanus Günther
2. B.melanostictus Schneider
3. B.stomaticus Lutken

Family : Ranidae

4. Amolops afghanus (Gunther)
5. Rana blanfordii Boulenger
6. R.cyanophlyctis Schneider
7. R.limnocharis Boie
8. Tomopterna breviceps (Günther)

Family : Microhylidae

9. Microhyla ornata Dum. & Bibr.

Note: Previously reported species of tree frogs have not been traced/collected, despite our best efforts.

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Table: Amphibian fauna inhabiting Tehri Dam Area

Name of the species	Teansect A				Transect B				Transect C & D		
	May	June	July	Oct.	May	June	July	Oct.	May	June	July
Buforidae											
1. Bufo himalayanus Gunther	-	-	-	-	-	+	-	+	-	-	+
2. Bufo melanostictus Schneider	+	+	+	+	+	+	+	-	+	+	+
3. Bufo stomaticus Luthen	-	+	+	-	-	+	+	-	+	+	+
Ranidae											
4. Amolops afghanus (Gunther)	+	*	-	+	-	-	-	+	-	-	-
5. Rana blanfordii Boulenger	+	+	-	+	+	+	-	+	-	-	-
6. Rana cyanophlyctis Schneider	+	+	-	+	+	+	+	+	+	+	+
7. Rana linnocharis Boic	+	+	+	+	+	+	+	+	+	+	+
8. Tomooterna breviceps (Schneider)	-	+	-	+	+	+	+	-	-	+	-
Microhylidae											
9. Microhyla ornata Dum & Bibr.	-	-	-	-	-	+	-	-	-	-	-
Total no. of species	5	7	3	6	5	8	5	5	4	5	5

PISCES

In a developing country like ours, the proper utilization of water resources, especially the river water, is very essential and it is being done by constructing dams for the purpose of irrigation and hydro-electric power generation and more attention needs to be paid to prevent deterioration of aquatic life, particularly the fish fauna. It has been observed during the past that, whenever a dam is constructed the fish fauna of that river is harmed tremendously as generally no proper arrangement is provided for free up and down movement of the fishes.

IMPORTANT FISHES OF THE AREA:

The fishes found in the streams and rivers along Himalaya are specially adapted for the survival in the torrential environment.

(i) Fishes Collected: During the recent five surveys undertaken between May and October, 1992, following fishes were actually collected :-

Order : Cypriniformes
Family : Cyprinidae
Class : Osteichthyes

1. Barilius vagra Hamilton-Buchanan
2. Tor chelynoides (McClelland)
3. Tor putitora (Hamilton-Buchanan)
4. Crossocheilus latius (Hamilton-Buchanan)
5. Garra gotyla (Gray)
6. Schizothoraichthys progastus (Mclelland)
7. Schizothorax richardsonii (Gray)

Family : Balitoridae

8. Nemacheilus montanus (McClelland)

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9. Nemacheilus rupecola (McClelland)
10. Glyptothorax pectinopterus (McClelland)

(ii) Other Fish Records from the Area: The following fishes have been recorded from the area as per the localities mentioned during the past (1977-1979) by other workers (Tilak & Saloni, 1984), but incidentally no material of these fishes was collected during the present surveys :-

Order: Cypriniformes
Family: Cyprinidae

1. Barilius bendelisis Hamilton-Buchanan - Jalkur nala, Lambgaon; river Balganga near Ghansali.
2. Tor tor (Hamilton-Buchanan) - River Bhilangna, Tehri; Nagni nala, Shivpuri.
3. Labeo dero (Hamilton-Buchanan) - River Bhilangna, Tehri, Ghansali; river Bhagirathi, Sirain; Nagni Nala, Shivpuri.

Family : Cobitidae

4. Botia dayi Hora - River Bhilangna; river Bhagirathi, Tehri.

Family : Balitoridae

5. Nemacheilus beavani Gunther - Jalkur nala; river Balganga.
6. Nemacheilus botia (Hamilton-Buchanan) - Nagni nala, Shivpuri.

Order : Siluriformes
Family : Schilbidae

7. Clupisoma montana Hora - River Bhagirathi, Sirain, Tehri; river Bhilangna, Tehri.

Family : Sisoridae

8. Glyptothorax alaknandi Tilak - River Bhilangna, Tehri.
9. Glyptothorax cavia (Hamilton-Buchanan) - River Bhilangna, Tehri; river Bhagirathi, Sirain.
10. Glyptothorax garhwali Tilak - Rivers Bhilangna and Bhagirathi, Tehri.
11. Pseudecheneis sulcatus (McClelland) - Jalkur nala; Nagni nala; Balganga river

Order : Perciformes

Family : Mastacembelidae

12. Mastacembelus armatus Lacepede - Nagni nala, Nagni.

BRIEF ACCOUNT

For proper management, a brief account of each species is given below:

1. Barilius vagra - Vagra Baril

Local Name: Chal, Chilwa

It is distributed throughout the base of Himalaya, Chindwin, Krishna and Kaveri drainages. It is a small sized silvery fish with blue bands. It attains about 12.5 cm in length. It, generally, inhabits the column of smaller tributary streams. It feeds on rotifers, earthworms, insects and their larvae, crustaceans, algae and other aquatic plants. It breeds before and during monsoon months. During the recent surveys, this fish was collected (2.77% of total fish catch) from Dharasu gad, Majun gad, Siasu nala, Koti gad the tributaries of river Bhagirathi within the proposed submergence line along Dharasu road and from river Bhilangna near Ghansali and its tributary Nailchami nala also near Ghansali above submergence line.

This species may not be affected by the dam as it is generally found in small streams and when the water level in the reservoir rises, these may move upwards in the respective streams and thrive there. They feed and breed in these streams.

2. Tor chelynoides - Black Mahseer

Local Name: Jalkawa machchi

It is distributed along Himalaya. This is the predominant-Mahseer in the area. It is blackish in colour with comparatively smaller scales. The fry and fingelings of this are found in almost all the tributaries of Bhagirathi and Bhilangna rivers, both within and above the proposed line of submergence. It grows to over 70 cm in

length. The longest specimens collected measured 27.5 cm. It feeds on aquatic insects and their larvae and the slime covering the stones. It breeds before the monsoon when ripe males and females ascend the tributaries of the main rivers.

It is well established in the area, being ca. 22.86% of the total fish catch during the present study. Its local population may not be affected much by the construction of dam except for the fishes held up below for breeding during the season.

3. Tor putitora - Golden Mahseer, Yellow-finned Mahseer
   Local Names: Sarow, Mahseer

It is the well known Mahseer of the Himalayan region and also the most endangered species of the area. It is a stoutly built, stream-lined fish with large scales, thick lips and yellow fins. It is a migratory fish, which for the purpose of propagation ascends to higher elevations ranging between 1,000 to 1,500 m where it spawns in smaller and quieter tributaries of main rivers during the monsoon months and returns back after spawning and once their upward way is blocked they are unable to reproduce for the continuance of their race. The adults feed mainly on insect diet, fish material, zooplankton and plant matter, whereas fry and fingerlings prefer algal matter, protozoans, rotifers, small insects, larvae and decayed organic matter. These fishes grow to quite a large size, i.e. over 2.7 m in length It is one of the largest food and game fishes of the area. It offers good sport on live bait.

It will be the most affected and harmed species of the area by the construction of the Dam. The affect is already evident as during the present surveys, not a single specimen was collected from river Bhagirathi and its tributaries along Dharasu and Koteshwar roads except for three specimens, one semi-adult (28.5 cm) from river Bhilangna at Tehri and two fingerlings (7.1 - 10.2 cm) from two tributaries near Ghansali. A grown up specimen was seen held up in a deep

below the Dam site. This constituted only ca 0.13%
total fish catch from the area during the present study.
the contrary, during earlier routine surveys (1973-1987)
the area, a good number of specimens of the species from
al , Tehri, and Dharasu were collected which indicates
t before the blocking of the main Bhagirathi river, this
ecies was common in the area, which is not so now.

4. Crossocheilus latius - Latia
Local Names: Dharaura, Jaknera

It is found in Ganga and Brahmaputra drainages along
Himalaya, Mahanadi drainage in Orissa, and upper reaches of
Krishna drainage in South. It is an elongated bottom living
fish measuring about 23 cm in length. Its mouth is ventral with
fringed upper lip. The head and body are flattened ventrally.
The scales on body are distinct. The body is dark brown or
olive green above with irregular dark spots. It feeds by
scrapping the algal matter covering the rocks and boulders.
It is rarely captured (only 0.04% during the present surveys)
due to its bottom-living habit. During the recent surveys,
a single specimen, measuring 22 cm , was collected from river
Bhilangna near village Jagdhar.

Being localised in its movements it may not be affected
by the construction of Dam.

5. Garra gotyla - Stone Fish
Local Names: Bhera, Bhagnera, Guling, Gotla

It is distributed all along the base of Himalaya,
Chota Nagpur plateau and Vindhya-Satpura range as mountain-
It is a bottom-living fish of torrents where it sticks by
creating vacum with its sheetally developed pad over chin
behind lower lip. The body is stoutly built and slightly
ventrally flattened head and thorax . The snout is fitted a
well-developed thorny proboscis. The scales on body are
moderate and thin. It is dark olive green

It feeds by scrapping the algal matter covering the rocks and boulders. The juveniles subsist on insect larvae and crustaceans. It breeds locally in small streams during monsoon months. It attain around 20 cm in length, in the present catch from river Bhilangna, the longest specimens measured was 23 cm . It is also very rarely netted (only 0.31% during the study period) due to its bottom dwelling habit.

It may not be affected by the construction of Dam due to its bottom living habit and localised movements. In the event of rising water level in the respective streams of the habitat these fishes may move further up wards and settle there.

6. Schizothoraichthys progastus - **McClelland's Snow Trout**
Local Name: Dinnawah, Pahari machhi

It is distributed all along Himalaya and inhabits around rocks and boulders in torrential streams. It is a stoutly built silvery fish with thick lips, subterminal mouth and body covered with minute scales. It is a column feeder and feeds mainly on algae or other plant matter. It migrates in higher reaches of Himalayan rivers (here Bhagirathi and its tributaries) for breeding before the onset of south-west monsoon and returns back after spawning. The fry and fingerlings live in shallow pools along small streams with clear water and moderate current. It attains a length of 50 cm.

It is an important food fish of the area. It comes on paste and gives good sport. During the recent surveys very few specimens of the species, as compared to Schizothorax richardsonii, were found in river Bhagirathi along Dharasu and Koteshwar roads (presently ca. 0.45% of total fish catch) which indicates that the population of this fish has been badly affected by the man made hindrances/barriers on river Bhagirathi. The longest specimen in the present lot measured 41.5 cm. Surprisingly, not a single specimen of this fish was collected from river Bhilangna - a major tributary of river Bhagirathi.

7. Schizothorax richardsonii - Richardson's Snow Trout

Local Name : Mashin, Jaat machchi, Asela, Sohal.

It is found all along Himalaya. It is a silvery fish with highly specialized suctorial disc on chin and minute scales on body. It prefers to live around the rocks and boulders on the bed of torrential rivers and streams. The suctorial disc helps the fish to stick to the boulder or rock in high currents. It feeds by scraping the algal metter and slime from the underwater rock and boulders. It breeds in smaller streams during winter and before monsoon months. Milting males and ripe females were seen in streams during the months of February. It is the most predominant (ca. 35% of total fish catch during the present study) and a well established species of the area and is distributed throughout the main rivers of Bhagirathi and Bhilangna and their tributaries. It grows to over 60 cm in length. In the present lot, longest specimens measured 47.0 cm. It is a valuable game fish of the area.

The breeding of this fish, ascending from down stream to higher elevations will be affected to some extent as observed during the months of June when ripe fishes, measuring 41.5 to 47.0 cm with bellies full of ova were found held up below the outlet of river Bhagirathi. These fishes were actually on their way to the breeding grounds along upstream. Further, the lake conditions may not suit these fishes due to their peculiar food habits and for want of highly oxygenated cold water.

8. Nemacheilus montanus and

9. Nemacheilus rupecola - Loaches

Local Name: Gadiyal

These fishes are distributed along Western Himalaya. These are small slippery loaches measuring upto 9.5 cm in

length. They are variously coloured with dark bands on greyish body. They inhabit the stony bed and found in almost all the tributary streams of rivers Bhagirathi and Bhilangna, both within and above the proposed line of submergence. They feed on micro-organisms, small insects and their larvae, algae and slime covering the stones. They breed during and after the rains. The population of Nemacheilus montanus was found to be ca. 15.53% and that of N.rupecola 22.82% of the total fish catch during the present study.

As these fishes live in crevices around the stones on bed of the stream and feed and breed locally, are the least affected fishes. In case of rising water level in the streams these may migrate upwards and settle there.

10. Glyptothorax pectinopterus - Mountain Catfish

Local Name: Machhwag, Pathar-chatti

This species is distributed all along the base of Western Himalaya. It inhabits the bottom of typical hill streams. It is a small sized peculiar catfish with depressed head, dorsally placed small eyes and an adhesive sucker on the chest. The sucker helps the fish in sticking to the stones in fast flowing streams. It feeds on crustaceans, insects and their larvae found around the stones and breeds locally during the monsoon period. In the present lot only two specimens (ca. 0.09% of total fish catch) measuring upto 8.6 cm could be collected from Dharasu gad at Dharasu and Saingarh gala on Koteshwar road, the tributaries of river Bhagirathi within the proposed submergence line.

This species is not likely to be affected by the coming up of the reservoir as with rise in the level of water, these fishes may ascend further in the streams of their habitat.

Table: DISTRIBUTION OF FISH FAUNA IN PROPOSED TEHRI DAM SITE

Classified list of Species	R.Bhilangna & tributaries, Ghansali road, Transect A								R.Bhagirathi & tributaries, Dharasu road, Transect B																	R.Bhagirathi & tributaries, Koteshwar Rd., Transect C						% of total catch
	WSL				ASL				WSL											ASL						WSL					ASL	
	R.Bhilangna	Barkot khala	Gadoli gad	Gadwanagad	R.Bhilangna	Nailchaminala	Semaltgadera	R.Balganga	R.Bhagirathi	Kotigad	Sirain nala	Uppu nala	Gadu gad	Jalkur nala	Siasu nala	Dikar gad	Nagun nala	Bhaneti nala	Badethi nala	Dharasu nala	Koti gad	Un gad	Jalkur nala	Nakuri nala	Darnigad	R.Bhagirathi	Stream nr. Dam	Leti gad	Dharamghat nala	Saingarh gadera	Bhaitogi nala	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Order : Cypriniformes Family : Cyprinidae																																
1. Barilius vagra Hamilton-Buchanan	+	-	-	-	+	+	-	-	-	+	-	-	-	-	+	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	2.77
2. Tor chelynoides (McClelland)	+	-	+	-	+	+	-	+	-	+	-	-	+	+	+	+	+	-	+	+	+	-	+	+	+	-	-	-	-	+	-	22.86
3. Tor putitora (Hamilton-Buchanan)	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	0.13
4. Crossocheilus latius (Hamilton-Buchanan)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04
5. Garra gotyla (Gray)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.31

cont'd.....

Classified list of Species	R.Bhilangna & tributaries, Ghansali road, Transect A		R.Bhagirathi & tributaries, Dharasu road, Transect B		R.Bhagirathi tributaries, Koteshwar Road, Transect C		% of total catch
	WSL	ASL	WSL	ASL	WSL	ASL	
1	2 3 4 5 6 7 8 9 10		11 12 13 14 15 16 17 18 19 20 21	22 23 24 25 26	27 28 29 30 31	32	33
6. Schizothoraichthys progastus (McClelland)	+ - - - - - - - +		- - - - - - - - - - -	- - - - - - - - - - -	+ - - - -	-	0.45
7. Schizothorax richardsonii (Gray)	+ - + + + + - + +		- + - + + + - + -	- - + - + + + - +	- - - - +	-	35.00
Family: Balitoridae							
8. Nemacheilus montanus (McClelland)	+ - - + + + - - +		+ + - - + + + + -	- + + - + + - - +	- - + - - -	-	15.53
9. Nemacheilus rupecola (McClelland)	- + + + + + + + +		+ + + + + + + - +	+ + - - + + + - +	+ - + + + +	+	22.82
Order : Siluriformes Family: Sisoridae							
10. Glyptothorax pectinopterus (McClelland)	- - - - - - - - -		- - - - - - - - - - +	- - - - - - - - -	- - - - +	-	0.03
Total no. of species in each river stream	8 1 3 3 5 6 1 4 4		4 3 1 3 4 5 3 4 1	2 6 2 1 4 4 2	4 1 1 1 4	1	

WSL = Within submergence line (proposed)
ASL = Above submergence line (proposed)

Pattern of Analysis

I. 1. Total no. of species from the study area .. 10

2. Total no. of species from WSL and ASL individually .. 10/6

3. Total no. of species common to both WSL and ASL .. 6/6

4. Total no. of species exclusive to WSL and ASL, respectively .. 4/0

II. 1. Mapping of species diversity along Transect A, B & C viz. Ghansali, Dharasu, Koteshwar roads: Refer Map

2. Total no. of species in ASL & WSL areas along each Transect as mentioned above

A = 6/9

B = 4/7

C = 1/7

III. Status of Schedule/Endemic species: None

IV. 1. Status of the group and possible impact of the proposed reservoir.

1. Tor putitora is most affected as only a few specimens (ca. 0.13%) from river Bhilangna and down streams of river Bhagirathi were found. No specimen from up streams of river Bhigirathi was collected.

2. Schizothorax richardsonii may be slightly affected as it may not adjust in lake conditions due to its peculiar food habits and other living conditions and may thrive in higher reaches. However, at present it is the most predominant fish in the area (ca.35.0%).

3. Schizothoraichthys progastus appears to be affected as its population has become very thin (ca. 0.45%) may be it also migrates up stream for breeding like that of Mahseer.

The other important fishes of the main rivers viz. Tor tor, the Red-finned Mahseer, Labeo dero, the Kalabans and Clupisoma montana, the Kocha-garda, although reported from the area by earlier workers, were not netted during the present study, which indicates that the population of these fishes has already been depleted, may be due to the Dam construction activity during the past.

All these fishes are widely distributed along the Himalaya. Tor tor is migratory in habit. The ripe fishes ascend towards headwaters at the beginning of monsoon and return downstream after spawning.

REFERENCE

TILAK, R. and BALONI,S.P. 1984. On the fish fauna of Tehri Garhwal, Uttar Pradesh. Rec. zool. Surv. India, 81(3-4): 255-271.

OTHER RELATED REFERENCES

BADOLA,S.P. and PANT, M.C. 1973. Fish fauna of Garhwal Hills. Part I. Indian J.zool., 14(1): 37-44.

GROVER,S.P. and BALONI,S.P. 1977. Some biological notes on the hill stream fishes of Tehri Garhwal. Geobios, 4(6): 248-251.

LEPIDOPTERA

The lepidopterous insects constitute one of the major insect-orders and comprise butterflies and moths, whose larval stages feed on plant-food either as pests on agricultural crops, plantations, forest-trees, shrubs/herbs/climbers, grasses, or as leaf-defoliators and leaf miners. As a result, extensive damage is caused due to their attack. Majority of these pests are belonging to moths which are mainly nocturnal for feeding and other activities whereas the butterfly-fauna is mainly diurnal in habit (i.e. mainly fly during day-time). Although their larval stages also feed on plant-food, mainly foliage and tender shoots, like moths, these constitute one of the very important component of the food-chain in nature. Majority of the insectivorous birds feed on their larvae, besides animal like lizards, frogs and toads feeding on these insects. Hence any imbalance in the nature of one group adversely affects the existence of the group directly depending upon them. In fact, the abundance of bird-fauna amply predicts the abundance of insect-groups in nature and can very easily be called as "Indicator-group".

The butterflies also act as pollinating agents since several species fly from flower to flower and during their life time, besides visiting their host plant for laying eggs upon, visit several flowers, unlike their caterpillars which confine themselves to their particular host-plant till their emergence.

The Tehri Dam, being one of the largest one, is going to be constructed at the confluence of rivers Bhagirathi and Bhilangana. As a result, a huge water-body is going to be created, extending upstream N. & N.W. along Bhagirathi upto Dharasu, upstream E. & S.E. along Bhilangana upto Ghansali, and down-stream South along the river upto Koteshwar. In a process, complete land mass upstream from

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Dharasu to Ghansali and downstream upto Koteshwar, will be submerged. The height of the Dam being about 840 m., so that from base-level of about 579 m., to the highest level, the maximum submergence level covers to about 260 m. The submergence will cover forests, agricultural crops etc., and as a result all the larval population, which feed on the plant-food will be completely exterminated, since these can not relocate themselves during the course of rising of water-level.

Nevertheless, the adult fauna being mobile and in habit of flying from one host to another, at the time of laying eggs, have the tenacity to survive and shifts to newer areas/habitats, provided their food plants are available.

It is, therefore, all the more essential for the THDC, to make serious efforts simultaneously for an afforestation programme and create similar habitats, so that the fauna can relocate itself immediately.

During the course of five surveys carried out during May to October, covering nearly dry-season, wet season and post-monsoon periods, as many as 81 species of butterflies were collected. The localities included both those falling within the Submergence Level (WSL) as well as Above Submergence Levels (ASL).

The details of the lepidopterous fauna has been appended and may be mentioned that collections were made right from Dam-site level at an alt. of about 579 m. to as high as 1950 m., much Above the Submergence Level. It brought to light as many as 18 species exclusively within Submergence Level and 22 species Above (ASL) the Submergence Level. The remaining 41 species are common to both the levels.

Out of 81 species, only two viz.. Diagora persimilis zella Butler and Athyma assura Moore are "Rare" in status, whereas all other are either common or very common in their habitat. But even these species are with wide range of

extension and not restricted to Tehri Dam Area. Although as many as 18 species have been exclusively from Within Submergence Level (WSL) particularly like *Delias eucharis* and *Eurema brigitta* (both Pieridae); *Trimula limniace leopardus* (Danaidae); *Euthalia garuda*, *Hypolimnas bolina*, *Aglais cashmirensis*, *Symbrenthia hippoclus*, *Childrena childreni*, *Cupha erymanthis* (all Nymphalidae) and a few Lycaenidae & Hesperidae, all but *Diagora persimilis* and *Athyma assura* are quite common and available to higher altitude too (ranging from sp. to sp.).

SUMMARY ANALYSIS

	Family	Total no. of species	No. of species exclusively ASL	WSL	AW (Common) (ASL/WSL)
I	Papilionidae	8	4	–	4
II	Pieridae	12	2	2	8
III	Danaidae	6	1	1	4
IV	Satyridae	10	5	–	5
V	Nymphalidae	28	6	8	14
VI	Acraeidae	1	–	1	–
VII	Erycinidae	3	1	–	2
VIII	Lycaenidae	7	–	4	3
IX	Hesperiidae	6	3	2	1
		81	22	18	41

I. PAPILIONIDAE

	Analysis	I	II	III	IV	V	Status
1. Chilasa clytia clytia (Linn.) ♀ form clytia	A/-/-	-	A	-	-	-	C
2. Papilio protenor protenor Cramer	A/W/-	A	A	W	W	W	NR
3. Papilio polyctor Boisduval	A/W/AW	AW	A	AW	W	W	C
4. Papilio polytes romulus Cramer	-/W/AW	AW	AW	AW	AW	W	VC
5. Papilio demoleus demoleus Linn.	A/W/AW	W	A	-	AW	AW	VC
6. Papilio machaon asiatica Menetries	A/-/-	-	A	-	A	-	NR
7. Graphium cloanthus cloanthus (Westwood)	A/-/-	-	A	-	-	-	NR
8. Graphium sarpedon sarpedon (Linn.)	A/-/-	-	A	A	-	-	C
Total B:	7/4/3						

Note: All the species are common to very common and have been collected in all the three areas selected for study i.e. Above SL and Within SL or both. Since the species are quite common, depending upon the food being widely distributed, these are not adversely affected by Dam.

Note : I to V refers to five surveys undertaken between May to October 1992.

A = Above Submergence Level (ASL)

W = Within Submergence Level (WSL)

AW = Common to both ASL & WSL

II. PIERIDAE

9. Appa agathon caphusa (Moore)	-/-/Aw	-	Aw	-	-	-	NR
10. Delias eucharis (Drury)	-/w/-	-	-	-	w	-	C
11. Artogeia canidia indica Evans	-/w/Aw	Aw	Aw	Aw	Aw	w	VC
12. Pontia daplidice moorei (Rober)	-/w/Aw	Aw	Aw	w	Aw	-	C
13. Catopsilia crocale (Cramer)	-/w/Aw	Aw	Aw	-	w	w	VC
14. Catopsilia pyranthe (Linn.)	-/w/Aw	-	w	w	w	Aw	VC
15. Gonepteryx rhamni nepalensis Doubleday	A/w/Aw	-	A	Aw	w	w	C
16. Eurema brigitta rubella (Wallarce)	-/w/-	-	-	-	w	-	VC
17. Eurema laeta laeta (Boisduval)	-/w/Aw	w	w	w	Aw	-	VC
18. Eurema hecabe contubernatis (Moore)	A/w/-	-	A	w	w	w	C
19. Colias erate (Esper)	A/-/-	-	A	-	-	-	C
20. Colias electo fieldi Menetries	A/-/-	-	A	-	-	-	C
Total 12:	2/2/8						

Note: Only two species are exclusively from the area within SL, but even these are quite commonly known to occur between 6000 - 7000' in D.eucharis and 12000' in E.brigitta. All the species are co mon to very common

III. DANAIDAE

21. Danaus chrysippus chrysippus (Linn.)	A/w/Aw	w	Aw	Aw	A	Aw	VC
22. Danaus genutia genutia (Cramer)	-/w/Aw	-	Aw	Aw	w	Aw	VC
23. Tirumala limniace leopardus Butler	-/w/-	-	w	-	-	w	VC
24. Tirumala melissa septentrionis (Butler)	A/-/-	-	A	A	-	-	VC
25. Parantica aglea melanoides (Moore)	-/w/Aw	-	Aw	-	w	Aw	VC
26. Euploea core core (Cramer)	A/w/Aw	-	A	A	w	Aw	VC
Total 6:	1/1/4						

Note: Only one species is exclusively known from within SL and although is very common throughout its area of occurrence.

IV. SATYRIDAE							
27. Mycalesis lepcha (Moore)	A/-/-	-	-	A	-	-	NR
28. Lethe rohria dyrta Felder	A/W/AW	-	A	-	AW	W	C
29. Pararge schakra Kollar	A/-/-	-	A	A	-	-	C
30. Callerebia scanda Kollar	A/W/-	-	A	-	A	W	NR
31. Ypthima nareda nareda Kollar	A/W/-	-	-	A	W	-	NR
32. Ypthima asterope mahratta Moore	A/-/-	-	A	-	-	-	C
33. Ypthima ceylonica huebneri Kirby	-/-/AW	-	-	AW	-	-	C
34. Ypthima baldus baldus Fabr.	A/W/-	-	-	A	W	-	VC
35. Ypthima sakra nikaea Moore	A/-/-	-	-	A	-	-	C
35a Melanitis leda ismene (Cramer)	A/-/-	-	-	A	-	-	C

Total 10:	5/-/5						

Note: None of the species are exclusively known from within SL

V. NYMPHALIDAE

35. Aglais cashmirensis aesis Fruh.	-/-/-	-	-	-	-	-	NR
34. Vanessa indica Herbst	A/-/-	-	-	-	-	-	R
33. Cynthia cardui Linn.	-/-/Aw	-	-	-	-	-	NR
32. Precis iphita siccata Stichel	A/-/-	A	-	-	-	-	C
51. Precis almana almana Linn.	-/-/Aw	-	-	-	-	-	R
50. Precis lemonias persicaria (Linn.)	A/-/-	-	-	-	-	-	NC
49. Precis orithya swinhoei Fruhstorfer	-/w/Aw	-	-	-	-	-	VC
48. Precis hierta (Fabr.)	-/w/Aw	-	-	-	-	-	NR
47. Kallima inachus huegeli Kollar	-/w/Aw	w	w	Aw	w	w	C
46. Hypolimnas bolina Linn	A/w/Aw	w	Aw	-	w	w	VC
45. Hypolimnas misippus Linn	A/-/Aw	Aw	Aw	A	-	-	VC
44. Pseudergolis wedah Kollar	B/w/-	-	A	Aw	Aw	Aw	VC
43. Neptis yerburyi Butler	-/w/-	-	A	w	-	-	VC
42. Neptis hylas astola Moore	a/-/-	-	-	-	w	-	NR
41. Athyma perius perius Moore	A/-/-	-	-	-	a	-	C
40. Athyma asura asura (Linn.)	-/-/Aw	-	-	-	-	a	C
39. Athyma opalina opalina Moore	A/w/Aw	Aw	A	-	-	-	NR
38. Euthalia garuda anagama (Kollar)	A/w/Aw	-	A	Aw	A	w	VC
37. Dichorragia nesimachus ranga Fruhstorfer	A/-/-	-	A	A	w	Aw	NC
36. Eriboea athamas zella Butler	A/w/Aw	-	A	-	w	-	C
	-/w/-	-	-	w	w	Aw	C
	A/-/-	-	-	A	w	-	NR

56. Symbrenthia hippoclus de N.	-/W/-	W	-	W	W	W	FC
57. Argyreus hyperbius hyperbius (Johansen)	A/W/AW	-	A	A	AW	W	NR
58. Childrena childreni sakontala Moore	-/W/-	-	-	-	-	W	NR
59. Issoria lathonia issoea Doubleday	A/-/-	-	A	-	-	-	C
60. Cupha erymanthis litis Sulz.	-/W/-	-	-	-	-	W	C
61. Phalanta phalantha (Drury)	A/W/AW	W	AW	W	AW	W	C
62. Vagrans sinha (Cramer)	-/W/-	-	-	-	-	W	C
63. Ariadne meriona tapestrina Moore	A/-/AW	-	A	AW	AW	AW	NR
Total 28:	6/8/14						

Note: As many as eight species are known from area WSL and all are common to very common, except D.persimilis and Athyma assura, which are rare.

VI. ACRAEIDAE

64. Acraea issoria anomala Kollar	-/W/-	-	W	-	-	- NR

Note: Only one is known in this area and has been collected from area within SL but is fairly common throughout its area of occurrence.

VII. ERYCINIDAE

65. Libythea myrrah sanguinalis Fruhs.	A/W/AW	-	A	-	W	AW C
66. Libythea lepita Moore	A/-/-	-	A	-	-	- C
67. Dodona durga Kollar	A/-/AW	-	A	-	AW	- C
Total: 3	1/-/2					

Note: None are exclusively to WSL

VIII. LYCAENIDAE							
68. Tarucus extricatus (Butler)	-/W/-	-	W	-	-	-	NR
69. Euchrysops pandava (Horsfield)	-/-/AW	-	-	AW	-	-	C
70. Zizeeria maha	-/W/-	-	-	-	-	W	C
71. Catochrysops strabo (Fabr.)	-/W/-	-	-	-	W	W	C
72. Heliophorus sena Kollar	A/W/AW	W	AW	A	A	W	C
73. Spindasis vulcanus Fabr.	-/W/AW	-	W	-	AW	W	C
74. Spindasis lohita himalayanus (Moore)	-/W/-	-	W	-	-	-	C
	-/4/3						

Total : 7

Note: Four species are WSL, but all are common to very common

IX. HESPERIIDAE							
75. Badamia exclamationis (Fabr.)	A/-/-	-	-	-	A	-	NR
76. Odontoptilium angulata Felder	A/-/-	-	-	A	-	-	NR
77. Potanthus dara Koller	-/W/-	-	-	-	W	-	NR
78. Parnara guttatus (Bremer & Grey)	A/W/-	-	-	W	W	A	C
79. Borbo cinnara (Wallace)	A/-/-	-	-	A	-	-	C
80. Potanthus pseudomaesa	-/W/-	-	-	-	W	-	C
	3/2/1						

Total : 6

Note: Only one is WSL but all are common species.

ODONATA

The Tehri Dam Project envisages the construction of earth and rock filled dam, across the river Bhagirathi, downstream the confluence of Bhagirathi and Bhilangana rivers - near Tehri Town at ca. alt. of 500 m., in the foot hills of Garhwal region. The height of the dam is proposed to be 260.5 m., with a catchment area of 6921 sq.km. and the submergence area of about 42 sq.km (reservoir), which will extend along the R.Bhagirathi to the extent of 45 km. upstream upto Dharasu, and 25 km., upstream along R.Bhilangna upto Chansali.

Since the creation of the reservoir will submerge a vast area, the fauna of the above proposed submerged area is likely to be affected to a greater extent. To assess the above changes, the scientists of Zoological Survey of India, Dehra Dun, have undertaken the studies on the impact assessment on the fauna of proposed Tehri Dam. Consequent to which, between May and October 1992, five extensive faunistic surveys were carried out in the above area.

The present paper deals with Odonata (dragonflies), an amphibiotic group of insects from the study area.

MATERIAL AND TECHNIQUES

The entire reservoir area is broadly "Y" shaped, and is conveniently divisible into three major villages (each being transversed by a road), which are used as TRANSECTS during the present study, viz., Ghansali Road (A), Dharasu Road (B) and Koteshwar Road (C), [illegible]. Each transect (30 - 40 km. in length) passing through both above submergence level (ASL) and within submergence level (WSL) category, thus giving six major codes, i.e., A, B & C for WSL and A, B & C for ASL; the additional seventh code D comprises localities of Top Terrace (TT) and New Tehri Town (NTT), both falling within ASL category (cf. Table - 1

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for details). For ultimate faunal analysis all the above transects, i.e., A, B, C & D were broadly classified into two categories, i.e. those located above the submergence level (ASL) and remaining which fall within the proposed submergence level (WSL), to have an assessment of the distribution pattern of the fauna along all the selected four transects within the study area. This would also help in determining the faunal pattern in the "trauma zone", i.e., the localities within the area of stud/ which are going to be changed from terrestrial to aquatic biotopes.

The dragonflies (Odonata) are a fresh water group of insects and are found in all types of permanent or temporary aquatic biotopes. These insects have three stages in their life history; the first two, i.e., the egg and the larval stages are aquatic; and it is only after emergence the aerial imagos comeout. The odonates occupy an important position in invertebrates food chain in fresh water biotopes because of being predator and preys as well. They are very useful ecological indicators of the stability and productivity of aquatic ecosystem since as aquatic insects they are immediately vulnerable to the destruction of freshwater habitats.

The dragonflies of western Himalaya (Garhwal hills) have attracted many of entomologists, consequent to which a fairly good number of publications have appeared [Cf. KUMAR & PRASAD, 1981; KUMAR (in press)] on these insects from the above region. In the present communication, 29 species have been reported from the study area, between the alt. of ca. 579 to 1950 m. Of these, 23 species are common both to above submergence (ASL) as well as within submergence level (WSL) localities. However, it was noted that while three species are exclusively found to be restricted to WSL, five species are limited to ASL.

It is noteworthy to mention that the richest representation of dragonflies is along the Ghansali Road i.e., transect 'A' (27 species), while 23 species have been

reported along Dharasu Road i.e., Transect 'B' and 16 species along Koteshwar Road i.e. Transect 'C'; Topterrace and New Tehri Township represent the poorest number, understandably because of lack of water resources along the Koteshwar road and New Tehri Town area.

Amongst the damselflies, species like Calicnemia eximia, Rhinocypha unimaculata, Bayadera indica and Anisopleura lestoides are most commonly distributed in THDC area. In addition, all the 10 species of damselflies are widely distributed in W.Himalaya (KUMAR & PRASAD, 1981; KUMAR (In press). Among Anisoptera, the most common species are Orthetrum pruinosum neglectum, O.triangulare triangulare, Palpopleura s. sexmaculata, Acisoma p.panarpoides and Trithemes festiva, which are again very commonly and widely distributed in Western Himalaya.

None of the species is either endemic, endangered or threatened and as such, not detrimental to its existence by the construction of dam.

DISCUSSION

Corbet (1962), Kumar (1972, 1973, 1985) have amply correlated that the size and shape of a body of water is directly important in habitat selection of Odonata and generally the distribution of dragonflies is affected by the nature of aquatic biotope. Kumar (l.c.) has dealt with the parochialism in a good number of species in tropics which confine themselves either to streams, lakes/reservoirs or at the effluent monsoon ponds.

The field observations on the distributional pattern of the dragonflies around the tributaries of Bhagirathi and Bhilangana (between the alt. 600 to 1,000 m.) in the open valleys, show a close semblance with the general pattern (Kumar l.c). it is noteworthy to mention that the most common dragonflies belong to genera like Drepanostricta, Calicnemia, Bayadara, Anisoplura and Anisogomphus - all

requenting the hill streams which are about 1.5 to 3 mt. n width and approximately 50 cm in depth and have a sand and pebble bed shaded by bushes on either side. Another such interesting species around the open, sunny stretches of these streams is Neurobasis chinensis chinensis. When these streams move to the main rivers in flatter valleys, the gradient become less, the surrounding area is open, the climate becomes warmer and the composition of dragonfly fauna changes there. The most common genera that occur at such places are Rhinocypha, Lamelligomphus, Orthetrum (O.triangulare triangulare being the most dominant species), Crocothemis and Trithemis.

Since most of the field surveys were carried out during summer and monsoon period, the occurrence of monsoon ponds and waterlogged paddy fields were very common in the study area resulting in presence of a very large number of static water breeding species, namely Acisoma panarpoides, Palpopleura s.sexmaculata and Orthetrum pruinosum neglectum.

Specimens of Lestes p. praemorsa, Pantala flavescens and Tramea virginia, all known monsoon migrants, were found to occur in the study area during the S.W. monsoon period.

The nearest natural lake at this altitude in western Himalaya, whose Odonata fauna has been studied in details (Kumar, 1976, 1978) at Renuka in dist. Sirmour (Himachal Pradesh) has 11 species common to the present study area. It is expected that with formation of proposed reservoir not only the population of the known species will increase manifold, but some of static water breeding species like those of genera such as Ischnogonphus, Anax, Orthetrum, Neurothemis, etc. are expected to be added to the fauna of the area.

SELECTED REFERENCES

1. Corbet, P.S., 1962. A biology of dragonflies. Witherby, London.

2. Kumar, A., 1972. The phenology of dragonflies in the Dehra Dun Valley (India). Odonatologica, 1:199-207.

3. Kumar, A., 1978. Some field notes on the Odonata around a fresh water lake in Western Himalaya (Renuka: Himachal Pradesh). J. Bombay nat. Hist. Soc., 74: 506 - 510.

4. Kumar, A., 1985. A review on the bio-ecology of Indian Dragonflies. Proc. First Indian Symp. Odonatal., pp 73-92.

5. Kumar, A. (in press). "Odonata" in "Studies on the Himalayan Ecosystem: Fauna of Western Himalaya (Utter Pradesh: India)".

6. Kumar, A., Juneja D.P. 1976. The Odonata of Renuka lake (Western Himalaya: Himachal Pradesh). Newl. zool. Surv. India, 2(3): 95-96.

7. Kumar, A. & Prasad, M., 1981. Field ecology, Znogeography and taxonomy of the Odonata of Western Himalaya, India. Rec. zool. surv. India, Occ. Publ., 20: 1-118.

SUMMARY ANALYSIS

	Total no.of species	No. of spp. (ASL)	No. of spp. (WSL)	No. of species (Common to both)
1. Family : Platystrictidas	01	01	01	01
2. Family : Platycnemididae	01	01	01	01
3. Family : Coenagriidae	01	01	01	01
4. Family : Lestidae	01	01	-	-
5. Family : Cholorocyphidae	02	01	02	01
6. Family : Epallagidae	03	03	02	02
7. Family : Calopterygidae	01	01	01	01
8. Family : Gamphidae	05	05	03	03
9. Family : Aeshnidae	02	02	02	02
10. Family : Libellulidae	12	11	10	09

Pattern of analysis: FAUNA OF THDC : ODONATA

I.

1. Total number of species from the study area.	..	29
2. Total number of species from Within Submergence Level (WSL)	..	23
3. Total number of species from Above Submergence Level (ASL)	..	23
4. Total number of species common to both WSL & ASL	..	15
5. Total number of species exclusively to WSL & ASL		
(i) WSL	..	03
(ii) ASL	..	05

II.

1. Total number of species in ASL & WSL areas along axis A, B, C & D

A. Ghansali Road:	WSL 18 ;	ASL 15;	Total = 27
B. Dharasu Road:	WSL 15 ;	ASL 13;	Total = 23
C. Koteshwar Road	WSL 04 ;	ASL 12;	Total = 16
D. Top Terrace & NTT	ASL 13		Total = 13

	W S L A	B	C	A S L A	B	C	D	Status Endangered/ Threatned	Endemic	Distribution in study area
(A) Suborder : Zygoptera										
I. Family : PLATYSTRICTIDAE										
1. Drepanostricta carmaechaali	-	+	-	+	+	+	-	-	-	R
II. Family : PLATYCNEMIDIDAE										
2. Calicnemia eximia Selys	-	+	+	-	+	-	+	-	-	C
III. Family : COENAGRIDAE										
3. Ischnura delicata (Hagen)	-	+	-	-	-	+	-	-	-	R
IV. Family : LESTIDAE										
4. Lestes praemorsa praemorsa Selys	-	-	-	-	-	-	+	-	-	R (season migran
V. Family : CHLOROCYPHIDAE										
5. Rhinocypha unimaculata Selys	-	+	+	+	+	+	+	-	-	VC
6. R.trifasciata trifasciata Selys	+	-	-	-	-	-	-	-	-	R
VI. Family : EPALLAGIDAE										
7. Bayadara indica Selys	+	-	-	+	+	-	+	-	-	VC
8. Anisoplura lestoides Selys	-	-	-	+	+	-	-	-	-	VC
9. A.comes Selys	+	-	-	-	-	+	-	-	-	C
VII. Family : CALOPTERYGIDAE										
10. Neurobasis c.chinensis Lin.	+	+	-	-	+	+	+	-	-	C
(B) Suborder : Anisoptera										
I. Family : GOMPHIDAE										
11. Anisogomphus occipetalis (Selys)	+	-	-	-	+	+	-	-	-	NC

cont'd.....

12. Onychogomphus m-flavum Selys	-	-	-	+	+	-	-	-	-	NC	
13. Lamelligomphus biforceps (Selys)	-	-	-	+	+	-	-	-	-	NC	
14. L.risi Fraser	+	+	-	-	-	+	-	-	-	NC	
15. Nepogomohus modestus (Selys)	+	-	-	+	-	-	-	-	-	NC	
II. Family : AESHNIDAE											
16. Anax guttatus (Burn.)	+	-	-	-	-	-	+	-	-	NC	
17. A.immaculifrons Rambur	+	-	-	-	-	-	+	-	-	NC	
III. Family : LIBELLULIDAE											
18. Orthetrum anceps	-	+	-	-	-	-	-	-	-	R	
19. O.chrysostrigna hizonicum (Brauer)	+	-	-	-	+	-	+	-	-	C	
20. O.pruinosum neglectum (Rmb)	+	+	+	+	+	+	+	-	-	VC	
21. O.triangulare triangulare	+	+	+	+	+	+	+	-	-	VC	
22. Palpopleura sexmaculata sexmaculata (Fabr.)	+	+	-	+	+	+	+	-	-	VC	
23. Acisoma panarpoides panarpoides Rambur	+	-	-	+	-	-	+	-	-	VC	
24. Crocothemis servilia servilia (Drury)	+	+	-	-	-	-	-	-	-	C	
25. Trithemis aurora aurora(Burm.)	+	+	-	+	-	-	-	-	-	C	
26. T.festiva (Rmb.)	+	+	+	+	+	+	+	-	-	VC	
27. T.pallitinervis (Kirby)	-	+	-	+	-	-	-	-	-	NC	
28. Pantala flavescens (Fabr.)	-	+	-	+	-	-	+	-	-	NC	(seasonal migrant)
29. Tramea virginia	-	-	-	+	-	-	+	-	-	NC	-do-
Total species	12	15	04	15	13	12	13	-	-		

HYMENOPTERA

A total of 24 species under 7 families have been identified based on the fauna of Hymenoptera collected from the area concerned. Out of these, 18 species belongs to ASL and 12 species to WSL, while six species are common to both ASL as well as WSL.

The study reveals that the species so far identified are common to very common except Scolia (Discolia) dehraensis Betrem, which is rare and hitherto known from district Dehra Dun only. All other species are either widely distributed in India or atleast known to occur in other areas of Western Himalaya, and hence not threatened.

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	A	B	C	D
Family : ICHNEUMONIDAE				
1. Metopius rufus rufus Cameron	-	ASL	-	-
2. Ischnojoppa luteator Fabricius	-	-	-	ASL
3. Holcojoppa sp.	-	ASL	-	-
Family : SCOLIIDAE				
4. Scolia (Discolia) quadripustulata Fabricius	-	-	-	ASL
5. Scolia (Discolia) affinis Guerin	WSL	-	-	-
6. Scolia (Discolia) dehraensis Betrem	WSL	-	-	-
7. Scolia (Discolia) wagneri Betrem	WSL	ASL	-	-
8. Campsomeriella collris collaris (Fabricius)	WSL	-	-	-
9. Campsomeriella annulata (Fabricius)	ASL/ WSL	-	-	-
10. Megacampsomeris prismatica (Smith)	-	-	-	ASL
11. Megacampsomeris sp.	-	-	-	ASL
Family : TIPHIIDAE				
12. Mesa sp.	-	ASL	-	-
13. Tiphia sp.	WSL	-	-	-
Family : VESPIDAE				
14. Parapolybia varia (Fabricius)	WSL	WSL	-	ASL
15. Polistes hebraeus Fabricius	WSL	WSL	-	-
16. Polistes maculipennis Saussure	WSL	ASL/ WSL	-	ASL
Family : EUMENIDAE				
17. Eumenes petiolata Fabricius	-	WSL	-	-
Family : SPHECIDAE				
18. Trirogma caerulea Westwood	-	ASL	-	-
19. Chalybion bengalense (Dahlbom)	WSL	WSL	-	ASL
20. Chlorion lobatum (Fabricius)	ASL	-	-	-
21. Ammophila atripes Fabricius	-	ASL	-	-
22. Ammophila punctata Fabricius	ASL	ASL	-	-
23. Sceliophron madraspatanum (Fabricius)	-	ASL	-	-
Family : APIDAE				
24. Bombus haemorrhoidalis Smith	ASL/ WSL	ASL	-	ASL

ARACHNIDA

Most of the spinders and scorpions collected are terrestrial. The spinders mostly belong to the family Lycosidae - the hunting spiders, and are mostly common. None is endangered or endemic and not threatened by the impoundment of the reservoir.

Order : Aranae
Family : Argiopidae

1. Araneus nympha Simon
2. Neoscone pavida Simon
3. Nephilia maculata (Fabricius)
4. Nephilia clavata Koch
5. Leucage decorata (Blackwall)
6. Lycosa goliathus Pocock
7. Lycosa masteri Pocock
8. Lycosa sp.
9. Pardosa altitudus Tikader
10. Pardosa annandelei Gravely
11. Pardosa heterothalmus (Simon)
12. Pardosa kukupa (Tikader)
13. Pardosa birmanica Simon
14. Pardosa sumatrana (Thorell)
15. Hippasa greenllae (Blackwall)

Family : Telragnathidae

16. Tetragnatha andamanensis Tikader
17. Tetragnatha sp.

Family : Heteropodidae

18. Heteropoda phasma Simon

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Family : Salticidae

19. Salticus ranjitus Tikader

Family : Eresidae

20. Stegodophus sarasinorum Karsch

Family : Oonopidae

21. Isnothyreus sp.

Order : Scorpionida
Family : Buthidae

1. Mesoluthus tamulus gangaticus Pocock

Family : Vaejoridae

2. Scorpiops (Scorpiops) montanus Karsch

MYRIAPODA
(Centipedes)

Only four specimens of centipede could be collected, two from Bhasong village (Within Submergence Level) on Koteshwar Road, and two from Gadolia Forest Nursery (Above Submergence Level) on Ghansali Road. All the four examples are referable to Rhysida monalii Khanna & Kumar.

Since Rhysida monalii and the previously known species Otostigmus amballae from the area are widely distributed, occuring throughout the Western Himalaya, U.P., North West Himalaya (H.P. and J & K), the construction of Tehri Dam would not, therefore, be detrimental to the existence of the species in nature.

Scolopendra morsitans Linn. and Cormocephalus dentipes Pocock, are the other two species which, though not collected in the present series of surveys, stand very fair chances of occurring in THDC area. But again these are neither endemic nor rare and their occurrence would not be affected by the destruction of their habitat, following the construction of Tehri Dam.

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IMPACT ASSESSMENT AND RECOMMENDATIONS :

During the present studies, a total of 282 species of the fauna, including 159 species of invertebrates and 123 species of vertebrates have been inventorised from the study area, which includes about 80 localities of the Transects A, B, C, & D. Nevertheless, the present list may only be a fragment of the actual fauna that may be occurring in the region.

The major groups dealt with in the present studies are Mammals, Aves (Birds), Reptiles (Snakes and Lizards), Amphibia (Frogs & toads) and Pisces (fresh water fishes) among the vertebrates and the invertebrates groups are generally of insects belonging to Order Lepidoptera (Butterflies), Odonata(Dragonflies), Hymenoptera (Wasps and bees) and other arthropods namely Arachnida (spiders and scorpions) and Myriapoda (centipedes).

The impact of the proposed reservoir on the faunal components of the above listed groups is detailed below :

MAMMALS: In all 18 spp. have been recorded from the study area, including the major cats like Panthera pardus (Leopard) and Felis bengalensis (the leopard cat). Although these species are listed in the Schedule I of Wild life (Protection) Act, 1972, but are widely distributed in Garhwal hills and study area as well, and were sighted from Above and Below Submergence localities. As discussed in detail in Section dealing with mammals, it is expected that the population of Lutra lutra monticola (the Otter) which was sighted only at few localities in Transect 'B' and 'C', is likely to be marginally effected by the construction of the proposed reservoir. However, it is heartening to note that this species is again widely distributed in the river systems of Himalaya. Hystrix indica (the Porcupine), a burrowing species has been sighted from some localities in the study area.

Consequent to the formation of the proposed reservoir, it may loose some of its established dwellings in the "Trauma zone". Nevertheless, it is well recorded that the distribution of this species in Western Himalayas has wide altitudinal variations, Therefore, it is expected that it may make up the lost ground by moving to the higher elevations (i.e., ASL Areas). The troops of varying sizes of "Rhesus Macaque" and "Hanuman Langur" in wild were seen along river Bhagirathi and also stray examples around T.T.Guest House. As they feed on wild fruits their population may be adversely affected locally and alternatively they may migrate to the nearby place due to the submergence of the forest patches in this zone. Hence, it is suggested that appropriate plantation of fruit bearing trees may be done by THDC authorities in areas above the line of proposed submergence to check the migration of population of non-human primates from the area, and to enable them to rehabilitate themselves in the newer habitats.

In the light of the above facts, no noticeable adverse impact is contemplated on the mammal fauna and major wildlife of the area.

AVES (BIRDS): Presently, 73 species of birds have been recorded from the study area. Of these, none is found to be listed in Schedule I of Wildlife (Prevention) Act, 1972. Additionally, all the above species are widely and commonly distributed in Western Himalayan Ecosystem. However, it is expected that a large number of species may further be added to the present number, if detailed and systematic studies of the area are carried out for next two - three years at least. It is pertinent to mention here that the formation of the proposed reservoir with a massive water exposure of about 42 sq. km., a large number of migratory birds may be attracted to the area, thus adding to the aesthetic and tourism aspects of the project.

REPTILES: There is no information on the occurrence of crocodiles (Mager, Gharial), turtles and tortoises in the area, and it is suggested that these may be introduced into the reservoir on experimental basis. The crocodiles generally inhabit large rivers, lakes and other quieter water bodies in plains and around 600 m in the hills. Turtles and tortoises of appropriate species may also flourish well in the lake conditions. With the coming up of this reservoir, plenty of food in the form of frogs, fishes (may be introduced ones), crustaceans and other organisms may be available for the survival of these creatures.

(A) Snakes: During the present study, six species of snakes were collected from the area. Out of these, Naja naja, (the Cobra) was found to be commonly distributed both Within and Above Submergence Level localities. Another species of snake, Xenochroptis piscator Striped Keelback, an aquatic snake, is generally found along irrigation channels and the banks of streams and rivers and feeds on small fishes and frogs. Since it can thrive in static water bodies too, it is expected that the species may thrive well in the aquatic vegetation at the bank of the reservoir, where its food in the form of frogs and small fish fry will be plentiful. The population of Elopte helena, the Trinket snake and Calotes vesicolor, the garden lizard being generally arboreal in habit, may have depletive impact of the coming up reservoir even if they shift to the adjoining areas for want of proper vegetative cover. It is, therefore, suggested that the periphery of reservoir should be suitably planted by bushes, shrubs and trees. This will help not only in the rehabilitation of these animals but will also attract other group of animals like birds. The bushes, shrubs and undergrowth may provide ideal shelter to lizard also.

(B) Lizards: Four species of Lizards have been collected/ observed, of which Varanus bengalensis (Monitor lizard), though widely distributed in these area, is listed in Schedule I of the Wildlife (Protection) Act, 1972. It generally inhabits bushes along the stream and rocky forest

patches both in ASL and WSL localities of the study area. With the impoundment of the proposed reservoir, it is expected that it may shift to the neighbouring vallays. One species of rare lizard namely Cyrtodactylus fasciolatus, the band toad "Banded Gecko" has been recorded for the first time from Garhwal Hills, at Ghansali (ASL).

AMPHIBIA: Nine species of frogs and toads have been recorded which are widely distributed. Tree frog, reported earlier, from the area was not traceable during the present study. The frogs may thrive well with the coming up of reservoir, especially along the margins where lot of submerged vegetation will be available.

PISCES: During the five surveys of the proposed Tehri Dam site between May and October, 1992, the following ten species of the fishes were collected :-

1, Barilius vagra
2. Tor chelynoides
3. Tor putitora
4. Crossocheilus latius
5. Garra gotyla
6. Schizothoraichthys progastus
7. Schizothorax richardsonii
8. Nemacheilus montanus
9. Nemacheilus rupecola, and
10. Glyptothorax pectinopterus

Incidentally Barilius bendelisis, Tor tor, Labeo dero, Botia dayi, Nemacheilus beavani, N.botia, Clupisoma montana, Glyptothorax alaknandi, G.cavia, G.garhwali, Pseudecheneis sulcatus, and Mastacembelus armatus, reported by earlier workers, were not found during present study. The bottom dwelling species might have escaped the collection, but the absence of column living fishes like Barilius bendelisis, Tor tor, Labeo dero , Clupisoma montana of streams and rivers is a mater of concern. Of these Tor tor, the Red-finned Maheer is a migratory fish and like Tor Putitora also

ascend upstream for breeding and hence its non-availability may be due to the impact of dam construction activity. However, to ascertain the present status of the population of all these fishes more investigations are suggested.

It has been observed that except for Tor putitora, the Golden Mahseer and Schizothoraichthys progastus, the Snow Trout or Dinnawah, all the species are well established and are not much threatened by the construction of the Dam. Further, out of these, Tor chelynoides, the Black Mahseer and Schizothorax richardsonii, the Snow Trout or Mashin are widely distributed in rivers Bhagirathi and Bhilangna and their tributaries. However, the ripe specimens of Schizothorax richardsonii ascending for breeding have been found held up during the month of June, near the outlet of river Bhagirathi causing check on their ascend and so also the breeding. The smaller fishes like Barilius, Nemacheilus and Glyptothorax are found only in tributary streams of main rivers and may ascend further when the reservoir is gradually filled up.

Since the construction of Dam is in its advance stage and no provision has been kept for thorough "fish ladders" or "fish passes" due mainly to the height of the Dam (260.5 m. high), following provisions may be made for the conservation of the fishes, especially Mahseers and Snow Trouts.

(1) Fish Ladders or Passes: Fish ladders or passes i.e. migratory passage for the fishes ascending upstream during breeding season may be provided atleast upto the base of the main Tehri Dam or a little above and from there the fishes should be lifted up through some mechanized device and in the same way while spent fishes return to the main rivers after spawning.

The design of the fish ladder maybe of "Pool and fall" or "Step system", wherein the water level is brought down through a series of short falls and pools alternately, so that water runs down from one step or pool to another

through a passage. The falls/steps should be round-edged and low, so that the fish can ascend easily. At the end of each step, the baffle wall should have a hole enough for the fish to pass. The fishes may ascend directly or through the hole. The gradient of the slope in the pass should be such that it provides gentle flow of water. The pass should be wide enough, so that during ascent or descent, the fishes should not strike against its wall. There should be sufficient natural light in the pass so that fishes do not hesitate to enter it.

(2) Monitoring During Breeding Season: During the breeding season, when the ripe fishes ascend towards higher elevations, mostly during south-west monsoon, the period should be declared as closed season for fishing in the area. The exact breeding season of migratory fishes in the area is to be observed as spawning frequency of these species varies from drainage to drainage.

(3) Developing of Rearing Centres: The fry and fingerlings rearing centres should be developed along the course of rivers for proper management of its population. These centres should act as stocking centres for release in the main rivers.

(4) Management:

(a) Check on Devasting Means: Devastation of the fish by various means (electrocuting, dynamiting, poisoning, water pollution, excessive netting especially in breeding grounds, fish ladders and river confluences, sudden closure of canals etc.) should be stopped by enforcing strict laws.

(b) Creation of Fish Sanctuaries: The breeding grounds, river confluences, fish ladders etc., where the fishes gather in large numbers or pass through, should be declared fish sanctuaries.

(c) Public Awareness: People of the area should be educated through some incentive for saving the wildlife.

(d) Introduction of Additional Species: Some appropriate species which have no competition with local fishes for food may be introduced into the reservoir to develop reservoir fishery resources. This may be done in consultation with State Fisheries Department or Central Inland Fisheries Research Institute, Barrackpore.

(5) Design of Side Wall of Reservoir: As the reservoir will be very deep, its ~~are~~ side walls atleast upper part at appropriate places may be designed in "step or stair system" with some boulders fixed on each step. It will help the fishes which feed on slims by scrapping from the boulders or rocks.

INSECTS:

LEPIDOPTERA (BUTTERFLIES): A total of 81 species have been collected from the study area, both from above and within submergence level localities. Of these, only two species viz., Hypolimnas missipus (Danaid egg fly) is listed in Schedule I of Wildlife (Prevention) Act, 1972. All the above species are widely and commonly distributed in Himalayan Ecosystem, both altitudinally and latitudinally, except Diagora persimilis and Athyma assura which are rare. Since the butterflies feed on foliage and flowers/fruits both in larval and adult stage, therefore, it is essential that keeping in view the rich fauna of Lepidoptera in the study area, the THDC authorities must make provision for a simultaneous afforestation programme of the common host plants in the "trauma zone", which are likely to be submerged consequent upon the impoundment of the reservoir. Besides butterflies form an important constituent of the food chain in nature for the birds and hence any depletion in butterfly population is likely to affect the avi-fauna also.

ODONATA (DRAGON AND DAMSEL FLIES): In all 29 species of dragonflies and damselflies have been collected both from lentic and lotic water bodies in the study area. Of the above species, Orthetrum triangulare triangulare, is found to be commonest both in distribution and abundance.

However, all other species are also widely distributed in the western Himalayan ecosystem. None of the species is endemic to the area.

Since the Odonata is a group of Amphibiotic insects creation of any additional aquatic biotope, like the proposed reservoir, will have a very beneficial impact on the restoration of Odonata fauna, depleted so far by the human activities in the study area. It is presumed that a large number of static water breeding species will colonise the reservoir and in turn their aquatic larvae will play a vital role in the food chain of the aquatic ecosystem.

HYMENOPTERA (WASPS): In all 23 species of which none is endemic, have been recorded from the study area. All the above species are widely distributed.

No adverse impact of the proposed reservoir, is contemplated.

ARACHNIDA AND MYRIAPODA: A total of 21 species of spiders and two species of scorpions and two species of centipedes have been recorded and none is endemic or threatened.

No adverse effect is envisaged.

FUTURE PLAN OF ACTION

Since the present project is going to be a unique one in the foot hills of the Western Himalaya and as such will have a great impact on the overall environment including the faunal components, not of the reservoir area alone, but on the surroundings as well. It is , therefore, felt necessary that a regular monitoring and appraisal of the faunal components must be carriedout both during impoundment as well as afterwards to formulate long term planning of the faunal conservation and management.

ANNEXURE -I

LIST OF PROTECTED SPECIES (FAUNA) IN THE PROPOSED TEHRI DAM RESERVOIR AREA

A. WILDLIFE (PROTECTION) ACT, 1972

Mammalia:

1. Felis bengalensis horsefieldi Gray - Leopard Cat
2. Panthera pardus Linnaeus - Leopard

Aves:

Aves:

1. Accipiter nisus melaschistos Hume, Indian Sparrow-Hawk

Reptilia:

1. Varanus bengalensis (Daudin)

Arthropoda : Insecta : Lepidoptera :

1. Hypolimnas misippus Linnaeus

B. ICUN RED DATA BOOK : List of threatened species

Mammalia :

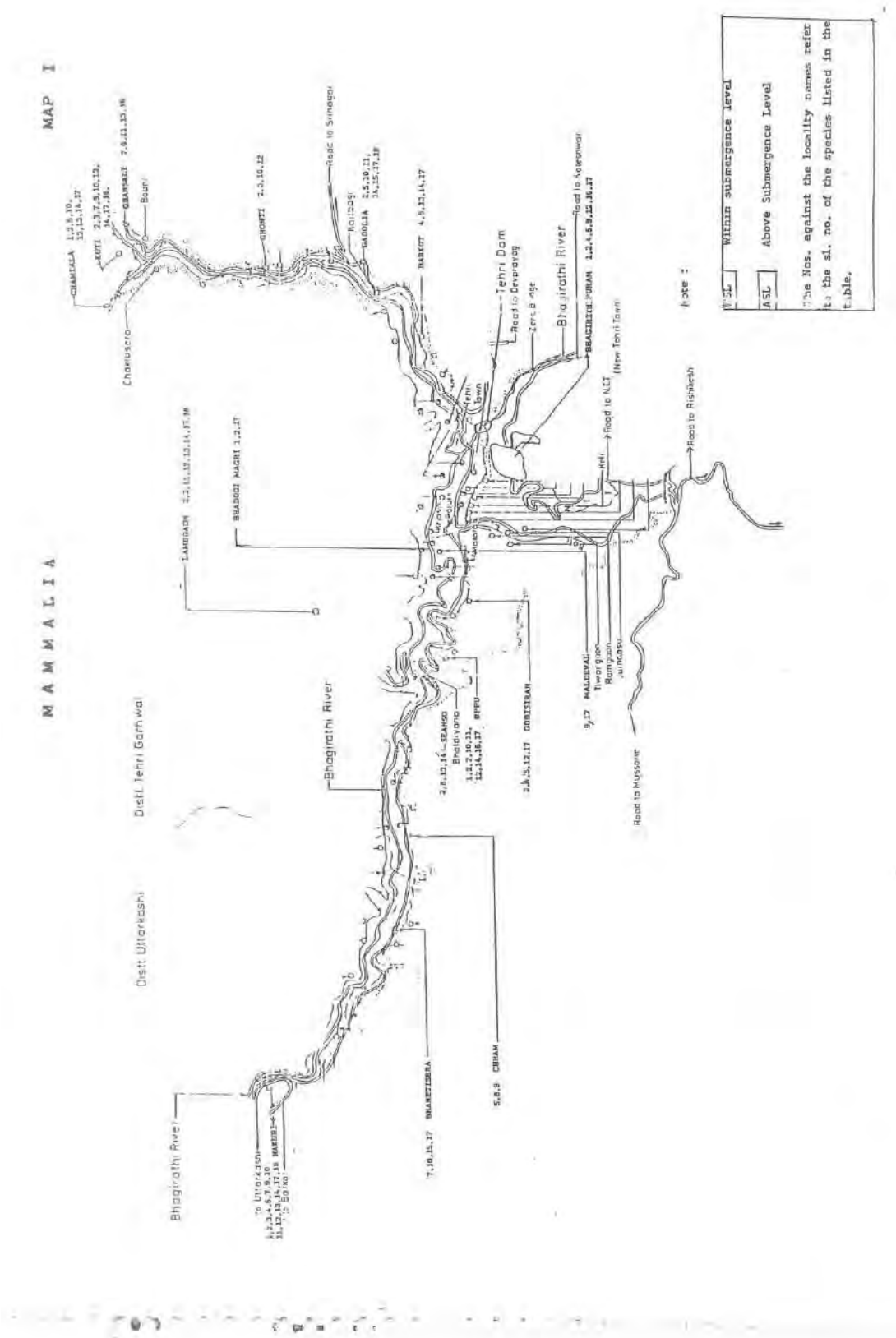
1. Panthera pardus Linnaeus - Leopard

Status - Threatened

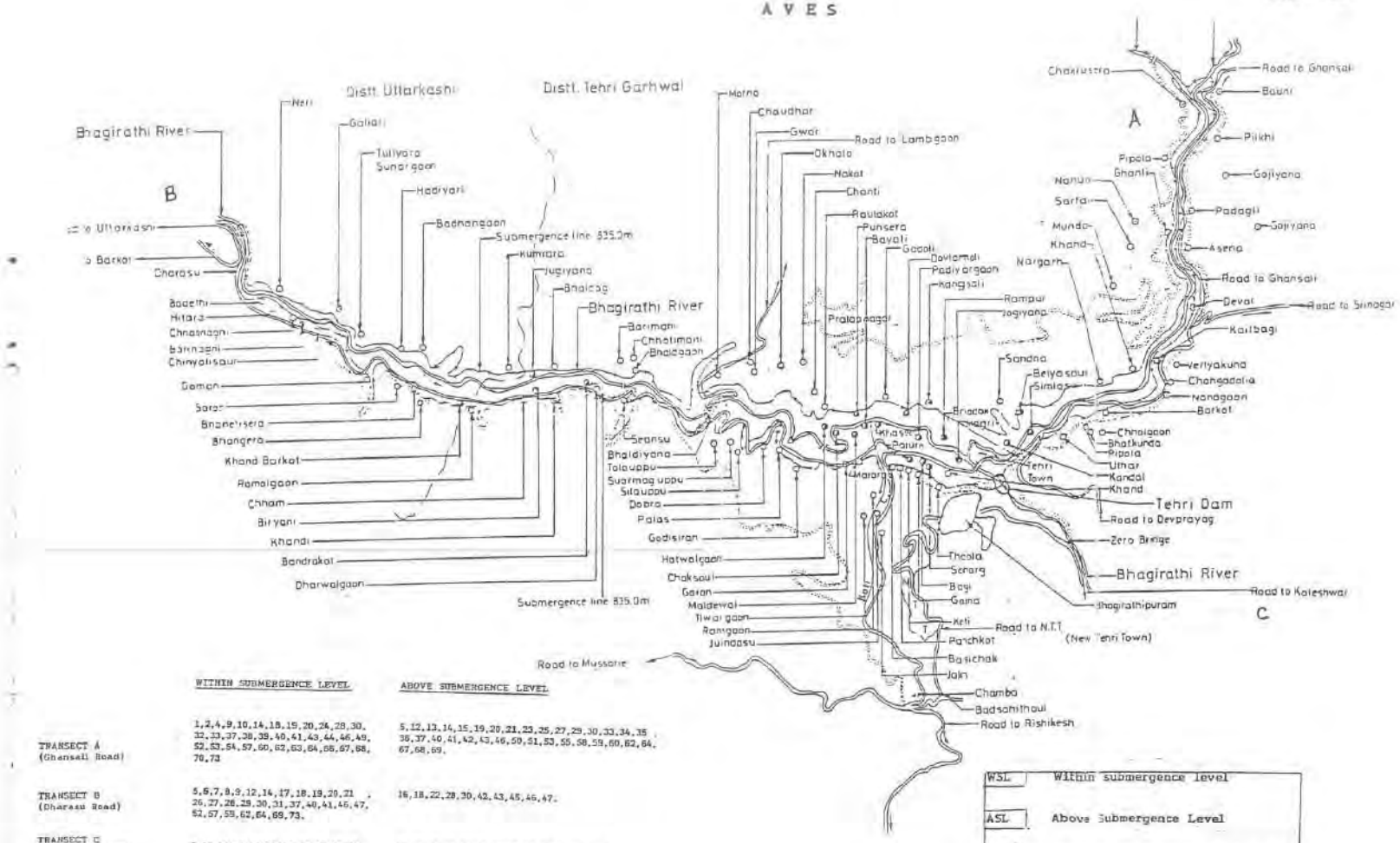
Aves:

1. Haliaeetus leucoryphus (Pallas), Ringtailed or Pallas's Fishing Eagle

Status - Rare


MAP I
MAMMALIA
Distt Tehri Garhwal
Distt Uttarkashi
Bhagirathi River
Tehri Dam
Road to Devprayag
Zero Bridge
Road to Kotespwar
Road to NIT
(New Tehri Town)
Road to Rishikesh
Road to Mussoorie
Road to Sundgoh
Chaurasera
Baun
Bhagirathi River
Within submergence level
Above Submergence Level
The Nos. against the locality names refer to the sl. no. of the species listed in the table.

A V E S



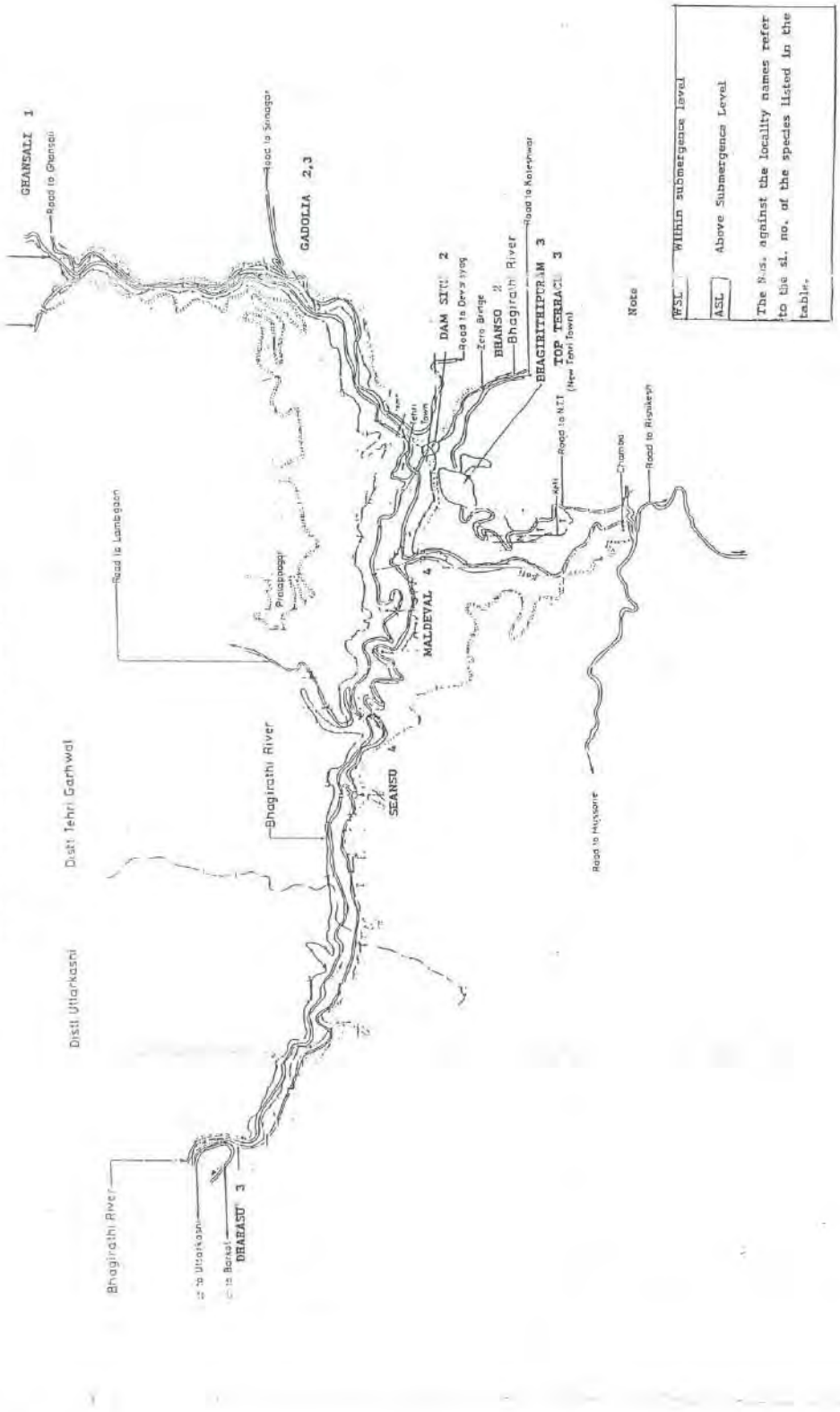
	WITHIN SUBMERGENCE LEVEL	ABOVE SUBMERGENCE LEVEL
TRANSECT A (Ghansali Road)	1,2,4,9,10,14,18,19,20,24,28,30, 32,33,37,38,39,40,41,43,44,46,49, 52,53,54,57,60,62,63,64,66,67,68, 70,72	5,12,13,14,15,19,20,21,23,25,27,29,30,33,34,35 36,37,40,41,42,43,46,50,51,53,55,58,59,60,62,64, 67,68,69.
TRANSECT B (Dharasu Road)	5,6,7,8,9,12,14,17,18,19,20,21 , 26,27,28,29,30,31,37,40,41,46,47, 52,57,59,62,64,69,73.	16,18,22,28,30,42,43,45,46,47.
TRANSECT C (Koteshwar Road)	3,11,12,13,19,21,30,31,42,43,48 , 67.	22,30,35,37,43,47,49,52,53,56,57,65,71,72
TRANSECT D (Top Terrace only)		2,20,23,27,34,41,45,46,47,59,60,61,69,73.

WSL	Within submergence level
ASL	Above Submergence Level

The Nos. against the locality names refer to the sl. no. of the species listed in the table.

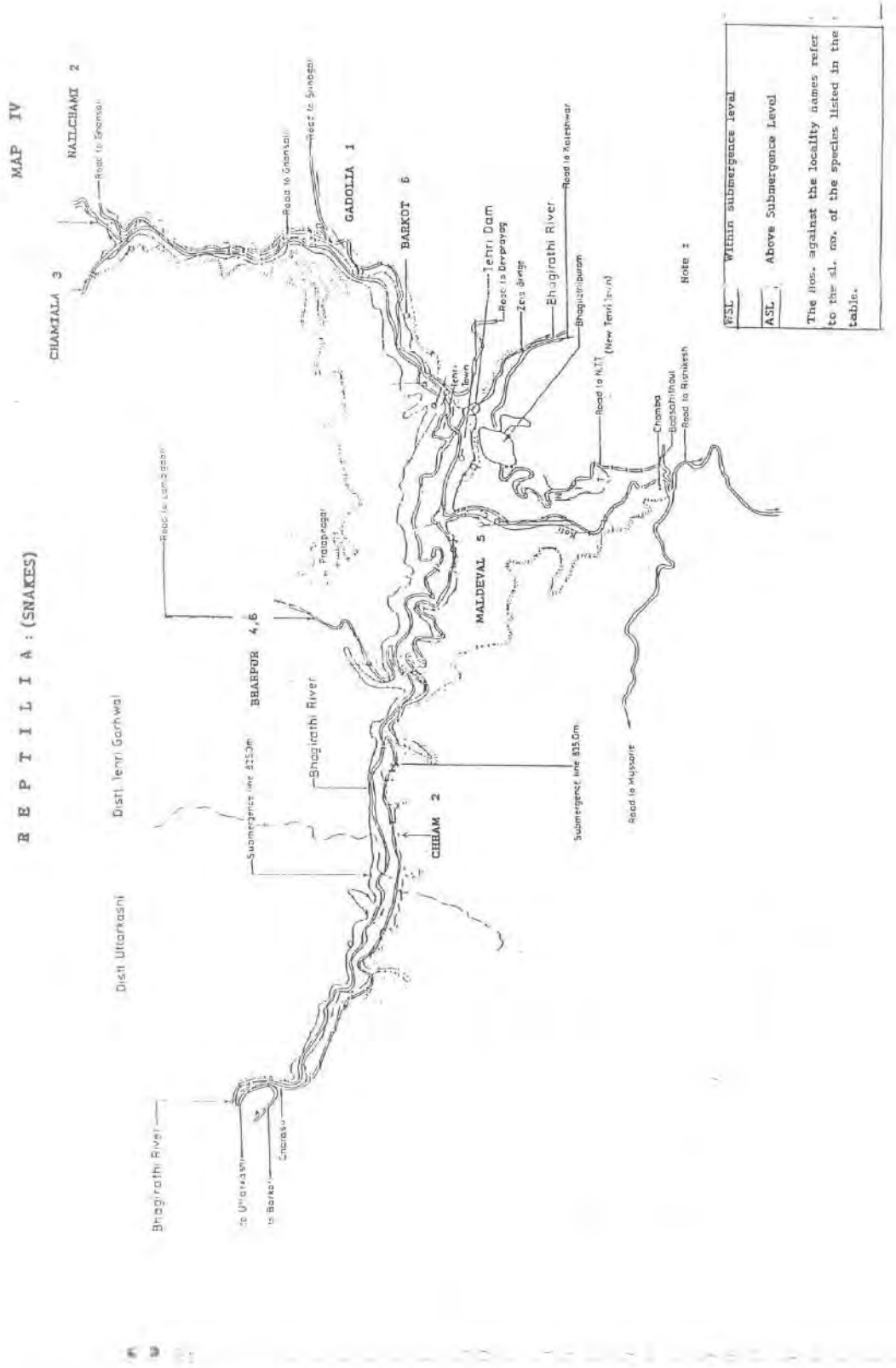
MAP III

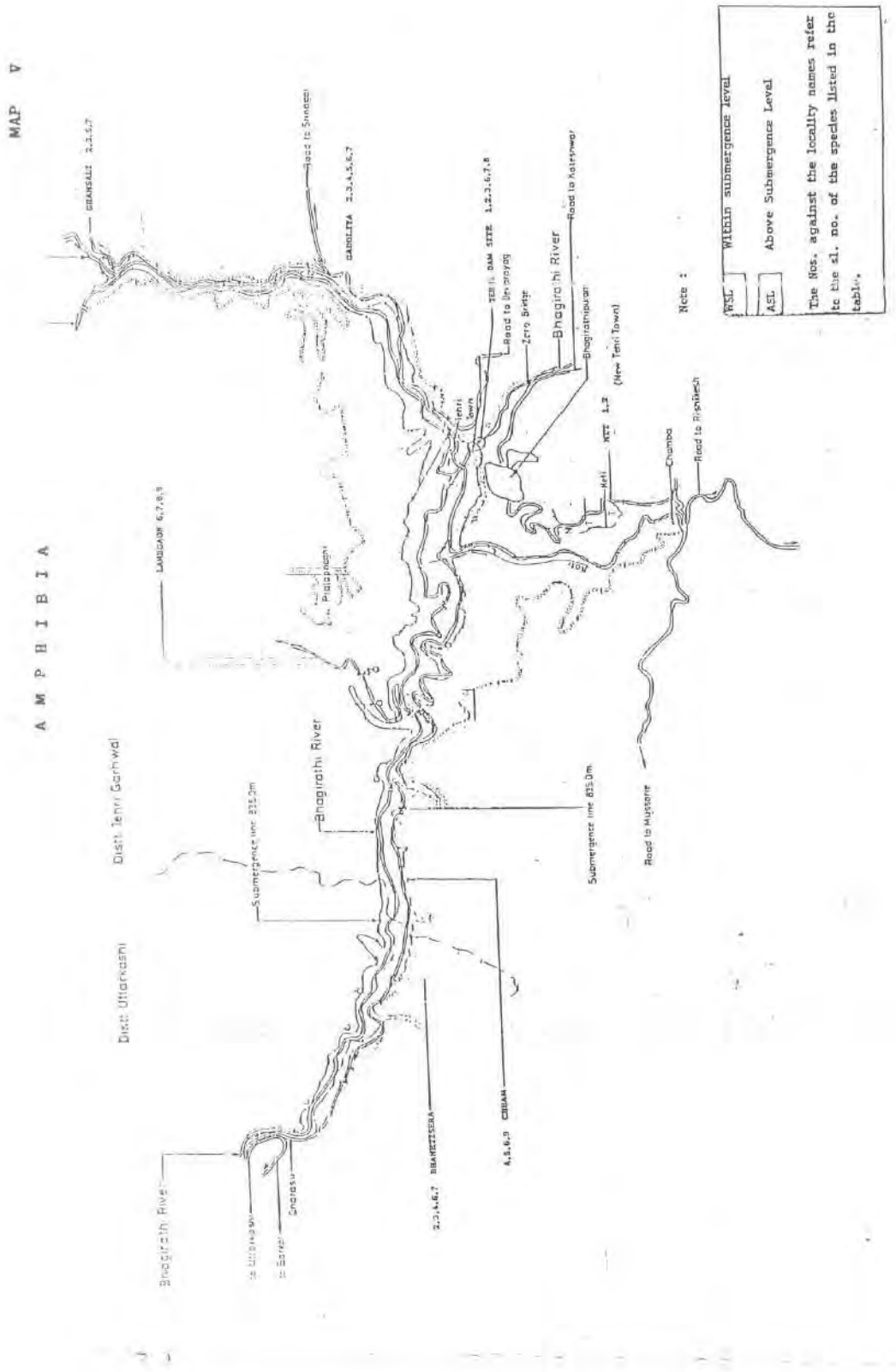
REPTILIA : (LIZARDS)



MAP IV

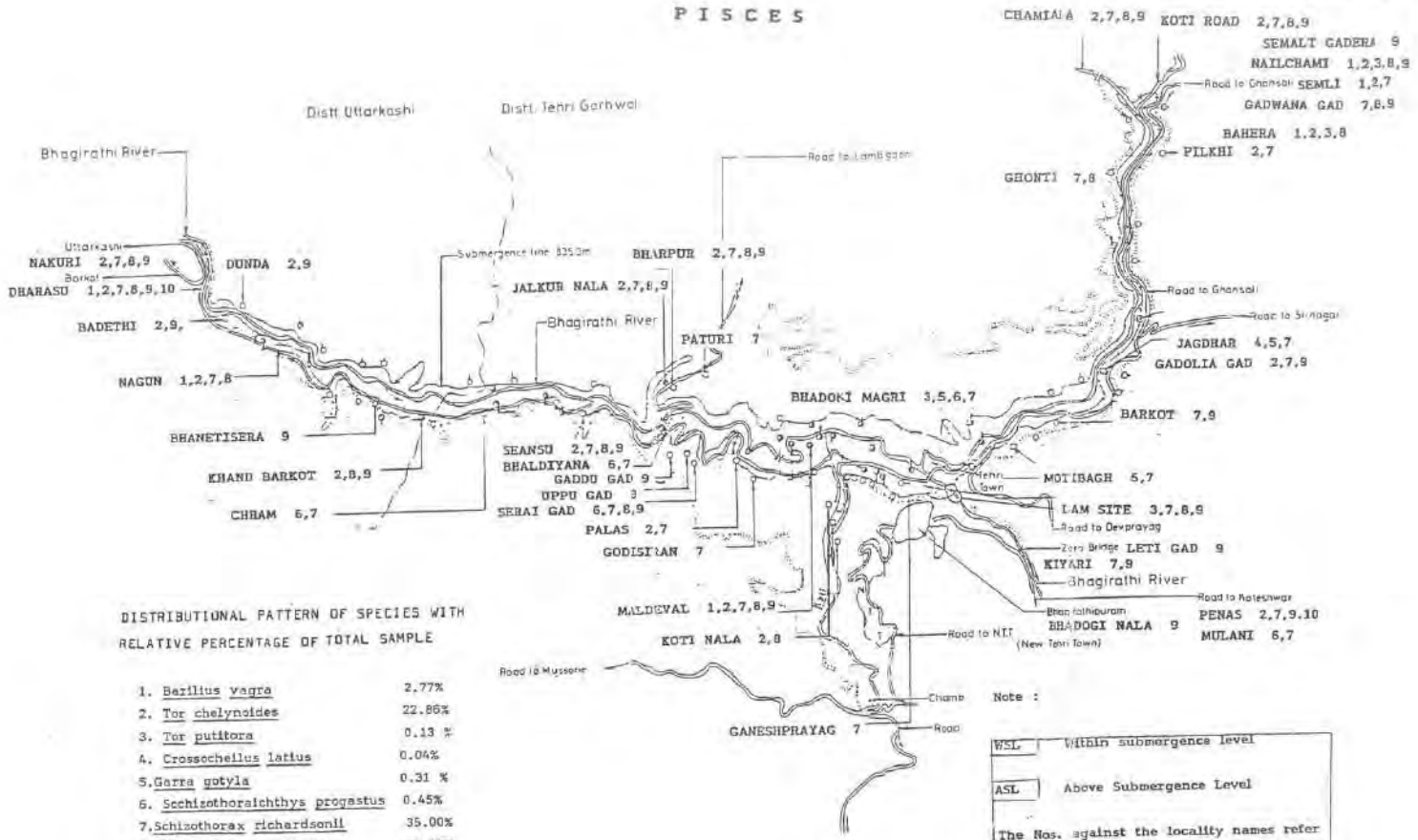
REPTILIA : (SNAKES)




MAP V
AMPHIBIA
Dist Tehri Garhwal
Dist Uttarkashi
Bhagirathi River
Bhagirathi River
Submergence line 835.0m
Submergence line 835.0m
Road to Mussorie
Road to Rishikesh
Chamba
Tehri
(New Tehri Town)
Bhagirathipuram
Zero Point
Road to Uttarkashi
Road to Koteshwar
Road to Sundesi
Pilalogani
Ghansali
Bhatwari
Gadoliya
Tehri Dam Site
Landsdor
Brahmkhal
Chiram
Bhagirathi River
Note :
FRL Within submergence level
ASL Above Submergence Level
The Nos. against the locality names refer to the sl. no. of the species listed in the table.

MAP VI

PISCES



DISTRIBUTIONAL PATTERN OF SPECIES WITH RELATIVE PERCENTAGE OF TOTAL SAMPLE

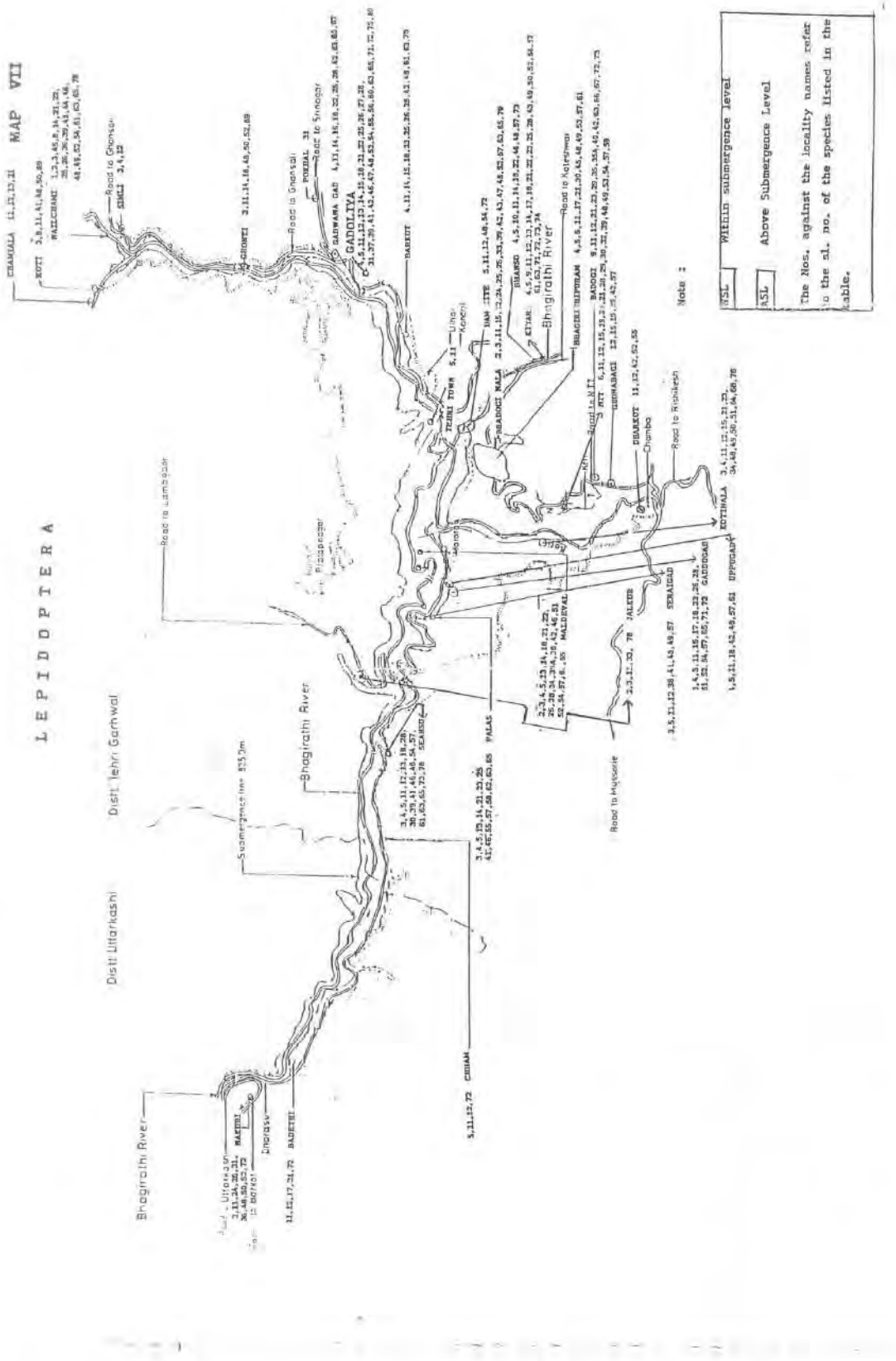
1. Barilius vagra	2.77%
2. Tor chelynoides	22.86%
3. Tor putitora	0.13 %
4. Crossocheilus latius	0.04%
5. Garra gotyla	0.31 %
6. Schizothoraichthys progastus	0.45%
7. Schizothorax richardsonii	35.00%
8. Nemacheilus montanus	15.53%
9. Nemacheilus rupecola	22.82%
10. Glyptothorax pectinopterus	0.09%

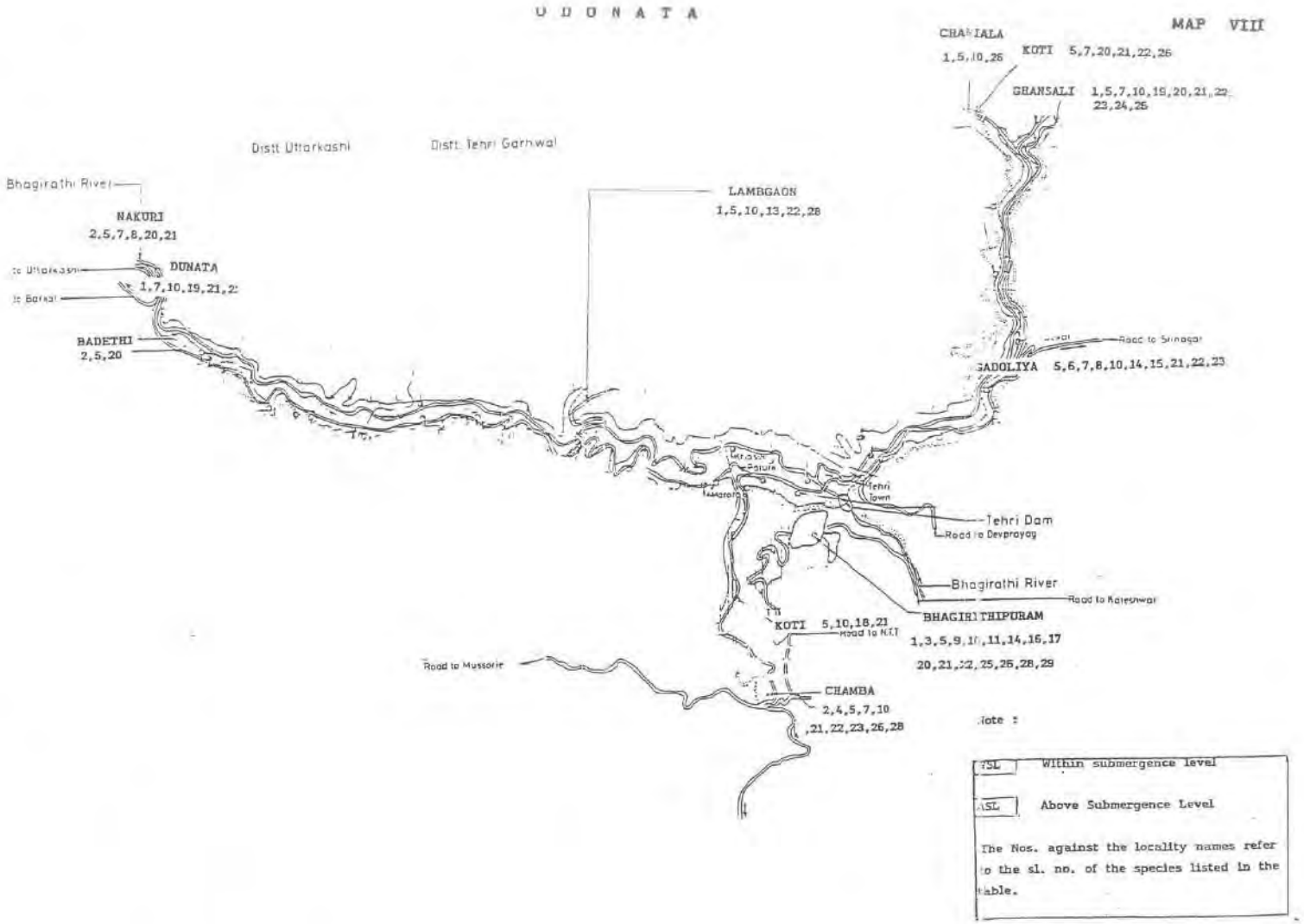
Note :

WSL | Within submergence level

ASL | Above Submergence Level

The Nos. against the locality names refer to the sl. no. of the species listed in the table.


MAP VII
LEPIDOPTERA
Distt Uttarkashi
Distt Tehri Garhwal
Bhagirathi River
Submergence line 835m
Road to Uttarkashi
Road to Ghansali
Road to Chamba
Road to Rishikesh
Road to Mussoorie
Road to Kaliasaur
Road to Kaliasaur
Note :
WSL Within submergence level
ASL Above Submergence Level
The Nos. against the locality names refer to the sl. no. of the species listed in the table.


U D U N A T A
MAP VIII
CHAMBALA
1,5,10,26
KOTI 5,7,20,21,22,26
GHANSALI 1,5,7,10,19,20,21,22,
23,24,25
Distt Uttarkashi
Distt. Tehri Garhwal
Bhagirathi River
NAKURI
2,5,7,8,20,21
DUNATA
1,7,10,19,21,2
to Uttarkashi
to Barkot
BADETHI
2,5,20
LAMBGAON
1,5,10,13,22,28
Road to Srinagar
GADOLIYA 5,6,7,8,10,14,15,21,22,23
Tehri Dam
Road to Devprayag
Bhagirathi River
Road to Koteshwar
BHAGIRATHIPURAM
1,3,5,9,10,11,14,16,17
20,21,22,25,26,28,29
KOTI 5,10,18,21
Road to N.I.T
Road to Mussorie
CHAMBA
2,4,5,7,10
,21,22,23,26,28
Note :
WSL Within submergence level
ASL Above Submergence Level
The Nos. against the locality names refer to the sl. no. of the species listed in the table.

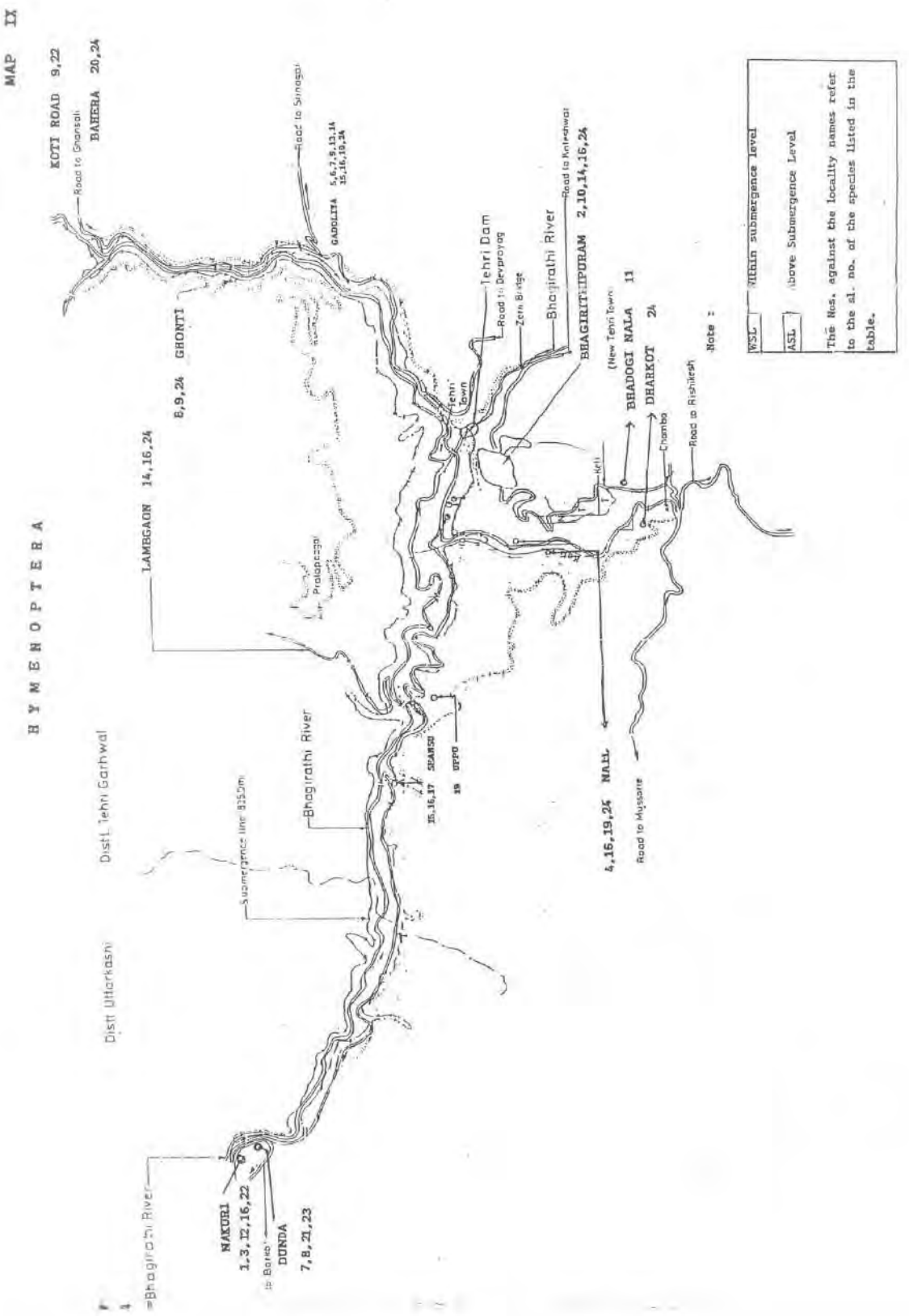
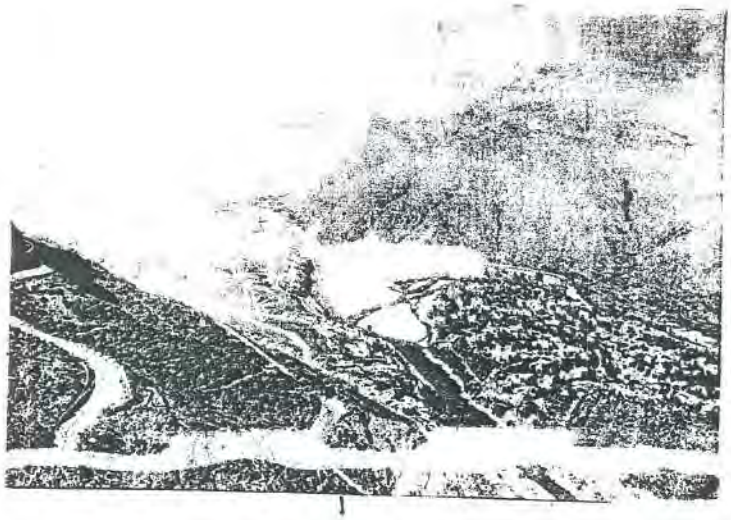

MAP IX
HYMENOPTERA
KOTI ROAD 9,22
Road to Ghansali
BAHERA 20,24
Road to Srinagar
GADOLITA 5,6,7,9,13,14 15,16,19,24
GHONTI 8,9,24
LAMBGAON 14,16,24
Pratapnagar
Tehri Dam
Road to Devprayag
Zero Bridge
Bhagirathi River
Road to Krishnapur
BHAGIRATHIPURAM 2,10,14,16,24
Tehri Town
(New Tehri Town)
Kirti
BHADOGI NALA 11
DHARKOT 24
Chamba
Road to Rishikesh
Note :
WSL Within submergence level
ASL Above Submergence Level
The Nos. against the locality names refer to the sl. no. of the species listed in the table.
Distt Tehri Garhwal
Distt Uttarkashi
Submergence line 935m
Bhagirathi River
15,16,17 SEARSIA
19 UPPO
4,16,19,24 NAIL
Road to Mussoorie
NAKURI 1,3,12,16,22
to Bareth
DUNDA 7,8,21,23
Bhagirathi River

PLATE I

1. A view of the confluence of R.Bhagirithi and R.Bhilangana, also showing the Old Tehri Town.

2. Zero point of the proposed reservoir (WSL).



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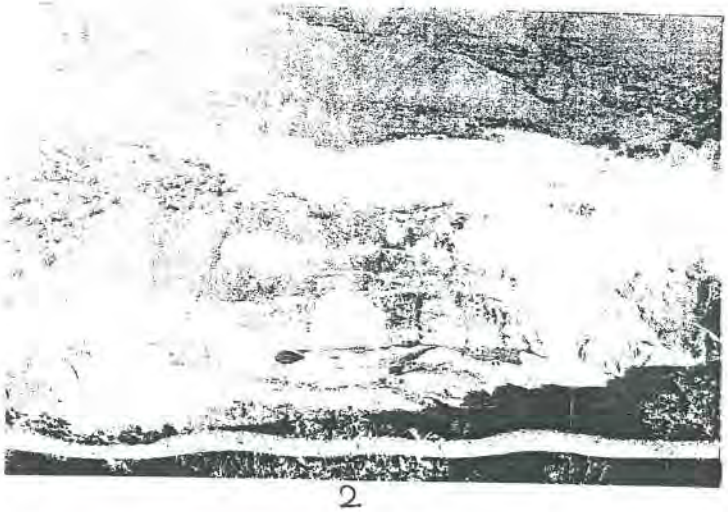

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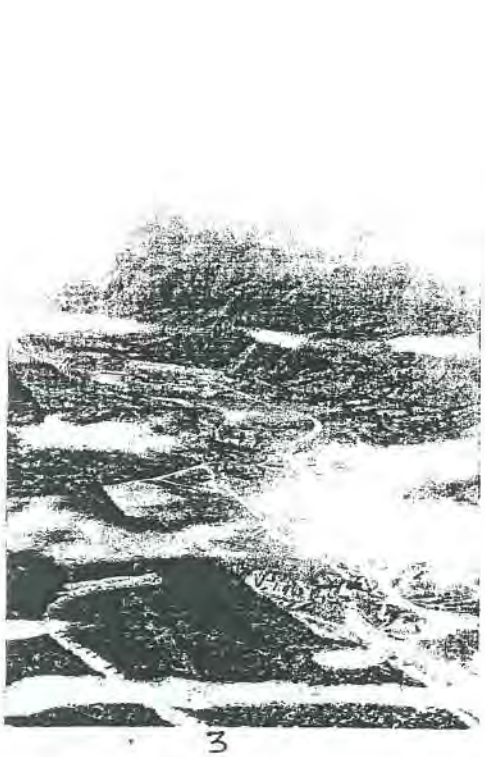
PLATE II

3-5. Proposed Dam Site.



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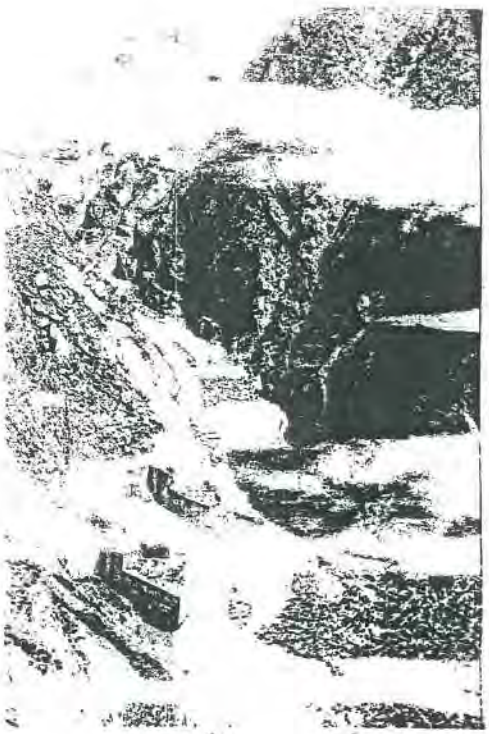

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PLATE III

6. Panoramic view of the WSL area along the R. Bhilangana.
7. Sampling of aquatic fauna from R. Balganga at Chamiala (ASL).
8. R. Bhilangana near Ghunti (WSL).

6

7

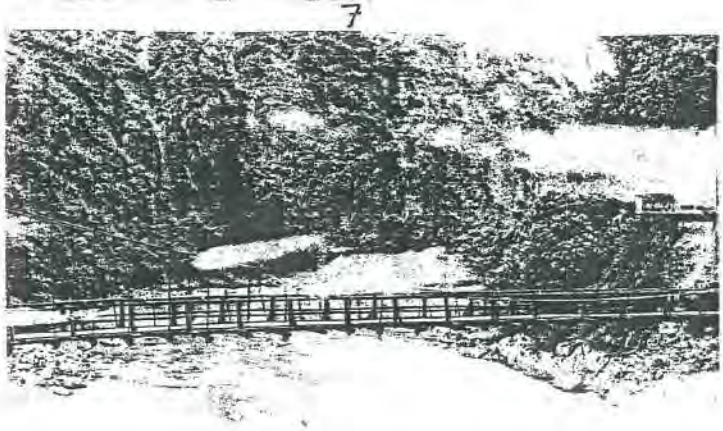
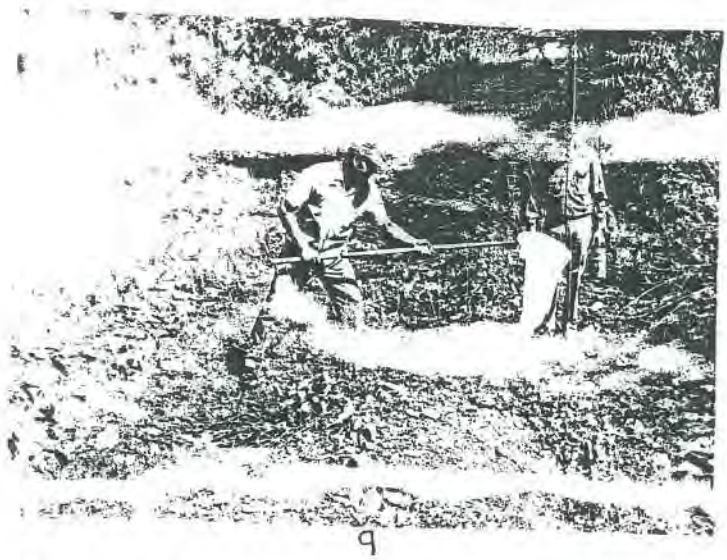


PLATE IV

9. Sampling of phytophagous fauna along Dharasu Road (WSL).
10. Sampling of aquatic fauna from a tributary of R. Bhagirithi (WSL).
11. Sampling of aquatic fauna from R. Bhagirithi (WSL)



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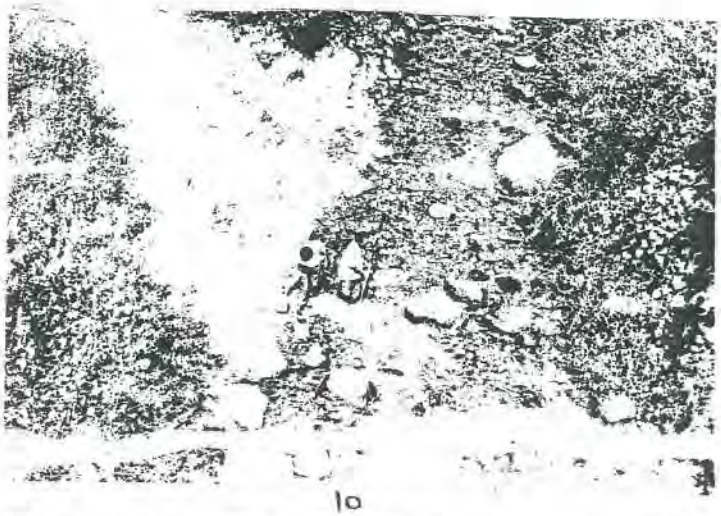

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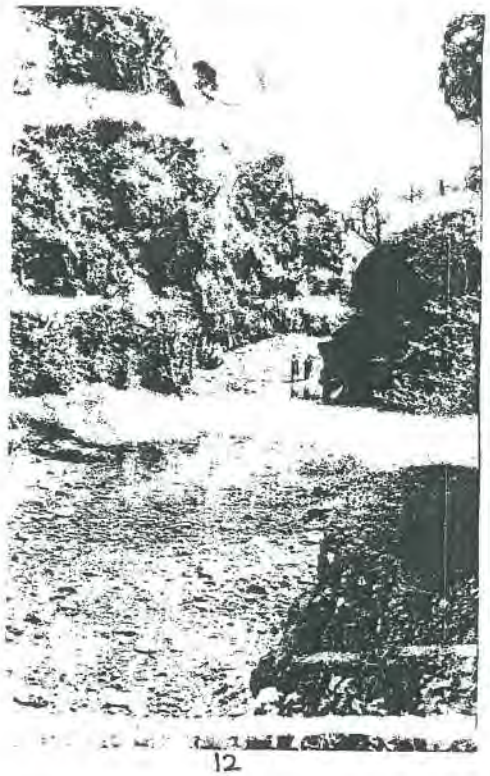
PLATE V

12. Sampling of aquatic fauna along Jalkur stream.
13. A view of a tributary of Jalkur stream near village Paturi.



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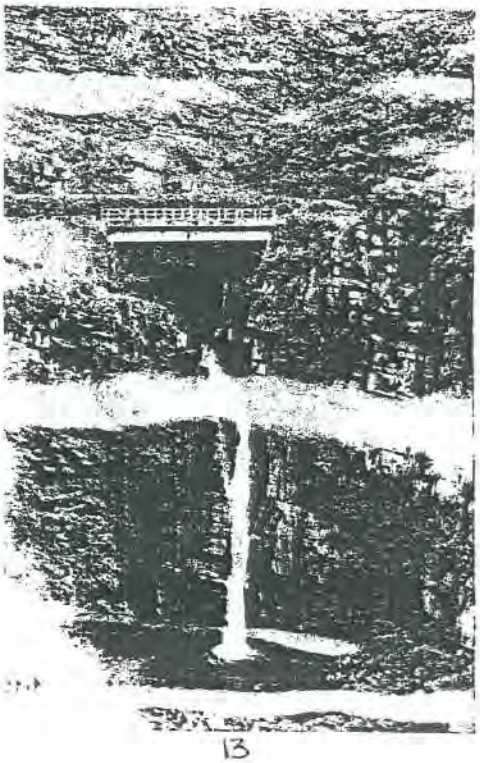

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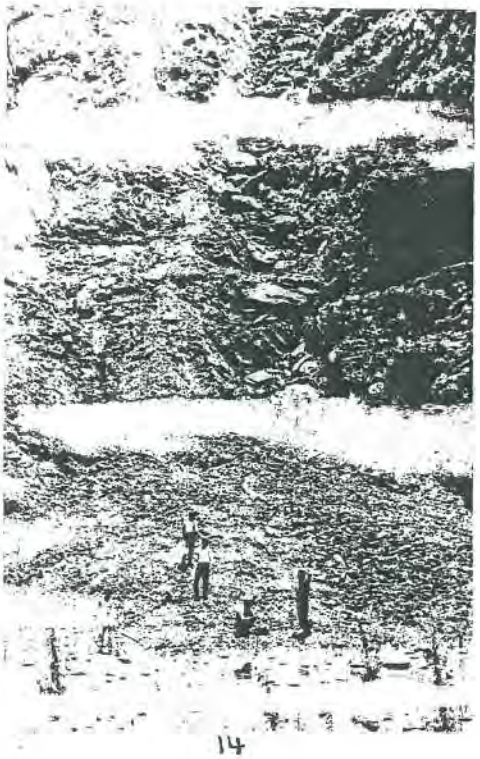
PLATE VI

14. Sampling of terrestrial fauna (WSL) along Koteshwar Road.
15. A view of R. Bhilangana gorge along Kotehwar Road to be submerged (WSL).
16. Sampling of aquatic fauna from R. Bhagirithi along Koteshwar Road (WSL).



14

15

16

PLATE VII

17. Forest dwelling troup of rhesus macaque along Koteshwar Road.
18. A village troup of rhesus macaque at feed in agricultural field along Ghansali Road.
19. A solitary rhesus male at Top Terrace.

17

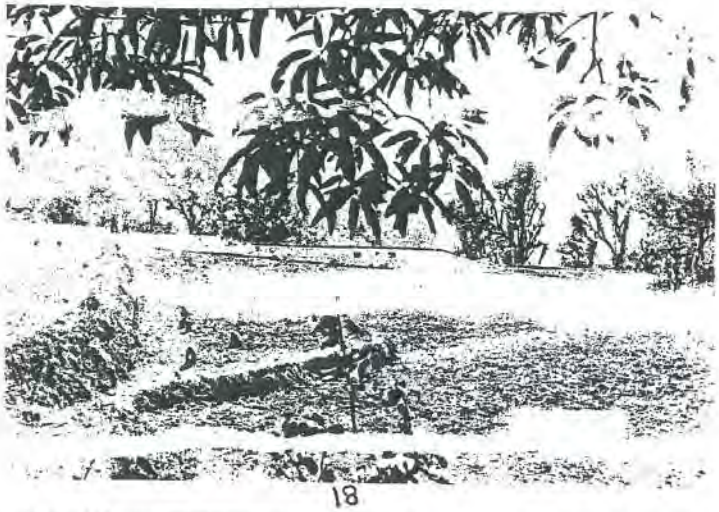


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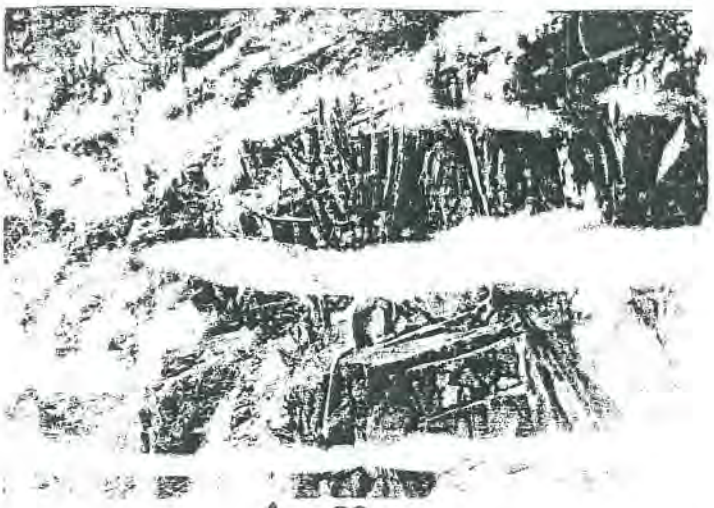
PLATE VIII

20. A solitary Hanuman Langur on Lambgaon Road.
21. Pug-marks of Leopard near Kiari on Koteshwar Road



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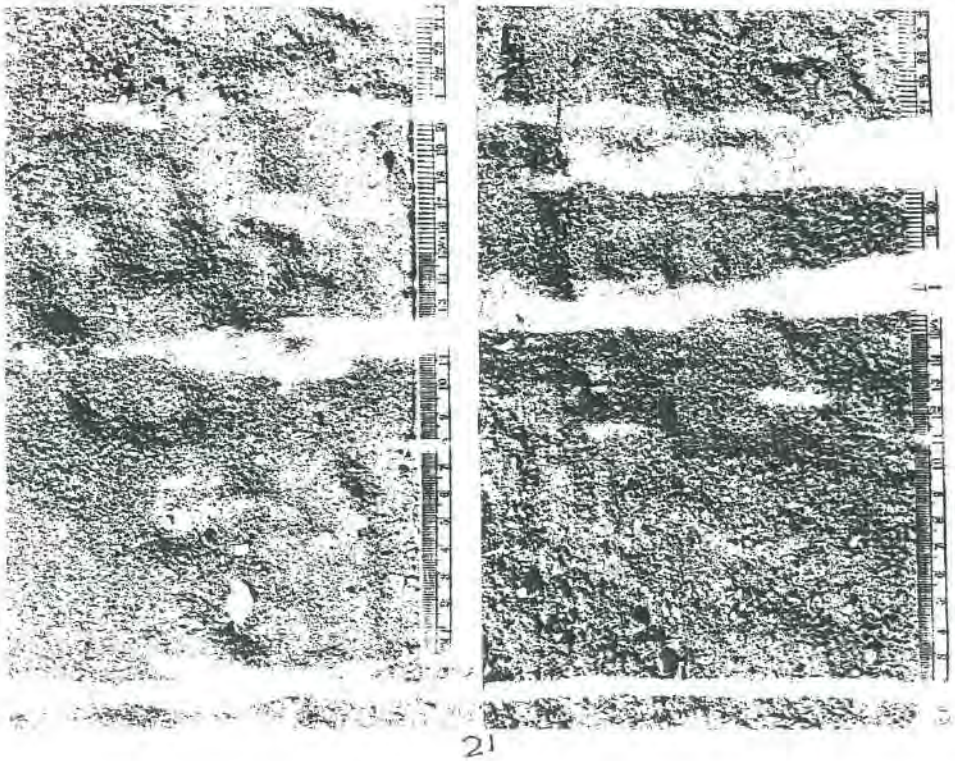

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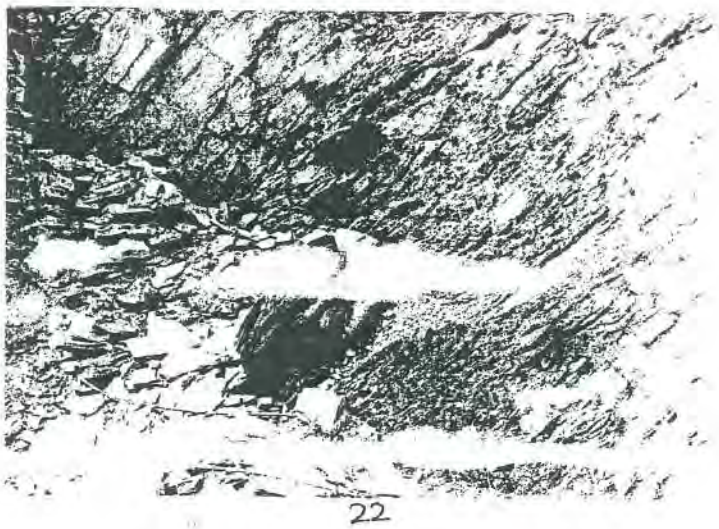
PLATE IX

22. White-backed Vulture at New Tehri.
23. Nest of White-backed Munia on a Mulberry tree at Ghansali (ASL).



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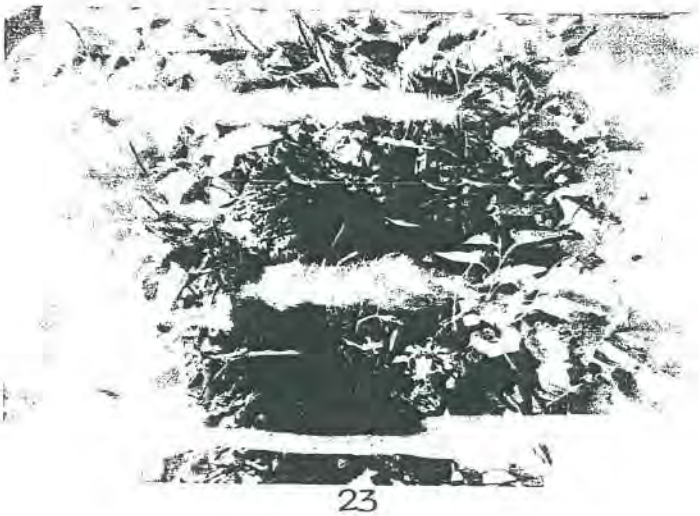

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24. Bent-toad Banded Gecko, a nocturnal lizard collected from Ghansali-Tilwara Road (ASL).
25. A rock lizard commonly found in study area.
26. A specimen of Trinket snake.

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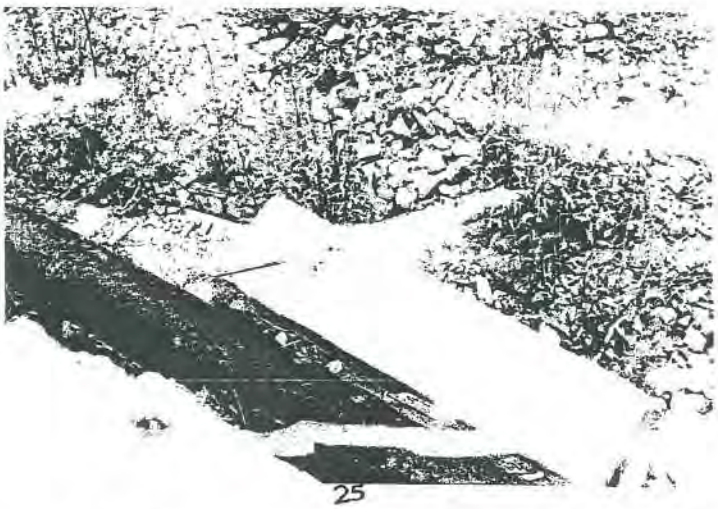

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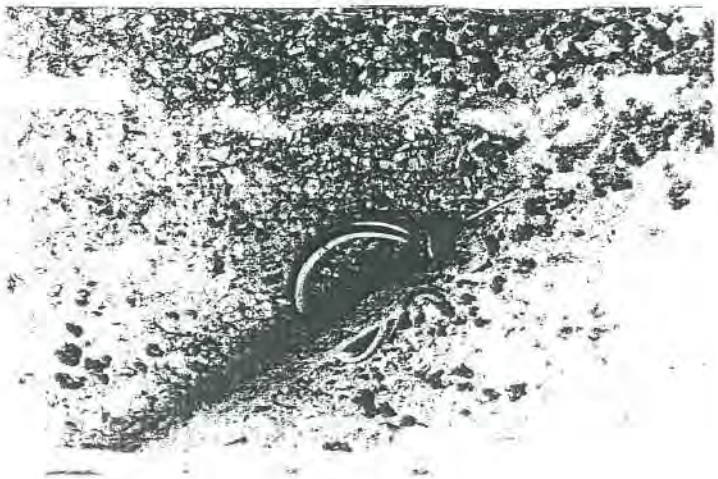
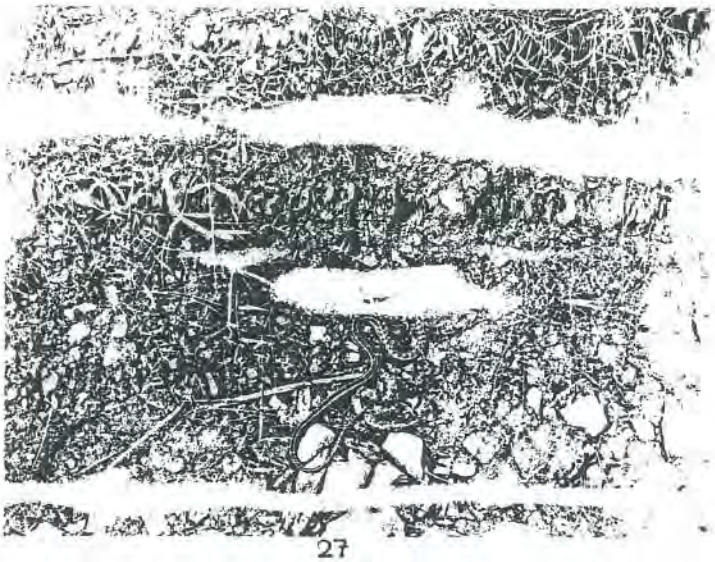


PLATE XI

27. A specimen of Keelbacked snake.
28. A Rat snake.
29. A injured specimen of Cobra snake.



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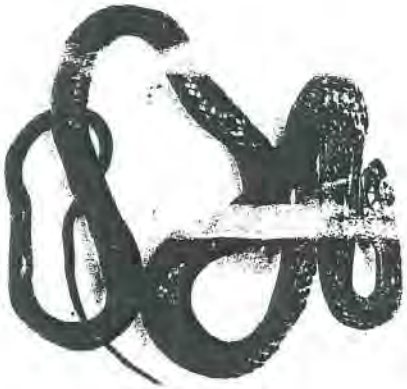

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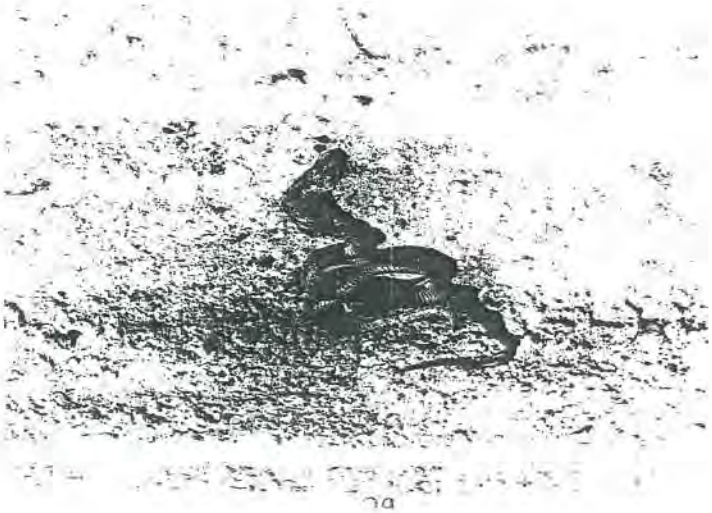

PLATE XII

30. A mounted pair of Toad.

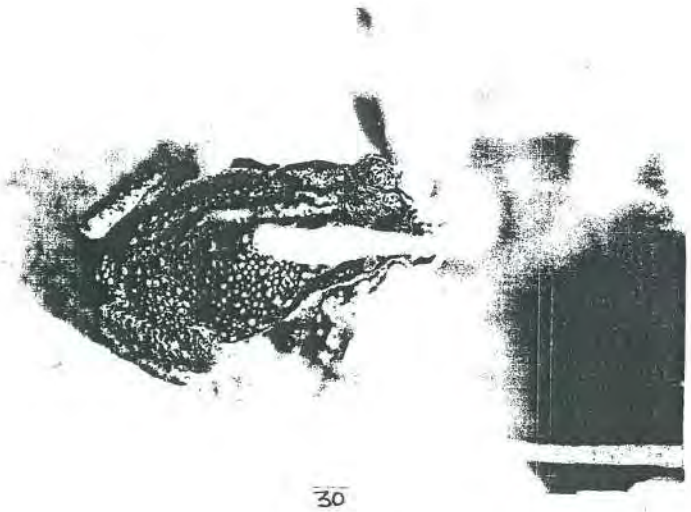

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PLATE XIII

31. Specimens of Vagra Baril.
32. The commonest fish of the study area, Richardson's Snow Trout.
33. Specimens of Latia.


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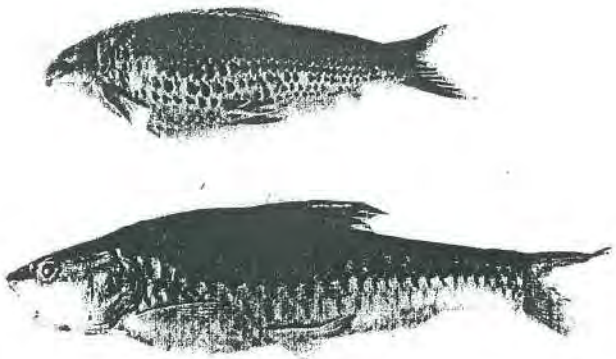
34. The Golden Mahaseer.
35. Dorsal and ventral views of Stone Fish.
36. Specimens of different age groups of Black Mahaseer.



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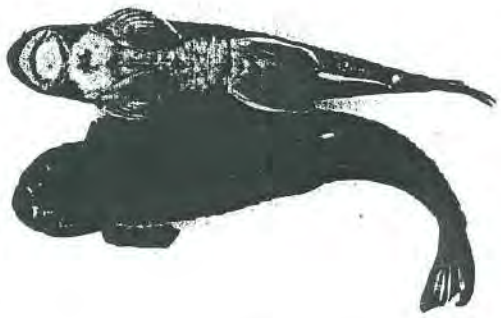

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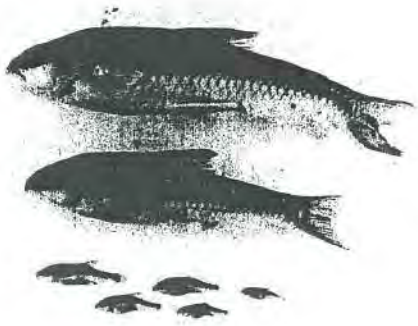

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PLATE XV

37. A Nymphalid butter-fly resting at a marshy place.
38. Another Nymphalis butter-fly alighting on a Lantana bush.
39. A dragon fly.
40. A leaf nest of spider.

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and compressed body with strongly keeled, spine-like dorsal row of scales and long tail. It is sandy grey in colour with more or less distinct dark brown cross bars above and on sides. It feeds primarily on insects; small birds, nestlings, frogs, etc. are also sometimes taken. The female lays 11 - 23 eggs in a clutch in a hole dug on soft soil under bushes during hot season.

These lizards were seen or collected from various localities (Dharasu, Chham, Gadolia, Top Terrace etc.) within and above the proposed line of submergence. The longest specimen measured 29 cm. With the submergence of their habitats, these lizards may shift to the adjoining area where bushes, shrubs and forest vegetation are easily available. To rehabilitate these lizards in the periphery of the reservoir, special care for growing vegetation will be useful.

4. Varanus bengalensis - Monitor Lizard

Local Name : Goh

It is widely distributed lizard and generally inhabits all types of biotopes from evergreen forests to the fringes of desert. It is giant in size, measuring upto 1.75 m in length, with elongated and flattened body, compressed tail and strong limbs. It is olive-grey with sparse black spots. It is carnivorous, feeding on small mammals, birds, lizards, snakes, fish, crustaceans, insects, spiders etc. The female lays 8 - 30 eggs in a clutch in a hole dug by her in debris under bushes during hot season.

During the present work, these lizards were generally encountered while crossing the road or basking in open along the nala side or trying to hide in the rock crevices or under the roadside bushes in all the three transects i.e. Ghansali, Dharasu and Koteshwar road sides. An adult specimen was collected near Siasu. The species is very common in the area. It has been included under Schedule I of Wild Life (Protection) Act, 1972 as it is much sought for the trade of its skin. The lizards may move to the adjoining areas when the reservoir is impounded.

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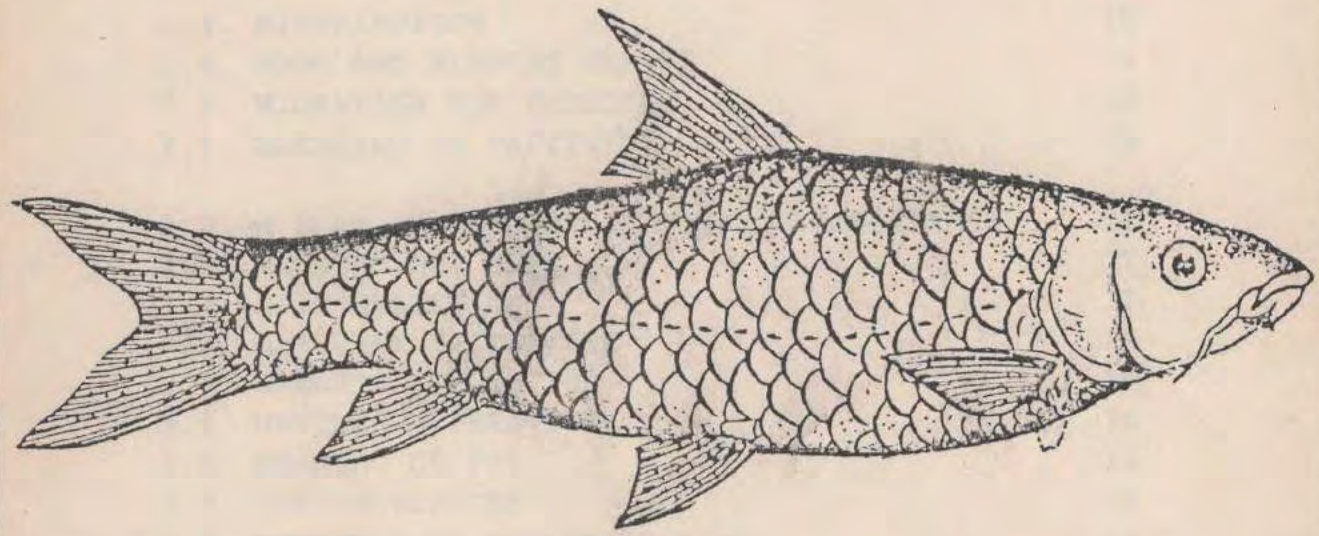
Annexure R/5

ACTION PLAN FOR MITIGATING THE POSSIBLE IMPACT ON MAHSEER FISHERY DUE TO CONSTRUCTION OF TEHRI DAM



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DELHI - 110 095

April 1994

CONTENTS

SUMMARY

SUMMARY

The Tehri Hydro Development Corporation (THDC) got prepared an Environmental Impact Assessment Study of the Tehri dam by the Zoological Survey of India (ZSI), who in their study recommended that action was needed for conservation of Mahseer fish which may not be able to ascend the river Bhagirathi across the Tehri dam for spawning purpose.

As the report of the ZSI did not contain the detailed action plan for conservation of Mahseer fish, the THDC engaged the Tropical Fisheries Consultancy Services (TFCS) to prepare an action plan for mitigating the possible adverse effects on Mahseer fishery due to the construction of the Tehri dam as well as to suggest other measures for enhancing fishery resources of Bhagirathi river.

The Tehri and Koteshwar dams on completion would obstruct the passage of Mahseers to reach the upper reaches of river Bhagirathi as well as river Bhilangana. Construction of fish ladders/passes with mechanical lifting devices on Tehri and Koteshwar dams would neither ensure the passage of Mahseers nor would be operationally effective. Even if Mahseers are allowed to go over these dams, the physico-chemical conditions above the Tehri dam would not be conducive for their natural breeding. Construction of such ladders/passes with mechanical lifting devices is also exorbitantly costly which would be infructuous in all probability and hence this recommendation of ZSI is not suggested to be executed.

It is recommended that a fish seed farm be established at an estimated cost of Rs.21 lakhs, for breeding of Mahseer artificially, produce the seed (fingerlings) and stock the Tehri & Koteshwar reservoirs to rehabilitate the Mahseer population in river Bhagirathi.

In order to enhance the fisheries resources, it is recommended that the fingerlings of important food fishes be raised, acclimatised in a rearing centre to be established at an estimated cost of Rs.13.60 lakhs and stocked in the reservoirs which is expected to yield a fish production of about 150 tons per year creating additional employment and income generating opportunities.

In order to create public awareness towards conservation of fish and wild life, it is proposed that an aquarium may be established at the New Tehri Town, which also would serve as a tourist attraction.

With the rehabilitation of Mahseer fishery in river Bhagirathi and reservoirs at Tehri & Koteshwar, there would be good scope for sport fishing for which an angling association be organised. Sport fishing could also be a major tourist attraction.

Other management recommendations like enforcing laws to ban destructive methods of fishing, declaration of closed seasons & fish sanctuaries, fall within the purview of the State Govt. (Fisheries, Forests and other Departments), who may initiate necessary action in this regard.

Another recommendation of the ZSI to construct steps/stairs and providing boulders on the side walls of reservoirs is neither necessary nor practicable as periphyton would grow naturally on the rocky face of the sides of the reservoir.

In order to facilitate implementation of the action plan suggested, this report also contains the details of possible sites for establishing fish seed farm, rearing centre, aquarium etc., their suggested designs, tentative layouts and cost estimates.

1. INTRODUCTION

1.1. BACKGROUND

1.1.1. The Tehri Hydro Development Corporation Ltd. (THDC) had entrusted the work of Faunal Analysis of the Bhagirathi River system to the Zoological Survey of India (ZSI) as a part of the overall Environmental Impact Assessment Study. The final report of the ZSI on the Faunal Analysis indicates the availability of only 10 species of fish and pointed out that the Mahseer fishery is likely to be affected due to construction of Tehri dam, along with some other fishes of minor importance, since their passage for upward migration will be blocked and consequently they will not get chance to breed in the upper reaches of river Bhagirathi. Though the preparation of action plan was not in the scope of ZSI studies, they had broadly recommended that following measures may be considered for conservation of fisheries:-

i. Technical measures which include construction of a "Pool and fall" or "Step system" of fish ladders/passes along with a mechanical lift to facilitate passage of ascending Mahseer upstream for breeding, introduction of additional species of fish suitable for lacustrine conditions and providing fish fry and fingerling rearing centres.

ii. The management measures to protect the river Bhagirathi fisheries including check on devastating means of fishing (electrocuting, dynamiting, poisoning etc.), creation of fish sanctuaries at the breeding grounds, confluence of rivers and at fish passes besides educating people to save wild life in the Garhwal Himalayas.

(The recommendations in detail, as made by the ZSI has

been reproduced at Appendix-1).

1.1.2. In order to examine these recommendations for implementation, the Tehri Hydro Development Corporation Ltd., entrusted the work of preparing an implemental and practical action plan for mitigating the possible impact on "Mahseer Fishery" due to construction of Tehri Dam, to the Tropical Fisheries Consultancy Services, Delhi with the scope of work as under:-

- Preparation of an Action Plan for conservation of Mahseer fishery in the Bhagirathi valley for mitigating the possible impact due to construction of the Tehri Dam.

- Examining the possibility of developing other fishery resources in the reservoir formed by the dam.

- Possibility of developing sport fishing for Mahseer in the valley and establishing an aquarium to develop tourist interest.

(Detailed terms of reference given at Appendix-2).

1.1.3. The THDC desired that the Consultants may give their action plan report within a period of three months. Dr. T.A.Mammen and Dr. Vijai Dev Singh of the Tropical Fisheries Consultancy Services, Delhi commenced the work from 1st December 1993. The consultants undertook two visits to Tehri and held discussions with the officers THDC at New Delhi, Tehri & Rishikesh, ZSI at Dehra Dun, scientists of the H.N.B.Garhwal University, Srinagar besides carrying out field investigations.

1.2. **TEHRI DAM**

1.2.1. The proposed Tehri dam across river Bhagirathi at

Tehri, District Tehri Garhwal, in Uttar Pradesh is designed to be the Asia's tallest dam with a height of 260.5 metres. In addition it is also proposed to construct a supplementary dam at Koteshwar, 22 kms. downstream of Tehri. It is proposed to produce 2,400 MW of electric power (2 x 1,000 MW at Tehri and additional 400 MW at Koteshwar) on completion of the project.

1.2.2. The salient features of these dams are as under:-

	Tehri	Koteshwar
Type	Earth & Rockfill	Concrete
Height	260.5 m	103.5 m
M.R.L.(above MSL)	835 m	615 m
D.S.L.(above MSL)	740 m	591 m
Gross Storage	3540 million m^3	86 million m^3
Submergence	42 km^2	2.55 km^2
Water Spread Area	4200 ha	255 ha

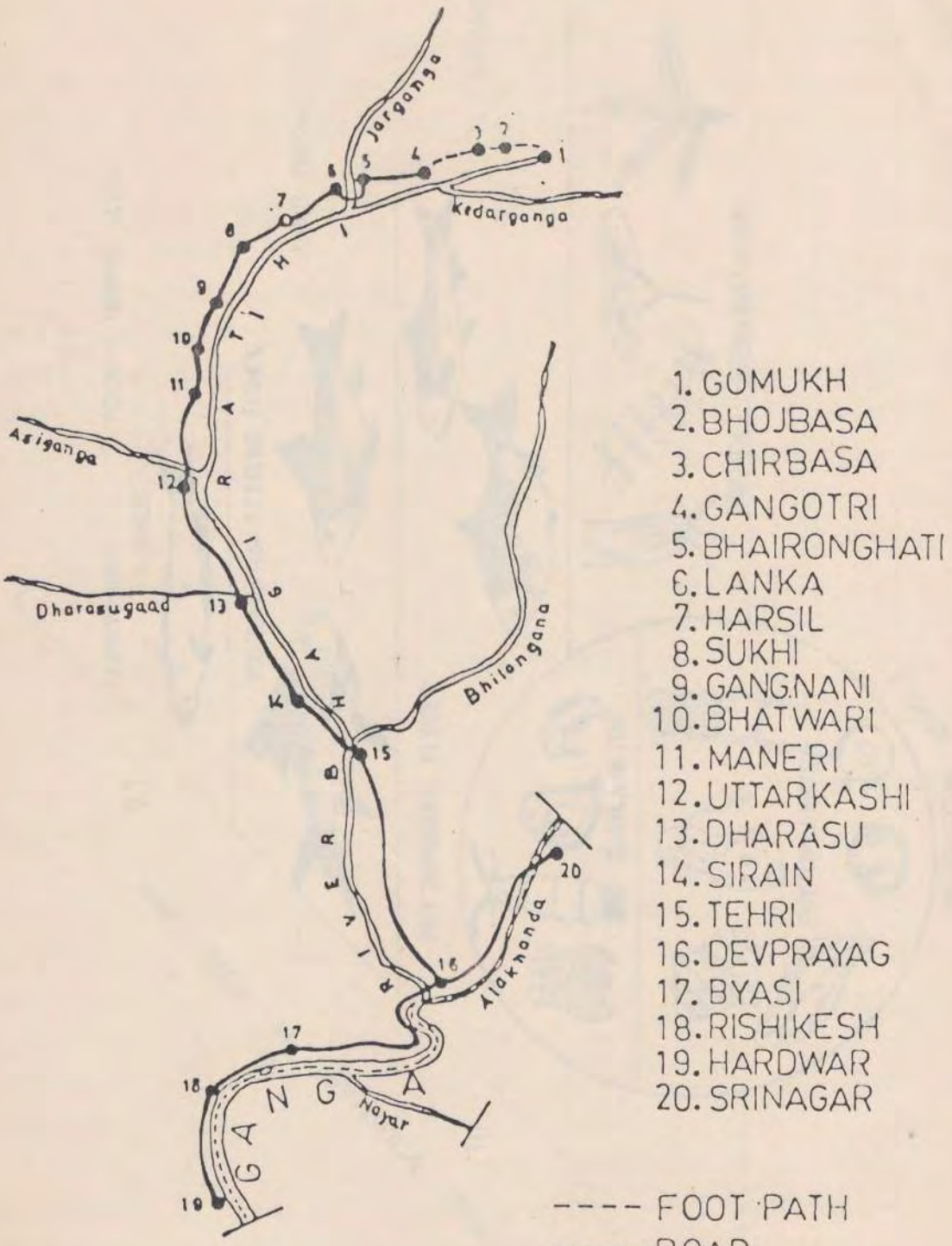
1.3. **RIVER BHAGIRATHI**

1.3.1. A net work of glacier-fed hill streams originating from the Himalayas between latitudes $29^{o}26'-31^{o}28'N$ and longitudes $77^{o}49'-80^{o}6'E$ drains north western region of Garhwal Himalayas into river Bhagirathi and north eastern & central region into river Alaknanda. The river Bhagirathi originates from Gaumukh glacier near Gangotri at an elevation of 3,900 metres above MSL, takes its course through Uttarkashi, Tehri and joins river Alaknanda at Devprayag from where onwards it is called river Ganga. At Tehri, river Bhilangana joins river Bhagirathi, below which the Tehri dam is being constructed. The other tributaries joining river Bhagirathi are Kedarganga, Jarganga, Asiganga and Jamuna. All these tributaries and main Bhagirathi are glacier-fed rivers. The maps showing (a) the rivers of Garhwal region and (b) the river Bhagirathi and its tributaries are given in Maps - 1 & 2 respectively.

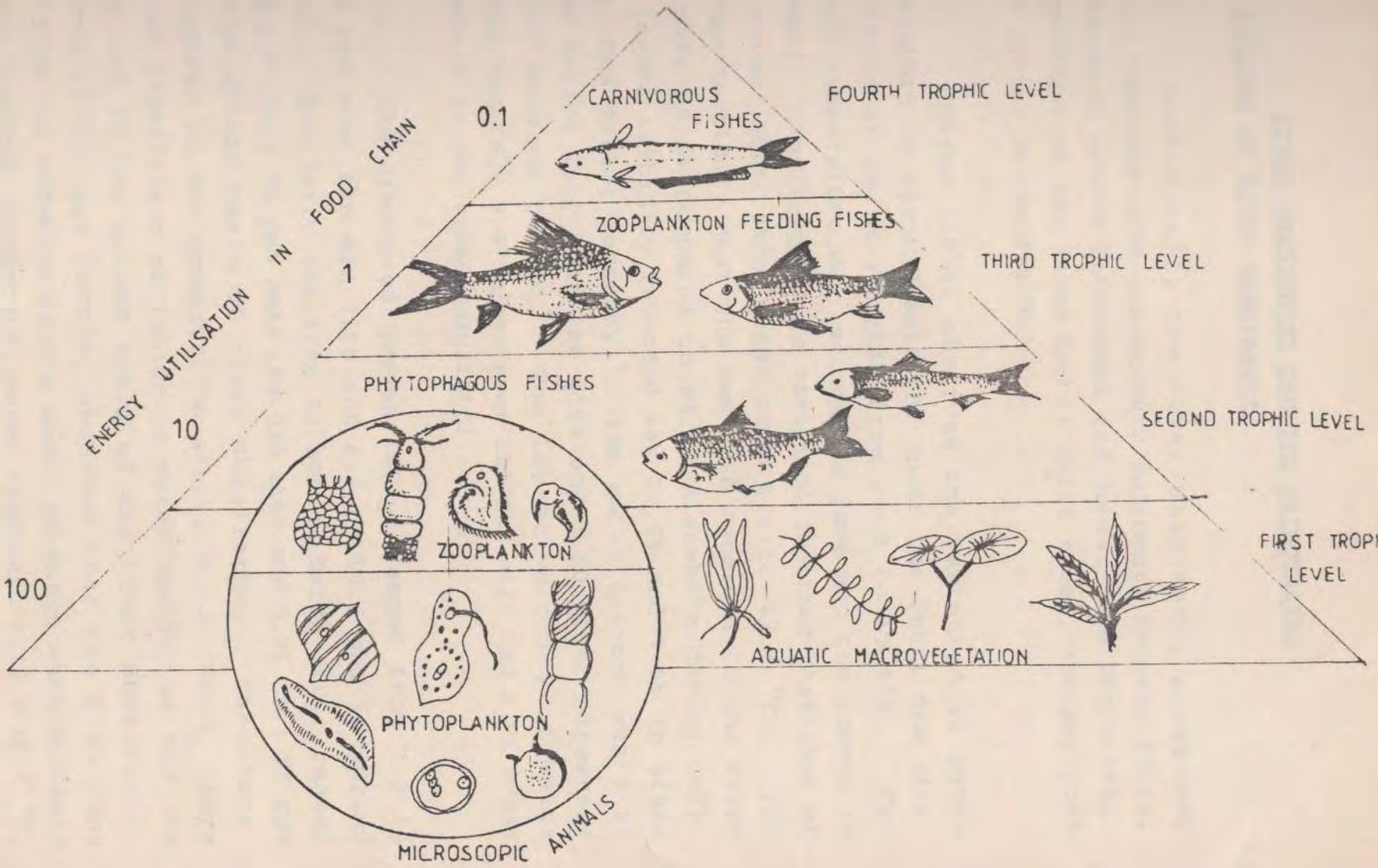
Map-1

RIVERS OF GARHWAL REGION

MAP-2



RIVER BHAGIRATHI AND ITS TRIBUTARIES



FOOD CHAIN IN A RIVER

RIVER BHAGIRATHI AND ITS TRIBUTARIES

1.4. ECOLOGY OF RIVER BHAGIRATHI

1.4.1. Geologically the river Bhagirathi possesses deposit terraces with quarternary sediments between Harsil and Gangnani around Uttarkashi and Dunda. To begin with, the gradient of the river bed is quite steep, steeper than other rivers in the region.

1.4.2. Sharma (1992) observed the variation in water temperature of river Bhagirathi (near the Tehri dam site) and found it to be ranging from 10.2 to 19.5^{o}C. The highest temperatute was recorded in June and the lowest in December. The temperature variation in other stretches of the river Bhagirathi range from 8.4 to 17.5 ^{o}C. The maximum turbidity near the dam site recorded in the river was only 96.5% compared to 94.8% elsewhere during July. The lowest turbidity recorded was 21.5% and 7.0% in other stretches during February. The water current was 3.01 m/sec during July near the site and 3.10 m/sec elsewhere during monsoon period. The lowest velocity of water current was only 0.67 m/sec near the dam site and 0.76 m/sec elsewhere in the river Bhagirathi.

1.4.3. The dissolved oxygen (DO_2) ranged from 7.8 to 15.2 ppm near the dam site and 8.7 to 17.6 ppm in upland basin. Similarly the free Carbon-di-Oxide (CO_2) ranged from 0.87 to 1.56 ppm near the dam site and 0.91 to 1.95 ppm in the upland basin of river Bhagirathi. Therefore, consequest to dam construction activities at Tehri, there are no significant variation in water quality at the dam site and in the upland basin of the river Bhagirathi. Sharma (1988) has further observed that the fish runs upstream for spawning in the month of March when suitable physio-chemical parameters (water temperature:15.6-19.4 ^{o}C,

turbidity:41.0-79.2%, hydromedien depth:2.034-4.396 m, water current velocity:0.56-1.781 m/sec, dissolved O_2:9.4-12 ppm, free CO_2:3.14-6.04 ppm and pH:7.81-9.1) prevail in the water of the river Bhagirathi. Typically glacier-fed streams are characterised by steep gradient, turbulent currents, low temperature, high dissolved oxygen, low nutrients, gravel substratum and as a result, the primary productivity is always low. The spring-fed streams on the other hand have low current, comparatively warm water, low dissolved oxygen, high pH, high total alkalinity and hardness resulting in higher primary productivity compared glacier-fed streams. Due to high primary productivity in spring-fed streams, they support diverse and dense macro-zoobenthos than glacier-fed streams. Consequently, the fish fauna is more diverse in spring-fed streams than in the glacier-fed streams.

1.5. FISHERIES OF RIVER BHAGIRATHI

1.5.1. Fishes are the best indicators of river type, its general basic ecology and the present health. Fishes have their own ranges, territories within which they live and move in a stream or river during different stages of life cycle for performing various biological needs such as breeding and feeding. Fishes are also on the top of the food chain among the organisms living within the river. However, every stream or river has at least one fish which is of local or national importance and also provides a table fish of local choice or offering opportunity for sport fishing in the region.

1.5.2. Fish zones or territories within a glacier-fed stream can be categorised on the basis of altitude, stream width and physico-chemical characteristics of the water. The following territories have been broadly recognised in a stream (Singh *et al.* 1991)

Territory-I	-	2,400 to 3,600 m above MSL - zone, melting snow, extremely cold water. No fish fauna .
Territory-II	-	1,800 to 2,400 m above MSL - rocky steep gradient, rapidly flowing ice cold water. *Glyptothorax* & *Pseudecheneis* zone.
Territory-III	-	1,200 to 1,800 m above MSL- rapidly flowing stream, moderately oxygenated cool water, steep sided valley. *Schizothorax spp.* (Snow trout) zone.
Territory-IV	-	600 to 1,200 m above MSL - less rapid stream, well oxygenated water, some slow reaches with flat bottom. *Tor spp.* (Mahseer) zone.
Territory-V	-	300 to 600 m above MSL - moderate currents, well oxygenated water, flat bottom. *Crossocheilus spp., Labeo spp., Barilius spp.* (Carps), zone.

1.5.3. However, certain requirements of fish greatly differ during their life time and they may not remain in the zones mentioned above during their entire life time. As for example, fishes from the point of view of migrating habits can be classified as follows:-

(i) Resident species which prefer to remain within the local territory and perform or meet their entire life time requirements within the territory itself.

(ii) Local migrants which move outside their territory to perform seasonal migration for breeding.

(iii) Long distance migrants which migrate annually long distances totally outside the territory for breeding.

1.5.4. *Tor spp.* (Mahseer) belongs to the second category mentioned above, whereas *Hilsa spp.* or *Anguilla spp.* (eels) migrate from sea to fresh waters and fresh waters to sea respectively for breeding and hence belong to the third category. In the upper reaches of the glacier-fed streams (like river Bhagirathi), the migratory fishes are limited to the local migrants like Mahseer in search of better conditions such as well oxygenated water without any turbidity, clean gravel bed etc.

1.6. FISHING METHODS PRACTICED

1.6.1. The common fishing gear employed in river Bhagirathi by fishermen are Jaal (Cast Net), Kanta (Angling), Faans (Hanging Net), Atwal (Stake Net), Karonch (Scoop Net). The destructive methods of fishing practiced are dynamiting, electric shocking and poisoning.

1.7. FISHES OF RIVER BHAGIRATHI

1.7.1. The following 23 species of fish fauna have been recorded from river Bhagirathi (Sharma, 1984 & 1988).

1. *Schizothorax richardsonii* - Snow trout
2. *Schizothorax plagiostomus* - Snow trout
3. *Schizothorax sinuatus* - Snow trout
4. *Schizothoraichthys progastus* - Snow trout
5. *Tor tor* - Red finned Mahseer
6. *Tor putirora* - Mahseer
7. *Labeo dero* - Carp
8. *Crossocheilus latius*
9. *Garra gotyla gotyla*

10. *Garra lamta*
11. *Barilius bendelisis*
12. *Barilius barna*
13. *Barilius vagra*
14. *Barilius barila*
15. *Noemacheilus rupicola*
16. *Noemacheilus beavani*
17. *Noemacheilus zonatus*
18. *Noemacheilus multifasciatus*
19. *Glyptothorax madraspatanum*
20. *Glyptothorax pectinopterus*
21. *Glyptothorax cavia*
22. *Pseudecheneis sulcatus*
23. *Clupisoma garua*

1.7.2. However, Singh *et al.* (1991) have recorded 66 fish species from the entire Garhwal Himalayas, which includes the above mentioned fishes and other fishes which are native of the spring-fed streams and the lower reaches of the rivers.

1.7.3. The ZSI (1993) in their report have recorded collection (between May and October 1992) of the following species only:-

1. *Barilius vagra*
2. *Tor chelynoides*
3. *Tor putirora*
4. *Crossocheilus latius*
5. *Garra gotyla*
6. *Schizothoraichthys progastus*
7. *Schizothorax richardsonii*
8. *Nemacheilus montanus*
9. *Nemacheilus rupicola*
10. *Glyptothorax pectinopterus*

1.7.4. According to ZSI, except for *Tor putirora*, the Golden Mahseer and *Schizothoraichthys progastus* the Snow Trout or Dinnawah, all the other species are well established and are not much threatened by the construction of the Dam. Further *Tor chelynoides* the Black Mahseer and *Schizothorax richardsonii* the Snow Trout or Mahsin are widely distributed in rivers Bhagirathi, Bhilangana and their tributaries. They have also noticed that the ripe specimens of *Schizothorax richardsonii* ascending for breeding being held up during the month of June near the outlet of river Bhagirathi causing check on their ascent and so also the breeding.

1.7.5. The main concern of THDC is the contentious adverse impact on the Mahseer fishery in river Bhagirathi due to the construction of the Tehri dam. Hence the THDC is interested in not only mitigating the possible adverse impact on Mahseer fishery, but also developing the fishery in the Tehri & Koteshwar reservoirs in general.

*****

References

1. Sharma, R.C., 1984. Ichthyofauna of the snow-fed river Bhagirathi of Garhwal Himalaya. Uttar Pradesh Journal of Zoology, 4(2), 208-212.

2. Sharma, R.C., 1988. Fish and fisheries of the snow-fed river Bhagirathi of Garhwal Himalayas. Proceedings of the National Academy of Sciences of India, 58(B), II, 181-192.

3. Sharma, R.C., 1992. Impact of Ecological changes on Fisheries of Ganga basin in Garhwal Himalayas - Recent Researches in Cold Water Fisheries. National Workshop on Research and Development Needs. Cold Water Fisheries. Ed. K.L.Saigal, Today & Tomorrow's Printers & Publishers, New Delhi, pp 79-91.

4. Zoological Survey of India, Dehra Dun., 1993. Environmental Impact Assessment Study - Report on Faunal Analysis.

5. Singh, H.R., Dobriyal, A.K. and Neeraj Kumar, 1991. Hill stream fishery potential development issues. Journal Inland Fisheries Society of India, 23 (2) : 60-68

2. THE MAHSEER

The Mahseer is called as the Tiger of the Indian rivers by the anglers and is one of the most important game fishes of India. As food fish, it is also highly esteemed and fetches the best price in certain regions. It is therefore, necessary that this valuable resource is properly managed, conserved and propagated both for food and sport. The etymology of the word Mahseer is probably derived from Maha Sir meaning big head or Maha Sher meaning Tiger of the water or the third alternative Maha Salka meaning big scaled fish. Hamilton (1822) puts Mahseer under the genus *Cyprinus* and recognised three main species viz. *Cyprinus putitora*, *Cyprinus tor* and *Cyprinus mosal*. Later workers classified Mahseer under the genus *Barbus* (Cuvier). The copper Mahseer belonging to a different genus altogether has been therefore, placed separately. MacClelland (1839) however, placed Copper Mahseer under *Barbus* genus but later came to be assigned under the genus *Lissocheilus* - finally to be put under the genus *Acrossocheilus*. The commonly found Mahseer in India are now placed under the genus *Tor* (Kulkarni & Ogale, 1991).

2.1. SPECIES

2.1.1. The scientific and common English names of different species of Mahseer found in India are given below.

	Scientific Name	Common English Name
1.	*Tor putitora* (Ham.)	Golden or putitor Mahseer
2.	*Tor tor* (Ham.)	Turia or Tor Mahseer
3.	*Tor mosal* (Ham.)	Copper or mosal Mahseer
4.	*Tor progeneius* (McClld.)	Jungha Mahseer
5.	*Tor khudree* (Sykes)	Deccan or khudree Mahseer
6.	*Tor mussullah* (Sykes)	Humpback or mussullah Mahseer

2.1.2. Of the above mentioned 6 species, *Tor putitora* & *Tor tor* have been recorded in the Bhagirathi river system. Both these species however are not exclusive to river Bhagirathi and are found in other Himalayan rivers also.

2.1.3. Anglers have been referring to one more fish as the Mahseer namely the Chocolate Mahseer or the Katli Mahseer which is scientifically identified as *Accrossocheilus spp.* (Kulkarni & Ogale, 1991). ZSI (1993), have reported *Tor chelynoides* (Black Mahseer). During the visit of the Consultants, Chocolate Mahseer was seen in the catches of river Bhagirathi at Tehri.

2.2. DIAGNOSTIC FEATURES

2.2.1. The diagnostic features of Mahseers are - Body elongate, moderately compressed. Abdomen rounded. Head small, broadly pointed. Snout angularly rounded. Mouth inferior, arched. Eyes far forward, large, and not visible from below ventral surface. Lips fleshy, continuous at angles of mouth; posterior lip with or without a median lobe and the post-labial groove continuous; lip condition variable. Four barbels, a pair each of maxillary and rostrum. Dorsal fin inserted above pelvic fins, with 12-13 rays (eight or nine branched) and a strong, stout, smooth spine. A scaly sheath present at base of dorsal fin. Anal fin with seven or eight rays (five branched). Caudal fin deeply forked. Scales large, with numerous parallel striae. Lateral line complete with 23-28 scales.

2.3. ADAPTABILITY

2.3.1. The above mentioned species of Mahseer inhabits different ecosystems of various rivers of the country ranging from tropical waters where temperature in summer

goes up to 35°C to sub-Himalayan region where winter water temperature drops to 6°C. They occur in waters hardly a few metres above Mean Sea Level (MSL) and are also found up to 2000 metres above MSL. Close studies on Mahseer indicates that as a group, they are remarkably adaptable fish and can adopt themselves in various environments of the country. The earlier understanding was that Mahseer is mainly a riverine fish, however, recent records show that Mahseer has well adopted in reservoirs also. Since Mahseer is omnivorous feeder it helps in controlling aquatic weeds, epiphyton, crabs, molluscs and forage fishes in the reservoir. Mahseer is well established in reservoirs like Walwhan, Shirwta Mulshi, Shivajisagar in Maharashtra, Sukta, Barna, Harsi, Halali, Gandhisagar in Madhya Pradesh, Pong and Govindsagar in Himachal Pradesh. They are also forming a good fishery in Kumaon lakes. Therefore, it is presumed that they could also be established as a fishery in Tehri and Koteshwar reservoirs which will be new abodes for Mahseer in Garhwal Himalayas offering food as well as sport fishery.

2.4. DISTRIBUTION

2.4.1. The largest of the Mahseer group the Putitor Mahseer or the Golden Mahseer, occurs in the sub-Himalayan rivers right from Jammu and Kashmir to Darjeeling hills and even further east up to Arunachal Pradesh in India. The second most important species, the Tor Mahseer inhabits waters of the Himalayan foot hills, north eastern region, the gangetic plains as well as the river Narmada and river Tapti basins of the central India. In addition to these, the Mahanadi basin harbours Mosal Mahseer or the Copper Mahseer. The two other Mahseers, Khudree and Mussullah are truly the peninsular species of rivers Godawari, Krishna and other rivers of the southern India.

2.5. FOOD AND FEEDING HABITS

2.5.1. The preferred food of Mahseer in nature comprises of small fish, crabs, earth worms, water beetles, grasshoppers, small flies, water and stone cricket, shrimps, molluscs and all kinds of aquatic weeds, seeds of many plants including bamboo seeds, un-husked rice etc. (Karamchandani, 1972). However, their most preferred food are crabs, molluscs and fish. The fry and fingerlings of Mahseer prefer to feed on algae, insects, small fish etc. The Putitor Mahseer is reported to be piscivorous feeding on small minnows. The Chocolate Mahseer (Katli) feeds on bottom weeds in shallower regions. It is mainly an aquatic vegetation feeder, feeding on filamentous planktonic algae, vegetable debris etc.

2.5.2. The Mahseer also responds to artificial feeding under culture conditions. The Consultants during their visit to Rishikesh observed Mahseers feeding on wheat flour dough just below the Shivanand bridge connecting Rishikesh town with temple area. In fact, there is a large scale congregation of Mahseer just below the bridge, waiting for artificial feed from the pilgrims who cross the bridge for going towards the temples. Mahseer is also fed on wheat dough at the Mahseer sanctuary at Jogendranagar in Himachal Pradesh. Similar instances are available at many places including Sringeri in Karnataka. The brood stock and young fry and fingerlings are also raised on artificial feed at Tata Electric Companies Farm at Lonavla in Maharashtra. Therefore, it is established that Mahseer could be raised on artificial feed under culture practices, while it may be useful as a minor predator to control the population of weed fishes and carp minnows.

2.6. MIGRATION FOR BREEDING

2.6.1. Mahseer being a migratory fish, it ascends from the plains to the upper reaches of rivers for spawning. The young ones and the spent fish descends back to the plains every year. Wherever there is a congregation of the fish due to obstruction in the path of this migratory fish, the ascending brood fish and the descending spent fish are being indiscriminately killed by fishermen and the local population either for their own consumption or for commercial marketing. These areas could be declared as Fish Sanctuaries and they can also serve as good source of brood stock for artificial breeding through stripping the gravid Mahseer for raising the spawn in fish seed farms.

2.6.2. Large scale migration of adult Mahseer in pre monsoon and monsoon months have been attributed to their spawning habits (Karamchandani, 1972). During floods, the Mahseer ascends considerable distances to reach the upper reaches of the rivers mainly for spawning purposes. The upward migration of Mahseer during floods is also attributed to the change in water temperature providing more congenial conditions for spawning. In Himalayan streams, where floods are caused due to influx of fresh water in the river by melting snow, lowering of temperature to 20-28^{o}C is reported to be congenial for the breeding of Mahseer even in May/June itself.

2.6.3. Since *Tor putitora* and *Tor tor* are the main Mahseer species occurring in river Bhagirathi, a more detailed account of these species is given below.

2.6.3.1. ***TOR PUTITORA*** - The Putitor Mahseer also known as the Golden or the Common Himalayan Mahseer occurs all along the Himalayas from Kashmir to Assam and grows to about 2.75 metres in length. It is not known to occur in central India. Two breeding seasons are reported, first during May-June and second during August-September (Sehgal *et al.*

1991). The fry hides under the boulders near the stream bends, whereas the fingerlings prefer the mid stream where the current is faster, preferring to remain in shoals. The Putitor Mahseer is reported to migrate from the main rivers to the Himalayan tributaries for spawning during August-September and return to the main rivers during October-November. The fry and fingerlings ranging in size from 25 to 130 mm. feed on algae, decayed organic matter, insects, rotifers, and protozoans. This fish, considered as a stream fish, was introduced in the lakes of Kumaon hills by Sir Ramsay in 1858, and is reported to be flourishing in all the lakes of Kumaon hills.

2.6.3.2. ***TOR TOR*** - The Tor Mahseer, a typical anglers fish in North India, is more stoutly built than the Putitor Mahseer and attains a length of about 1.5 m. This fish besides occurring in Himalayan region, is also found in the rivers Narmada and Tapti. The Tor Mahseer is reported to be insectivorous in its juvenile stages, but becomes herbivorous in adult phase. The protrusive and suctoral mouth of the fish and presence of large quantities of sand, mud and debris in the guts are suggestive of its bottom feeding habits (Karamchandani *et al.*, 1967). The fish spawns in three spurts at interval of 2 to 3 weeks in between two spawning. The fish is reported to attain its first maturity in the size range of 273-290 mm. The younger fish breeds earlier in the season than the older fish. The spawning season commences from July and extends up to September.

2.7. BREEDING IN CAPTIVITY

2.7.1. Despite their abundance at one time in the rivers, the Mahseer population is declining in numbers and size due to various reasons including construction of barrages and dams across the rivers. The National Commission on

Agriculture (1976) in their report on fisheries stated that **"There was general decline in the Mahseer fishery due to indiscriminate fishing of brood and juvenile fish and the adverse effect of river valley projects"** and suggested extensive surveys and detailed ecological and biological investigations.

2.7.2. Though exact numerical assessments of the catches of Mahseers are not available because of lack of species-wise catch statistics of inland fish landings, the figures available from few isolated surveys as well as observations of anglers and fishery biologists indicate a decline of the fishery. Remarkable dwindling catches has been observed in Narmada & Tapti rivers and similar position has been reported from Jammu & Kashmir, Himachal Pradesh, Haryana, Punjab and Uttar Pradesh. In the peninsular India also, the Deccan Mahseer and the Humpback Mahseer have declined from the Bhima, Krishna and Koyna rivers. It is also reported that the Mussulah Mahseer is also declining in the rivers and lakes of peninsular India. The Mahseer of Ganga basin in Garhwal Himalayas is also reported to be declining due to killing of both brood fish and juveniles by illegal methods of fishing.

2.7.3. In recent years, the conservation of Mahseer has been engaging the attention of scientists, environmentalists and the Government. It was realised that declaring of a particular area of a river as fish sanctuary and prohibition of fishing during the breeding season may not be adequate to counter the depletion of Mahseer, as ecological changes in riverine system due to construction of dams across several streams all over India have also threatened the Mahseer population. Since, the developmental activity like construction of dams are essential for general well being and prosperity of the country as a whole, a compromise has to be struck, as is done in the case of the famous Salmon

fisheries in Europe and America, either to allow them passage to their natural spawning ground or establish hatcheries to artificially breed the fish. Since it is not practicable to provide fish ladders/passes and attempts to construct fish ladders/passes have not been successful for Mahseer anywhere in the country, the best course is to establish fish seed farms for breeding, raising the stock and releasing them in the natural streams, rivers and reservoirs.

2.7.4. Wherever, the natural breeding grounds have been lost due to various ecological changes, the stock can be replenished or augmented by artificial breeding the endangered fish in captivity and stocking the water bodies. The artificial propagation of Golden Mahseer (*Tor putitora*) has been attempted in Bhimtal and Naukuchiatal lakes in Kumaon (Sehgal, 1991). In brief, it involves collection and selection of brood stock from the natural population from lakes/streams, stripping of eggs, fertilising, water hardening, hatching of eggs in trays/troughs having a flow through system and raising of fry and fingerlings on artificial diet. The prerequisites for setting up of artificial propagation systems are availability of ample water supply with dissolved oxygen ranging from 7 to 9 ppm and a temperature range of 20 to 25^{o}C.

2.7.5. In this connection, a notable contribution has been made by Tata Electric Companies at Lonavla in breeding *Tor khudree* on a large scale for rehabilitating the Mahseer fishery in Tata hydel projects (Walwhan reservoir) and making complimentary supply of Mahseer seed to many states in India as well as abroad for rehabilitation of Mahseer. The seed transplanted from Lonavla has also revived the Mahseer fishery of the river Kaveri. They have also been successful in breeding of Khudree Mahseer in ponds without induced breeding.

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References

1. Jayaram, K.C. 1981. The freshwater fishes of India - A Handbook. Zoological Survey of India, Calcutta.

2. Karamchandani, S.J. 1972. Mahseer - A Sport Fish of India. Silver Jubilee of CIFRI Souvenir. 132-137.

3. Karamchandani, S.J., Desai, V.R. & Pisolkar, M.D. 1967. Biological investigations on the fish and fisheries of Narmada river. Bulletin of the Central Inland Fisheries Institute., 19 : 1-39.

4. Kulkarni, C.V. and Ogale., S.N. 1991. Conservation of the mighty Mahseer of India - Monograph.

5. National Commission on Agriculture, 1976. Ministry of Agriculture, New Delhi.

6. Sehgal, K.L. 1991. Artificial propagation of the Golden Mahseer *Tor putitora* in the Himalayas. Special Publication of the National Research Centre on Cold water Fisheries, Haldwani.

7. Zoological Survey of India, Dehra Dun., 1993. Environmental Impact Assessment Study - Report on Faunal Analysis.

ACTION PLAN FOR REHABILITATION OF MAHSEER

3. ACTION PLAN FOR REHABILITATION OF MAHSEER

The ZSI, in their faunal analysis of the river Bhagirathi in relation to Tehri dam construction, suggested the need for certain mitigating action (Appendix-1), which could be grouped into two broad categories *viz.* Technical and Management.

Technical

1. Fish Ladders or Passes - Provide a migratory passage for Mahseer through fish ladders or passes combined with mechanical lift across the 260.5 m high Tehri dam for upward breeding migration and safe return passage for spent fish.

2. Introduction of Additional Species - Introduction of new fish species suitable for lacustrine (lake) environment which have no competition with local fishes for food.

3. Developing of Rearing Centre - Development of rearing centre along the course of the river for rearing fry and fingerlings for stocking in the main rivers for management of its population.

Management

1. Check on Devastating Means of Fishing - To ensure that the devastating or destructive methods of fishing such as electrocuting, dynamiting, poisoning, water pollution excessive netting specially in breeding grounds, fish ladders, river confluences, sudden closure of canals should be stopped by enforcing strict laws.

2. Creation of Fish Sanctuaries - The breeding grounds, river confluences, fish ladders etc. where the fishes gather in large numbers or pass through should be declared as fish sanctuaries.

3. Public Awareness - People of the area should be educated through some incentive for saving the wild life.

The recommendation of the ZSI regarding the fish ladders/passes has been discussed in detail as under:-

Fish Ladders or Passes: The ZSI has recommended "Fish ladders or passes i.e. migratory passage for the fishes ascending upstream during breeding season may be provided at least up to the base of the main Tehri dam or a little above and from where the fishes should be lifted up through some mechanised device and in the same way while spent return to the main rivers after spawning.

The design of the fish ladder may be of "Pool and fall" or "Step system", wherein the water level is brought down through a series of short falls and pools alternately, so that water runs down from one step or pool to another through a passage. The falls/steps should be round-edged and low, so that the fish can ascend easily. At the end of each step the baffle wall should have a hole enough for the fish to pass. The fishes may ascend directly or through the hole. The gradient or the slope in the pass should be such that it provides a gentle flow of water. The pass should be wide enough so that during ascent or descent, the fishes should not strike against its wall. These should be sufficient natural light in the pass so that fishes do not hesitate to enter it."

While the first para of the above recommendation is

about providing fish ladders or passes and a mechanical lift system, the second para gives some details of the ladder under the presumption that the fish ladder is the sole provision for conserving the population of migratory fish in the rivers & reservoirs. If the use of fish ladder or pass is only to enable migratory fish to reach up to the base of the dam or a little above, this may as well be dispensed with, as there is no obstruction to any fish reaching up to that level. On the other hand, if the intention is to help fish to negotiate the dam through "pool and fall" or "step system" combined with a mechanical lifting device, number of serious problems are envisaged, which are discussed below.

(a) If the above recommendation is to be accepted, fish ladders/passes and mechanical lifting devices have to be provided at both Tehri and Koteshwar dams.

(b) So far no work has been done on the behaviour of the migratory fish (Mahseer and Snow Trout) of river Bhagirathi. The study on response of fish and design testing will be time consuming and will be costly and would delay the rehabilitation and propagation of fish in the river Bhagirathi. If the fish are to respond to the flow of water through fish pass, an optimum flow would be required, which has not been worked out. The problem is further compounded because Mahseers of 0.5 kg to 45 kg (largest recorded in the Himalayan region) are to use the ladder. The hydraulic discharge pressure which fish can negotiate cannot be adjusted to cater to the need of a fish weighing 45 kg and a fish weighing 0.5 kg. Obviously, what is required for small fish would not be suitable for the big fish and vice-versa. This situation is in sharp contrast to the American and European Salmon where mostly 4 year class Salmons of a near uniform size ascend the rivers for breeding. Evidently the Salmon model cannot be adopted here.

(c) Further it is to be considered whether the Mahseer will have the stamina to leap through about 250-500 troughs to scale the Tehri dam, which can be tested with only a full scale model. If the fish does not respond or fail to jump through all the pools/troughs, the entire expenditure on construction of fish ladder would be infructuous.

(d) There is a big difference between the Dead Storage Level (DSL) and the Full Reservoir Level (FRL) in these reservoirs, ranging from 16.5 m at Koteshwar to as much as 90 m at Tehri. If a ladder is designed for the FRL of the reservoir, it would not be operational at lower levels. On the other hand, if the same is designed for lower levels, the force of water with increase in water level would be so great that the fish would not be able to swim against the current. The option in that case would be to provide a series of outlet gates for every 2 m, which would be prohibitively costly and pose several constructional & operational problems, not possible to solve.

(e) The fish passes to be successful should take into consideration the hydraulics of the stream and behaviour of the migrating fish. The flow properties of a fish pass should be such that the effort required on the part of the fish to negotiate the fish pass is well under the capability of the fish to do so. In India, several fish passes were constructed without due regard to the ability of the species that might make use of them. These fish passes have proved unsuccessful. They serve as traps for fishes rather than as an aid to their migration. Lack of knowledge of fish behaviour and leaping capacities of migratory fish, combined with exorbitant cost of fish passes have prevented the construction of right type of fish passes (Jhingran, 1983).

(g) The ZSI report is silent about the type & details of

the mechanical device for bodily lifting the fish from the river to the reservoir above. Such devices would be costly and there is no guarantee that these devices will really serve the purpose of transplanting the migratory fish to the reservoirs. In any case, it is undoubted that no such mechanical device can work for returning the spent fish back to the lower reaches of the river, as the fish will be distributed throughout the reservoir and not congregated at any one point.

(h) Besides, an important biological aspect to be considered is that, the Mahseer migrates to shallow streams having pebbles where the waters are comparatively warm (19-28^{o}C) for breeding as well as to ensure the survival of the offsprings. With the formation of Koteshwar and Tehri dams, river Bhagirathi would have lacustrine conditions up to 60 kms upstream of Koteshwar dam. Only beyond Uttarkashi, one can expect to find shallow riverine conditions with pebbly bottom. However, temperature in this snow fed region would be much lower than what is required for Mahseer for its breeding. In other words, even if Mahseers are assisted to go past these dams, biologically it would not be possible for the fish to breed and ensure survival of the spawn, since the hatchlings would get washed down to deeper waters of the reservoir and get destroyed.

Considering the enormous cost, practical problems in providing fish ladders/passes with mechanical lift devices and the remote chance of achieving the objective of successful breeding and repopulation of Mahseer, it is advisable not to invest on the construction of fish ladders/passes & mechanical lifting devices. The provision of fish ladders/passes on dams is an old concept when the technique of production of fish seed by artificial means was not available. Now the breeding of fish under captivity as well as rearing of fish seed has become a widely accepted

technology for most fishes including Mahseer. Therefore, the best course would be to establish a Mahseer hatchery as has been demonstrated by Tata Electric Companies at Lonavla and follow the recommendations of the Ministry of Forests and Environment which envisage pari passu action on the conservation of the fish fauna affected during the construction period of the Dam.

The management recommendations basically fall within the purview of the State Govt. (Department of Fisheries or Department of Forests) who are to take necessary action in this regard.

The action plan proposed for rehabilitation of Mahseer fishery in the river Bhagirathi is described below.

3.1. MAHSEER HATCHERY

3.1.1. Technology is available for artificial propagation of Mahseer (Kulkarni & Ogale, 1991 and Sehgal, 1991). The artificial propagation of Mahseer however, will require a fish seed farm for production of Mahseer seed. The setting up of a proper Mahseer hatchery/fish seed farm will require a detailed survey to select a suitable location for the hatchery, a location based layout for the hatchery with physical facilities such as availability of brood stock in close vicinity, assured source of water supply etc. The are discussed below.

3.2. SITE SELECTION

3.2.1. The following are the considerations in site selection for establishing a fish seed farm, particularly keeping in view the need for breeding of Mahseer and raising fingerlings:-

- A moderately flat land of about 2.5 ha, free from flooding with good approach road.

- The soil should have adequate clay content (above 8%) to prevent seepage.

- Assured water supply free from pollution and acidity preferably free from turbidity and within a temperature range of 19-28^{o}C during monsoons.

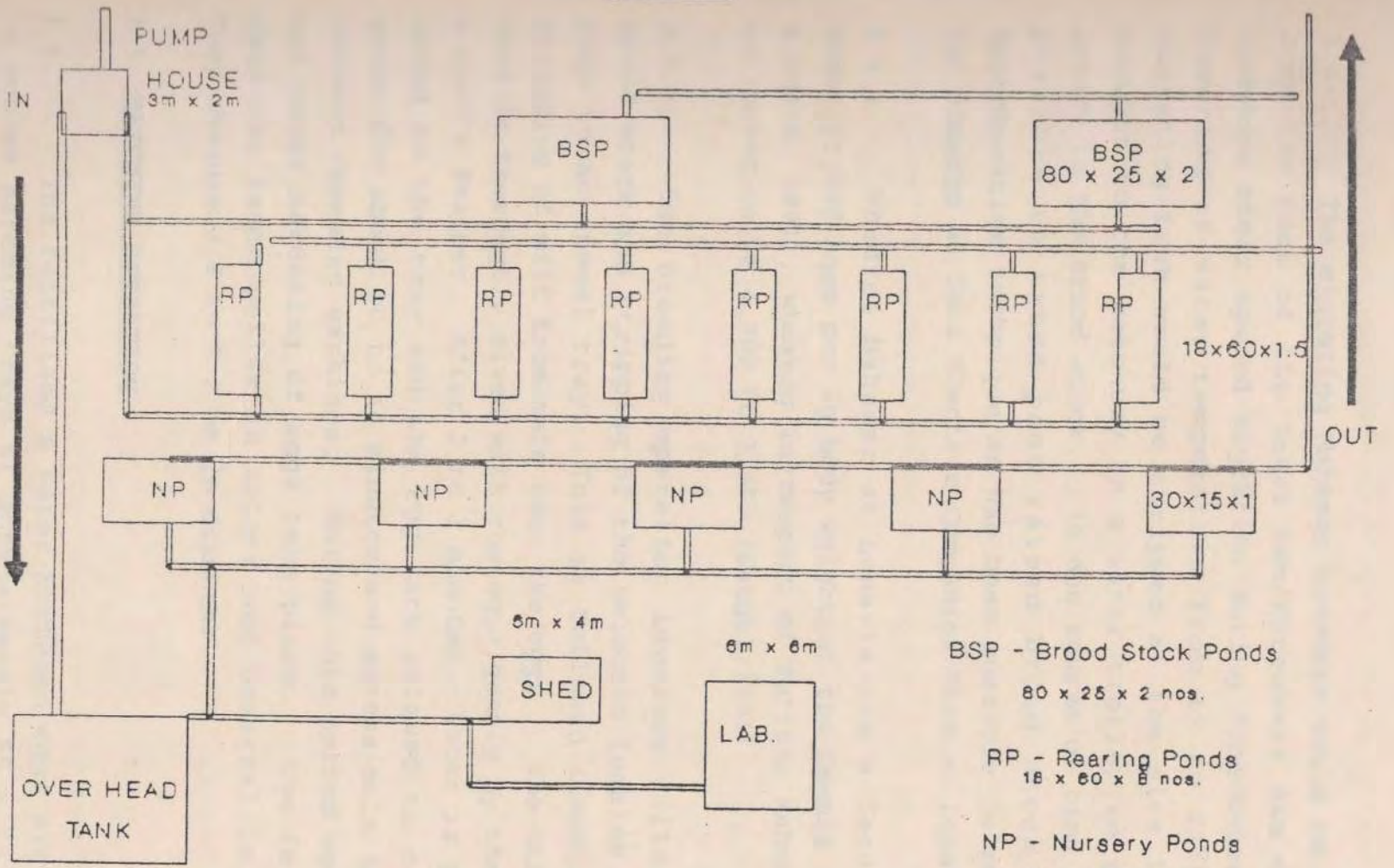
3.2.2. The Consultants visited the river course of Bhagirathi right from Uttarkashi to Koteshwar and from Devprayag to Rishikesh but could not find any site fulfilling all the desirable criteria. The biggest problem was in finding flat land as flat lands are rare and the few that are available are either under cultivation or under forests. The clay content of practically all the sites was nearly nil in all cases and it would appear that suitable measures like plastic lining and covering the plastic under a thick layer of earth and grouting the side walls would be necessary to prevent seepage.

3.2.3. The sites considered suitable for further detailed examination are indicated below.

a) At <u>Jajal</u> about 0.5 km towards Rishikesh on Chamma -Rishikesh road. The area is a terraced agricultural land approximately 25-30 ha with a village road leading to the site from the village Jajal.

b) At <u>Khadi</u> about 4-5 km towards Rishikesh from Nagini on Chamma-Rishikesh road. It is a terraced agricultural land close to the main road, but will need an approach road and bridge over Nagini stream which is very narrow here.

Figure-1



BSP - Brood Stock Ponds
80 x 25 x 2 nos.

RP - Rearing Ponds
18 x 60 x 8 nos.

NP - Nursery Ponds
30 x 15 x 5 nos.

(measurements in metres)

TENTATIVE LAYOUT OF THE PROPOSED MAHSEER HATCHERY

3.4. **BREEDING OPERATION**

3.4.1. The migrating Mahseer breeders would be collected from the foot of the Tehri dam/Koteshwar dam when they commence their upward migration during June-August due to lowering of water temperature from 19 to 21°C. The migrating fish would be stripped at the site itself or brought to the hatchery in a water trolley to avoid any injury to the brood stock. In due course of time it may be possible to breed pond raised brood stock also by hypophysation technique as has been possible in respect of *Tor khudree* at Tata Electric Companies Farm at Lonavla.

3.4.2. Khudree Mahseer at Lonavla has a fecundity of about 15,000 eggs per kg body weight of the female (Kulkarni & Ogale, 1991), whereas in respect of Putitor Mahseer it is estimated to be 4,700 to 7,900 (Sehgal,1991).

3.4.3. The breeding operation involves collection of brood stock and stripping of the selected females of their eggs in an enamel tray. This is followed immediately by stripping of milt from male over the eggs. The milt of the male is thoroughly mixed with the eggs gently by the help of a bird's feather. After 2 to 3 minutes, water is gradually added to the tray and the eggs are allowed to remain in water for about 30 to 40 minutes and excess milt should be removed repeated washings. During this period eggs swell and water hardening of eggs take place. The fertilised eggs are lemon yellow in colour and demersal in nature. They measure 2.8 to 3.2 mm in diameter.

3.5. **HATCHING OPERATION**

3.5.1. The fertilised & water hardened eggs are hatched in wooden hatching trays of approximately 55 x 55 x 12 cm lined with 1 mm mesh plastic or velon netting at the bottom.

In each wooden tray about 30,000 eggs can be accommodated for hatching. The flow rate of water is to be maintained at 1-2 liters per minute. 8 such trays can be placed in a cement cistern of 2.5 x 1.2 x 1.2 m size. The trays are kept floating the cement cisterns having water sprinkling arrangement to ensure supply of fresh oxygenated water during the period of 60 to 96 hrs. An over head tank supplying clean, silt free water with a total capacity of 10,000 liters is another prerequisite for the hatchery to carry out the hatching operation systematically. The hatching period however, varies from species to species and is also affected by the temperature of the water. While the eggs of *Tor khudree* hatch out in 60 to 80 hrs at a water temperature of 24 to 28°C (Kulkarni & Ogale, 1991), the eggs of *Tor putitora* are reported to take 80 to 96 days for hatching at a temperature of 22-24°C (Sehgal, 1991). and 80 to 85 hrs in respect of *Tor tor* (Kulkarni & Ogale, 1991). The hatchlings with the yolk sacs are allowed to remain in the cisterns for about 6 days for Khudree Mahseer and 10-12 days for Putitor Mahseer for full absorption of the yolk sac. The average survival is about 80%.

3.6. REARING OF FRY

3.6.1. The hatchlings would absorb the yolk sac in about 2 weeks and would swim freely in the wooden trays. A survival of 70-80% is observed. The fry (after absorption of yolk sac) needs immediate feeding to avoid heavy mortality of the early fry stage. The fry is fed on boiled yolk of hen's egg in an emulsified condition every two hours at 10% of body weight for about a fortnight. The fry attains a length of 10 to 15 mm. At this stage they are shifted to nurseries and artificially fed on formulated feed made from roasted soybean powder, shark liver oil, casein and essential vitamins and minerals. Feed formulated using powdered groundnut oil cake & rice bran, sieved through fine

mesh may also be fed about 3-5 times a day during this stage. The feeding at about 5 to 8% of body weight. In addition, the formulated commercial fish feed could also be used for feeding the fry to rear them to fingerling sizes. In case the rearing facilities are not adequate at the hatchery site. The fry produced in the hatchery can be transported easily (in Oxygen packed containers) to other rearing area.

3.6.2. The nurseries to rear the spawn to fry stage could be stocked @ 10 lakhs/ha with a water flow of 25 to 50 lts/minute wherein a survival of about 80% may be obtained. The fry may be reared to fingerlings in earthen rearing ponds which may be stocked @ 2 lakhs/ha and fed with artificial feed consisting of groundnut oil cake, fish meal and rice bran in the ratio of 1:1:1. The fry would grow to about 60-75 mm size in about 12 weeks.

3.6.3. The fingerlings thus raised can be used to stock the Tehri reservoir which would migrate to the upper reaches of the rivers Bhagirathi, Bhilangana and other tributaries upstream. In addition to this, the fingerlings could also be stocked in the Koteshwar reservoir and the remaining stock in the down stream of Koteshwar dam.

3.6.4. In addition to the seed of Putitor Mahseer (*Tor putitora* proposed to be reared in the hatchery, seed of other species of Mahseer (*Tor tor* and *Tor khudree*) may also be introduced in the reservoir, by importing the same from Tata Electric Companies Farm at Lonavla.

3.7. **COST ESTIMATES**

3.7.1. The estimated cost of the various components and the recurring costs including staff emoluments is given below:-

a) Capital Cost

Item		Rs.in lakhs
Cost of land - 2.5 ha @ Rs.1.80 lakhs/ha		4.50
Brood Stock ponds (80 X 25 X 2 m - 2 nos.)		1.60
Covered Shed (Asbestos Roofed) (6 X 4 m)		0.24
Cement cisterns (2.5 X 1.2 X 1.2 m - 3 nos.)		0.24
Nurseries - Earthen (30 X 15 X 1 m - 5 nos.)		0.61
Rearing Ponds - Earthen (60 X 18 X 1.5 m - 8 nos.)		2.59
Laboratory-cum-Office-cum-Store (6 X 6 m)		1.44
Over Head Tank (10,000 liters)		0.54
Pump house (3 X 2 m - 1 no.)		0.24
Pumps (5 hp - 2 nos.)		0.60
Pipes & fittings		1.00
Electrification		0.50
Jeep with Trailer		4.00
Miscellaneous		1.80
Equipment		1.00
Wooden Trays	5,000	
Oxygen Cylinder kit	10,000	
Nets	5,000	
Water Testing Equipment	10,000	
Induced Breeding Equipment	10,000	
Dissection Microscope	30,000	
Furniture	20,000	
Others	10,000	
Total		20.90
	or Say	Rs.21 lakhs.

b) Staff Emoluments

The staff proposed for operation of the hatchery as

well as for conservation of the Mahseer in the river is given below along with the suggested annual emoluments for the staff.

Post	Monthly Emoluments	Annual Emoluments
Manager - Fisheries	6,500	78,000
Assistant Manager - Fisheries	5,000	60,000
Farm Assistants (2 posts)	2,500	60,000
Typist-cum-clerk	2,500	30,000
Driver	2,500	30,000
Attendants/Watchmen (4 posts)	1,500	72,000
Total		3,30,000

c) Recurring Costs

The annual recurring costs for the hatchery and its related activities are indicated below.

	Rs. in lakhs
Salaries of Staff	3.30
Brood Stock cost	0.20
Fish food	0.60
Pond Manuring	0.05
Replacement of equipments	0.05
Pond maintenance	0.50
Office expenditure	0.50
Transport	0.30
Training & Research	0.50
Chemicals/Glassware etc.	0.25
Miscellaneous	0.20
	6.45

3.8. SCHEDULE OF IMPLEMENTATION

Activity	Duration	Starting month
Site acquisition	3 months	1
Detailed site investigation, preparation of layouts, plans & estimates	3 months	4

Preparation of tender documents, tender floating and awarding contracts	3 months	7
Construction	6 months	10
Staff selection and appointment	3 months	13
Training of staff	1 month	16
Operationalisation		17

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References

1. Jhingran, V.G. 1983. Fish and Fisheries of India. Hindustan Publishing Corporation (India), Delhi.

2. Kulkarni, C.V. and Ogale, S.N. 1991. Conservation of the mighty Mahseer of India - Monograph.

3. Ogale, S.N. 1992. Management of hatchery practices and production of stocking material of *Tor Khudree* (Sykes). Recent researches in cold water fisheries in the National Workshop on Research and Developmental need for Cold water Fisheries : pp 177-184.

4. Sehgal, K.L. 1991. Artificial propagation of the Golden Mahseer *Tor putitora* in the Himalayas. Special Publication of the National Research Centre on Cold water Fisheries, Haldwani.

RESERVOIR FISHERIES DEVELOPMENT

4. RESERVOIR FISHERIES DEVELOPMENT

From time immemorial, damming of streams for the formation of impoundment and use of water for irrigation has been in vogue all over the world. In principle, dams, weirs, barrages and anicuts are created by construction of earthen, stone masonry or concrete bunds across the streams for multipurpose objectives viz. for public water supply, irrigation, hydroelectric power generation, flood control, recreation and development of food & sport fisheries. Reservoirs in India are located both in hilly regions as well as in plains. It is estimated that the area of reservoirs in the country is about 19.73 lakh ha. with Madhya Pradesh (2.91 lakh ha.), Orissa (2.56 lakh ha.), Gujarat (2.43 lakh ha.), Andhra Pradesh (2.34 lakh ha.), Karnataka (2.11 lakh ha.), Maharashtra (1.65 lakh ha.), Uttar Pradesh (1.50 lakh ha.) and Rajasthan (1.20 lakh ha.) having majority of the reservoir area.

4.1. EFFECT OF DAMS ON FISHERIES

4.1.1. River valley projects change the riverine environment, inevitably affecting the fishery resources of the concerned rivers. The effect of change may be adverse, beneficial or indifferent, depending on the particular situation and the fish fauna inhabiting the river concerned. Effects of dams and other structures on fish population can be categorised as obstructive and ecological.

4.1.2. Dams, weirs and barrages act as physical barriers to migration tending to prevent access of the fish to their usual breeding, hatching, rearing and feeding grounds. The denial of migration may result in reduction of the fish stocks in upper reaches of the river.

4.1.3. Consequent to the dam construction and reservoir

formation, substantial morpho-ecological changes may occur in the river both above and below the dam site. These include conversion of the running water into a water body of slow discharge characteristics, radical transformation of long established inter-relationships between organisms, replacement of existing fauna by new ones; shift of some species to new spawning and migration range and change of egg laying substrata. As a result, anadromous fish tend to settle down to new regions, local fish population may undergo drastic change and intraspecific biological differentiation of fish occurs. Other changes also occur such as fluctuations in water levels; alterations in the physico-chemical conditions including formation of thermocline, change in turbidity and dissolved oxygen levels.

4.1.4. Considerable reduction of flow in the residual river tailing below the dam, significantly alters the ecology of the spawning grounds, which may even dry up. The reduction of water levels in the residual river results in the formation of shallow areas which impede or obstruct fish movement.

4.1.5. Effects of dams on fisheries are not always deleterious. The construction of a dam across a river results in the creation of a reservoir which makes available larger areas of water for fish production and exploitation of varieties of fish suitable for such environments.

4.2. TRANSITION FROM RIVERINE TO LACUSTRINE ECOLOGY

4.2.1. A new reservoir passes through three trophic phases viz. (i) initial fertility or the trophic burst, (ii) trophic depression and (iii) trophic stabilisation. The filling of a reservoir inundates terrestrial vegetation which starts decaying soon after submergence. The

putrefaction of submerged vegetation gives rise to initial fertilisation of the water leading to high production of benthic fauna, plankton etc. followed by rapid establishment of new aquatic vegetation resulting in a burst in fish production in the first 2-3 years. This phase is followed by a trophic depression during which stage, there is continuous sedimentation as well as an increase in the volume of impounded water, which reduces the primary production due to dilution and usage of available nutrients for the trophic burst. Regular withdrawal of water from reservoir further reduces the nutrient availability, thereby reducing the primary productivity. This phase is called as the trophic depression and may last 5 to 10 years. After the trophic depression, the fertility stabilises depending upon the accumulation of organic substances in bottom soil. The extent and duration of the three phases/stages of evolution of lacustrine ecology differs from reservoir to reservoir.

4.3. RESERVOIR ECOLOGY

4.3.1. The chemical characteristics of water of the reservoir vary with its age. Stratification in respect of some of the physical and chemical parameters have been observed. This includes temperature, pH, carbonates, bicarbonates and free carbon dioxide etc.

4.3.2. In the initial filling stages of reservoir, extensive deoxygenation may occur in the deeper zone due to rotting of submerged vegetation. Such deoxygenation may result in an extensive damage to the original riverine population of organisms, but these damages are rarely complete because oxygenation in the upper strata where river water is flowing in. Dissolved oxygen levels generally show a declining trend with the increase in depth, as oxygenation by wave action and photosynthesis takes place

only in the photogenic layer, while dissolved oxygen is rapidly used up in the decay of accumulated organic matter at the bottom (tropholytic layer). In the photogenic layer carbon dioxide is taken up by the plants, generally from bicarbonates, resulting in a decrease in the bicarbonates, increase in pH and carbonates and production of oxygen. On the other hand in the tropholytic layer, oxygen is consumed and carbonates are converted into bicarbonates resulting in lower pH.

4.3.3. The reservoirs in temperate region often develop a thermal stratification with a top layer of warm water (epilimnion) followed by a layer of sudden lowering of temperature (metalimnion) followed by a layer of gradual lowering of temperature (hypolimnion). Sometimes, an ill-defined thermal stratification may occur. Reservoirs in Northern India and more specifically deeper reservoir show well defined thermal stratification particularly during summer. The wind action and influx of monsoon waters serve to minimise the stratification, with warmer and consequently lighter water at the surface and colder and heavier water at the bottom. With the advance of summer, the thermal stratification becomes more pronounced. The absence of mixing of the nutrient rich hypolimnion with the oxygen rich epilimnion, leads to wasteful accumulation of nutrient matter at the bottom of deep reservoirs. The dead storage level of most deep reservoirs more or less corresponds to the hypolimnion, giving that part of the deep reservoirs, the status of a nutrient sink.

4.4. BENEFICIAL EFFECTS

4.4.1. Even though the construction of dams reduces the quantum of water available in the down stream river, leading to a decline in riverine capture fishery, the benefits accruing in the form of facilities created for fish

production from reservoirs, ponds and tanks more than compensates the loss in riverine fishery. The average production from the Indian reservoirs is estimated at about 15 kg/ha/year. If proper management practices are followed, there is potential to raise the production from reservoirs up to 60 to 80 kg/ha/year in the major reservoirs and 150 to 300 kg/ha/year in small and medium reservoirs.

4.4.2. Other beneficial aspects of the reservoirs are the availability of water area for rearing fish seed as well as table fish in pens and cages on the peripheral areas and development of sport fishing.

4.5. STOCKING OF FISH IN RESERVOIRS

4.5.1. The purpose of stocking fish seed of indigenous and exotic species of fishes in a reservoir is to utilise all the ecological niches in a reservoir; increase desirable species of fish in the fishery; and restore balanced population in all the ecological niches (surface, column and bottom).

4.5.2. All the species of fish, indigenous or exotic, stocked should be as far as possible, feeding close to the base of food chain or food available in the reservoir and be acceptable to the people. The main purpose however, is mainly devoted to producing maximum yield of fish from the reservoir.

4.5.3. The fish production in a reservoir is affected by morphological, physical, chemical and biological factors. The physio-chemical and biological details collected during pre-impoundment study will give an idea of the basic productivity of the reservoir. Based on food and feeding habits the fishes found in the reservoirs can be grouped into 3 groups viz. (i) Planktophagus or Phytophagus (ii)

Detritophagus and (iii) Carnivorous.

4.5.4. The major carps of India are the most economically important fishes for stocking in the reservoirs. They are fast growing planktophagus or phytophagus fishes which feed on the lower links in the food chain in the reservoir. The major carps have however, different feeding zones in a reservoir. For example, Catla feeds on zooplankton in the surface layer of the reservoir while Rohu feeds in the column and to some extent in the bottom layer on vegetable debris, algae etc. The third major carp commonly stocked in the reservoirs is Mrigal which feeds on the bottom layers on the vegetable detritus matter. In addition to this, Common Carp, Mirror Carp, Silver Carp and Grass Carp have also been introduced in India for raising the productivity of tanks and ponds. However, so far, the introduction of Grass Carp and Silver Carp in open water systems is not permitted by the Govt. to prevent harm to the indigenous fish fauna of the country.

4.6. ACTION PLAN FOR RESERVOIR FISHERIES DEVELOPMENT

4.6.1. Keeping in view the need to augment fish production from reservoirs, data on parameters of limnology, quantitative biology and production potential of reservoirs has to be estimated. The following parameters have to be studied prior to, during and after impoundment:-

Water

Temperature
Transparency
pH
Dissolved Oxygen
Total Solids
Nitrates
Phosphates

Soil

Organic Carbon
Available Nitrogen
Available Phosphorus

Quantitative Biology

Plankton
Benthos
Fish - species-wise, gear-wise fish landing record
Maturity, breeding & natural repopulation etc.
Growth, year-class distribution.
Energy conversion, primary productivity etc.

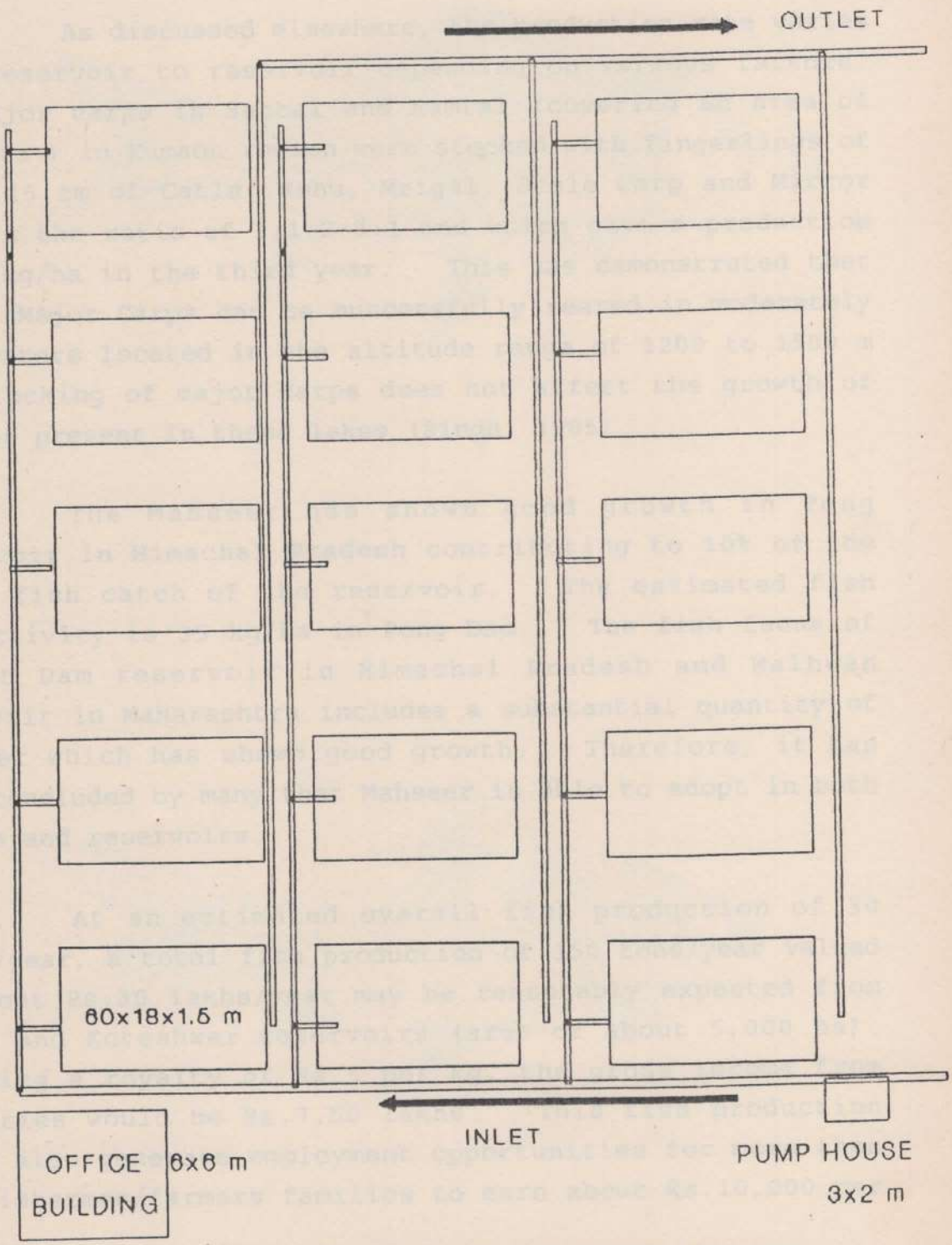
4.7. PROPOSED STOCKING OF TEHRI DAM

4.7.1. The species proposed on trial basis for introduction in Tehri & Koteshwar reservoirs are (i) Mahseer (ii) Catla, (iii) Rohu, (iv) Mrigal and (v) Mirror Carp. The stocking rate will be 150 fingerlings per ha in the ratio of Mahseer-30%, Catla-25%, Rohu-25%, Mrigal & Mirror Carp-20%, fingerlings per ha. As the Indian Major Carps may not attain maturity and breed in cold climates, fish seed has to be imported from hatcheries within the State or outside. It is suggested that the hatchlings or early fry may be brought from the hatcheries and reared to fingerlings at a rearing centre. This will facilitate their acclimatisation to cold waters as well as the survival in the cold waters of Tehri dam. The suggested layout of the rearing centre is given in Figure-2.

4.8. GROWTH MONITORING AND STOCK MANIPULATION

4.8.1. Based on the analysis of the parameters earlier stated, the stocking rate and species combination may have be modified according to the carrying capacity of the

Figure-2



TENTATIVE LAYOUT OF THE REARING CENTRE

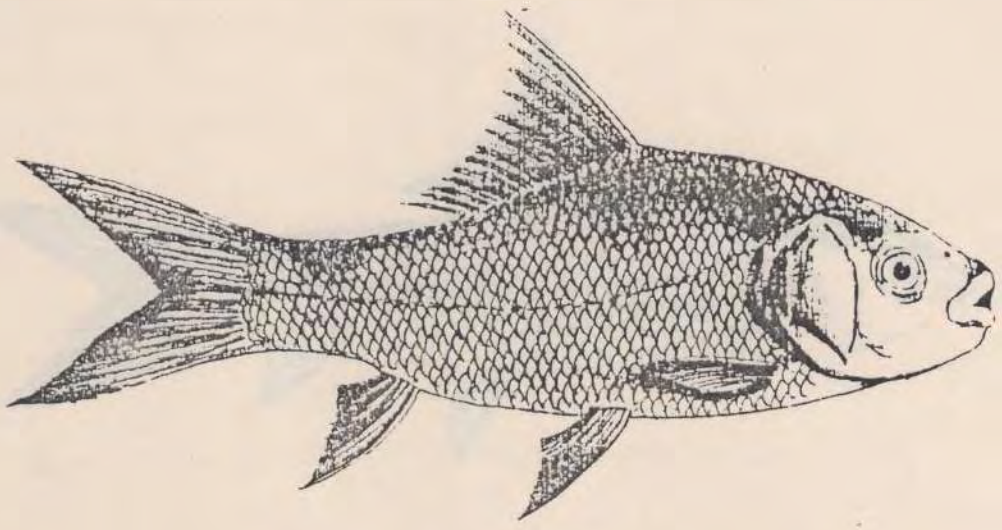
reservoir, survival and growth of the fish stock.

4.9. **PRODUCTION**

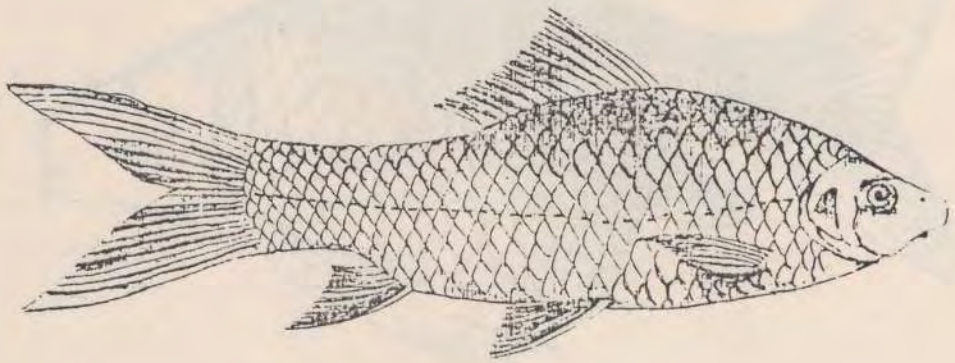
4.9.1. As discussed elsewhere, the production rate varies from reservoir to reservoir depending on various factors. The major carps in Sattal and Ramtal (covering an area of 24.79 ha.) in Kumaon region were stocked with fingerlings of 10 to 15 cm of Catla, Rohu, Mrigal, Scale Carp and Mirror Carp in the ratio of 3:1:2:3:1 and which gave a production of 53 kg/ha in the third year. This has demonstrated that Indian Major Carps can be successfully reared in moderately cold waters located in the altitude range of 1200 to 1500 m and stocking of major carps does not affect the growth of Mahseer present in these lakes (Singh, 1985).

4.9.2. The Mahseer has shown good growth in Pong reservoir in Himachal Pradesh contributing to 10% of the total fish catch of the reservoir. The estimated fish productivity is 35 kg/ha in Pong Dam. The fish fauna of Pandoh Dam reservoir in Himachal Pradesh and Walhwan reservoir in Maharashtra includes a substantial quantity of Mahseer which has shown good growth. Therefore, it has been concluded by many that Mahseer is able to adopt in both rivers and reservoirs.

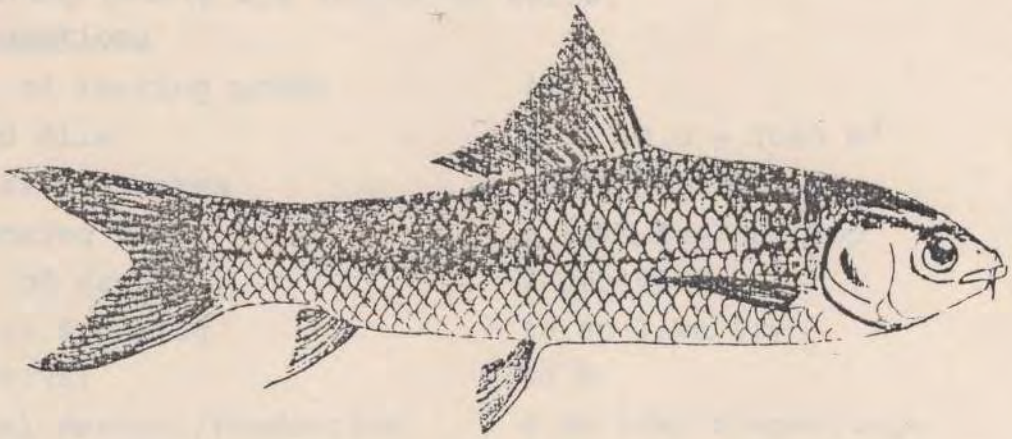
4.9.3. At an estimated overall fish production of 30 kg/ha/year, a total fish production of 150 tons/year valued at about Rs.30 lakhs/year may be reasonably expected from Tehri and Koteshwar reservoirs (area of about 5,000 ha). Assuming a royalty of Rs.5 per kg, the gross income from fisheries would be Rs.7.50 lakhs. This fish production would also generate employment opportunities for more than 200 fishermen/farmers families to earn about Rs.10,000 per annum.



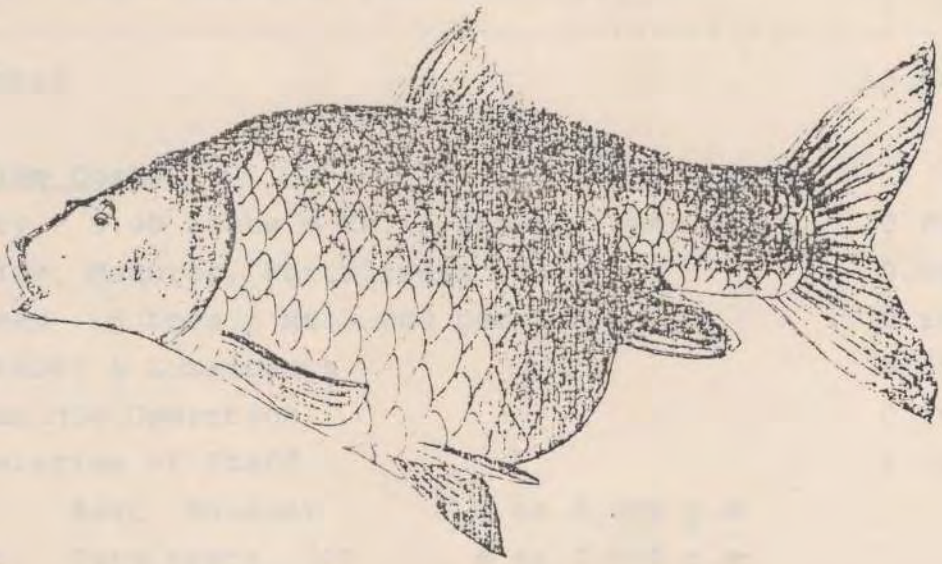
CATLA, CATLA CATLA



ROHU, LABEO ROHITA



MRIGAL, CIRRHINUS MRIGALA



COMMON CARP, CYPRINUS CARPIO

4.10. COST ESTIMATES

4.10.1. The estimated capital and recurring costs of the rearing centre are indicated below.

Assumptions

No. of rearing ponds	15
Pond Size	60 X 18 m = 1080 m^2
Total Pond area	16200 m^2 = 1.6 ha
Stocking Rate	2 lakh fry/ha/crop
No. of crops	2 per year
Total Stocking	10.80 lakh fry
Survival	50 %
Total Harvest/Production	5.40 lakh fingerlings

Capital Costs		Rs. in lakhs
a.	Land - 2.5 ha @ Rs.1.8 lakh/ha	4.50
b.	Ponds Construction - 1.35 ha @ Rs. 2 lakh/ha	2.70
c.	Building - 40 m^2 @ Rs.4000 per m^2	1.60
d.	Vehicle with trailer	4.00
e.	Equipments	
	i. Pumps - 5 hp X 2 nos. @ Rs.30,000	0.60
	ii. Nets, Buckets, Furniture etc.	0.20
	Total	13.60

Recurring Costs		
a.	Fry - 5.40 lakhs @ Rs.12,000 per lakh	0.65
b.	Lime, Manures, Fertilisers etc.	0.05
c.	Feed - 5 tons @ Rs.3,000 per ton	0.15
d.	Diesel & Lubricants	0.15
e.	Vehicle Operation	0.30
f.	Salaries of Staff	2.16
	i. Asst. Manager - @ Rs.5,000 p.m.	
	ii. Farm Assts. (2) - @ Rs.2,500 p.m.	
	iii. Typist/Clerk - @ Rs.2,500 p.m.	
	iv. Driver - @ Rs.2,500 p.m.	
	v. Watchmen/Peons (2) - @ Rs.1,500 p.m.	
g.	Pond maintenance	0.15
h.	Miscellaneous	0.19

4.11. SCHEDULE OF IMPLEMENTATION

Activity	Duration	Starting month
Site acquisition	3 months	1
Detailed site investigation, preparation of layouts, plans & estimates	3 months	4
Preparation of tender documents, tender floating and awarding contracts	3 months	7
Construction	6 months	10
Staff selection and appointment	3 months	13
Training of staff	1 month	16
Operationalisation		17

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References

1. Bhukaswan, T. 1980. Management of Asian reservoir fisheries. FAO Fisheries Technical Paper No.207, pp.1-69.

2. Jhingran, V.G. 1983. Fish and Fisheries of India. Hindustan Publishing Corporation (India), Delhi.

3. Natarajan, A.V. and Pathak, V. 1983. Pattern of energy flow in fresh water tropical & tropical impoundments. Central Inland Fisheries Research Institute Bulletin, 36. p 27.

4. Singh, C.S. 1985. Development of high altitude lake fisheries with reference to Kumaon lakes of Uttar Pradesh. Punjab Fisheries Bulletin IX(1-2). pp 48-54.

AQUARIUM

5. AQUARIUM

Tehri will be one of the tallest dams of Asia with a height of 260.5 metres. The people from different parts of the country as well as abroad are likely to visit Tehri and the place may become a tourist attraction in due course of time. The pilgrims going to Uttarkashi, Kedarnath and Badrinath may also travel via Tehri to see Tehri dam and the new township. With the various activities connected with the construction of the dam, like power generation, irrigation, water supply, horticulture, forestry, fisheries, and shifting of the district head quarters to Tehri, considerable increase in the resident as well as floating population can be expected. To provide added attraction to the visitors and create public awareness towards protection of wild life, including fish, especially among children, students etc. it is proposed that THDC may consider to set up an aquarium as a hobby/recreational spot, as well as to provide office accommodation for sport fishing, research activities etc.

5.1. LOCATION

5.1.1. Land at Koti in Vishwakarmapuram near the proposed stadium or any other suitable vantage point located on/near the main road may be earmarked for establishing the proposed aquarium.

5.2. BUILDING

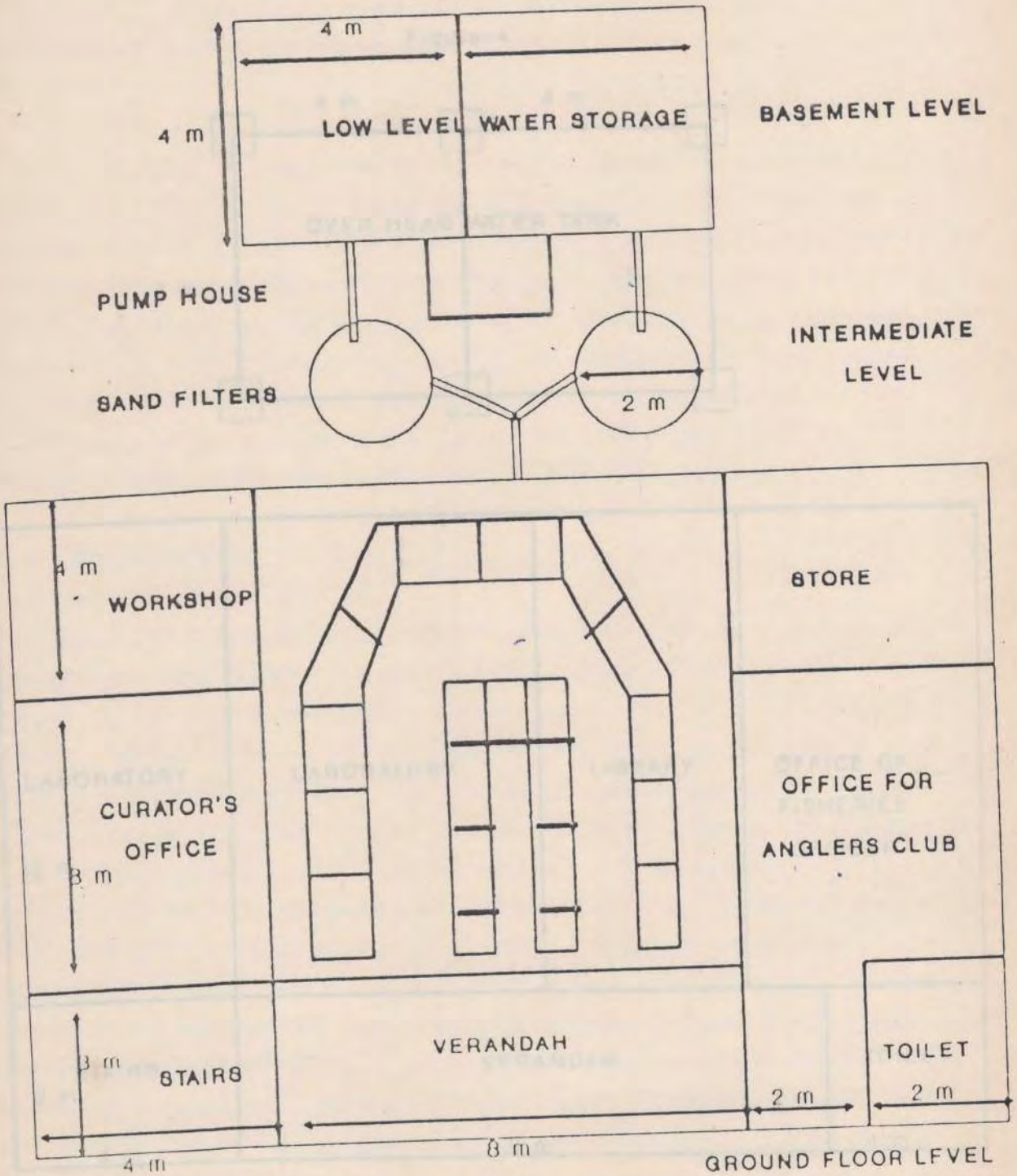
5.2.1. A three storied building with the front facing the road and the rear close to the water to facilitate water pumping of water to sedimentation tanks and later to the over head tanks etc. would be required. The building should be of framed concrete construction on a site free from risk of subsidence as any subsidence later may result

in cracking of the large glass panels of the aquarium tanks. The basement floor projecting beyond the main building may house the low level water storage tank and the pump room. The ground floor may house the aquarium, and have a horse-shoe shaped viewing gallery with aquarium tanks on either side and space for service gallery, offices etc. The first floor of the building may have a laboratory, office for the Anglers Association etc. A suggested layout of the proposed aquarium is given in Figures - 3 & 4.

5.3. **AQUARIUM TANKS**

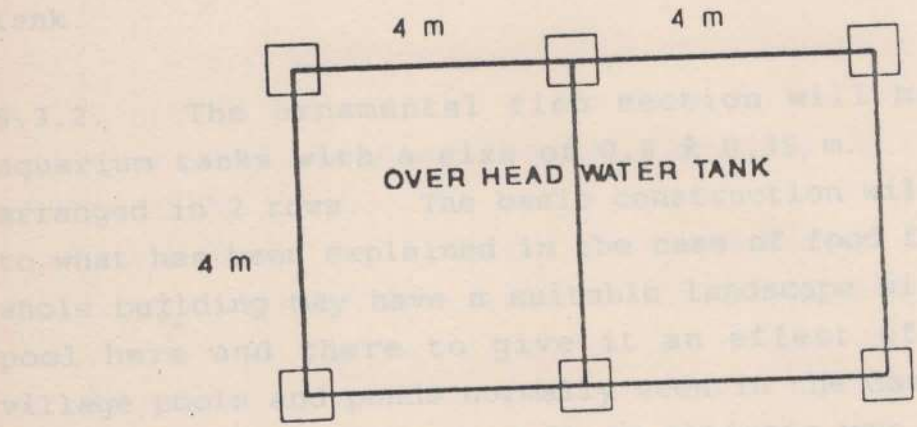
5.3.1. The aquarium would have 2 sizes of tanks. While the larger tanks would be for food fishes, the smaller tanks would be for the ornamental fishes. The food fishes will be of two categories i.e. warm water and cold water species. The aquarium will have heating facilities both for ornamental fishes and warm water species during the winter months. The food fish tanks would be of size 1.5 x 1 x 1 m. The glass front will have a size of 1.25 x 0.75 m, and will be the main front view for the visitors. Each aquarium tank will be of reinforced concrete with grooves in the front for holding 25 mm sheet glass. The glass will be inserted in the groove and sealed with suitable water proof resins/fixers. The aquarium tanks will be so designed that they have a gradually curving sides and back. The back and sides can be lined with thin glass with suitable underwater scenes to give a diorama view of the underwater world to the visitors. Each aquarium tank will have multiple concealed fluorescent tube lights, while the viewing gallery will be dimly lit. Water will enter the aquarium tank through water jets which will provide aeration also. Each aquarium tank will have one or two outlets to maintain the desired water level. It is also proposed to provide compressed air, preferably from a pressure tank, through an oil vapour separator to provide additional oxygenation of water. This

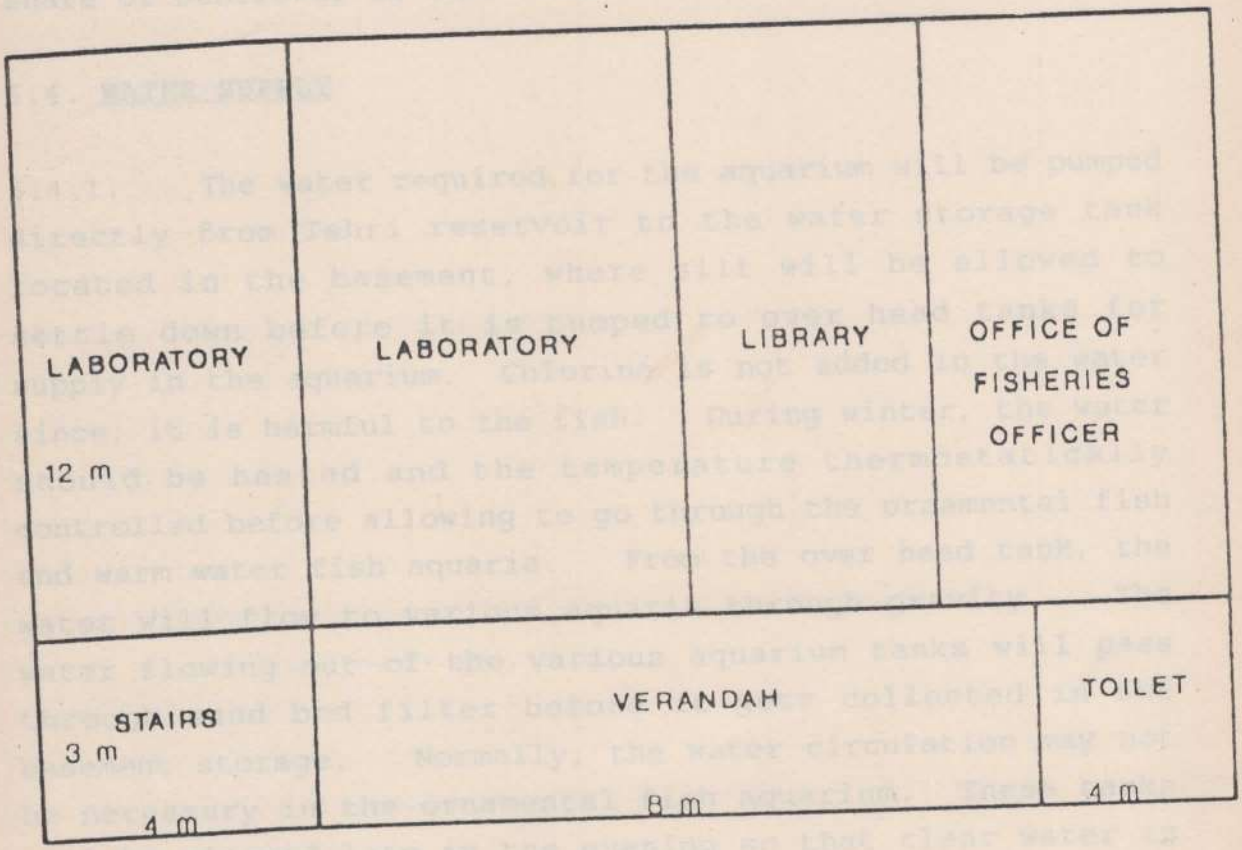
Figure-3



SUGGESTED LAYOUT OF THE AQUARIUM
(BASEMENT AND GROUND FLOOR)

Figure-4





SUGGESTED LAYOUT OF THE AQUARIUM BUILDING
(FIRST FLOOR ARRANGEMENT)

system of aeration can be made use of to operate various moving aquatic toys normally used in domestic aquaria. The tank bottom will have rock, gravel, boulders and live or artificial plants to give an effect close to the natural habitat of the fish which are on display in that particular tank.

5.3.2. The ornamental fish section will have smaller aquarium tanks with a size of 0.6 x 0.35 m. They can be arranged in 2 rows. The basic construction will be similar to what has been explained in the case of food fishes. The whole building may have a suitable landscape with the lotus pool here and there to give it an effect of the common village pools and ponds normally seen in the Garhwal region. The landscaping may be done in an artistic way to give it a share of Sunflower or Palm tree.

5.4. WATER SUPPLY

5.4.1. The water required for the aquarium will be pumped directly from Tehri reservoir to the water storage tank located in the basement, where silt will be allowed to settle down before it is pumped to over head tanks for supply in the aquarium. Chlorine is not added in the water since, it is harmful to the fish. During winter, the water should be heated and the temperature thermostatically controlled before allowing to go through the ornamental fish and warm water fish aquaria. From the over head tank, the water will flow to various aquaria through gravity. The water flowing out of the various aquarium tanks will pass through sand bed filter before it gets collected in the basement storage. Normally, the water circulation may not be necessary in the ornamental fish aquarium. These tanks will be cleaned late in the evening so that clear water is available for viewing next day. Feeding in all the aquaria will be about 2 hours before the cleaning operations late in the evening or at night. Wherever possible the feed given

to the fishes will be the standard pelleted feed which is available for purchase. However, some fishes require special live feed which should be provided.

5.5. DISPLAY

5.5.1. Every aquarium tank will have a legend printed on plastic giving the details of the fish in the aquarium under display, such as food and feeding, breeding habits, and its importance for the Garhwal and other regions of the country. This legend is intended to educate the visitors , particularly the school children about the general habitat of the fish and its importance in the nature. A big panel can also be displayed showing the general anatomy of the fish, its respiratory mechanism, and other details, which are exclusive to fishes.

5.6. COST ESTIMATES

5.6.1. Capital Cost

Cost of land (Free)	
Building Cost	12.00
(approx. 300 sq.m. @ Rs.4,000 per sq.m.)	
Storage Tanks & Over Head Tank	3.30
Sand filter	0.30
Pump House	1.00
Aquarium tanks	1.00
Glass plates	1.50
(25 mm thickness of size 1.5 x 1.00 m x 16 nos.)	
Piping, caulking, water proofing	0.10
Office equipment, furniture etc.	0.20
Pumps, aeration equipment,	1.50
heaters, aquarium novelties etc.	
Lighting, illumination etc.	0.30
Painting, finishing etc.	0.10
Miscellaneous	0.50

Total	21.80

5.6.2. Operating Costs

Cost of Ornamental/food fishes	0.20
Salaries of staff	2.04
Curator - 1 @ Rs.5000 pm	
Clerk - 1 @ Rs.3000 pm	
Attendants - 2 @ Rs.2000 pm	
Gardener - 1 @ Rs.2000 pm	
Watchman/Peon - 2 @ Rs.1500 pm	
Electricity	0.50
Fish Food	1.00
Repairs & Maintenance	0.40
Contingencies	0.20
Total	4.34

SPORT FISHING

6. SPORT FISHING

6.1. ANGLING AS A SPORT

6.1.1. Angling is one of the oldest avocation the nomadic people practiced using spears, bows & arrows in search for food and pleasure. Sport fishing or angling is a well known outdoor recreation all over the world. It is considered a healthy pursuit to go out to the country side with family for fishing on week ends. Akin to hunting, it has the thrill of conquest and pleasure of sport. Angling is supposed to reduce stress and strain of the modern living and as a sport it excels others because it is basically a game of patience. It is estimated that in USA alone there are 20 million anglers followed by 4 million in England and their numbers are increasing every day.

6.1.2. In India, the first angling club was formed in 1900 by Frank G.Mitchell with the support of few dedicated sportsmen and patronage of the then His Highness Raja Amar Singh of Kashmir and Sir Geoffrey Godwin the then British Resident. Each club member contributed £ 50 to introduce trout, an exotic Scotland fish, for angling in the hill streams of Kashmir. After few unsuccessful attempts during 1905-1911, finally trout got established in India. It was the brown trout that got acclimatised in the snow fed streams of north India, while in the south Indian rain fed hill streams, it was rainbow trout. The establishment of trout in India including establishment of trout hatcheries could be made a reality due to continuous effort of the Department of Fisheries in Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh and Tamil Nadu.

6.1.3. The sporting habits of the Indian fishes especially Mahseer were for the first time highlighted by H.S.Thomas in his books "Tank Angling in India" (1873) and

"Rod in India" (1897), followed by the book of S.Dhu "Anglers in India on the Mighty Mahseer" (1923). The fighting qualities of Mahseer, the tiger of Indian rivers with all the detail of its availability, fishing spots, sizes caught by various anglers etc. were narrated in most exciting and interesting details by A.J.S.MacDonald in his world famous book "Circumventing the Mahseer and Other Sporting Fishes" (1948). These publications and notes kept by anglers and angling clubs brought out forcibly the special qualities of Mahseer as a anglers dream fish.

6.2. CONSERVATION THROUGH PROPAGATION

6.2.1. Despite wonderful sporting qualities and availability in all the major riverine systems of the country, no efforts were made until recently to establish Mahseer hatcheries on the lines of trout hatcheries in any state to develop sport fishing of Mahseer.

6.2.2. Late S.Moolgaokar former Chairman of Tata Engineering and Locomotives Company Ltd.(TELCO), and S.P.Manaktala Managing Director of Tata Electric Companies (TEC), both sport and wild life loving anglers discussed the problem of growing decline of Mahseers due to man-induced environmental modifications in India with Dr. C.V.Kulkarni, Retired Director of Fisheries, Govt. of Maharashtra and a well known fisheries scientist. Dr. Kulkarni suggested a closer study of the problem on scientific basis and a plan of action was chalked out for artificial propagation of Mahseer on a large scale and rehabilitation in depleted waters by stocking fry and fingerlings. The first batch of 14,000 artificially fertilised eggs of Khudree Mahseer were obtained in 1970 for rearing in the TEC fish farm at Lonavla and rehabilitation in rivers.

6.2.3. In the last two decades, fry and fingerlings

produced at Lonavla have been distributed to various Departments of Fisheries for stocking in their state rivers and reservoirs for rehabilitating Mahseer and developing sport fishing. The TEC organised three national level workshops on conservation and artificial propagation of Mahseer to give hands-on training in obtaining eggs and milt from the spawners to effect fecundation. This approach has paid off specially in restoring Khudree Mahseer in Tata Hydel Reservoirs and other rivers of South India. This has built up self confidence in adopting induced breeding techniques not only for Deccan Mahseer, the species tried at Lonavla, but also other species of Mahseer.

6.3. CONSERVATION OF MAHSEER THROUGH ANGLING ASSOCIATIONS

6.3.1. A band of dedicated anglers and wild life enthusiasts of the Wild Life Association of South India, Bangalore took on lease a stretch of the river Kaveri for rehabilitation of Mahseer. They stocked Mahseer fingerlings in the river stretch, followed by strict patrolling to check unauthorised fishing and introducted strict licensing system to regulate angling by sport enthusiasts. These efforts have resulted in restoration of Mahseer population in the river Kaveri.

6.3.2. On the same lines, the Himachal Angling Association - formed in 1978 by a group of conservation oriented sport anglers for development of Mahseers in the Kangra valley, also took on lease a stretch of the river Beas between Sari Molag and Dehra Gopipur in Kangra for development of sport fishing. The efforts of the association were remarkable which prompted Air India in co-operation with Trek-N-Tour Himachal (Angling Division) to bring out a publicity brochure on "Mahseer Fishing" for attracting foreign tourists to come to India for Mahseer angling.

6.3.3. Another pioneering work was by Assam (Bhoroli) Anglers Association, Tezpur by undertaking conservation of Mahseer in snow fed Bhoroli river in the upper Assam to popularise Mahseer angling as a sport.

6.3.4. Recently Govt. of Arunachal Pradesh organised an international angling festival to popularise Mahseer angling in the rivers bordering Assam and Arunachal Pradesh.

6.3.5. Other notable angling associations are Maharashtra Fish Association in Powaii Lake and West Bengal Angling Association which provide fish angling facilities to their members. To coordinate the activities of the state level angling associations, a national level Angling and Aquatic Conservation Society of India was constituted with head quarters at Bhadkal Lake (Haryana) and the Society in association with the Himachal Angling Association organised a symposium on the conservation of National Fisheries Wealth and all India Open Angling Competition in Pong Reservoir (Dist. Kangra) on 27-28 October 1984.

6.4. ANGLING ASSOCIATION AT TEHRI

6.4.1. As a first step towards, popularising fish angling in Garhwal region, it is proposed that after Mahseer hatchery proposed in this report becomes operational and stocking of Mahseer in the river Bhagirathi is undertaken for a few years, an Angling Association at Tehri may be formed. Some of the details of the proposed Association are given below.

Name - Tehri Angling Association.

Objectives - To protect notified and assigned areas of rivers & reservoirs from poaching.

- To encourage sport fishing.
- To provide fishing tackle to members.
- To organise angling competitions.
- To gather and spread information on angling.
- To organise conferences, lectures, seminars, workshops, training programmes etc. for conservation of fisheries and sport fishing.
- To have affiliation with other associations of similar activities and objectives in India and abroad.
- To obtain representation on boards/ commissions/committees set up by the Govt. in furtherance or for the purpose of the objects of the association.
- To maintain statistics and information pertaining to sport fishing.
- To have contact with the Govt./Research Institutions for conservation of fish.
- To help the members in procuring equipment for angling.
- To get affiliated with any other associations of similar objects in India and abroad.
- Any other activities related to angling, conservation of fishery resources etc.

Area - The area of activity may be the notified portions in the river Bhagirathi from Uttarkashi to Devprayag including Tehri and Koteshwar reservoirs.

Membership - The membership may be open to all anglers, angling associations, institutions, organisations related to conservation of fisheries resources and promotion of angling as a sport.

Fees - For individuals - Admission fee Rs.100
Annual subscription Rs.50
Life membership Rs.500
For institutions- Admission fee Rs.100
Life subscription Rs.1000

Funds - By membership fees, subscription, donations, loans, grants and gifts.

Management - 1. General Body.
2. Executive Committee consisting of President, Vice President, Secretary, Treasurer and 4 Members.

Based on the above, the detailed memorandum/bylaws/ rules of association may be framed by a nucleus committee constituted for the purpose. It is suggested that the THDC may take initiative in this regard in association with the Fisheries Department of the State and extend all possible facilities for the functioning of the Association. The THDC may further patronise the association and provide initial grants-in-aid to purchase fishing tackles, boats, equipments etc. and provide suitable office accomodation.

*****

References

1. Anonymous 1959. Fishing in India. Directorate of Advertisement & Visual Publicity, Ministry of I & B., Dept. of Tourism, Govt. of India, New Delhi.

2. Anonymous 1981. Mahseer Fishing. Air India.

3. Anonymous 1983. The Mighty Mahseer. The Himachal Angling Association.

4. MacDonald, A.st J. 1948. Circumventing the mahseer and other sporting fish in India & Burma. Journal of the Bombay Natural History Society, 49, pp 306.

5. Sehgal, K.L. 1987. Sport Fisheries of India, Indian

Council of Agricultural Research, New Delhi.

6. Thomas, H.S. 1873. Tank Angling. Thacker Spink, London, pp 182.

7. Thomas, H.S. 1897. The Rod in India. William Clawes and Sons, London, pp 435.

APPENDIX-1

Appendix-1

RECOMMENDATIONS OF THE ZOOLOGICAL SURVEY OF INDIA

The Zoological Survey of India (ZSI), in the Environment Impact Assessment Study have made the following recommendations:-

(1) Fish Ladders or Passes: Fish ladders or passes i.e. migratory passage for the fishes ascending upstream during breeding season may be provided at least up to the base of the main Tehri dam or a little above and from where the fishes should be lifted up through some mechanised device and in the same way while spent return to the main rivers after spawning.

The design of the fish ladder may be of "Pool and fall" or "Step system", wherein the water level is brought down through a series of short falls and pools alternately, so that water runs down from one step or pool to another through a passage. The falls/steps should be round-edged and low, so that the fish can ascend easily. At the end of each step the baffle wall should have a hole enough for the fish to pass. The fishes may ascend directly or through the hole. The gradient or the slope in the pass should be such that it provides a gentle flow of water. The pass should be wide enough so that during ascent or descent, the fishes should not strike against its wall. These should be sufficient natural light in the pass so that fishes do not hesitate to enter it.

(2) Monitoring During Breeding Season: During the breeding season, when the ripe fishes ascend towards higher elevations, mostly during south-west monsoon, the period should be declared as closed season in the area. The exact breeding season of migratory fishes in the area is to be observed as spawning frequency of these species varies from

drainage to drainage.

(3) Developing of Rearing Centres: The fry and fingerling rearing centres should be developed along the course of the river for proper management of its population. These centres should act as stocking centres for release in the main rivers.

(4) Management:

(a) Check on Devastating Means: Devastation of the fish by various means (electrocuting, dynamiting, poisoning, water pollution, excessive netting specially in breeding grounds, fish ladders and river confluences, sudden closure of canals etc.) should be stopped by enforcing strict laws.

(b) Creation of Fish Sanctuaries: The breeding grounds, river confluences, fish ladders etc. where the fishes gather in large numbers or pass through, should be declared fish sanctuaries.

(c) Public Awareness: People of the area should be educated through some incentives for saving the wildlife.

(d) Introduction of Additional Species: Some appropriate species which have no competition with local fishes for food may introduced into the reservoir to develop reservoir fishery resources. This may be done in consultation with State Fisheries Department or Central Inland Fisheries Research Institute, Barrackpore.

(5) Design of Side Wall of Reservoir: As the reservoir will be very deep, its side walls at least upper part at appropriate places may be designed in "step or stair system" with some boulders fixed on each step. It will help the fishes which feed on slime by scraping from the boulders or rocks.

APPENDIX-2

Appendix-2

TERMS OF REFERENCE

As per letter No.THDC/C-524/1339 dated 20.11.93, the terms of reference for preparing an Action Plan for mitigating the possible impact on "Mahseer" fishery due to construction of Tehri dam are as under:-

1.0 **Scope of Work**

1.1 Preparation of an Action Plan for conservation of Mahseer fishery in the Bhagirathi valley for mitigating the possible impact due to construction of the Tehri Dam.

1.2 Examining the possibility of developing other fishery resources in the reservoir formed by the dam.

1.3 Possibility of developing sport fishing for Mahseer in the valley and establishing an aquarium to preserve fish gene of the valley as well as to develop tourist interest.

2.0 The report is to contain the following :

2.1. Fish and fishery of river Bhagirathi as the background of the report.

2.2. Review of literature available on Mahseer.

2.3. Mahseer fishery of the valley in relation to the fishery in other parts of the country.

2.4. Action Plan for items 1.1 to 1.3 indicated above including site selection, layouts and cost estimates.

CURRICULUM VITAE OF CONSULTANTS

CURRICULUM VITAE

DR. T. A. MAMMEN

Expertise :	Fisheries Development & Policy Aquaculture, fresh & brackish water Fish handling, processing and marketing Fisheries extension
Education & Training	B.Sc., Zoology, Botany & Physiology - Madras University. M.Sc., Zoology with specialization in Fish - Sagar University. Ph.D., Marine Biology - Kerala University Training in Oceanography as under-study to Norwegian Oceanographer - Kerala University. Training on board USSR Research Vessel 'Akademic Knipovich' in Black sea and Mediterranean - FAO Training in Fish Handling, Processing, Plant Sanitation and Quality Control - FAO/DANIDA.
Organizations Served	Kerala University, Trivandrum; Central Marine Fisheries Research Institute, Mandapam; Central Fisheries Extension Units, Bangalore, Mandapam & Hyderabad.; Ministry of Agriculture, New Delhi, Marine Products Export Development Authority, Cochin, Government of Kerala, Trivandrum, Asian Development Bank, Manila and Tropical Fisheries Consultancy Services, Delhi.
Countries Visited.	Sri Lanka, Maldives, Bangla Desh, Thailand, Malaysia, Philippines, Australia, USSR, Bulgaria, Turkey
Languages:	English, Malayalam, Tamil. Hindi.
	Date of birth: January 25, 1927 Nationality: Indian
Awards	Award from Investions Promotion Council, Govt. of India for developing 'Splashless tank and aeration equipment' (First to get and Invention in Fisheries).
Research work	Hydroids of South India. Swim bladder in fish Live fish transport
Assignments:	
1950-57	Research Scholar, Research Asstt., Research Officer University of Kerala, Trivandrum and Central Marine Fisheries Research Institute, Mandapam.

1957 -64	Asstt. Fisheries Extension Officer, Fisheries Extension Unit, Bangalore/Mandapam/Hyderabad.
1964-70	Fisheries Research & Investigation Officer, Ministry of Agriculture, New Delhi.
1970-72	Assistant Commissioner (Fisheries Extension), Ministry of Agriculture, New Delhi.
1972-77	Deputy Commissioner (Fisheries Planning, Ministry of Agriculture, New Delhi.
1977-79	Director, Marine Products Export Development Authority, Cochin (Ministry of Commerce).
1979-81	Jt. Commissioner (Fisheries), Ministry of Agriculture, New Delhi.
1982-84	Fisheries Development Adviser and Ex-Officio Secretary to the Govt. of Kerala.(Part time)
1982 to date	Managing Director and Chief Consultant, Tropical Fisheries Consultancy Services, Delhi.
Professional Affiliations	Member, Academy of Zoology, Agra. Member, Marine Biology Association of India, Cochin. Member, Fishery Technologist's Association of India, Cochin.

(Dr. T.A. Mammen)

1967-73	:	Chief Training Superintendent, Central Institute of Fisheries Education, Bombay.
1963-67	:	Fisheries Training Superintendent/ Demonstrator (Fish Processing) Central Institute of Fisheries Education, Bombay.
1962-63	:	Research Assistant, Central Inland Fisheries Research Institute, Barrackpore, West Bengal
1960-62	:	Assistant Fisheries Training Superintendent, Central Inland Fisheries Research Institute Barrackpore, West Bengal.
1957-60	:	District Fisheries Officer, Govt. of Madhya Pradesh, Bhopal.

Professional Affiliations

1.Vice President, Asian Fisheries Forum (Indian Branch), Mangalore.
2.Founder Member, Asian Fisheries Forum, Manila, Phillippines
3.Member, Executive Committee - Angling and Aquatic Conservation Society of India.

(DR. VIJAI DEV SINGH)

Annexure R/6

Government of India
Ministry of Water Resources

सत्यमेव जयते

भारत सरकार
जल संसाधन मंत्रालय

केन्द्रीय जल और विद्युत अनुसंधान शाला
CENTRAL WATER AND POWER RESEARCH STATION

TECHNICAL REPORT NO.: 3821 SEPTEMBER 2001

MATHEMATICAL MODEL STUDIES TO INVESTIGATE HYDRODYNAMICS OF THE TEHRI RESERVOIR, TEHRI, UTTARANCHAL

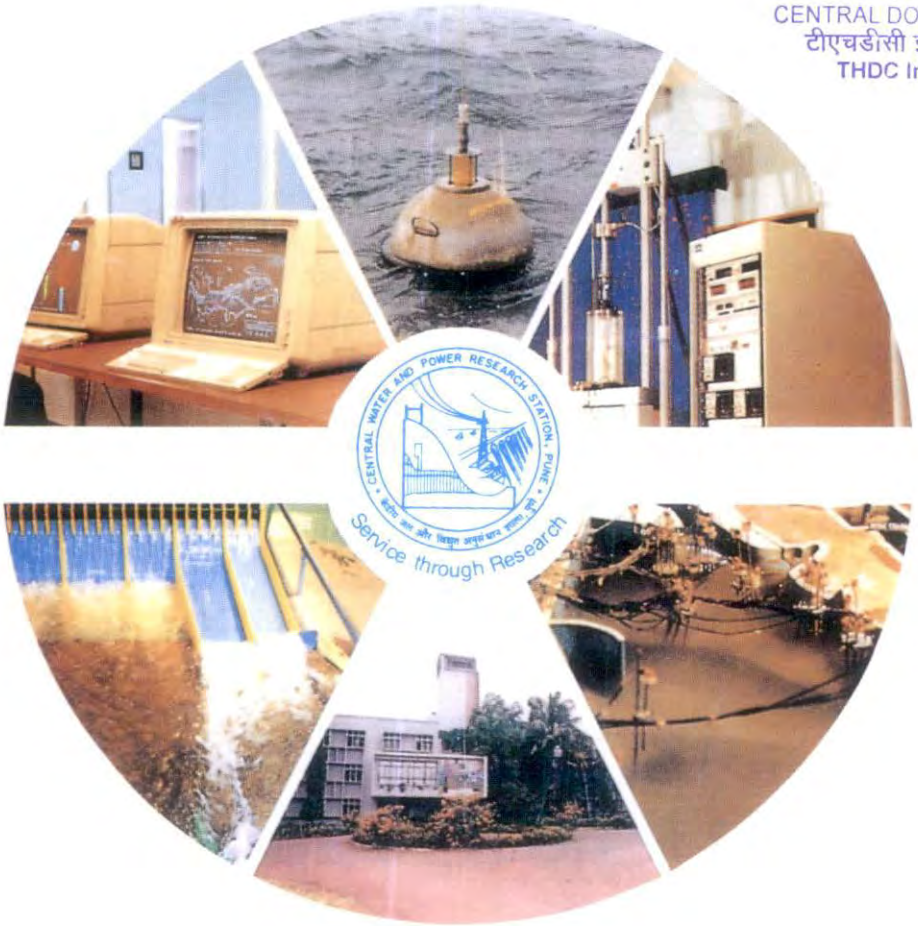
MRS. V. M. BENDRE
DIRECTOR

6/55

Government of India
Ministry of Water Resources

सत्यमेव जयते

भारत सरकार
जल संसाधन मंत्रालय



केन्द्रीय जल और विद्युत अनुसंधान शाला

CENTRAL WATER AND POWER RESEARCH STATION

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MATHEMATICAL MODEL STUDIES TO INVESTIGATE HYDRODYNAMICS OF THE TEHRI RESERVOIR, TEHRI, UTTARANCHAL

MRS. V. M. BENDRE
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GOVERNMENT OF INDIA
CENTRAL WATER AND POWER RESEARCH STATION
PUNE – 411 024

MATHEMATICAL MODELLING CENTRE

TECHNICAL REPORT NO.: 3821
SEPTEMBER 2001

MATHEMATICAL MODEL STUDIES TO INVESTIGATE HYDRODYNAMICS OF THE TEHRI RESERVOIR, TEHRI, UTTARANCHAL

Mrs. V.M. BENDRE
Director

Government of India
Central Water and Power Research Station
PO: Khadakwasla Research Station, Pune 24

REPORT DOCUMENTATION SHEET

Technical Report No.	Month & Year
3821	September 2001

Title
MATHEMATICAL MODEL STUDIES TO INVESTIGATE HYDRODYNAMICS OF THE TEHRI RESERVOIR, TEHRI , UTTARANCHAL.

Type of Report
Final

Name and Address of the organisation conducting the studies

MATHEMATICAL MODELLING CENTRE
CENTRAL WATER AND POWER RESEARCH STATION,
PO: KHADAKWASLA R.S., PUNE 411 024.

Sponsoring Authority

Director (Technical)
Tehri Hydro Development Corporation Limited (THDC Ltd.),
PO: Tehri, Rishikesh, Uttaranchal

Key words
Bathymetry, Hydrodynamics, Flow Field, Discharge, Inflow, Outflow, Meteorological data, Residence time, Concentration, Power outlet, Monsoon season, Winter season, Velocity field, Layer, Simulation, Circulation.

Synopsis
This report describes the outcome of the mathematical model studies carried out at CWPRS, Pune, to determine the hydrodynamics of Tehri reservoir, Tehri (Uttaranchal). The study indicates that due to the construction of the proposed reservoir, the following conclusions on the hydrodynamics of the reservoir may be drawn. The Tehri reservoir completes the cycle of replenishment of its storage every year. There is no possibility of permanent stagnation of water in the reservoir. During the period of active monsoon, incoming river water travels along the bottom of the reservoir due to high sediment content and the storage below MDDL is replaced by fresh river inflow. During winter season, the river water travels at the level of outlet and gets released. During the intervening period between winter and monsoon, the inflow water gets well mixed in the reservoir. The 3-Dimensional circulation prevails in the reservoir at all times of the year. The studies reveal that the time taken to reach the location of the outlet by inflow of the river Bhagirathi is in the range of 17 to 100 days.

PREFACE

The study of hydrodynamic behaviour and water quality parameters of Tehri reservoir in the state of Uttaranchal was referred to Central Water and Power Research Station (CWPRS), Pune by Tehri Hydro Development Corporation Limited (THDC Ltd.), Rishikesh. The application of 3-D mathematical model viz. MIKE 3 developed by DHI, Denmark was deemed suitable for the study. This model was made available by WAPCOS, New Delhi, for these studies. In the first phase, mathematical modelling studies were carried out for the assessing the flow circulation process due to inflow from two rivers Bhagirathi and Bhilangana and outflow due to release through power outlet.

The draft technical report based on these studies was sent in the month of September 2001. The report was finalised after incorporating the comments of the project authorities.

The mathematical model studies to investigate hydrodynamic behaviour of the Tehri reservoir were conducted at Mathematical Modelling Centre, CWPRS, Pune, India. The studies were carried out by Dr. S.K. Das, Senior Research Officer and Shri J. Sinha, Research Officer. Shri D.N. Deshmukh, Chief Research Officer, Mrs. A.S. Barve, Senior Research Officer, and other staffs of the Mathematical Modelling Centre were also involved during the period of studies and preparation of the report. These studies and analysis were done under the overall supervision of Dr. L.K. Ghosh, Additional Director and Shri C.N. Kanetkar, Joint Director.

Dr. A.K. Singh, Deputy Manager (Design) of THDC Ltd. actively interacted during the course of the studies and also during preparation of the report. Shri S. Thakudesai, Deputy Chief Engineer, WAPCOS, Pune, was also associated with preparation of data in the initial phase of studies.

Mrs. V.M. Bendre was the Director during the conduct of the studies and also during preparation and submission of the report.

Government of India
Central Water and Power Research Station
PO: Khadakwasla Research Station, Pune 24

Technical Report No. 3821

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MATHEMATICAL MODEL STUDIES TO INVESTIGATE HYDRODYNAMICS OF THE TEHRI RESERVOIR, TEHRI, UTTARANCHAL

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पो. आ. खडकवासला रिसर्च स्टेशन, पुणे 24

तकनीकी रिपोर्ट संख्या :3821 सितम्बर 2001

टेहरी जलाशय टेहरी, उत्तरांचल की द्रवगतिकीय जाँच का गणितीय प्रतिमान द्वारा अध्ययन

सारांश

टेहरी बहुउद्धेशीय जल विद्युत परियोजना उत्तरांचल राज्य के भागीरथी और भीलंगना नदियों के संगम स्थल पर निर्माणाधीन है । इस योजना के अन्तर्गत 260.5 मी ऊचें मिट् एवं चट्न युक्त बाँध बनाया जाएगा जिससे जलाशय की सकल संचय क्षमता 3540 MCM (दस लक्ष घनमीटर) होगी जिसमें निम्नतम जलावतलन निशान के नीचे 925 MCM का संचय होगा । इस योजना के प्रथम चरण में संस्थापित विद्युत क्षमता 1000 MW (250 x 4 MW) होगी ।

टेहरी जल विकास निगम लिमिटेड, कृषिकेश ने पत्र क्रमांक THDC/RKSH/D&E-II दिनांक जुन 11, 2001 को के. ज. और वि. अ. शाला, पुणे को टेहरी जलाशय के द्रवगतिकीय व्यवहार और जल गुणता के अध्ययन का काम सौपा । DHI, डेनमार्क द्वारा विकसित MIKE 3 नामक त्रियामी गणितीय प्रतिमान को इस अध्ययन के लिए उपयुक्त माना गया क्योंकि भौतिक प्रतिमान द्वारा अधिक अध्ययन करना कठीन होता ।

गणितीय प्रतिमान के द्वारा दोनों नदियों भागीरथी और भीलंगना से आनेवाले प्रवाह तथा विद्युत संयंत्र के लिए बहिर्वाह से उत्पन्न प्रवाह परिसंचरण प्रकिया का अध्ययन किया गया । इसके अलावा वर्ष के विभिन्न खंडो मे जलाशय में नदी जल द्वारा अपनाये गये पथ का भी अध्ययन किया गया ।

गणितीय प्रतिमान के लिए आवश्यक क्षेत्र आकडों में मुख्यत: नदी के तल हटी का नक्शा, अंतर्वाह बहिर्वाह विसर्जन श्रेणी, मौसमी आकडें, जल

गुणता अन्वयों और जलाशय के प्रचालन सम्बन्धी आकडें आदि लिए गये। उपयुक्त सभी आकडें परियोजना अधिकारियों द्वारा उपलब्ध कराये गये ।

जलाशय और उसके सुनिश्चित प्रचालन के परिपेक्ष्य में प्रवाह के मूल विशेषताओ को ध्यान में रखते हुए उपयुक्त आकडों का विश्लेषण किया गया । इन विश्लेषणों से यह पाया गया कि बाँध क्षेत्र में होने वाले वार्षिक वाह का दो तिहाई हिस्सा शिखर मानसून के 100 दिनों में तथा शेष एक तिहाई हिस्सा वर्ष के अन्य समयों में प्रवाहित होता है । मानसून अवधि में औसत दैनिक प्रवाह लगभग 52.8 MCM प्रति दिन अनुमानित किया गया जिससे निम्नतम जलावतलन स्तर पर जलाशय में जल की आवासीय अवधि 17 दिन और कुल संचय पर 67 दिन निकाली गयी ।

प्रस्तुत प्रतिवेदन में प्रतिमान के अनुप्रयोग और ह्रवगतिकीय अध्ययन के अन्वेषण का उल्लेख किया गया है । जलाशय में कत्रिम जल जमाव के पश्चात होने वाले जल गुण अवयवों के व्यवहार का अध्ययन कार्य CWPRS में जारी है और इस अध्ययन की अलग रिपोर्ट बाद में प्रकाशित की जाएगी ।

ह्रवगतिकीय अध्ययन के लिए जलाशय के प्लान को 250 m × 250 m के ग्रिड में तथा गहराई को 20 m – 20 m के स्तर पर बाँटा गया है । गणितीय अनुकरण के लिए परिसीमा प्रतिबंध जलाशय के ऊर्ध्व प्रवाह में भागीरथी तथा भीलंगना नदियों के जल की गहराई तथा उसकी गति और जलाशय के अनुप्रवाह में विद्युत निर्गम से बहिर्वाह आस्राव के रूप में किया गया है । प्रारम्भिक शर्त के रूप में, जलाशय के जल के तापमान तथा उसके स्तरण को जरूरत के अनुसार यातो हिसाब लगाया गया या फिर पूर्व अनुसरण से लिया गया । अनुसरण को शुरू करने के लिए गति रहित शर्त्त को प्रारम्भिक शर्त के रूप में लिया गया ।

जलाशय में परिसंचारण क्रिया को अनुसरित करने के लिए गणितीय प्रतिरूप द्वारा निम्नलिखित प्रयोग किये गये :

i) जुलाई से शुरूकर अगले साल के जून तक का पूरे एक वर्ष का अनुसरण ।
ii) नवम्बर से फरवरी तक का शीतकालीन अनुसरण ।
iii) मार्च से जून तक का बसन्त तथा ग्रीष्म ऋतु का अनुसरण ।

प्रस्तुत अध्ययन का स्पष्ट निश्कर्ष निम्नलिखित है :

– चुकि टेहरी जलाशय का प्रचालन बिना अवशेष संचयन के वार्षिक है अत: जलाशय प्रत्येक वर्ष अपने संचयन की पुन : पुर्ति करता है । यद्यपि अध्ययन से ज्ञात होता है कि वर्षा ऋतु में **MDDL** के नीचे की जलाशय संचय नदियों के ताजा अन्तर्वाह द्वारा प्रतिस्थापित होता है । अत : जलाशय के **MDDL** के निम्न क्षेत्र में भी जल जमाव के नियमित प्रगतिरोध की संभावना नही है ।

– जुलाई तथा अगस्त जो तीव्र वर्षा ऋतु की अवधि है , नदियों का अन्तर्वाह अध्यधिक तलछट से हुए रहता है और उनका प्रभावी घनत्व भी काफी ज्यादा होता है । फलस्वरूप, ऐसा भारी जल जलाशय के निम्नतम क्षेत्र से प्रवाहित होता है और जल के आस पास काफी जलगति उत्पन्न करता है । इस अवधि के दौरान, **MDDL** के नीचे का जल जमाव नदियों के ताजा अन्तर्वाह द्वारा पूर्ण रुपसे प्रतिस्थापित हो जाता है । (चित्र 5.1 व 5.2) ।

– सितम्बर और अक्तुबर के महिने के दौरान जो वर्षाकाल का शेष भाग होता है , जलाशय अपने उच्च स्तर पर रहता है । इस दौरान निलंबित तलछट अंश कम हो जाता है और अन्तर्वाही जल जलाशय में मध्य भाग से होते हुए निर्गम स्थान तक पहुचेंता है । इस समय **MDDL** के नीचे के स्तरों में काई खास बदलाव नहीं होता है यद्यपि अन्तर्वाह के ज्यादा होने तथा विद्युत निर्गम के सविराम संचालन से विपरीत बहाव उत्पन्न होता है जो ऊपर की ओर अग्रसारित होता है । ये अंतर्गहीत क्षेत्र के ऊपर एक प्रकार का परिसंचारण उत्पन्न करता है । (चित्र संख्या 5.5 व 5.6) ।

– शीत ऋतु (नवम्बर व दिसम्बर) के दौरान नदी का जल तलछट रहित होता है फिर भी उसका घनत्व निम्न तापमान के कारण जलाशय के ऊपरी स्तर से कुछ ज्यादा ही होता है । इस दौरान नदी का जल निर्गम स्तर के आस पास से गुजरता हुआ वहिर्गमन कर जाता है । साथ ही, बहिर्वाह के अन्तर्वाह से ज्यादा होने के कारण जलाशय जमाव का कुछ भाग भी निर्गमित हो जाता है । (चित्र सं. 5.9 व 5.10) ।

– शीत ऋतु और वर्षा ऋतु के मध्य अवधि (मार्च से जून तक) में नदी का अन्तर्वाह हिमगलन के कारण ज्यादा होता है । इस समय जलाशय का स्तर भी निम्न होता है और जलाशय की लम्बाई भी घट जाती है । जलाशय के चारों तरफ तापमान ज्यादा होता है और तलछट सामग्री पुन : उत्पन्न होने लगती है। इन सबों का सम्मिलित प्रभाव यह होता है कि अन्तर्वाही जल उर्ध्व में पूर्ण रुप से सम्मिलित हो जाता है और निर्गम स्थल की ओर बढने लगता है (चित्र सं.5.13 व 5.14) ।

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– क्षैतिज परिसंचरण प्रक्रिया जलाशय प्लान में प्रेरित परिसंचारण की उपस्थिति ज्ञात कराती है तथा जलाशय के परिसंचरण की प्रकृति को तीन मितीय होने की स्वीकृती देती है। क्षैतिज गति के चित्रों के अनुसार ऐसा प्रतित होता है कि वर्षोत्तर माह (नवम्बर से जून तक) में नदी अन्तर्वाह, जलाशय निर्गम स्तर पर प्रवाहित होता है और अपने मात्रा के अनुसार जलाशय की पूरी चौडाई को प्रभावित करता है । (चित्र सं.5.17 से 5.24)

– यद्यपि तीन मितीय परिसंचरण प्रक्रिया जलाशय में वर्षभर होती रहती है फिर भी परिसंचारण के कारण अधिकतम प्रेरित गति **10 cm/s** के आस पास होती है ।

– अनुरेखक तत्तव के लंग्रेंगीयन (**Langrangian**) प्रेक्षण से ज्ञात होता है कि भागीरथी नदी का अन्तर्वाह निर्गम स्थल तक कम समय (17 दिन में वर्षा ऋतु के प्रारम्भीक माह जून जूलाई के दौरान) में पहुचँता है जब जलाशय स्तर **MDDL** के पास होता है । जलाशय स्तर बढने के साथ साथ अन्तर्वाही जल द्वारा निर्गम स्थल तक पहुचँने में अधिकतम **100** दिन (नवम्बर दिसम्बर में) लगता है जब अन्तर्वाह अत्यधिक कम रहता है और जलाशय स्तर भी ऊचाँ होता है वर्ष के शेष समयों में भागीरथी नदी का अन्तर्वाह निर्गम स्थल तक पहुचँने में **55–75** दिन का समय लेता है । भीलंगना नदी के अन्तर्वाह द्वारा स्थल तक पहुचँमें में कुछ कम समय लिया जाता है क्यों कि उस नदी की जलाशय लम्बाई कुछ कम है ।

– वर्षा ऋतु के दौरान अन्तर्वाही आयतन, जो **MDDL** स्तर तक के संचयन के लगभग बराबर है, मात्र **17** दिनों में जलाशय में एकत्रित होता है अत: **MDDL** स्तर के नीचे सम्पूर्ण संचयन का मात्र **17** दिनों में पूर्ति होता है जब कि सम्पूर्ण जलाशय आयतन की पूर्ति तीव्र वर्षा काल के दौरान लगभग **67** दिनों में हो जाती है ।

– अन्तत: सम्पूर्ण रूप से यह निश्कर्ष निकाला जा सकता है कि वर्षोत्तर काल (अक्तुबर से जून तक) के दौरान जलाशय के जल का पूर्ण रूप से परिसंचारण होता है। अत: जलाशय में जल के अवरूद्ध होने की कोई संभावना नही है ।

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MATHEMATICAL MODEL STUDIES TO INVESTIGATE HYDRODYNAMICS OF THE TEHRI RESERVOIR, TEHRI, UTTARANCHAL

Executive Summary

Tehri Hydroelectric Project is a multipurpose project under construction at the confluence of rivers Bhagirathi and Bhilangana in the State of Uttaranchal. The project envisages the construction of a 260.5 m high earth and rock fill dam which will give rise to a storage reservoir having gross storage capacity of 3540 MCM out of which 925 MCM is the storage below Minimum Draw Down Level (MDDL). The installed power capacity in Stage-I of the project is 1000 MW (4 x 250 MW).

The study of hydrodynamic behaviour and water quality parameters of Tehri Reservoir was referred to Central Water and Power Research Station (CWPRS), Pune, by Tehri Hydro Development Corporation Limited, Rishikesh, vide their letter No. THDC/RKSH/D&E-II, dated June 11th, 2001. Application of a 3-D mathematical model, namely MIKE-3 developed by DHI, Denmark, was deemed suitable for the studies as the physical model dealing with the multiple variables involved becomes extremely complex to generate. The mathematical modelling studies were carried out for assessing the flow circulation processes due to inflow from two rivers Bhagirathi and Bhilangana and outflow due to release through power plant. Further, studies were carried out to trace the path of river water through the reservoir for various flow scenarios during different parts of the year.

The field data requirement for mathematical modelling mainly comprises river bathymetry, inflow-outflow discharge series, meteorological data, water quality parameters and reservoir operation schedule. All the above data were supplied by the project authorities for the purpose of this study.

Analysis of data has been carried out to ascertain basic characteristics of flow pattern with reference to reservoir and its operation schedule. It has been observed that about 2/3rd of annual runoff at the dam site occurs during 100 days of peak monsoon and the remaining 1/3rd occurs over the rest of the year. Average daily flow during the monsoon period is estimated to be about 52.8 MCM/day from which residence period works out to be 17 days for the storage at MDDL and 67 days for the total storage.

The present report deals with the model application and findings thereof for hydrodynamic studies. The study of post impoundment behaviour of water quality parameters (DO, BOD and temperature) is under progress at CWPRS and a separate report shall be issued for the same.

For the hydrodynamic study the reservoir has been discretised on a 250 m x 250 m grid in plan and the depth of impoundment has been discretised through layers of 20 m thickness. The boundary conditions for the mathematical simulations are given in the form of water depth and flow velocities at the upstream end of reservoir on Bhagirathi as well as Bhilangana and outflow discharge at the location of power outlet. As initial condition, the reservoir water temperatures and extent of stratification have been worked out or taken from the previous simulation as the case may be. For starting the simulations no flow condition has been taken as the initial condition.

Experiments have been carried out on the mathematical model to simulate the process of circulation within the reservoir for the following conditions :

(i) Simulation for complete one year starting from July and ending on June next year.

(ii) Simulation for winter season i.e. from November to February

(iii) Simulation for spring and summer i.e. from March to June.

The broad findings of the study are as follows :

- Since the operation of Tehri reservoir is on yearly basis, with no carry over storage, the reservoir completes the cycle of replenishment of storage every year. However, the study shows that during the monsoon period, the reservoir storage below MDDL is also replaced by fresh inflow from the river. Thus, there is no possibility of permanent stagnation of water in the reservoir, even in the zone below the MDDL.

- During July and August, which is the period of active monsoon, the incoming river water is highly sediment laden and thus has a high effective density. Consequently, the heavier water travels along the bottom of the reservoir generating higher velocities near the bed. During this period the storage below MDDL is replaced by the fresh river inflow. (Figs. 5.1 & 5.2)

- During the month of September-October, which is the fag end of monsoon, the reservoir is at relatively higher level. The suspended silt content (and hence the density) drops down and the inflow water travels into the reservoir at intermediate level close to the level of outlet. There is hardly any agitation in the storage below MDDL. However, inflow being more than the releases and power outlet being closed intermittently for peaking schedule, the reverse flow takes place which is directed towards top. This generates circulation in the zone above the intake level (Figs. 5.5 & 5.6).

- During winter (i.e. November and December) the river water is practically devoid of sediment but still has a little higher density than top layer of reservoir because of low

temperature of inflow. During this period the river water travels nearly at the level of outlet and gets released. Some reservoir storage also gets released as the scheduled release is more than the river inflow. (Figs. 5.9 & 5.10)

- During the intervening period between winter and monsoon (i.e. March to June) the river inflow shows some increase because of snowmelt. The reservoir is at fairly low level and the reservoir length also reduces accordingly. The ambient temperatures are high and some bed material load starts appearing again. As a combined effect of all these the inflow water gets well mixed over the vertical and moves towards the outlet. (Figs. 5.13 & 5.14)

- The horizontal circulation process indicates the presence of induced circulation in plan, thus confirming the three dimensional nature of reservoir circulation. The plots of horizontal velocities indicate that during all non-monsoon months (Nov. to June) the river inflow finds its way at the level of reservoir outlet and influences the entire width of the reservoir depending upon the magnitude of inflow discharge. (Figs. 5.17 to 5.24)

- Although, the three-dimensional circulation prevails in the reservoir at all times of the year, the maximum induced velocities due to circulation are of the order of 10 cm/sec. at the locations of maximum impoundment.

- The Langrangian observation of tracer material, as it passes through the reservoir reveals that the Bhagirathi river inflow reaches the location of the outlet in relatively smaller time; minimum being 17 days during beginning of monsoon period (June-July), when the reservoir is near MDDL. As the reservoir level (and thereby length) increases the river water takes more time to reach outlet, the maximum period being only 100 days during Nov.-Dec., when inflow is very low and reservoir level is high. For the rest of the year (Feb. – May), it takes Bhagirathi water 55-75 days to reach the

outlet. The time for Bhilangana water is still smaller as the reservoir length on Bhilangana is smaller.

- During the monsoon period the inflow volume, nearly equal to the storage below MDDL, is added to the reservoir in just 17 days thus replenishing the whole storage below MDDL in 17 days whereas, the total reservoir volume is input into the reservoir within 67 days of active monsoon.

- On the whole, it can be concluded that there is substantial circulation of reservoir water during the whole of non-monsoon period (Oct. to June) and thus there is no possibility of stagnation of water in the reservoir.

MATHEMATICAL MODEL STUDIES TO INVESTIGATE HYDRODYNAMICS OF THE TEHRI RESERVOIR, TEHRI, UTTARANCHAL

1.0 INTRODUCTION

The Tehri dam is proposed to be constructed at the junction of rivers Bhagirathi and Bhilangana in Uttaranchal, to tap vast power potential. Although, the dam site was identified as early as in the year 1949, reconnaissance survey was carried out only during the year 1961-62 to select the suitable location. In 1963, detailed surface and subsurface exploration was undertaken and finally the project was approved by the Planning Commission in 1972. Subsequently, the detailed studies were carried out. At present, the project is in an advanced stage of construction.

The Tehri dam is a high earthen and rock fill dam of proposed height of 260.5 m with 1000 MW power generation potential in the first stage. After the construction of the dam and impoundment of the reservoir, the backwater would extend 45 km in the river Bhagirathi and about 20 km in the river Bhilangana which have an average bed slope of 1:200 and 1:100 respectively. The Tehri reservoir plan is shown in Fig.1.1. The salient features of the dam are given below :

River Bed level at dam site	:	600 m
Irrigation outlet level	:	700 m
Power outlet level	:	720 m
Dam crest level	:	839.5 m
Full reservoir level (FRL)	:	830 m
Minimum draw down level (MDDL)	:	740 m
Gross storage	:	3540 Mm^3
Storage below MDDL	:	925 Mm^3
Water surface area at FRL	:	42 sq km

Very recently, a strong concern has been expressed by some people that the water quality to the downstream of the dam as regards the self purifying nature attributed to the Bhagirathi would be affected particularly in the post-monsoon months. In order to investigate the hydrodynamics in the reservoir vis-a-vis inflow/outflow and the effects on water quality, the matter was referred to the Central Water and Power Research Station, Pune, for study of hydrodynamic behaviour and water quality parameters of Tehri reservoir through mathematical modeling.

2.0 SCOPE OF WORK

As proposed Tehri reservoir extends to 45 km on river Bhagirathi and about 20 km on Bhilangana, having large surface area and storage volume, the physical modelling of the system is not practical. Moreover, the processes of hydrodynamics and water quality are governed by multiple parameters e.g. water temperature, atmospheric conditions, solar insolation, sediment inflow, dissolved oxygen, B.O.D. and microbiological, bactereological and chemical decay processes which makes model similitude extremely complex. In view of the above, it was proposed that the mathematical modelling studies would be carried out for assessing the flow circulation processes due to inflow from the two rivers, Bhagirathi and Bhilangana and outflow due to discharge through power intakes. Further, an attempt would be made to trace the path of Bhagirathi river inflow of water through the reservoir. The water quality aspects of the reservoir would be studied with the help of water quality modelling. Apart from reservoir hydrodynamics, three important water quality parameters would be considered for detailed investigation, viz., BOD, DO and temperature. As the hydrodynamic process in Tehri reservoir is governed by inflow and outflow induced circulation, and as temperature induced stratification plays a dominant role in reservoir dynamics, a three-dimensional mathematical model was required to simulate the flow processes. Accordingly, a widely used and proven model MIKE-3D developed by DHI, Denmark, has been used for this purpose.

3.0 DATA ANALYSIS

The field data required for mathematical modelling studies were provided by Tehri Hydro Development Corporation (THDC). These data included river discharge, sediment load, outflow discharge, water quality (BOD, DO), water temperature and bathymetric survey for Bhagirathi-Bhilangana river system. Besides these, the data for atmospheric conditions like air temperature, humidity, cloud cover, wind velocity etc were also supplied by THDC.

3.1 Bathymetry data

The Tehri reservoir is located at latitude 30° 23' N and longitude 78° 29' E. The reservoir area (Fig.3.1) extends up to 45 km in the river Bhagirathi and 20 km in the river Bhilangana with bed slope of 1:200 and 1:100 respectively. The bed is very uneven, rocky with unstable slope. The river Bhagirathi traverses almost straight towards south direction before meeting the Bhilangana river at Tehri which is almost concave in shape. The reservoir bed level at the dam site is 600 m. The width of the river Bhagirathi varies between 40m at the upstream end of the reservoir to 500m at the dam site at FRL with very steep side slopes. The width of the Bhilangana river is quite narrow with steep slopes and increases gradually before meeting the river Bhagirathi at Tehri. The flow directions of the rivers Bhagirathi and Bhilangana are 180° and 90° with respect to the North. The bathymetric plan supplied by the Project Authority for the year 1993 was used for mathematical modelling purpose. As the bathymetric survey forms the basic input data for the model, two survey charts, one for river Bhagirathi and other for river Bhilangana in the scale 1:25000 with 40 m contour interval were used. For creating bathymetry data, necessary interpolation was done while preparing the model grids.

As a verification of the discretized geometry of the reservoir and bathymetric information adopted for model simulation, the water surface area and reservoir volume at various levels, worked out by Project Engineers through surveys and toposheets, were compared to those computed with the discretized data. The plot showing this comparison is

given in Fig. 3.2 and it can be observed that the discretized data are in agreement with the actual reservoir geometry, which indicates that the reservoir has been adequately represented in the mathematical model.

3.2 Discharge Data

3.2.1 River discharges

Daily observed and ten daily average discharge of the river Bhagirathi at Tehri were made available for a 32 year series from 1963-64 to 1994-95. Ten daily average values of discharge have been used in the model and these are reproduced in Annexure-I. It may be seen that the discharge generally peaks in July end / beginning of August. Out of total 32 years, the peak ten daily discharge exceeded 1000 m^3/s in 1/3 of the years. The average discharge during this period, i.e. the first ten days of August was 845 m^3/s, and the 75% value was 613 m^3/s, (the discharge dropping below this value only once in four years) The monsoon flows commence in the third 10 daily period of June and continue upto the 3rd 10 daily period of September. The average discharge during monsoon was about 600 m^3/s. After monsoon, the river discharge recedes between 50 and 100 m^3/s in the month of December. The discharge once again begins to rise in the first 10 daily period of March, due to snow melt which increases very slowly in the first and second 10 daily periods of June, before the monsoon flows commence. In order to obtain a comprehensive view of the annual flow, the discharge for 10 daily periods have been plotted in Fig.3.3 on average year basis.

3.2.2 Water yield and proposed reservoir storage

The water yield for the 32 year data series has been worked out and reproduced in Annexure - II in descending order. It may be seen that the variation from the maximum to the minimum flow is 11830 Mm^3 to 5520 Mm^3, a ratio of 2:1 which is very typical feature of Himalayan rivers. The median year water yield is worked out as 7735 Mm^3. It is important to note here that the proposed above MDDL storage of the Tehri reservoir amounting to 2600 Mm^3, is less than 50% of the minimum of 32 year series (5520 Mm^3) and less than 25% of the maximum (11830 Mm^3). In the median year the storage is about 1/3 of the average annual runoff (7735 Mm^3). About 75 km downstream of the dam at Deoprayag, another

major stream named Alaknanda joins the river Bhagirathi and downstream of this confluence the river is named Ganga. Considering the fact that at Deoprayag, the ratio of discharge contribution of Bhagirathi and Alaknanda is 1:2, the storage volume at Tehri will be about 10% of the annual runoff at Deoprayag.

3.2.3 Residence Time

Residence time is a parameter which indicates the effect on water quality. It is defined as ratio of volume of reservoir to mean inflow rate. The residence time for Tehri reservoir, worked out for gross storage i.e. 3540 Mm^3 and storage of 925 Mm^3 below MDDL, are given hereunder. The mean inflow rate of 52.8 Mm^3/day during monsoon period has been used for this purpose.

Residence Time	=	3540/52.8 67 days for total storage
Residence Time	=	925/52.8
	=	17 days for storage below MDDL

Above residence time for Tehri reservoir is much smaller than many other reservoirs in India and abroad. For many large reservoirs in the world the residence time is several years. With the residence time of 67 days, the Tehri reservoir will be flushed during monsoon period which extends over 100 days.

3.2.4 Mass Balance Computations

Considering mean 10 daily flows (computed from 32 years data) and average outflows, simple mass balance computation were performed starting with reservoir level at RL 740 m (MDDL) and storage volume of 925 Mm^3 at the beginning of monsoon. Following are broad outcome of this study :

- Within first 25 days of monsoon the total inflow volume exceeds the volume below MDDL (i.e. more than 925 Mm^3).
- After about 70 days of monsoon period (i.e. by the end of August) the reservoir reaches FRL. The inflow volume of nearly 3 times the storage volume below MDDL, is stored in the reservoir. During the same period a

total of about 1550 Mm^3 is released from the reservoir through power outlet or spillways.

- For the rest of the period, i.e period from September to June, total inflow volume of about 3500 Mm^3 (equal to gross storage volume at FRL) is added to the reservoir. However, the releases from the reservoir being about 6000 Mm^3, the reservoir depletes down to MDDL by middle of June.

3.3 Sediment Load

The sediment load as assessed from measurement of suspended silt load at the steel grider bridge at Tehri is given in Annexure-III. The data extends from 1973 to 1993 and indicates an average sediment yield of 13 million tonnes per annum. Using the data, the average concentration of suspended sediment has been worked out which has been used for computation of density of the river inflow.

3.4 Suspended sediment data

The data of suspended sediment concentration was available for 20 years period from 1973 to 1993 with the exception of the year 1979 for which the observed data were not available. Monthly average concentration of suspended sediment has been worked out in PPM and the effect of this suspended sediment on the inflow density has been accounted for by using the following equation.

$$\rho_m = \rho_w + \frac{c}{1000}\left[1 - \frac{\rho_w}{\rho_s}\right]$$

Where,

ρ_m = Density of water sediment mixture (kg/m^3)

ρ_w = Density of water (kg/m^3)

ρ_s = Density of sediment (kg/m^3)

C = Concentration of suspended sediment (ppm)

Monthly average suspended sediment concentration shows the variation from 80 to 2500 ppm. The variation of sediment concentration is shown in Fig. 3.4 and resulting

effective density of water sediment mixture is given in Table 2. These monthly values have been used as model input. Though the discharge variation has been considered on ten daily basis, the density variation has been considered month wise, thus, the density remains constant over all the three ten day periods of a particular month.

3.5 Temperature

The analysis of river water temperature data for 5 years indicates that the average water temperature lies between 8° C to 12° C during winter and 15° C to 16.5° C during summer for the river Bhagirathi and river Bhilangana. It is observed that there is an average temperature difference of 1° C to 2° C between Bhagirathi water and Bhilangana water, the Bhagirathi water being colder. The monthly maximum and minimum temperatures for Bhagirathi and Bhilangana river are shown in Fig.3.5.

3.6 Meteorological data

Thermal regime of the reservoir is an important aspect of the hydrodynamic simulations. In order to incorporate the process of heat exchange between reservoir and surrounding atmosphere, certain meteorological parameters are required as input to the model. Primarily, the required data is atmospheric temperature, inflow water temperature, wind velocity, relative humidity and cloud cover. Out of these, the data on atmospheric temperature, inflow water temperature and wind velocity was supplied by THDC for five years period. The monthly average values have been used for model simulations. The data on relative humidity and cloud cover has been obtained from quarterly volumes of "Indian Weather Report" published by India Meteorological Department. About five years of data on the above two parameters was analysed at Mukhim and Dehradun stations which are in the same meteorological region. Besides this, some scanty data on relative humidity and cloud cover at Tehri station is also available in the IMD reports. Monthly average values of these parameters have been used for model simulations. The values of various meteorological parameters as adopted for model use are given in Table 3 which are representative of the area under consideration.

4.0 DESCRIPTION OF MATHEMATICAL MODEL

A commercially available three dimensional model (MIKE 3D) developed by DHI (Danish Hydraulic Institute) has been used for this study.

MIKE 3D solves the time dependent conservation equation of mass and momentum in three dimensions, the Reynolds averaged Navier Stokes equations. The flow field and pressure variation are computed in response to a variety of forcing functions, when provided with the bathymetry, bed resistance, wind field and hydro-graphic boundary condition etc. In stratified environment the conservation equations for heat and salinity are included in the solution. The following hydrodynamic phenomena are included in the equation.

* water level wave propagation
* effects of stratification
* turbulent diffusion and dispersion
* coriolis forces
* barometric pressure gradients
* wind stress
* variable bathymetry and bed resistance
* hydrodynamic effects of rivers and outfalls
* sources and sinks (both mass and momentum)
* heat exchange with the atmosphere, including evaporation and precipitation

4.1 Schematisation

The area covered in the mathematical model is shown in fig.4.1. The entire backwater reach of 42 km in the Bhagirathi river and 20 km for the Bhilangana river was selected. A uniform square grid of 250 m x 250 m was considered giving rise to 141 grid points along x-direction and 101 grid points along y-direction when reservoir is at FRL (830 m). In the vertical direction 11 layers were considered having thickness of 20 m each, with an additional buffer layer of 10 m above the topmost layer. The downstream boundary is specified as

closed boundary with an outlet located at elevation of 720 m of the dam which is the location of power outlet.

During summer months when the reservoir is at MDDL (EL 740 m), 6 layers were considered. Provision was also kept in the model to consider irrigation outlet at EL 700m. The following boundary conditions were taken for model simulation.

1) Two upstream boundary conditions, one each for Bhagirathi and Bhilangana river discharge, at the upstream end of the reservoir on the two branches respectively.

2) Downstream boundary as discharge due to power outlet (considering step function).

3) Bottom boundary condition as partial slip.

4) Initially, there is no flow in the reservoir. This is being considered as initial condition.

5) A typical initial temperature profile for the reservoir is assumed.

6) Inflow river temperatures at the upstream boundaries for Bhagirathi and Bhilangana rivers.

5.0 MODEL SIMULATIONS

Ideally, the model should be run for a cycle of one year incorporating seasonal variation of discharge and taking into account the temperature and density variation due to variation of inflow temperature and inflow sediment load.

At the start of the model run (say July) the existing total depth is required to be divided into certain number of fixed layers. One buffer layer on the top is included by defining surface elevation. Due to imbalance of inflow and outflow, only the thickness of buffer layer changes while the thickness of fixed number of layers below buffer layer remain same. While hydrodynamics as well as transport characteristics of all the layers including the buffer layer are correctly reproduced, the model gives information only for the fixed layers. The model does not run while top layer gets depleted when outflow exceeds inflow.

Thus to run the model for complete cycle it was planned that July conditions when the reservoir level is at 760 m and monsoon flow starts, would be defined as initial condition. As this is a rising phase of reservoir level, the fixed layer will not deplete. Therefore, the cycle comprising the rising phase of surface layer from 760 m to 830 m (F.R.L.) and then the falling phase of reservoir level i.e. 830 m to 760 m could be simulated. However, with this simulation while it is possible to see what is happening below 760 m, it is not possible to see the hydrodynamics of the buffer layer. Thus to investigate the hydrodynamics of the upper zone, it was required to plan few more experiments besides the complete cycle modelling.

Though the reservoir circulation is a continuous process, the physical conditions of the reservoir can be described by the three distinct situations :

i) Monsoon season
ii) Winter season
iii) Interval between end of winter and beginning of monsoon

To cover these periods, three experiments have been carried out, which are :

i) For the complete one year starting from July and ending in June.

ii) For winter season starting from November when the reservoir is full and ending on February.

iii) For the period between end of winter and beginning of monsoon starting from March when snowmelt water starts coming.

The monsoon period experiment has not been done separately as the first part of the complete cycle experiment describes the monsoon period hydrodynamics quite adequately.

The initial temperature profiles were worked out by considering inflow temperature in the preceding months and seasonal temperature variation in the reservoir. For monsoon period (Starting in July) the initial temperature profile varies between 13^0 C to 18^0 C with minor stratification over the depth due to the effect of earlier summer months. The initial Temperature profile for the end of monsoon simulation (Starting in September) is nearly constant over the depth with only 1^0 C temperature difference between top to bottom layer. For winter season (starting in November), the initial temperature varies between 14^0 C to17^0

C with almost linear variation across the depth. At the end of non-monsoon period (June) the temperature of reservoir water varies between 13^0 C to 18^0 C due to the inflow of snowmelt water in the immediately preceding months.

The boundary conditions for each set of experiments have been described in respective subsections.

5.1 Boundary conditions

To run the model it is necessary to prescribe proper initial conditions and boundary conditions. The details of initial and boundary conditions are mentioned below.

5.1.1 Upstream boundary

Two boundary conditions are considered each for Bhagirathi as well as for Bhilangana rivers. The upstream boundaries are treated as source point for both the rivers. It may be noted that for complete one year cycle run, the initial reservoir level has been considered as 760 m and consequently the length of backwater upstream of dam would be reduced. Accordingly, along the Bhagirathi, the upstream boundary is located at about 25 km away from the dam location and along Bhilangana river, it is located at about 10 km away from the dam location.

a) Discharge

The records of observed daily discharge data of river Bhagirathi (downstream of its confluence with river Bhilangana) are available for a period of 31 years. Observed, daily discharge data for river Bhilangana is not available. However, some intermittent observations of discharge on Bhilangana (twice a week) are given in the records. From these intermittent discharge values for different parts of the year, it was estimated that Bhilangana carries about one third of the total discharge at the junction, the remaining two third being the contribution of Bhagirathi. Accordingly, it is assumed that two third of a particular discharge is coming from Bhagirathi and one third is coming from Bhilangana. The depth of flow for each river for these discharge and river conditions works out to be in the range of 1 to 2 m and

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accordingly the corresponding flow velocity remains in the range of 0.5 to 1.0 m/sec only. These flow parameters have been taken as model input which are quite realistic when compared to actual observations.

b) Temperature

In Bhagirathi river, snowmelt water is flowing particularly in non-monsoon period. So for the purpose of modeling, inflow temperature of Bhagirathi river is considered 1^{o} C less than that of Bhilangana river as indicated by actual observations. The inflow temperature during monsoon period is ranging from 13^{o} C to 15^{o} C for both the rivers.

c) Concentration of tracer material

To visualise the flow pattern, a hypothetical tracer material of concentration of 100 ppm is applied at the upstream boundary for both the rivers. This is a conservative type (non-decaying) dye which helps to examine the extent of circulation and to trace the path of river water as it passes through the reservoir. The observation of tracer material also gives an indication of the path of inflow as it passes through the reservoir. Besides, concentration of tracer material helps to visualise the instantaneous mixing of river inflow with the reservoir water.

d) Alignment

As the boundary condition is defined with the help of source point, it is important to align the source point along the flow. In view of this the source point is kept at the upper layer in both the cases. The horizontal and vertical alignment is kept along the flow direction of both the rivers.

5.1.2 Downstream Boundary

As per the requirement, downstream boundary is considered as closed barrier allowing discharge equal to power release through power outlet and intermediate level outlet which are not working simultaneously in this case.

a) Power Outlet

The power outlet is at the level of 720 m i.e. 110 m below the F.R.L. This outlet will be supplying a discharge of 600 cumecs alternately for 4 hours with 8 hours break. The flow velocity through this outlet was calculated accordingly which worked out to about 2 m/sec.

b) Intermediate level

The intermediate level outlet is at the level of 700 m i.e. 130 m below the F.R.L. This outlet has three basic functions viz. 1) to release the desired quantity of water during initial controlled filling of the reservoir 2) to release the committed discharge for irrigation use during idling (shut down, repair, maintenance etc) of the power house and 3) to evacuate the reservoir in case of an emergency, distress or inspection. This outlet will be working during the non-monsoon period. It was also taken into consideration that both power outlet and intermediate level outlet will not operate simultaneously. The flow velocity at the intake of this outlet is kept 2.0 m/sec to 5.0 m/sec depending upon the outflow discharge.

5.2 Model setup for Case-I (One year simulation)

Model set up has been done for complete one year starting from July and ending in June considering the initial reservoir level at 760 m. As the bed level is at 600 m, the entire water depth has been divided into eight layers with uniform thickness of 20 m. Although the deepest part of the reservoir can have eight layers in the upstream region, the number of layers decreases depending upon the available depth. In numbering, the layers are counted from bottom in vertically upward direction. In order to understand the change in the mixing process due to the seasonal change combined with the inflow discharges, model runs were carried out for two months at a time. In the model setup, upstream boundary conditions for Bhagirathi and Bhilangana were treated as source points. The upstream boundaries were located at 25 km and 10 km away from the dam location for Bhagirathi and Bhilangana river respectively. The available discharges during this period were taken from actual inflow into the reservoir, considering average flow year as 1962-63. The results for two months simulation were stored as hot-start data for next simulation (starting with September). The

time step for computation was taken as 20 sec for which maximum Courant number becomes 3.21. It was observed that for stability purpose, maximum Courant number should be less than 5.0 for this type of simulation. In the model setup, the options for Coriolis force and hot start condition were enabled. The source points were prescribed (for reference of grid system refer Fig.4.1) at the point (28, 9, 8) and (28, 10, 8) for Bharigathi river, (126, 82, 8) and (126, 83, 8) for Bhilangana river. One sink point at the grid (121, 36, 6) was prescribed as dam outlet for power generation. Although in the model setup flooding and drying depth was prescribed as 0.1 m and 0.2 m respectively, no significant effect was noticed. One of the important aspect in the model is setting up of turbulence scheme. Considering the number of grid points, total period of simulation and the number of empirical constants to be prescribed, Smagorinsky formulation was considered. In the bed resistance module, bed friction was included and a constant value of 0.1 m was adopted. The bed resistance (shear) was in terms of a drag coefficient formulation according to the following relation.

$$\frac{\tau\, bottom}{\rho} = c_D u^* |u^*|$$

in which τ bottom is the bottom shear stress, ρ the density, C_D is drag coefficient and u^* the first computational speed encountered above the bottom. C_D is determined according to the selected turbulence closure model. In the Smagorinsky eddy formulation, C_D is given by the relation

$$C_D = \left[\frac{2\sqrt{2}}{3} \frac{D}{l} \left\{ \left(1 - \frac{Zm}{D}\right)^{3/2} - \left(1 - \frac{Z}{D}\right)^{3/2} \right\} + \frac{l}{k} \log\left(\frac{Zm}{k_s/30}\right) \right]^{-2}$$

where Z_m is the distance above the reservoir bed and l is the length scale. The recommended value for bed roughness length scale lies between bed undulation. The Smagorinsky coefficients were taken as 0.1 in the horizontal direction and 0.2 in the vertical direction. The eddy viscosity coefficients in the horizontal and vertical direction are taken as 0.1 and 0.2 respectively. The interfacial damping across the layers was considered with vertical coefficient as 10.0. No horizontal damping coefficient was considered. In the model set up, no precipitation and wind conditions were considered. In the heat exchange module, air temperature, relative humidity and clearness coefficients were supplied for complete one year period. The other heat exchange parameters were supplied as follows :

i) Constant in Dalton's law = 0.5
ii) Wind coefficient in Dalton's law = 0.9
iii) Sum coefficient, a in Angstrom's law = 0.295
iv) Sum constant, b in Angstrom's law = 0.371
v) Displacement (summer time) = 0
vi) Standard meridian for time zone = 78
vii) Beta in Beer's law = 0.6
viii) Light extinction coefficient = 0.1

In the advection-dispersion module, two components of conservative type were specified. The dispersion limit in the x, y and z directions were allowed to vary between (0-312.5), (0-312.5) and (0-2) respectively for components no.1 and 2. A conservative substance (no decay) was supplied at the source points of the model.

5.3 Model Study for Case II and Case III

As the Case II corresponds to beginning of winter season and Case III corresponds to end of winter season, the corresponding discharges at the upstream boundary were taken from Table 1 which gives the discharge and their characteristics for the complete year. In either case the setup for the model remains same as used in the complete year experiments.

5.4 Discussion on Experimental Results

The velocity field in the reservoir was simulated for every 15 sec. The typical velocity fields were selected for analysis. For presenting hydrodynamics, the season wise velocity fields were selected. The chosen timings are as follows :

1) Monsoon season (July - August)
2) End of monsoon season (September - October)
3) Beginning of winter season (November)
4) End of non-monsoon season (June)

Based on outflow characteristics, there are two conditions, one is when the power outlet gate is open discharging regular flow for power generation and the other is when this gate is completely closed. Besides velocity field, conservative tracer material was introduced along with upland discharge to trace the path of river water coming into the reservoir. The concentration fields of the tracer material were also examined.

a) Monsoon Period

Fig.5.1 shows the velocity field in the reservoir during monsoon season when the gate is open. It may be noted that during this season, water level is rising because inflow is more than outflow. However, the velocity field of eight layers below 760 m was examined. From Fig.5.1, it may be seen that there is more velocity in the bottom layer than in the top layer. While in the bottom layer flow is towards the dam, in the top layer the flow is away from the dam thereby generating circulations. Near the outlet the flow is high, but at the same level in the middle, flow is negligible. This figure indicates velocity field in vertical plane. The vectors are the combination of horizontal and vertical velocity. There are tilts in the vectors in vertical direction indicating there is vertical velocity but these are negligibly small. But the flow field clearly indicates that there is circulation in the reservoir in the anticlockwise direction. This circulation will help to take the bottom material to the top. In the rainy season, the incoming sediment-laden water is heavier than the water present in the reservoir. The heavier water dives down to the bottom. As such more velocity is observed at the bottom layer. The colour code shows the velocity contour. It may be seen that velocity field above 10 cm/s is present only near the outlet as well as at the end of reservoir. The velocity contour in between 5 - 10 cm/s which is present at the bottom rises near the dam location and reaches to the level slightly higher than outlet. Fig.5.2 shows velocity field when the gate is closed. The figure indicates that circulation process set before by the inflow and outflow is still present when the outflow is stopped. Only the velocity near the gate has reduced. The velocity contour field also remains smaller. However, area under each contour value has changed. The concentration contour which traces the path of inflowing water is shown in Fig.5.3. Colour code shows the extent of dilution of conservative substance. It can be seen that dilution increases non-uniformly along the vertical direction. The dilution is nearly 50% at the bottom and at outlet level, and is observed to be greater than 50% in the upper layer. This is due to the inflow of sediment laden heavier water replenishing the lighter one. It can be observed that contours with smaller value indicating lighter material comes down from top layer near the dam axis due to the influence of discharge through the outlet. However, there is no significant change in concentration contour profiles due to opening and closing of outlet as seen in Figs.5.3 and 5.4.

b) ***End of Monsoon Season***

Figures.5.5 and 5.6 show the velocity field in the reservoir during end of monsoon season i.e. for the months of September and October when the gate is open and closed respectively. During this season water level has a rising trend as inflow is higher than outflow. It may be observed from Fig.5.5 that there is no velocity at the bottom layer although some velocity is noticed in the upper layers. This indicates poor circulation at the bottom of the reservoir i.e. up to a vertical distance of 60 m from the reservoir bed level. The vectors showing positive and negative direction of velocity indicate presence of internal waves. The waves generated by reflection at the dam face move up and down increasing local mixing at the adjoining layers. Figure 5.5 shows a typical opening case in which the flow is noticed to be streamlined at the outlet (720 m) level. Fig.5.6 shows the effect of closure, causing strong return flow and mixing in the upper layers. However, the hydrodynamic circulation is still poor near the bed as in the case of opening. The variation of concentration field has been shown in Fig.5.7. It can be observed that the higher concentration sinks down to the bottom and moves towards the outlet. The sharp front edges indicate the typical opening case. In the case of a closure (Fig.5.8), blunt edges of concentration contour are formed. In both the cases, the dilution is less than 50% while it reaches near the dam.

c) ***Beginning of Winter Season***

In order to analyse the hydrodynamics at the beginning of winter season i.e. starting with November, when the reservoir is full (830 m), the entire water depth of the reservoir has been divided into eleven layers with 20 m thickness. An additional buffer thickness of 10 m has been provided over the top layer to avoid possible model blow up during the simulation. Fig.5.9 shows the velocity field in the reservoir when the gate is opened. During this simulation, the order of inflow is equal to the order of outflow. The velocity field of eleven layers below 80 m indicates that flow exists only in the upper layers, in between sixth layer to ninth layer. The maximum velocity near the outlet is found to be 0.1 m/s. It appears that in the bottom layers (below sixth layer) there is very little or almost negligible velocity field

during this period. This may be due to incoming snowmelt water taking a path in between top and bottom layer is passing through the outlet. Fig.5.10 shows the typical closure case in which circulation process set before by the inflow and outflow is still present when the outflow is stopped. Therefore, the velocity contour field is away from the dam axis. In general, velocity is less than 2 cm/s everywhere. In the bottom layers, hardly any mixing can be seen when there is no flow from the outlet. The concentration contour which traces the path of inflowing water during this period has been shown in Figs.5.11 and 5.12 for gate opened and closed cases respectively. Although, significant amount of dilution takes place for inflow, concentration during this simulation period, it also shows the unique path of plume movement to reach before the dam outlet. It can be observed that the mixing takes place between 5th to 11th layers only. It does not pick up water from the bottom layer. There is very little/no mixing in the bottom layers. This is also confirmed from the hydrodynamic simulation.

d) End of Non-monsoon Period

Model experiments were carried out for the end of non-monsoon season, i.e. for the month of May to obtain the reservoir hydrodynamics when the reservoir level is at 740 m. During this simulation period, reservoir outflow is more than inflow and inflow water is relatively free from suspended sediment. In order to simulate this case, entire depth of the reservoir has been divided into seven layers with 20 m of each layer thickness. The power outlet position remains the same, i.e. at 720 m level. Fig.5.13 shows the flow pattern when the power outlet is opened. The velocity vectors indicate that the flow is relatively streamlined in the upper layers i.e. (in between 5th to 7th layer). The velocity contour appears jet like features indicating the influence of discharge through the lower outlet. However, no significant velocity vectors are being observed within 80 m from the reservoir bottom. The maximum velocity is found to be less than 0.1 m/s which is mainly prevalent in the sixth layer. Colour code as shown in the plot indicates contours with small negative velocity, particularly in bottom layers. This shows that there exists very slow circulation across the entire depth, although, it is not been shown by the velocity vectors. The Fig.5.14 shows the velocity field when the gate is closed. This figure indicates the effect of closure when the inflow is still in continuation. The deep blue contour indicates the positive velocity

field and the lighter blue shows the negative velocity casing flow induced circulation. It can also be mentioned that the velocity vector below 5th layer still remains absent because of being very small in magnitude. This is similar to the case when the gate is open. Figs.5.15 and 5.16 shows the concentration movement across the depth of the reservoir. It can be seen that dilution takes place more than 50% over the complete depth of the reservoir while the plume line is 2 km away from the dam axis. Further dilution of concentration plume takes place in two stages with nearly 500 m of interval. This result shows that the concentration is vertically well mixed and moves as a slice pushing the flow towards the dam. It can also be observed that the contour line advances faster in between 5th to 7th layer due to the influence of outflow.

5.5 Horizontal Velocity Field

In order to understand the possible hydrodynamic circulation at the outlet (720 m) level for four different scenarios viz. i) monsoon season (July-August) ii) End of monsoon season (September-October) iii) Winter season (November, December) iv) End of non-monsoon season (June), horizontal velocity fields were analysed. As the outlet is positioned in the sixth layer, all velocity plots were analysed at this layer only. The outlet is located at grid points 121 and 36 in longitudinal and transverse direction respectively. Fig.5.17 shows the horizontal velocity field during monsoon period when power outlet is open. It can be observed that the inflow from the river Bhagirathi and Bhilangana and outflow due to the power house intake causes induced circulation in this layer. At the river outfall, the flow is unidirectional. Near the outlet the flow is towards the dam, but on the sides there are return flows. At this location Bhilangana water causes more circulation in this region. However, the velocity is high near the outlet and is less than 5 cm/sec in this domain. The horizontal velocity field when the power outlet is closed is shown in Fig.5.18. It can be observed that there is no significant change in the velocity field except near the outlet where velocity is reduced due to the closure.

The horizontal velocity field at the end of non-monsoon while power outlet is open is shown in Fig.5.19. It can be seen that the velocity vectors are restricted only in the central

part of the channel extending towards the upstream up to a distance of 4 km when the gate is open. Fig.5.20 shows that due to the closure of power outlet, induced circulation takes place and the flow is pushed towards the side boundaries.

The horizontal velocity during winter is shown in Fig.5.21 when the outlet is open. This figure clearly shows the path of river water confined in the central zone of the channel at the level of outlet. This is happening as the reservoir is at the lowest level and the incoming water is slightly lighter than reservoir water.

The closure of power intake has significant effect on flow field which is shown in Fig.5.22. There is significant return flow near the dam outlet which causes draw down of water level at this location. This causes rush of water from the sides which is distinctly visible in the figure. The upstream velocity still persists. At the middle low velocity is observed.

At the end of non-monsoon period when the discharge of snow melt water increases the flow covers complete width of the reservoir and becomes unidirectional (Fig.5.23). However, higher velocity is observed at the outlet.

In this particular season when the gate is closed the Bhilangana water is pushed by the Bhagirathi water in horizontal direction (Fig.5.24). This will improve the vertical circulation.

6.0 CONCLUSIONS

1) Tehri reservoir completes the cycle of replenishment of storage every year. The study shows that during the monsoon period, the reservoir storage below MDDL is also replenished by fresh inflow from the river. Thus, there is no possibility of permanent stagnation of water in the reservoir.

2) During the period of active monsoon (July-August), the incoming river water having high density because of sediment content, travels along the bottom of the reservoir

and generates higher velocities near the bed. During this period the storage below MDDL is replaced by the fresh river inflow. (Figs. 5.1 & 5.2)

3) During winter (i.e. November and December), the river water travels nearly at the level of outlet and gets released. Some reservoir storage also gets released as the scheduled release is more than the river inflow. (Figs. 5.9 & 5.10)

4) During the intervening period between winter and monsoon (i.e. March to June), the inflow water gets well mixed over the vertical and moves towards the outlet. (Figs. 5.13 & 5.14)

5) The plots of horizontal velocities indicate that during all non-monsoon months (Nov. to June) the river inflow finds its way at the level of reservoir outlet and influences the entire width of the reservoir depending upon the magnitude of inflow discharge. (Figs. 5.17 to 5.24)

6) Although, the three-dimensional circulation prevails in the reservoir at all times of the year, the maximum induced velocities due to circulation are of the order of 10 cm/sec. at the locations of maximum impoundment.

7) The Langrangian observation of tracer material, as it passes through the reservoir, reveals that the time taken for Bhagirathi river inflow to reach the location of the outlet remains in the range of 17 to 100 days.

8) During the monsoon period the inflow volume, nearly equal to the storage below MDDL, is added to the reservoir in just 17 days thus replenishing the whole storage below MDDL in 17 days whereas, the gross storage volume is input into the reservoir within 67 days of active monsoon.

Table 1

COMPUTED TEHRI RESERVOIR TEMPERATURES WITH INITIAL TEMPERATURE 15° C

Month	Period	Initial Reser. Level	Initial Volume	Initial Reser. Water Temp.	Inflow Volume	Inflow Temp.	Dilution	Reser. Temp. Post Mixing	Outflow Volume	New Reser. Volume
		(m)	(Mm^3)	(^oC)	(Mm^3)	(^oC)		(^oC)	(Mm^3)	(Mm^3)
June	III	740	900	15.00	379	16.5	0.30	15.44	129.6	1149.4
July	I	750	1149.4	15.44	474	16.5	0.29	15.75	129.6	1493.8
	II	765	1493.8	15.75	573	16.5	0.28	15.96	129.6	1937.2
	III	782	1937.2	15.96	677	16.5	0.26	16.10	129.6	2484.6
Aug	I	803	2484.6	16.10	730	16.5	0.23	16.19	129.6	3085
	II	820	3085	16.19	701	16.5	0.19	16.25	129.6	3656.4
	III	830	3600	16.25	625	16.5	0.15	16.29	260	3965
Sept	I	830	3600	16.29	510	17	0.12	16.37	345	3765
	II	830	3600	16.37	359	17	0.09	16.43	345	3614
	III	830	3600	16.43	258	17	0.07	16.47	345	3513
Oct	I	828	3513	16.47	170	11.5	0.05	16.24	108	3575
	II	830	3575	16.24	132	11.5	0.04	16.07	108	3599
	III	830	3599	16.07	106	11.5	0.03	15.94	108	3597
Nov	I	830	3597	15.94	89	9.5	0.02	15.78	108	3578
	II	829	3578	15.78	77	9.5	0.02	15.65	108	3547
	III	829	3547	15.65	68	9.5	0.02	15.54	108	3507
Dec	I	828	3507	15.54	59	8	0.02	15.41	194	3372
	II	826	3372	15.41	55	8	0.02	15.29	194	3233
	III	824	3233	15.29	52	8	0.02	15.18	194	3091
Jan	I	822	3091	15.18	41	9.5	0.01	15.10	194	2938
	II	817	2938	15.10	47	9.5	0.02	15.01	194	2791
	III	813	2791	15.01	47	9.5	0.02	14.92	194	2644
Feb	I	807	2644	14.92	46	10.5	0.02	14.85	194	2496
	II	802	2496	14.85	47	10.5	0.02	14.77	194	2349
	III	794	2349	14.77	48	10.5	0.02	14.68	194	2203
March	I	790	2203	14.68	50	12.5	0.02	14.63	194	2059
	II	784	2059	14.63	57	12.5	0.03	14.58	194	1922
	III	779	1922	14.58	67	12.5	0.03	14.51	194	1795
April	I	775	1795	14.51	65	15.5	0.03	14.54	194	1666
	II	770	1666	14.54	78	15.5	0.04	14.58	194	1550
	III	766	1550	14.58	92	15.5	0.06	14.64	194	1448
May	I	762	1448	14.64	115	16	0.07	14.74	216	1347
	II	758	1347	14.74	133	16	0.09	14.85	216	1264
	III	753	1264	14.85	152	16	0.11	14.97	216	1200
June	I	752	1200	14.97	211	16.5	0.15	15.20	216	1195
	II	752	1195	15.20	256	16.5	0.18	15.43	216	1235

Table 2

COMPUTATION OF DENSITY OF SEDIMENT LADEN FLOW FOR TEHRI RESERVOIR

(BASED ON AVERAGE OF 20 YEARS DATA)

Sl. No.	Month	Total Runoff (Mm^3)	Total Sediment inflow x 10^3 (kg)	Suspended Sediment Concentration (ppm)	Effective Density of Water Sediment Mixture
1	January	133.70	10.82	80.93	1000.05
2	February	114.45	14.63	127.83	1000.08
3	March	168.80	41.42	245.38	1000.15
4	April	242.35	59.45	245.30	1000.15
5	May	454.14	239.20	526.71	1000.32
6	June	852.56	1311.25	1538.01	1000.9
7	July	1779.70	4256.95	2391.95	1001.47
8	August	2018.86	5195.70	2495.70	1001.54
9	September	1177.05	1952.85	1659.11	1001.02
10	October	444.24	250.00	562.76	1000.35
11	November	238.81	47.60	199.32	1000.12
12	December	191.32	20.53	107.31	1000.07

Effective Density of Water Sediment Mixture can be worked out as per the following equation:

$$\rho_m = \rho_w + C / [1000 . \{1 - (\rho_w / \rho_s)\}]$$

Where

ρ_m = Density of water Mixture in kg/m^3

ρ_w = Density of water in kg/m^3 → say 1000 kg/m^3

ρ_s = Density of sediment in kg/m^3 → say 2600 kg/m^3

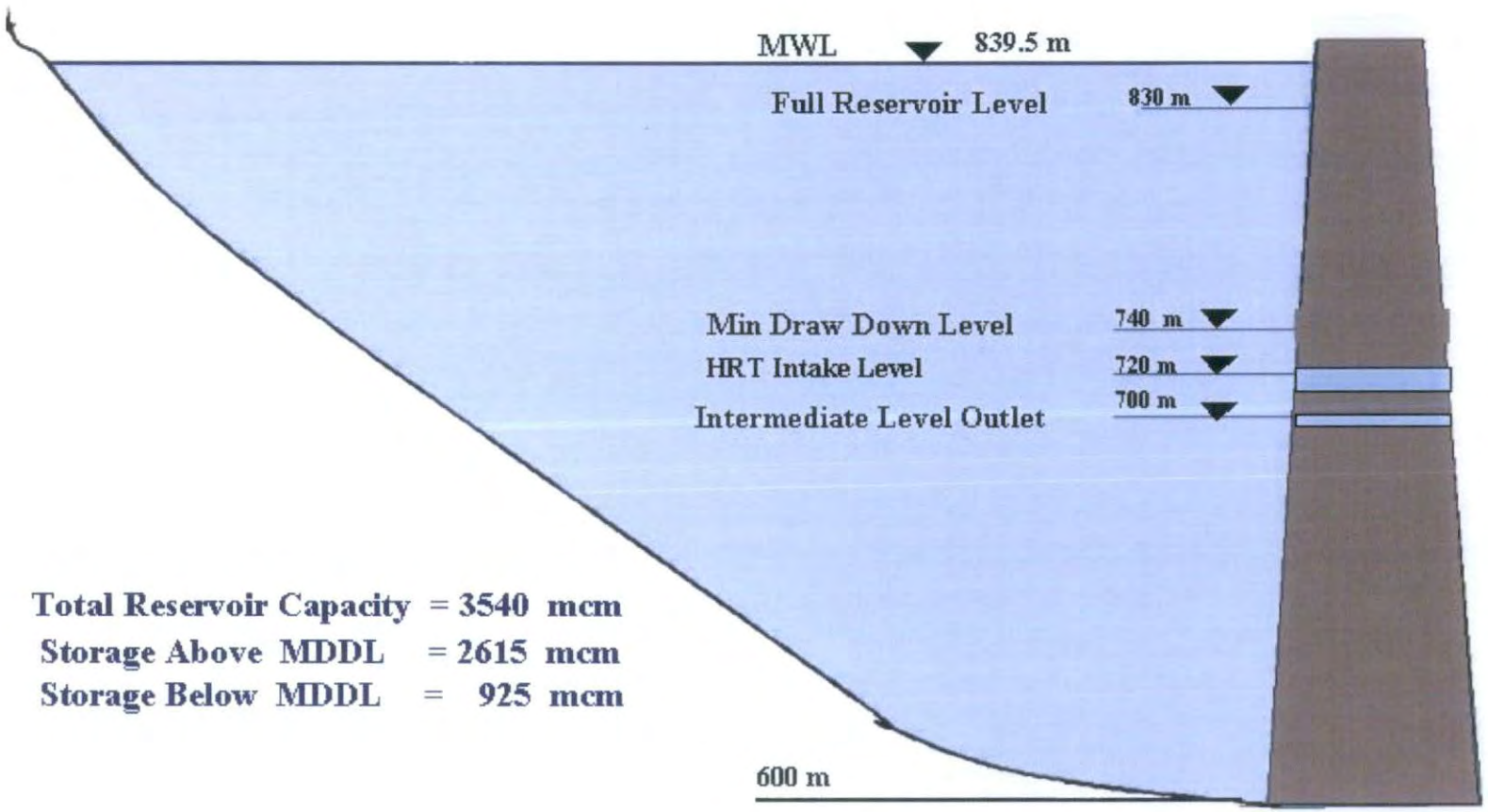
C = Concentration of suspended sediment in mg/l

Table 3

METEOROLOGICAL DATA ADOPTED

(32 Years Average)

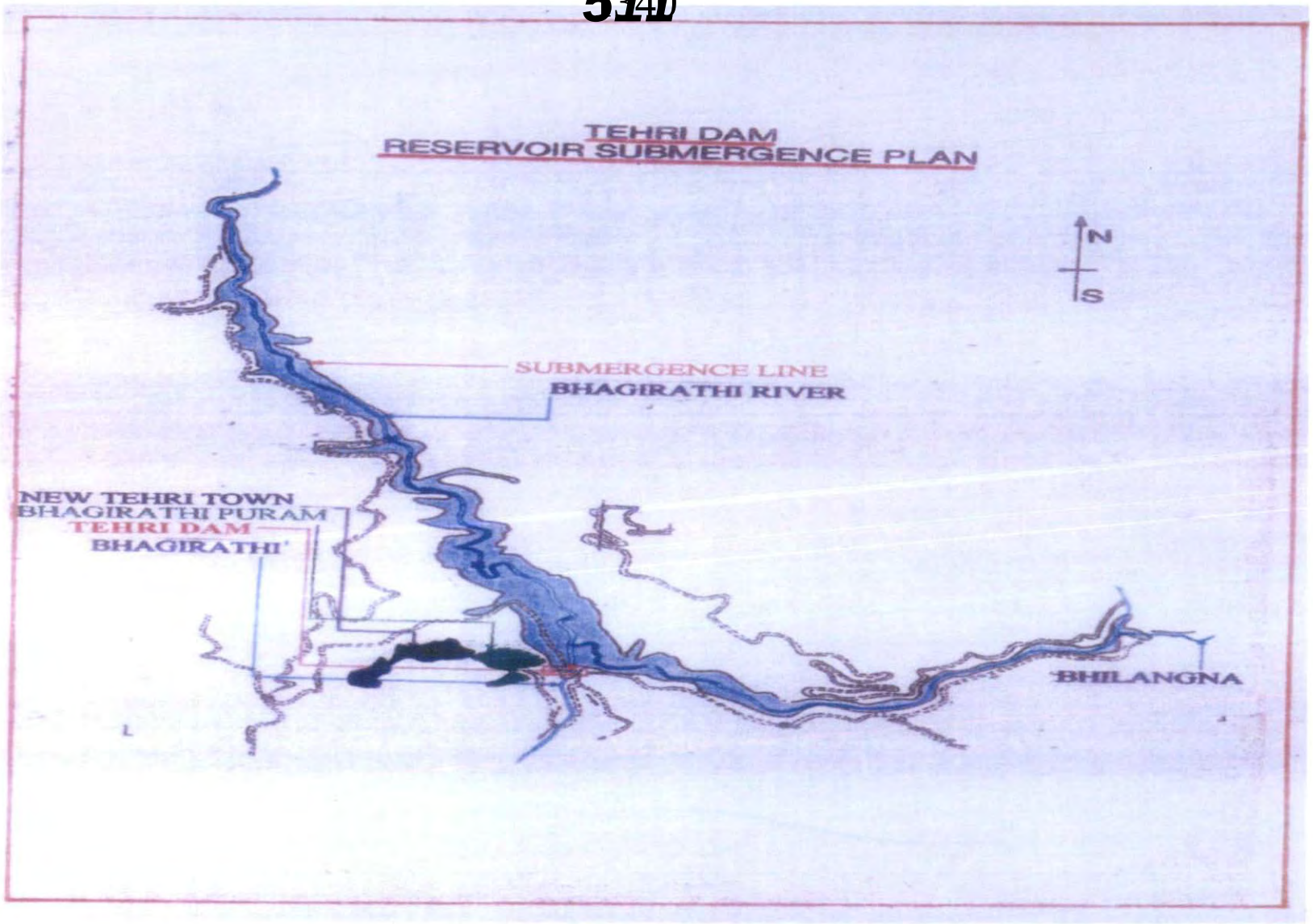
Sl. No.	Month	Relative Humidity (%)	Cloud Cover (OKTAS)	Number of Rainy Days
1	January	76	2.0	2
2	February	68	2.5	2
3	March	59	1.5	4
4	April	53	2.0	3
5	May	52	2.2	3
6	June	50	2.5	4
7	July	88	6.2	23
8	August	92	7.0	25
9	September	82	5.1	14
10	October	75	1.8	1
11	November	72	1.2	0
12	December	78	1.5	2



TEHRI RESERVOIR

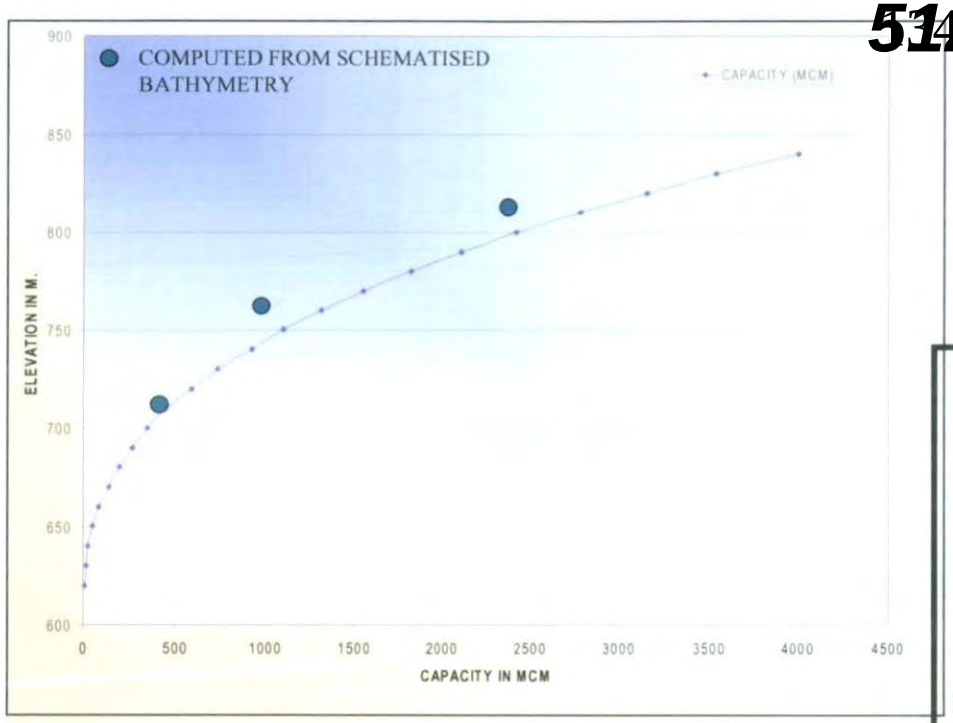
IMPORTANT WATER LEVELS OF THE RESERVOIR

Fig. 1.1



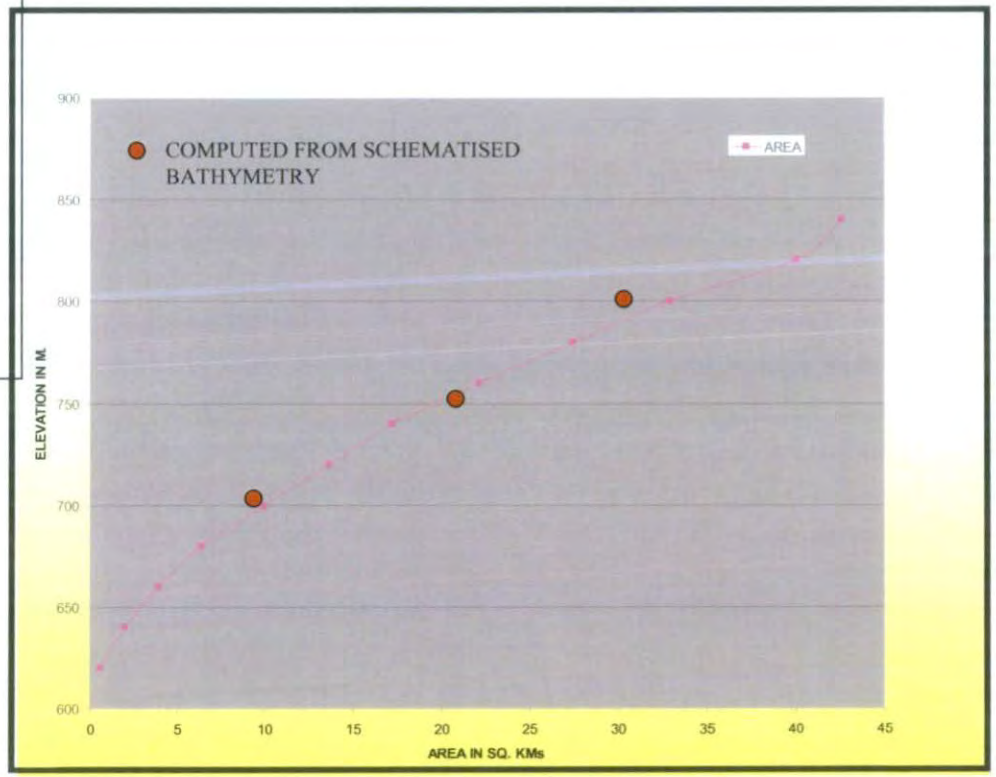
TEHRI BATHYMETRY DATA

Fig 3.1



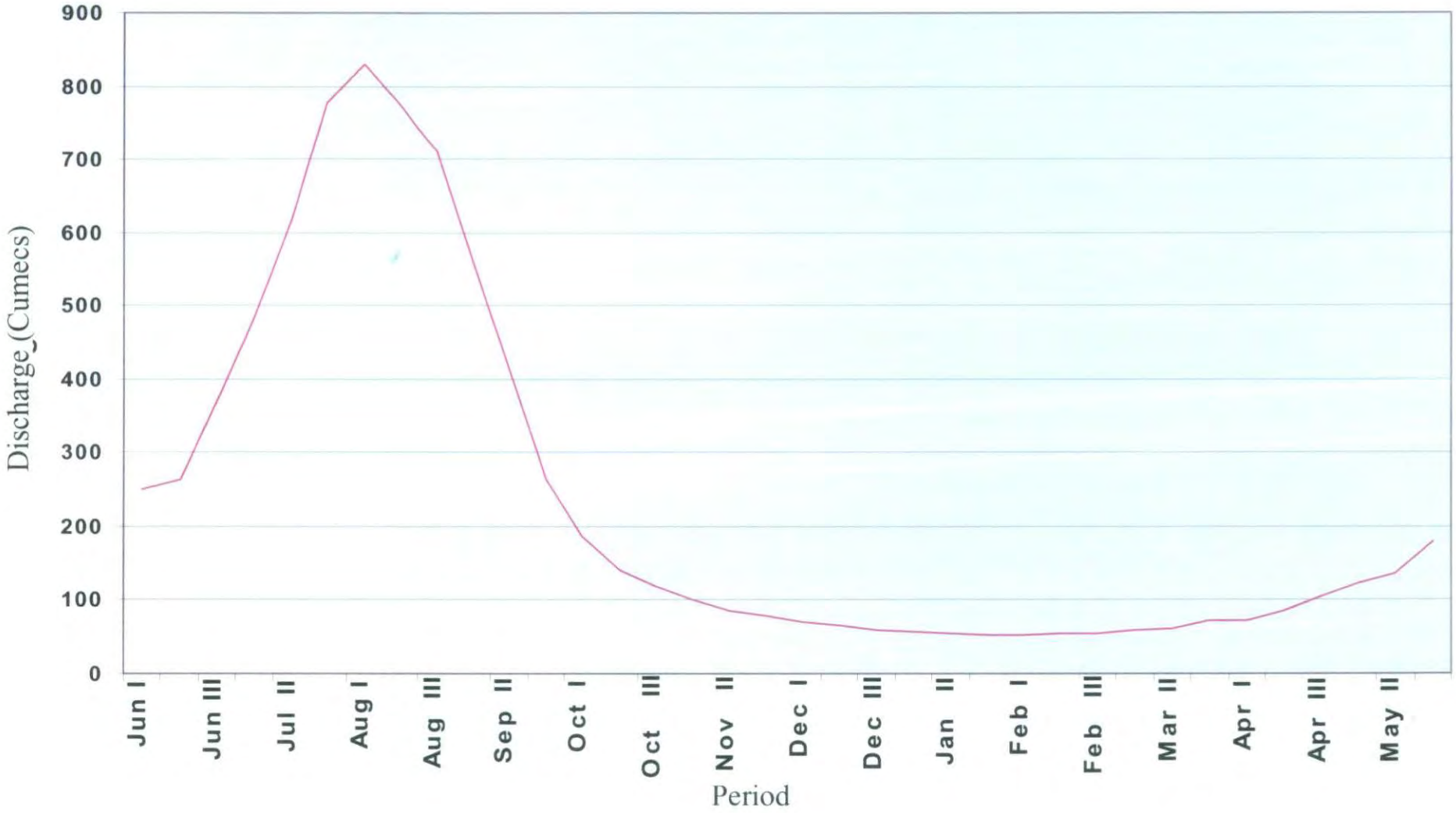
CAPACITY CURVE

AREA CURVE



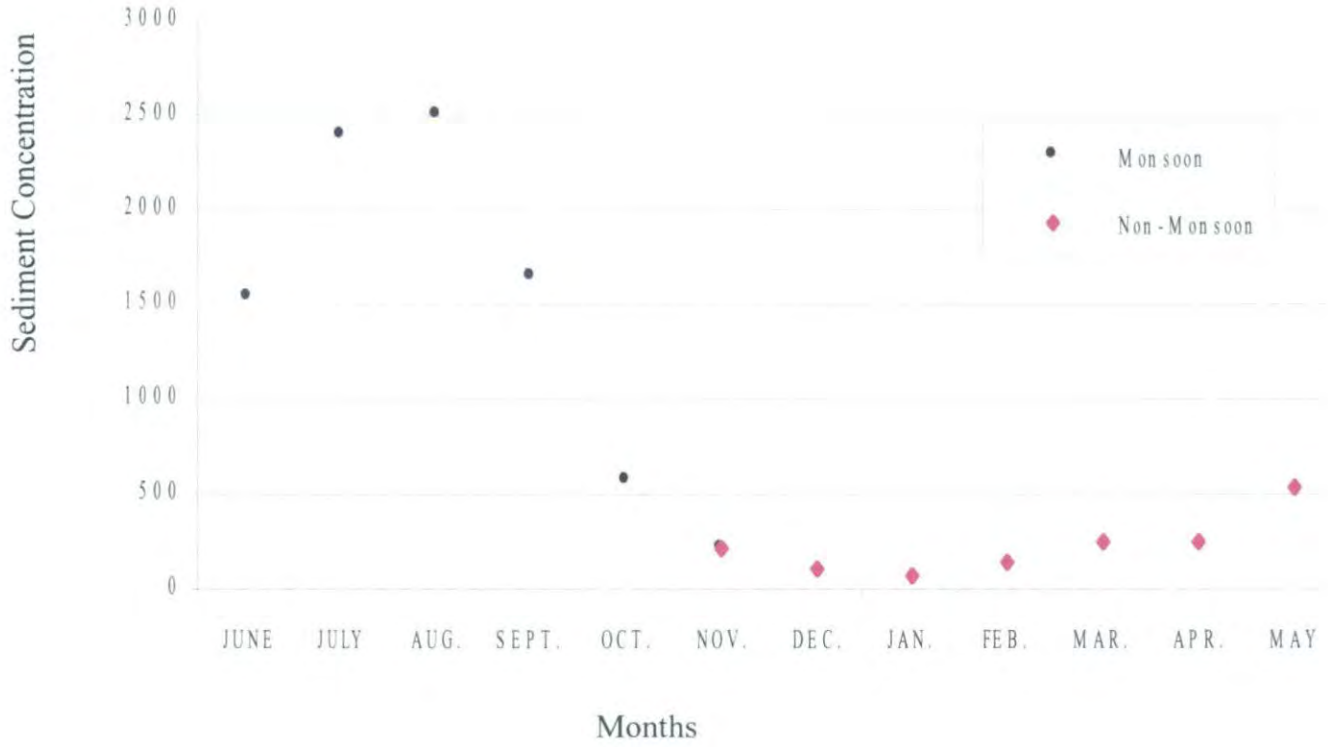
Verification of Discretised Reservoir Bathymetry

Fig. 3.2



10 DAYS AVERAGE DISCHARGE (CUMECS) AT TEHRI

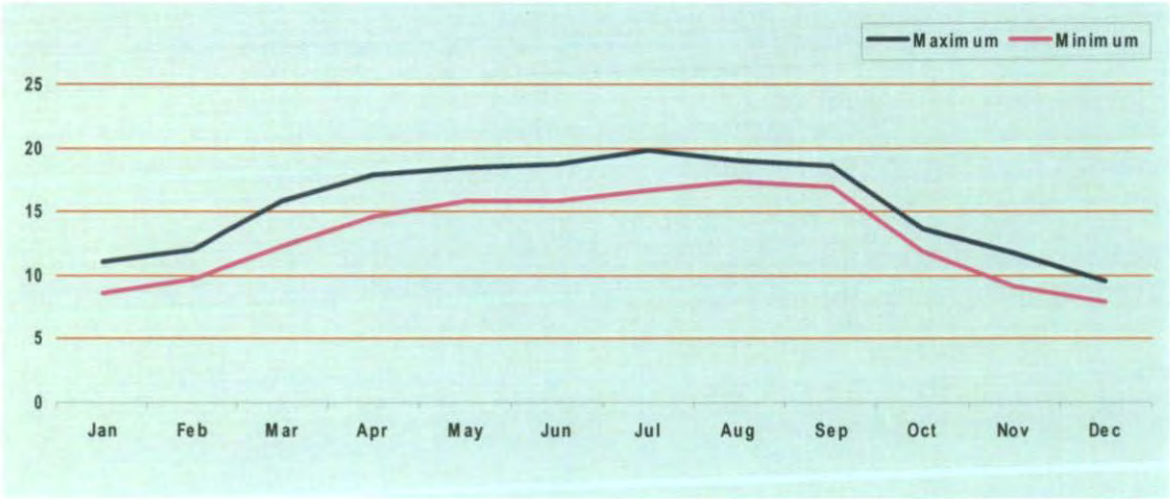
Fig 3.3



Average Sediment Concentration (ppm) at Bhagirathi

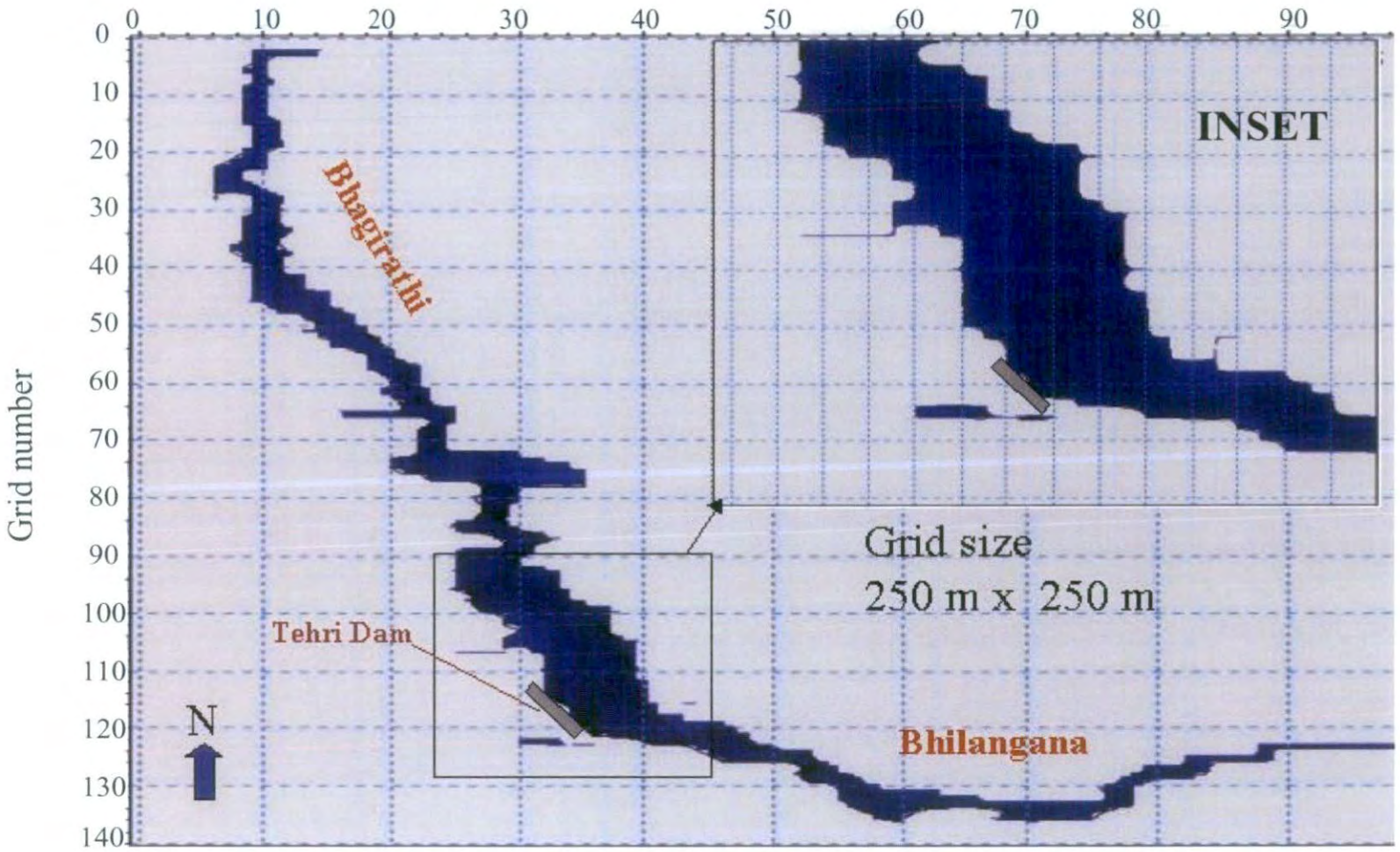
Fig 3.4

BHAGIRATHI - MAX-MIN TEMPERATURE IN °C



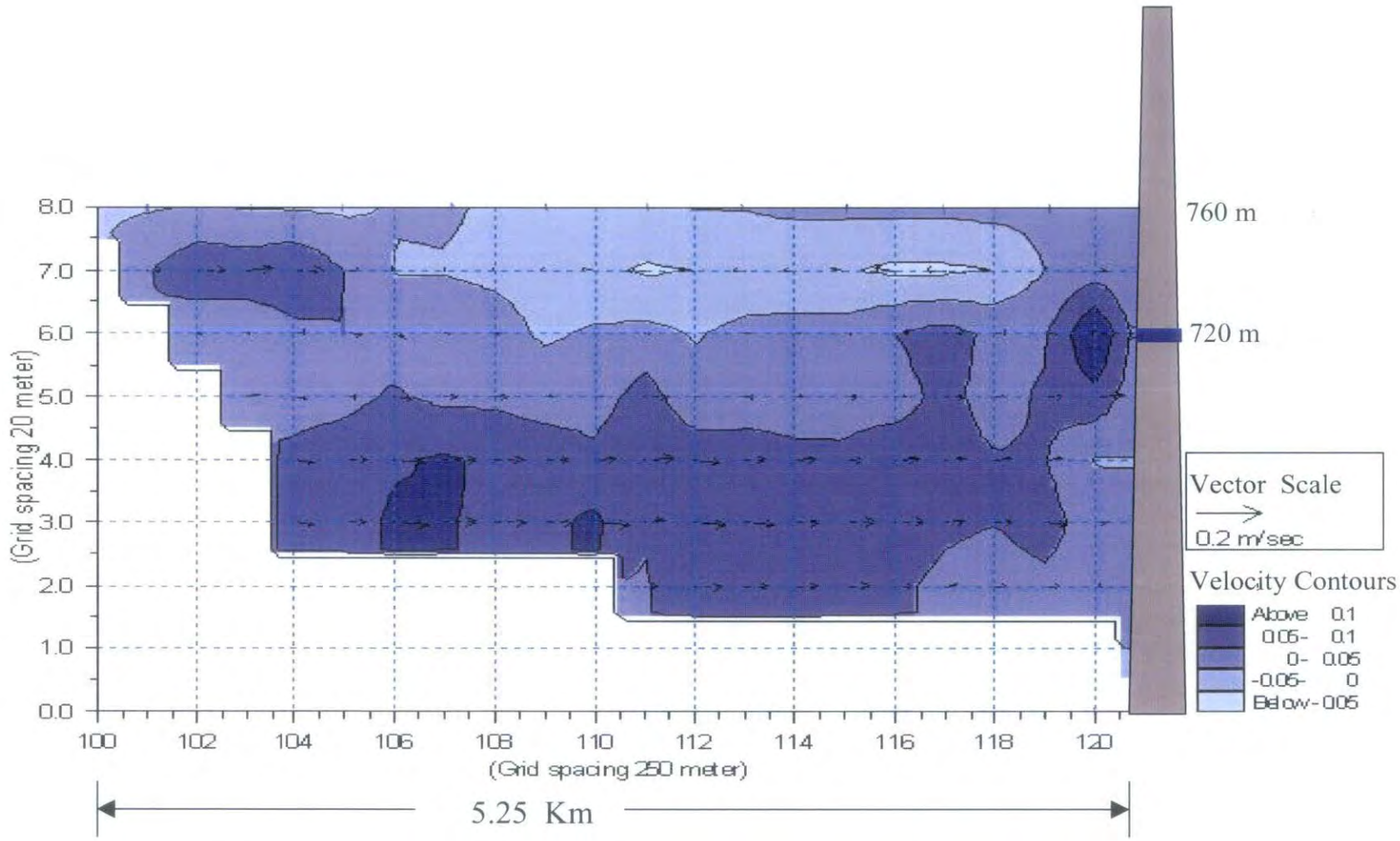
BHILANGANA - MAX-MIN TEMPERATURE IN °C

Fig 3.5



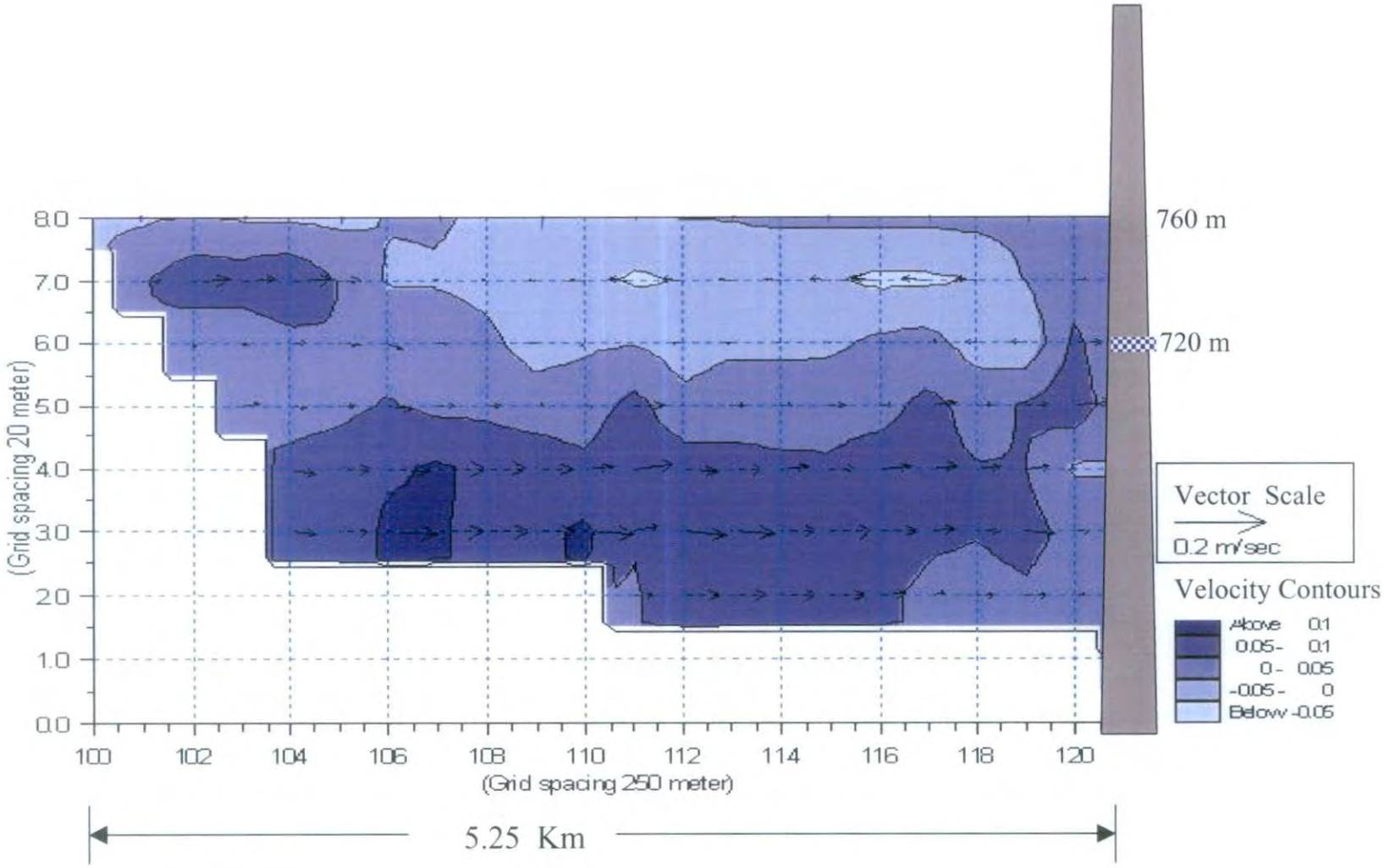
AREA COVERED IN MATHEMATICAL MODEL

Fig 4.1



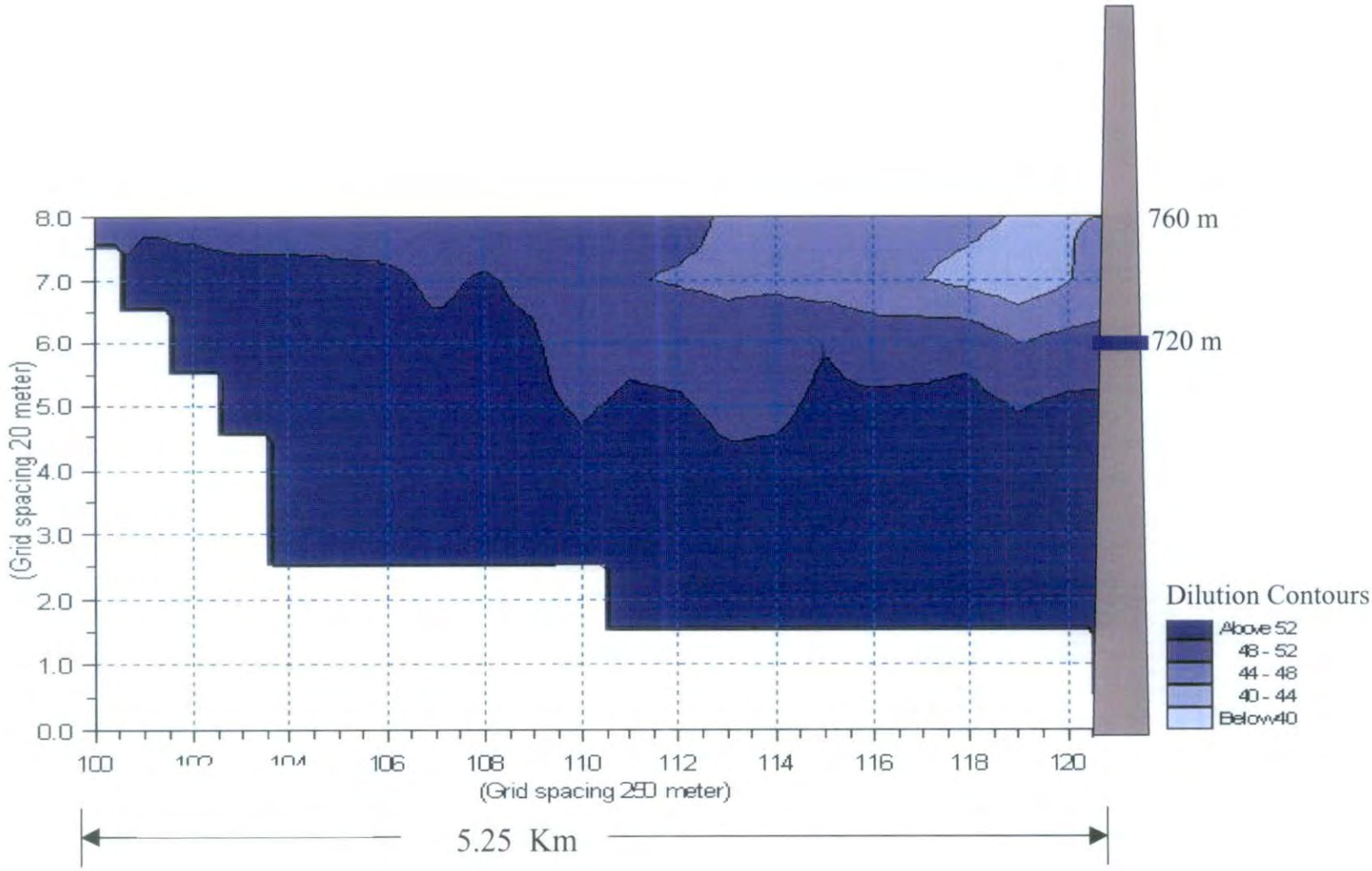
Vertical Velocity Field (Monsoon : Power Outlet Open)

Fig. 5.1



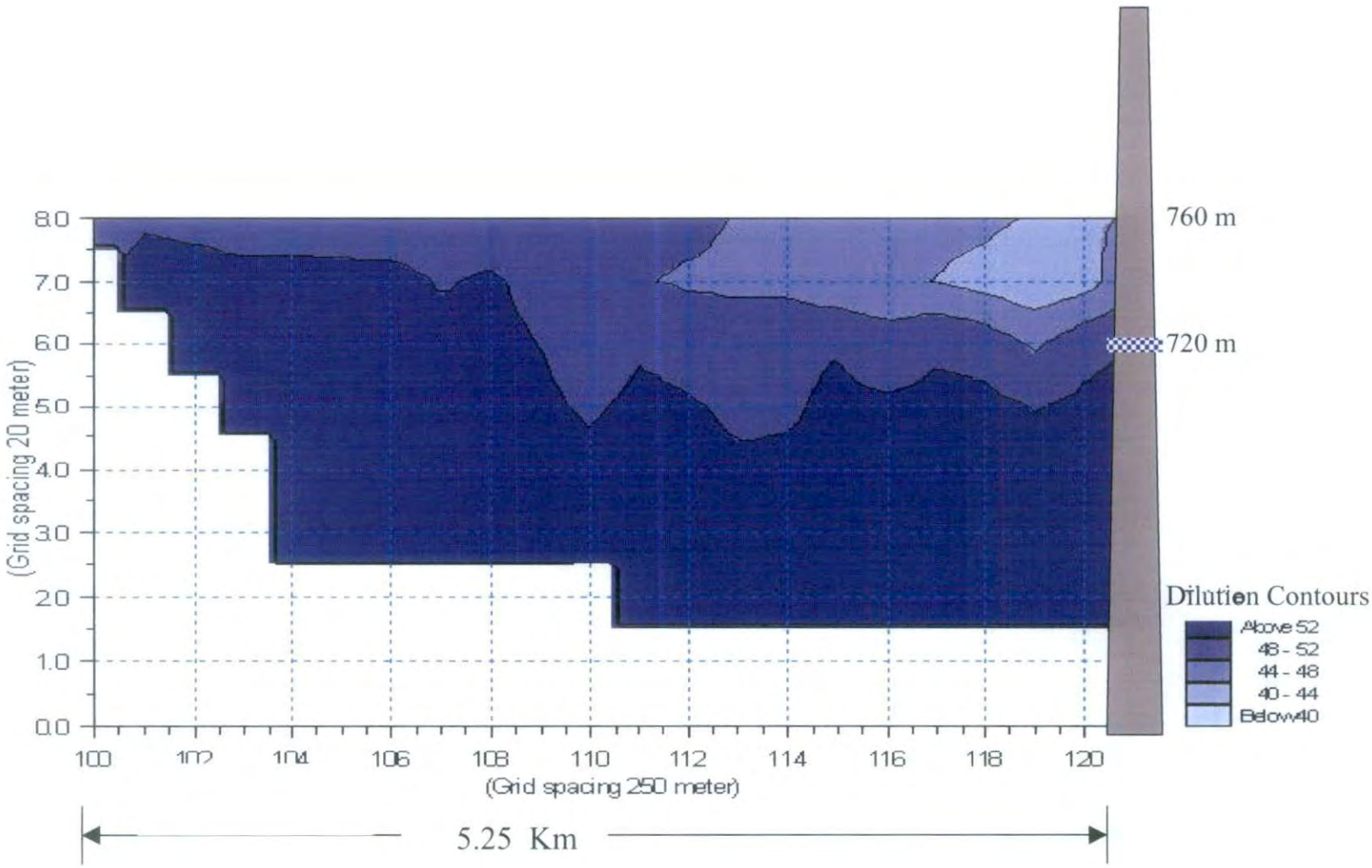
Vertical Velocity Field (Monsoon : Power Outlet Closed)

Fig. 5.2



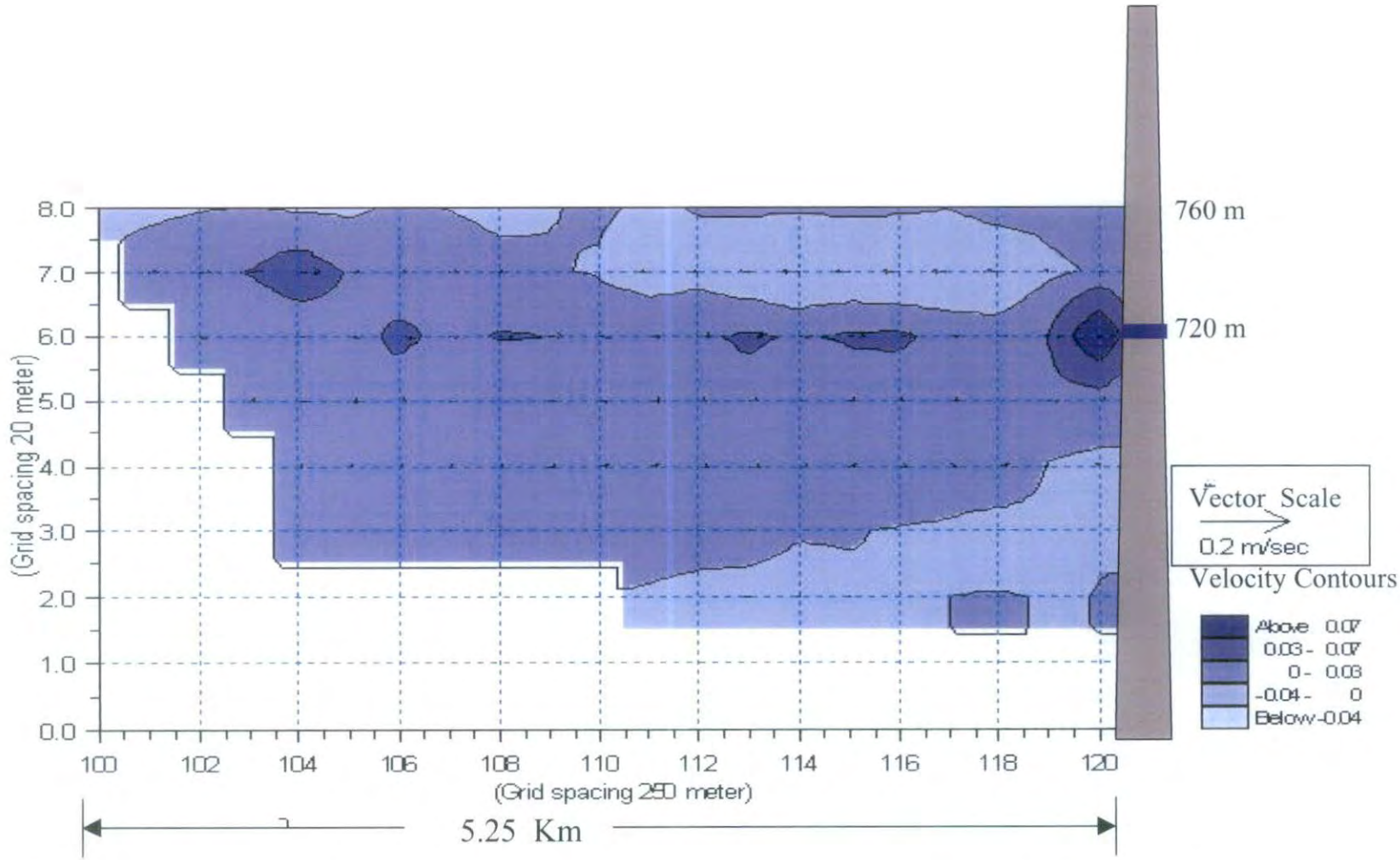
Vertical Dilution of River water in the Reservoir (Monsoon : Power Outlet Open)

Fig. 5.3



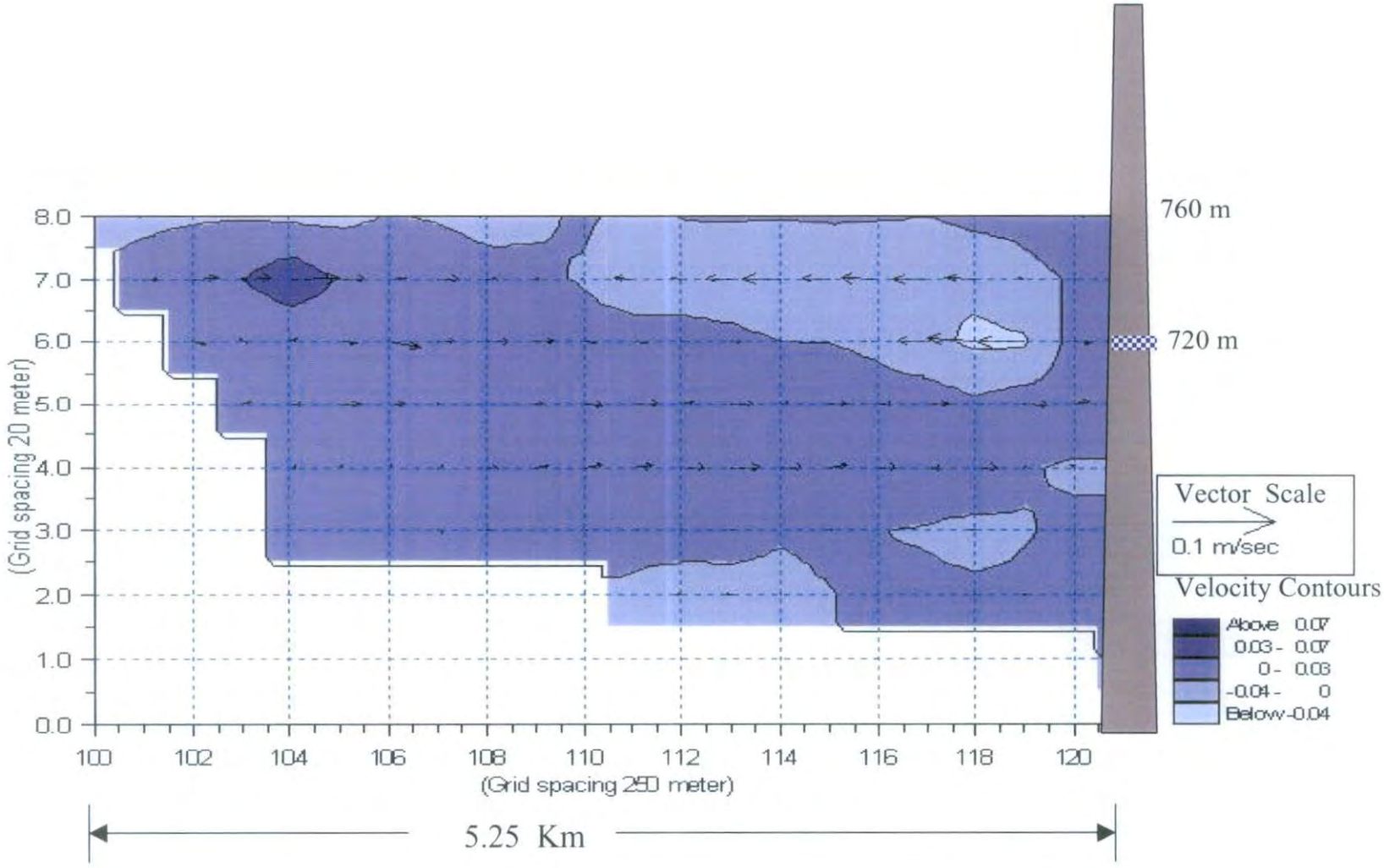
Vertical Dilution of River water in the Reservoir (Monsoon : Power Outlet Closed)

Fig. 5.4



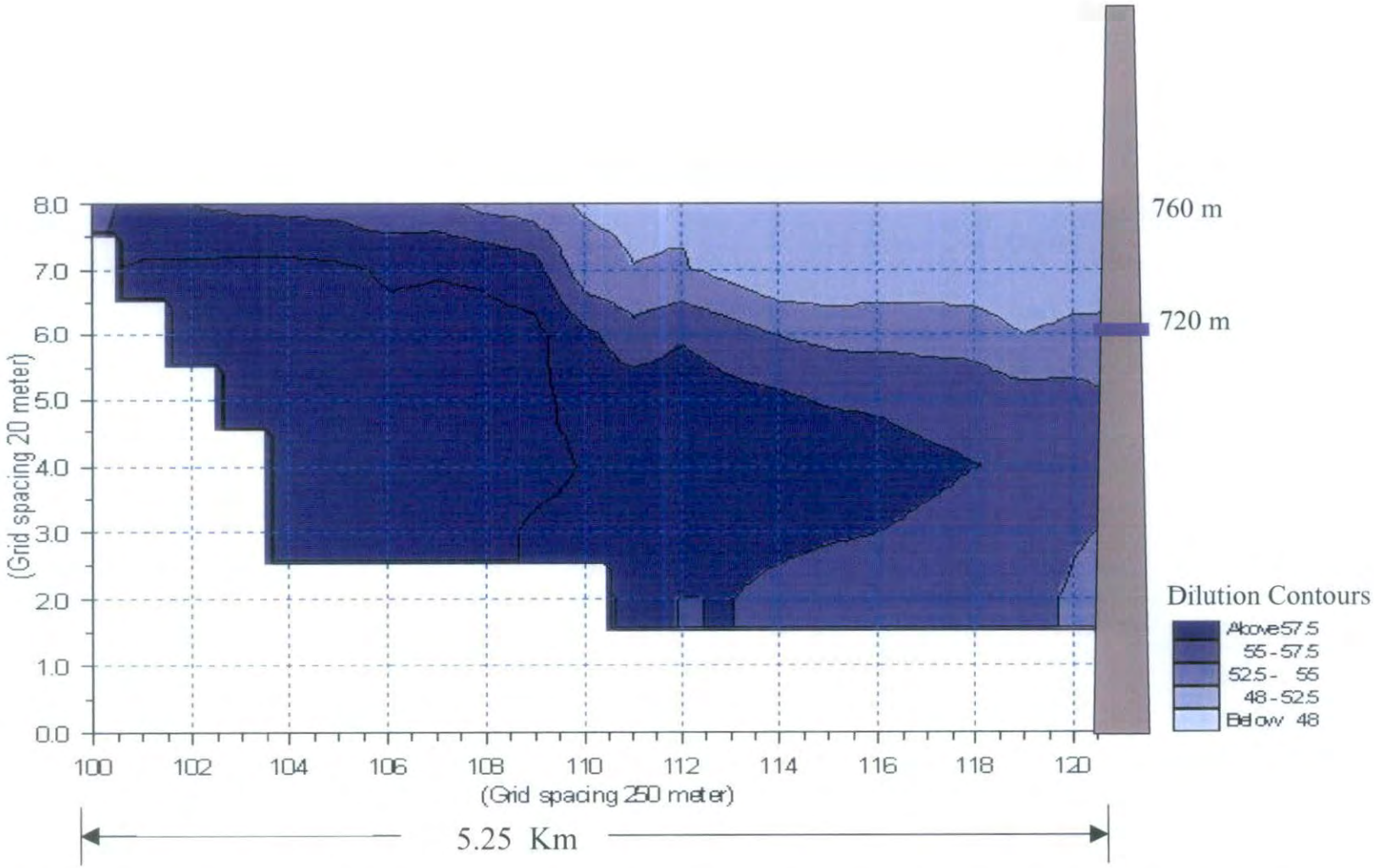
Vertical Velocity Field (End of Monsoon : Power Outlet Open)

Fig. 5.5



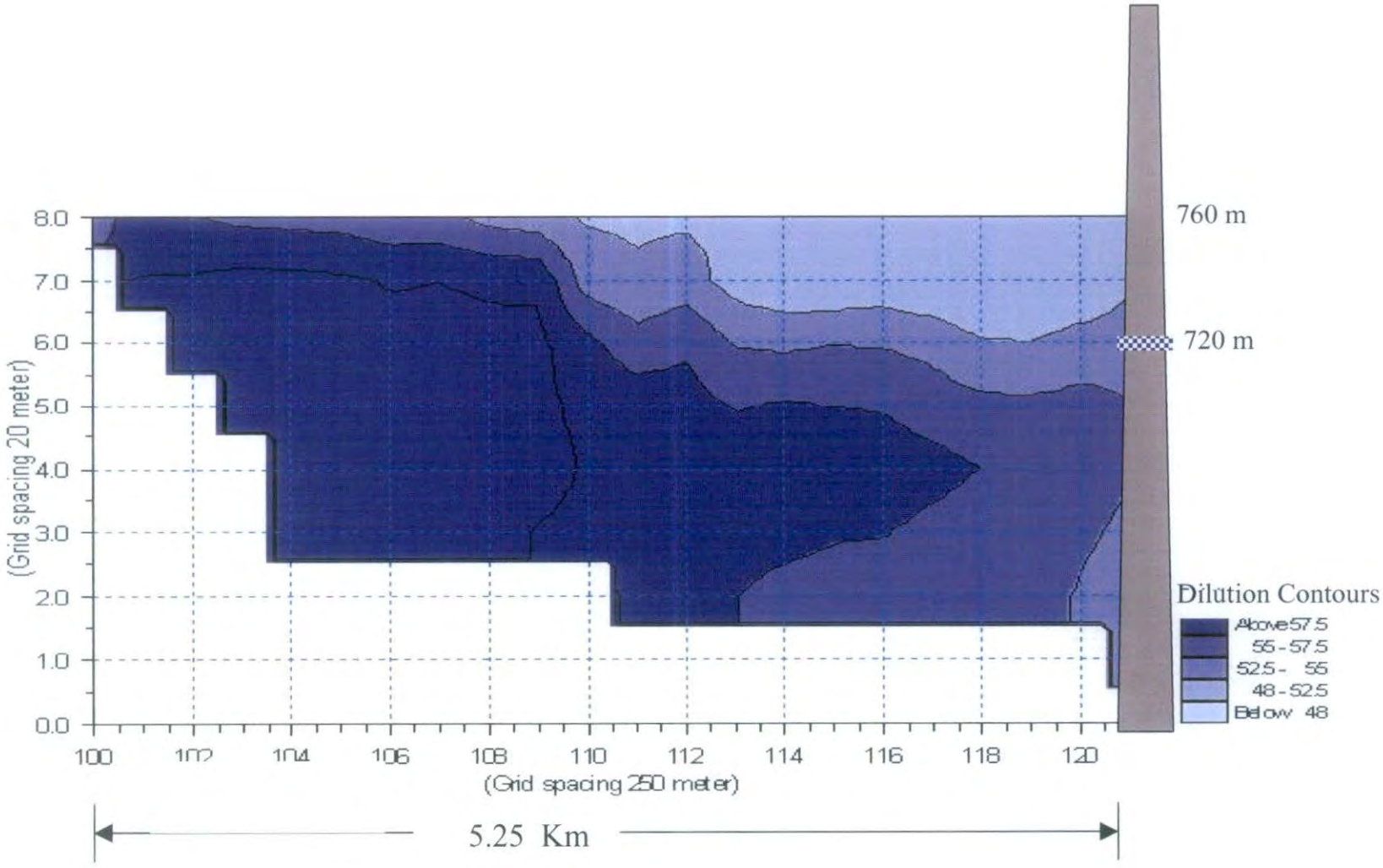
Vertical Velocity Field (End of Monsoon : Power Outlet Closed)

Fig. 5.6



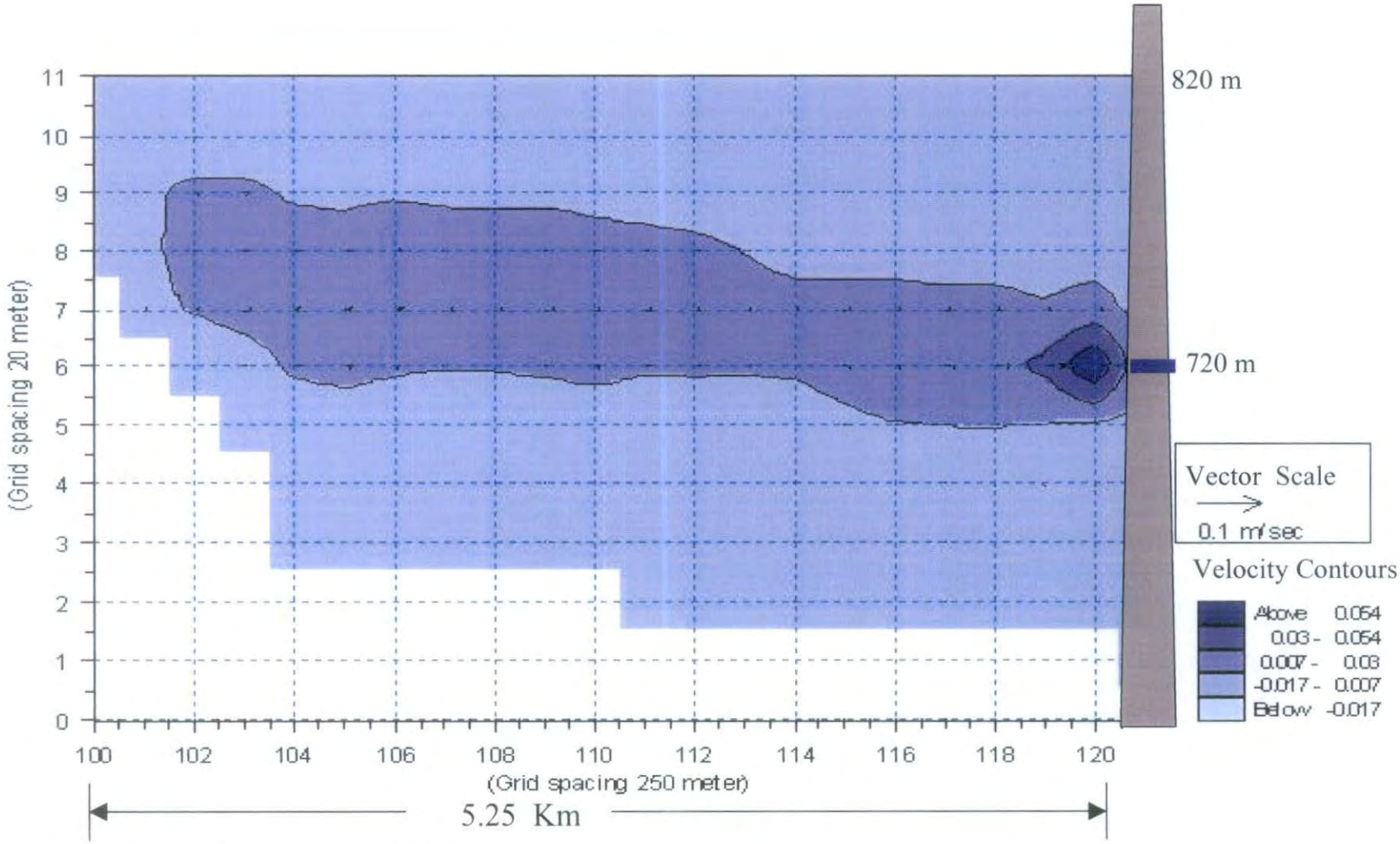
Vertical Dilution of River water in the Reservoir (End of Monsoon : Power Outlet Open)

Fig. 5.7



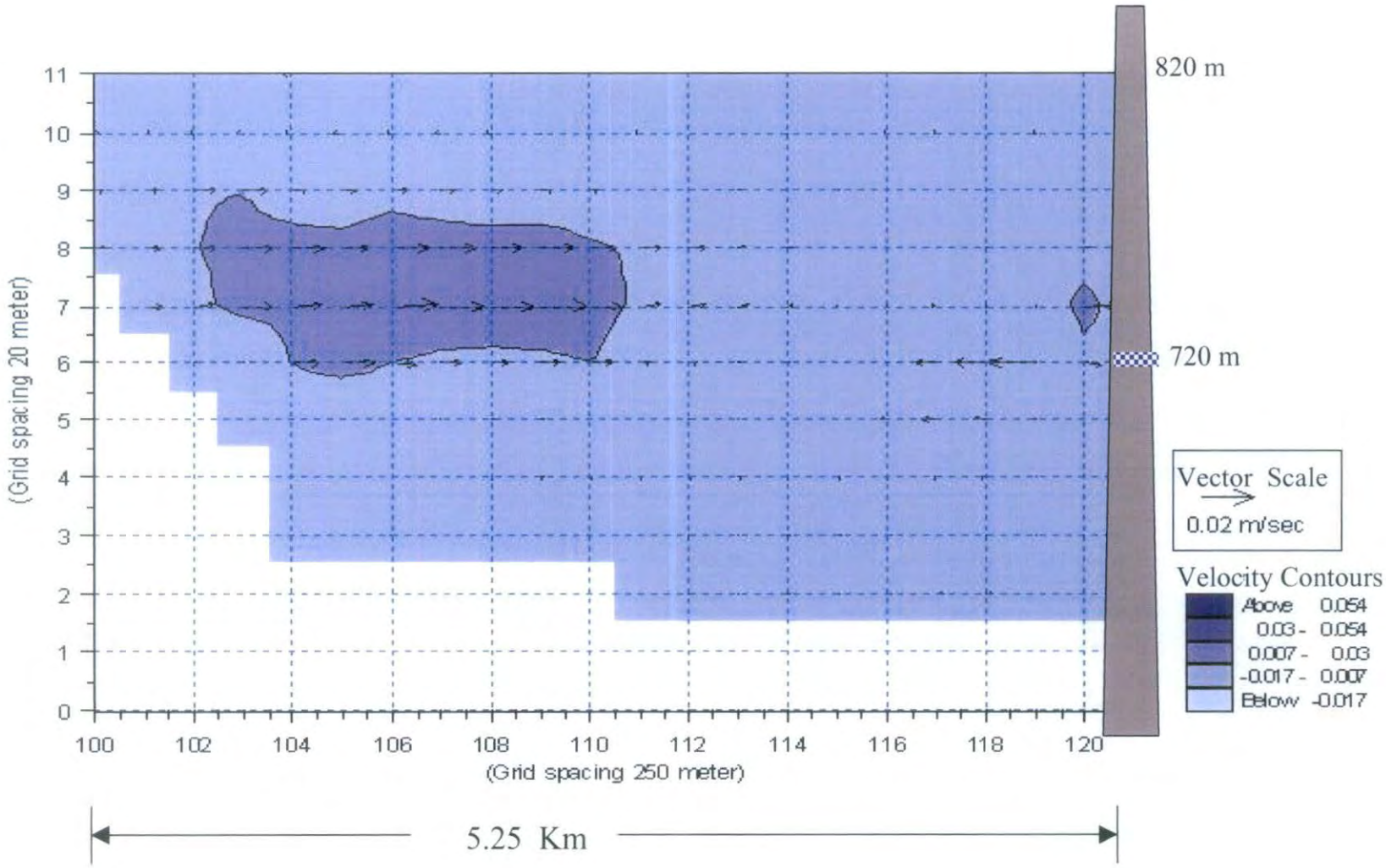
Vertical Dilution of River water in the Reservoir (End of Monsoon : Power Outlet Closed)

Fig. 5.8



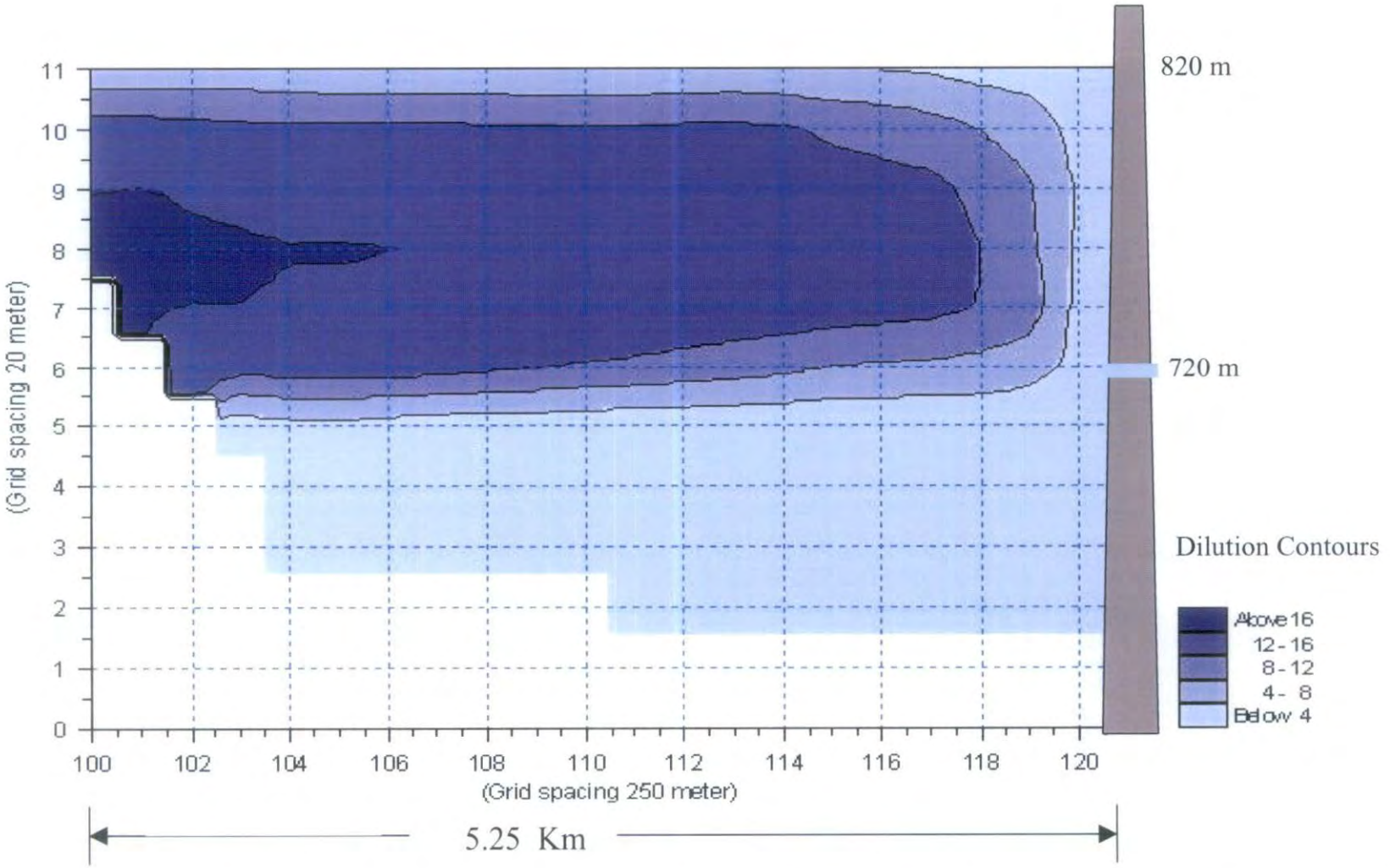
Vertical Velocity Field (Winter Season : Power Outlet Open)

Fig. 5.9



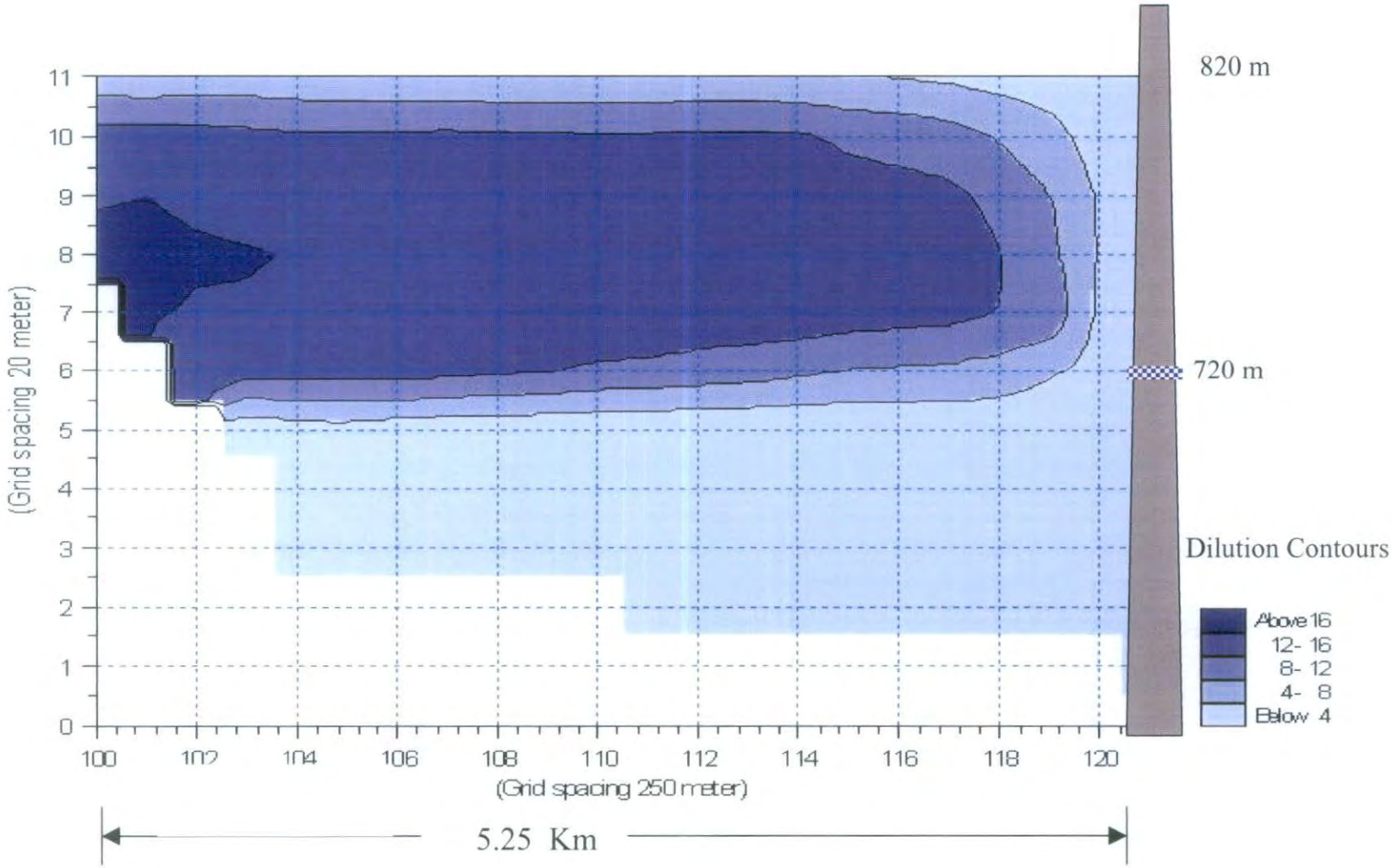
Vertical Velocity Field (Winter Season : Power Outlet Closed)

Fig. 5.10



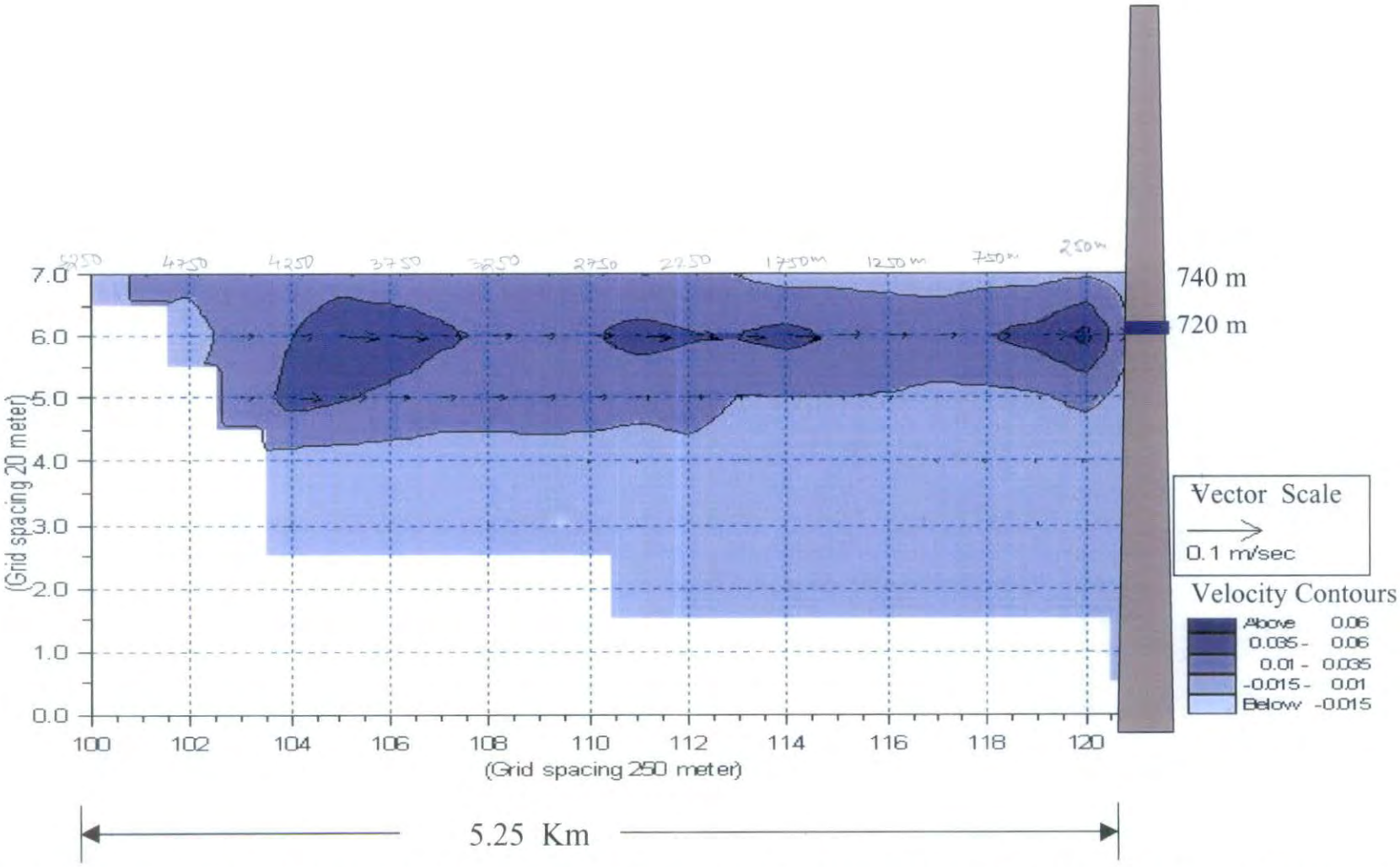
Vertical Dilution of River water in the Reservoir (Winter Season : Power Outlet Open)

Fig. 5.11



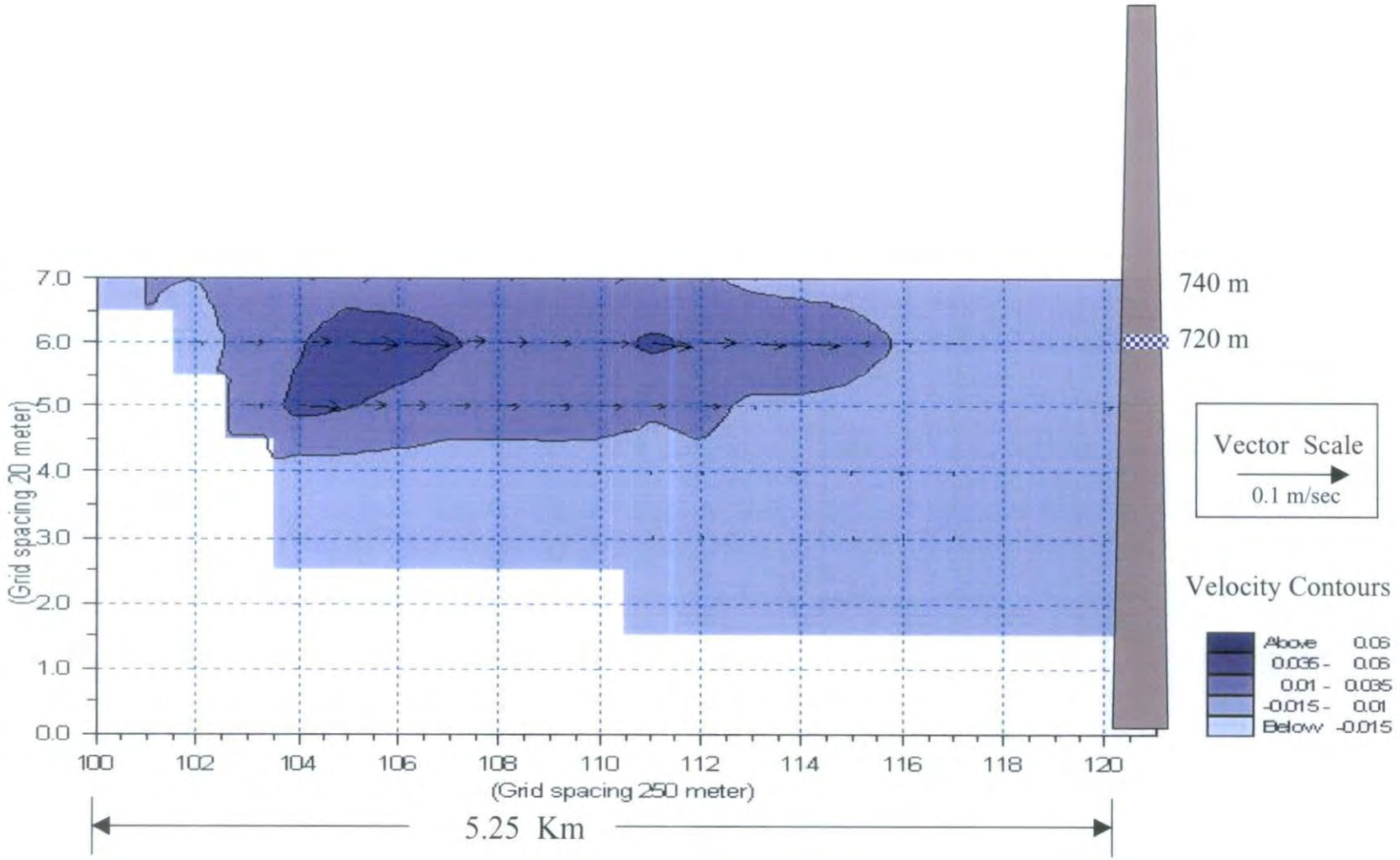
Vertical Dilution of River water in the Reservoir (Winter Season : Power Outlet Closed)

Fig. 5.12



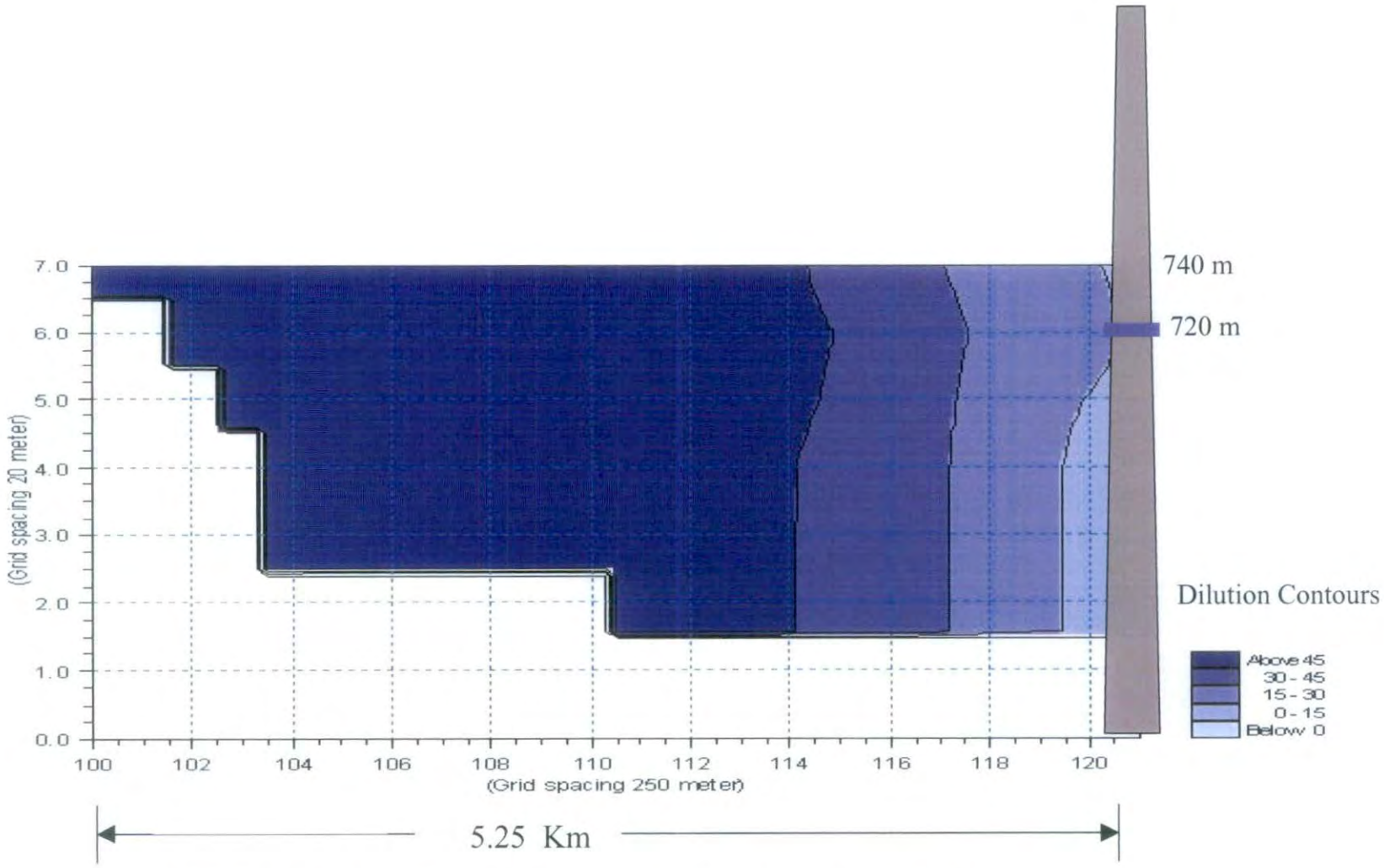
Vertical Velocity Field (Interval Between Winter and Monsoon : Power Outlet Open)

Fig. 5.13



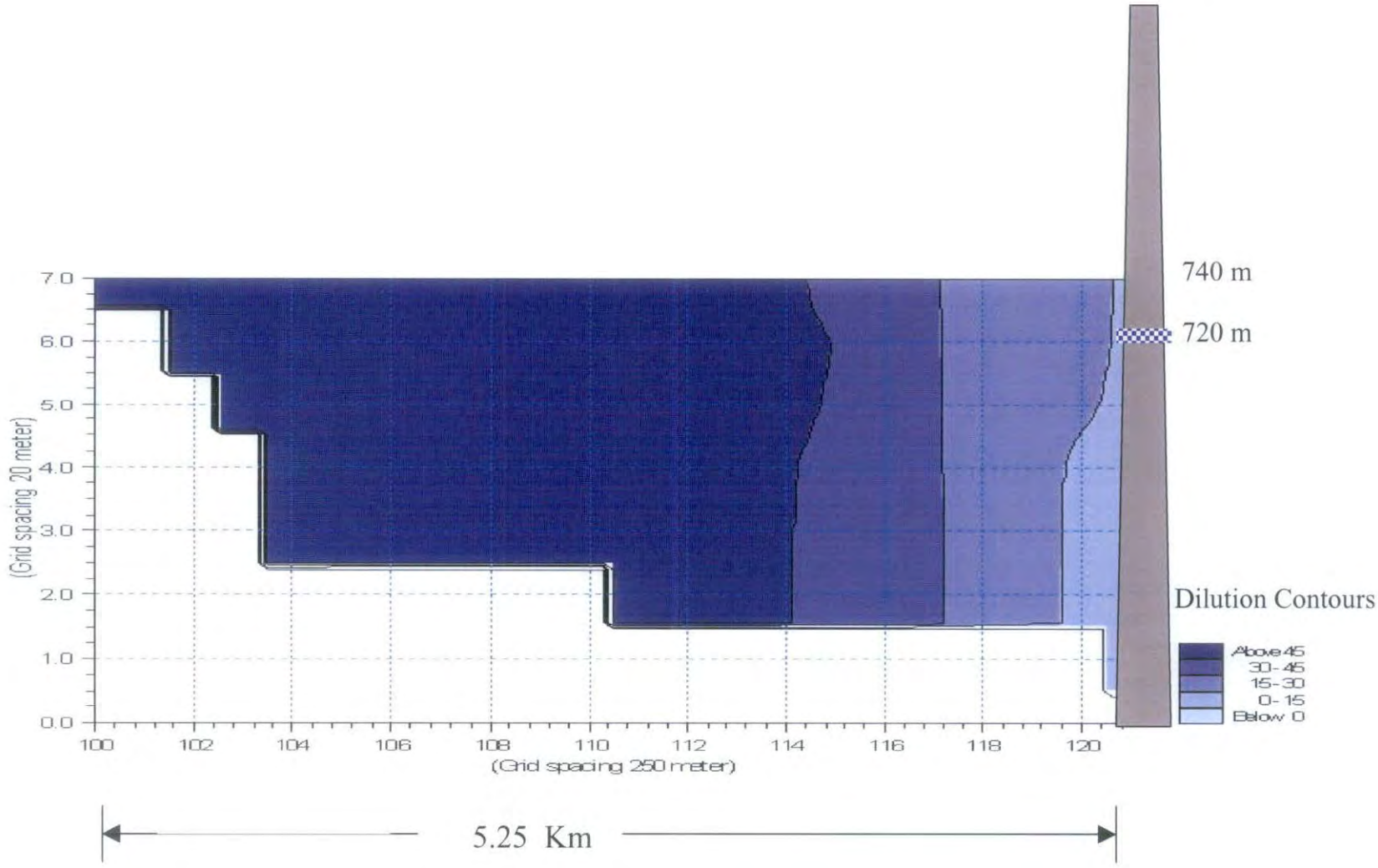
Vertical Velocity Field (Interval Between Winter and Monsoon : Power Outlet Closed)

Fig. 5.14



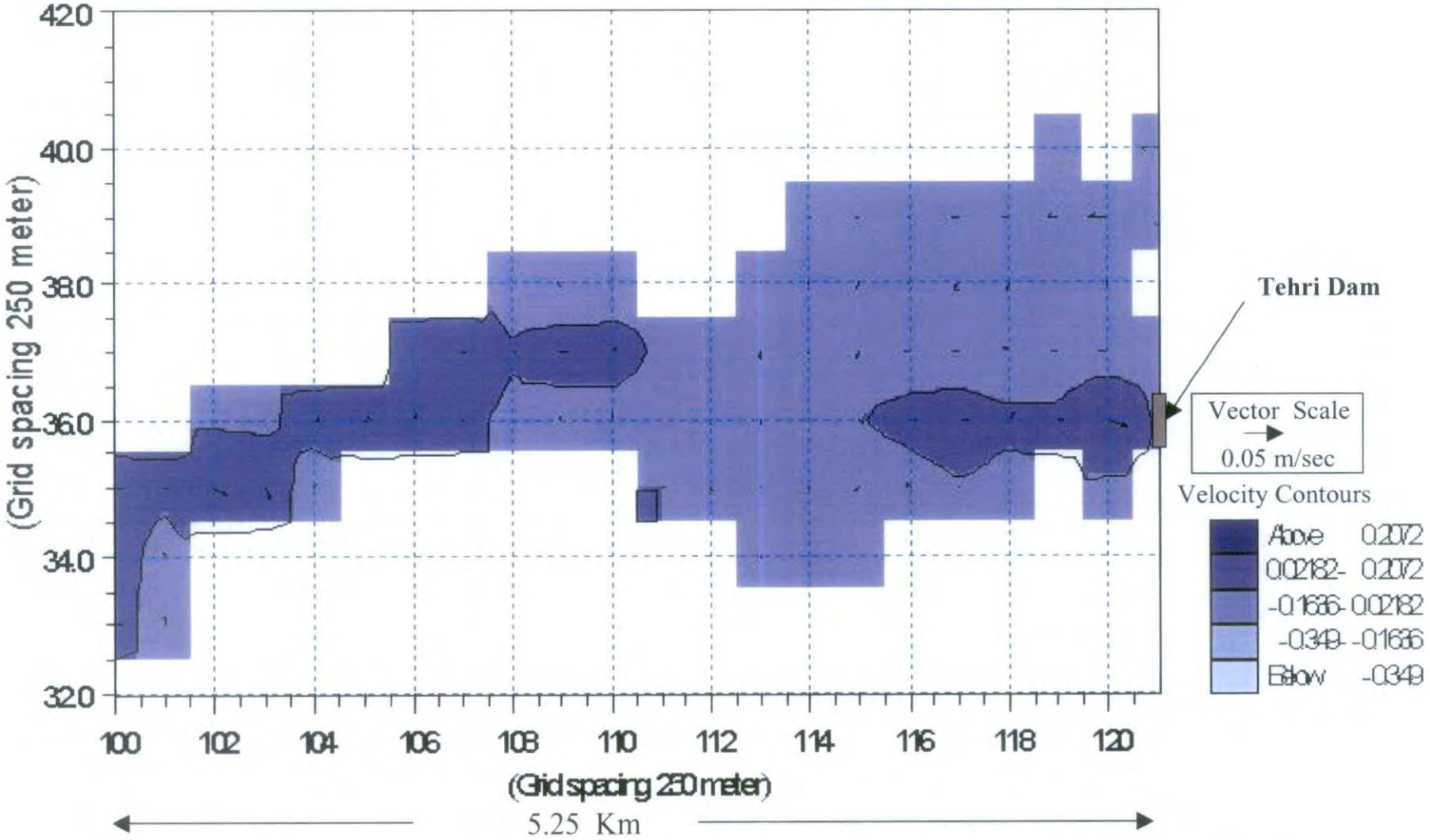
Vertical Dilution of River water in the Reservoir
(Interval Between Winter and Monsoon : Power Outlet Open .)

Fig. 5.15



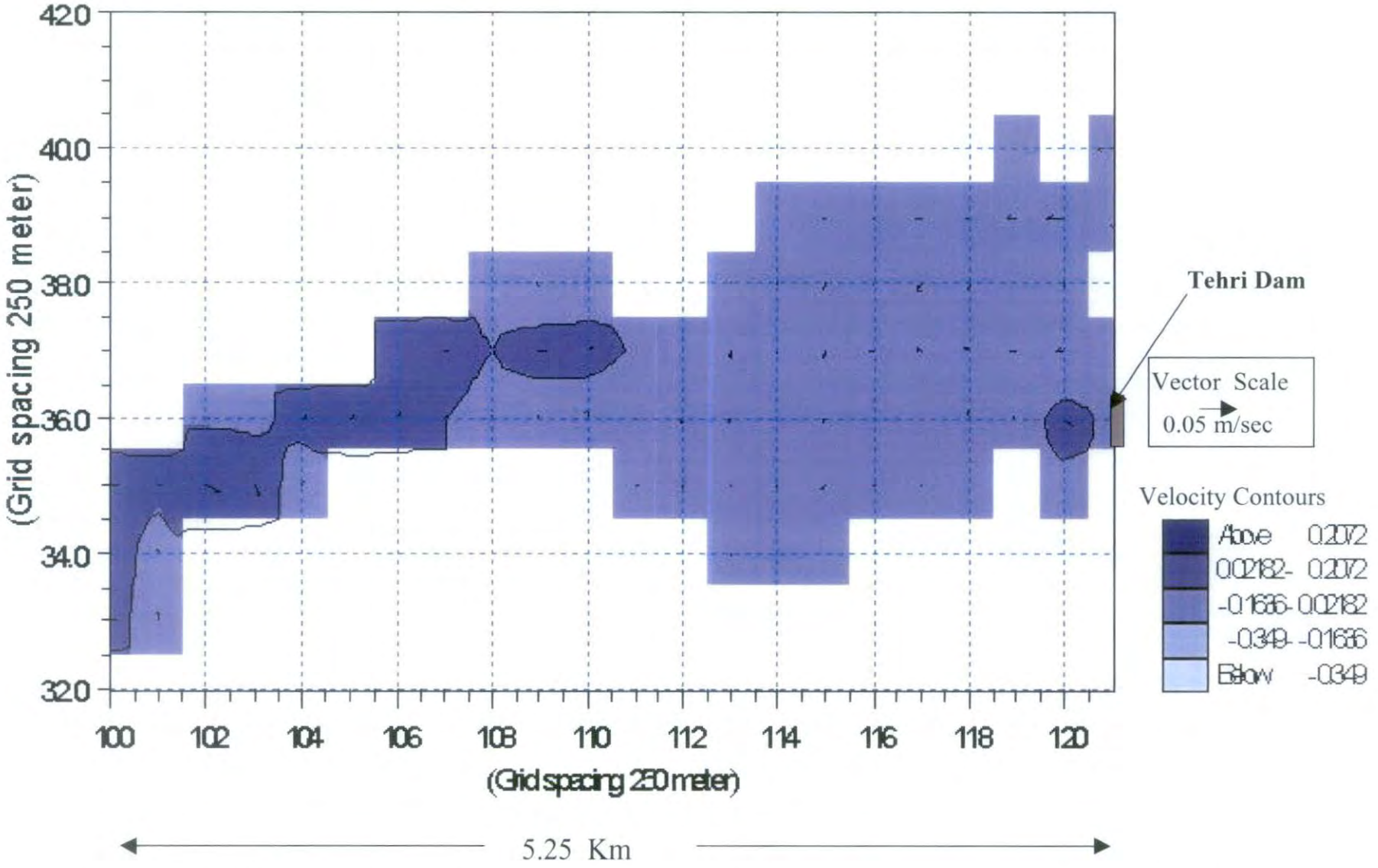
Vertical Dilution of River water in the Reservoir
(Interval Between Winter and Monsoon : Power Outlet Closed)

Fig. 5.16



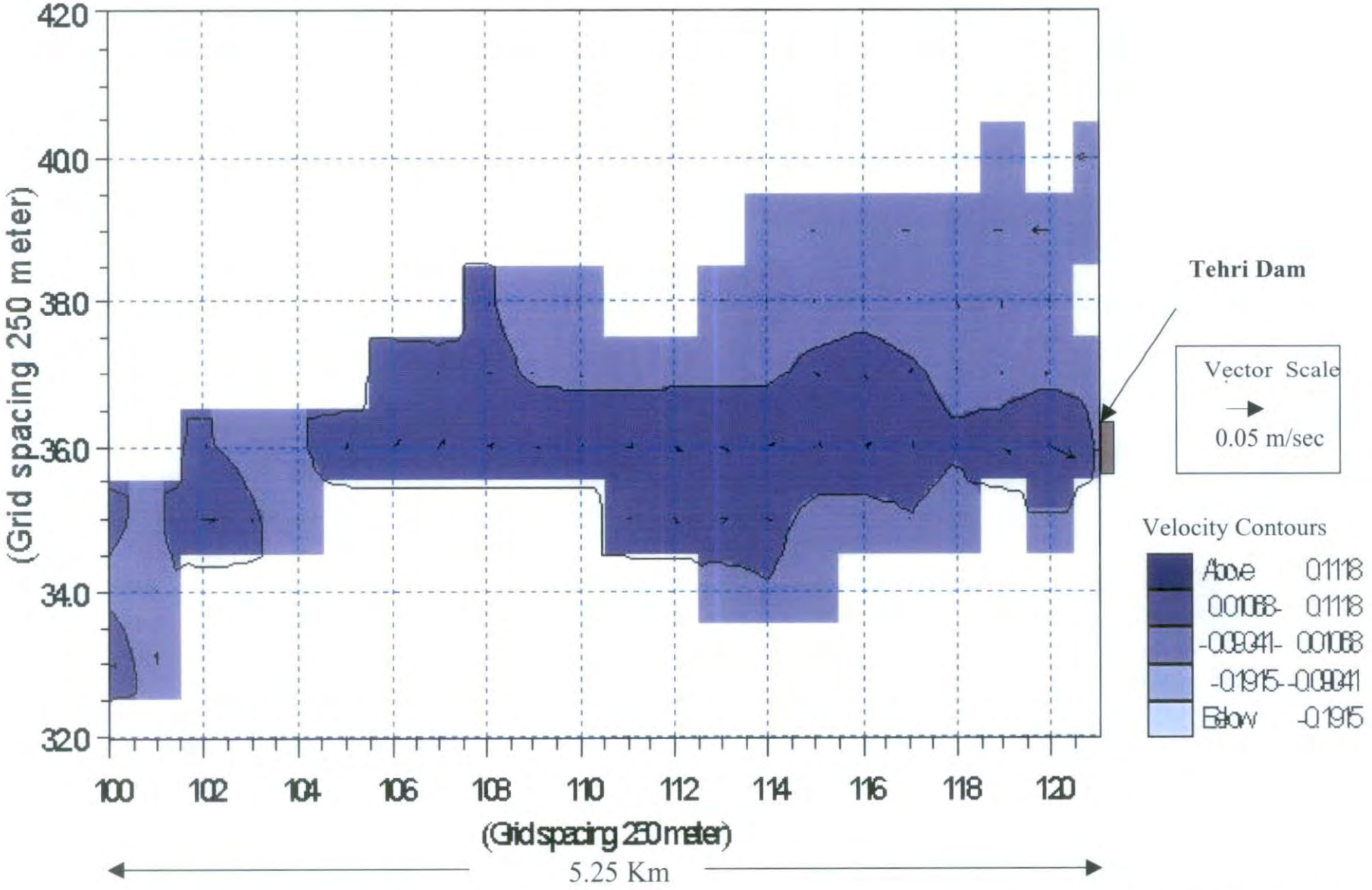
Horizontal Velocity Field at Level 720m (Monsoon : Power Outlet Open)

Fig. 5.17



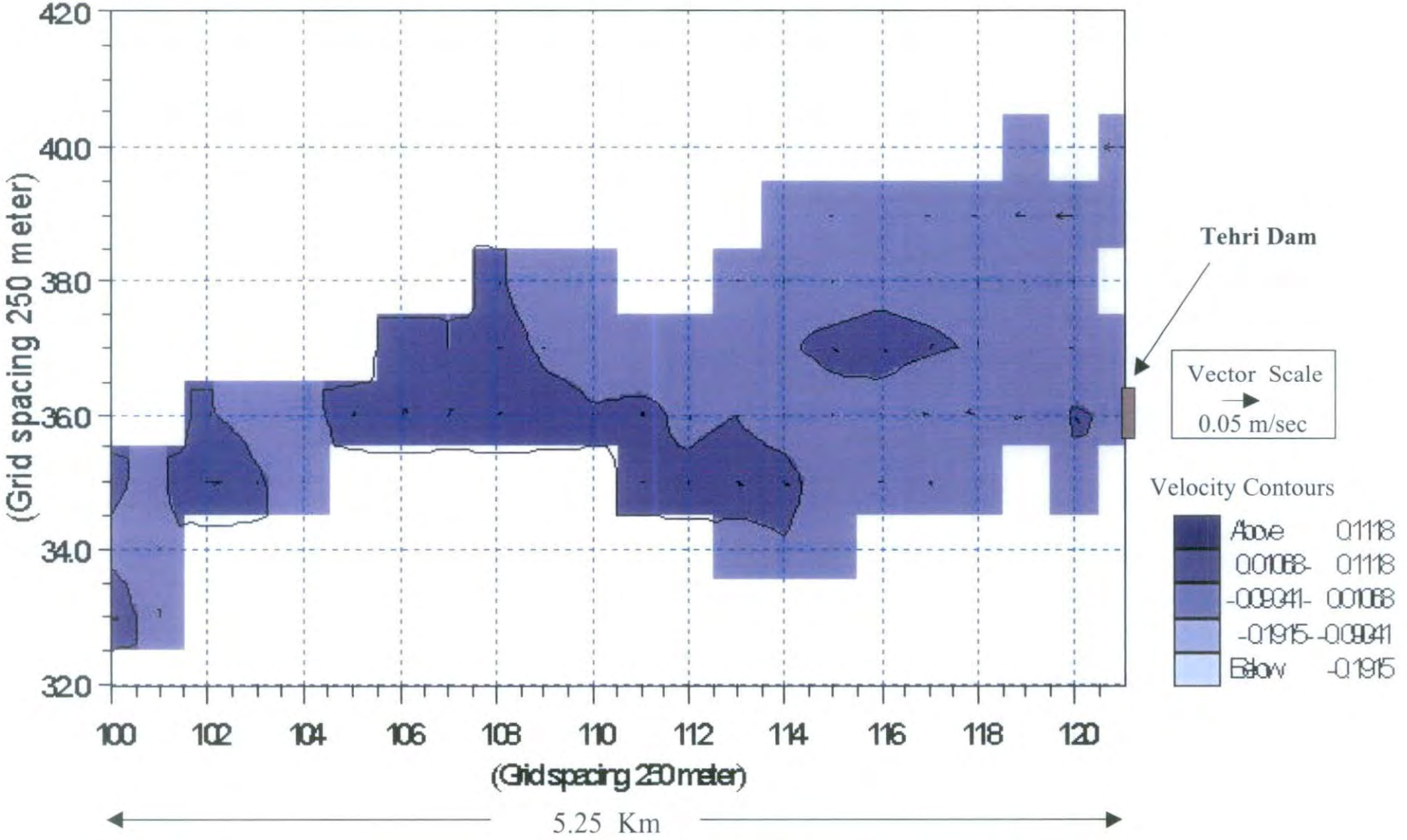
Horizontal Velocity Field at Level 720m (Monsoon : Power Outlet Closed)

Fig. 5.18



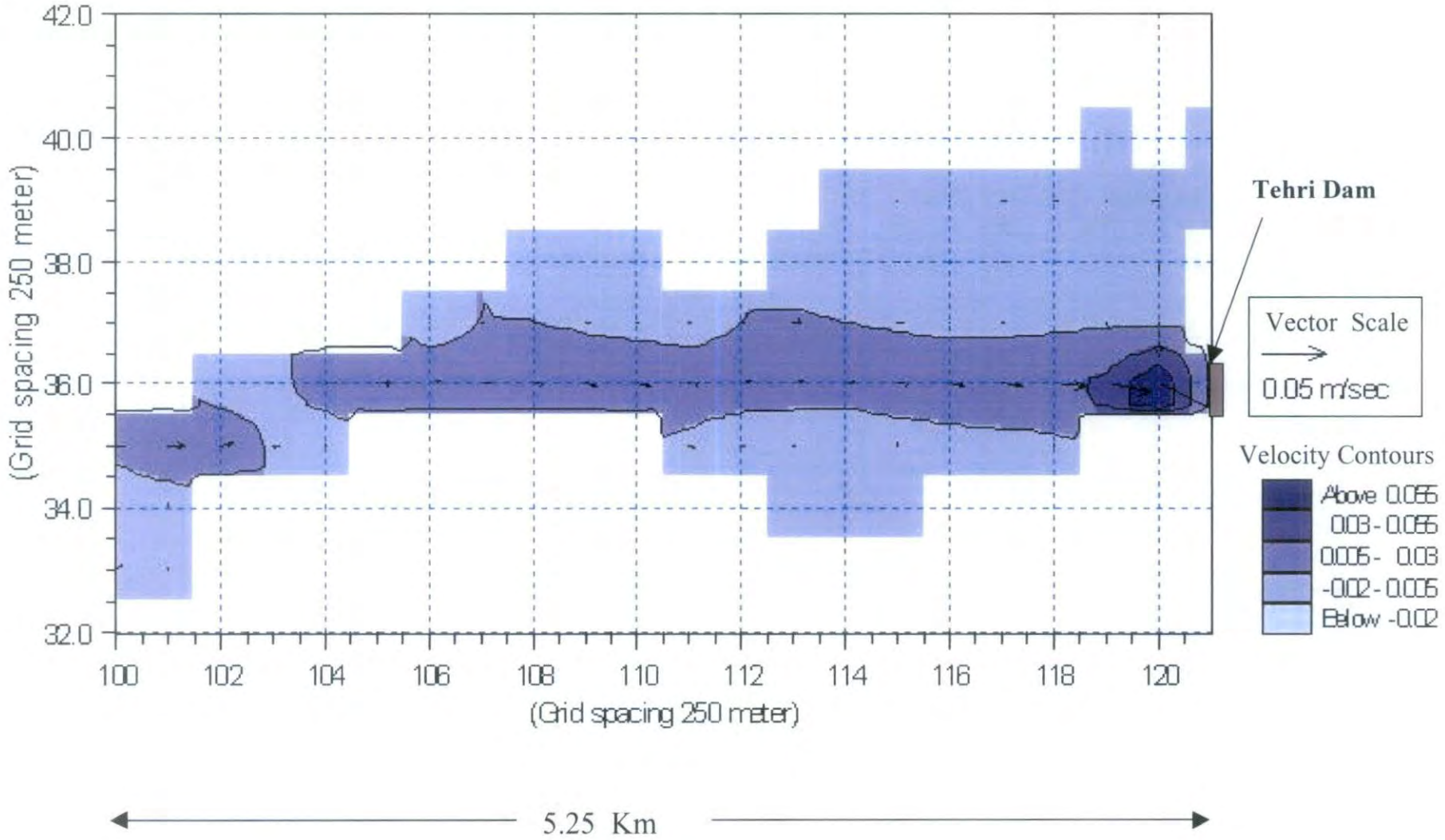
Horizontal Velocity Field at Level 720m (End of Monsoon : Power Outlet Open)

Fig. 5.19



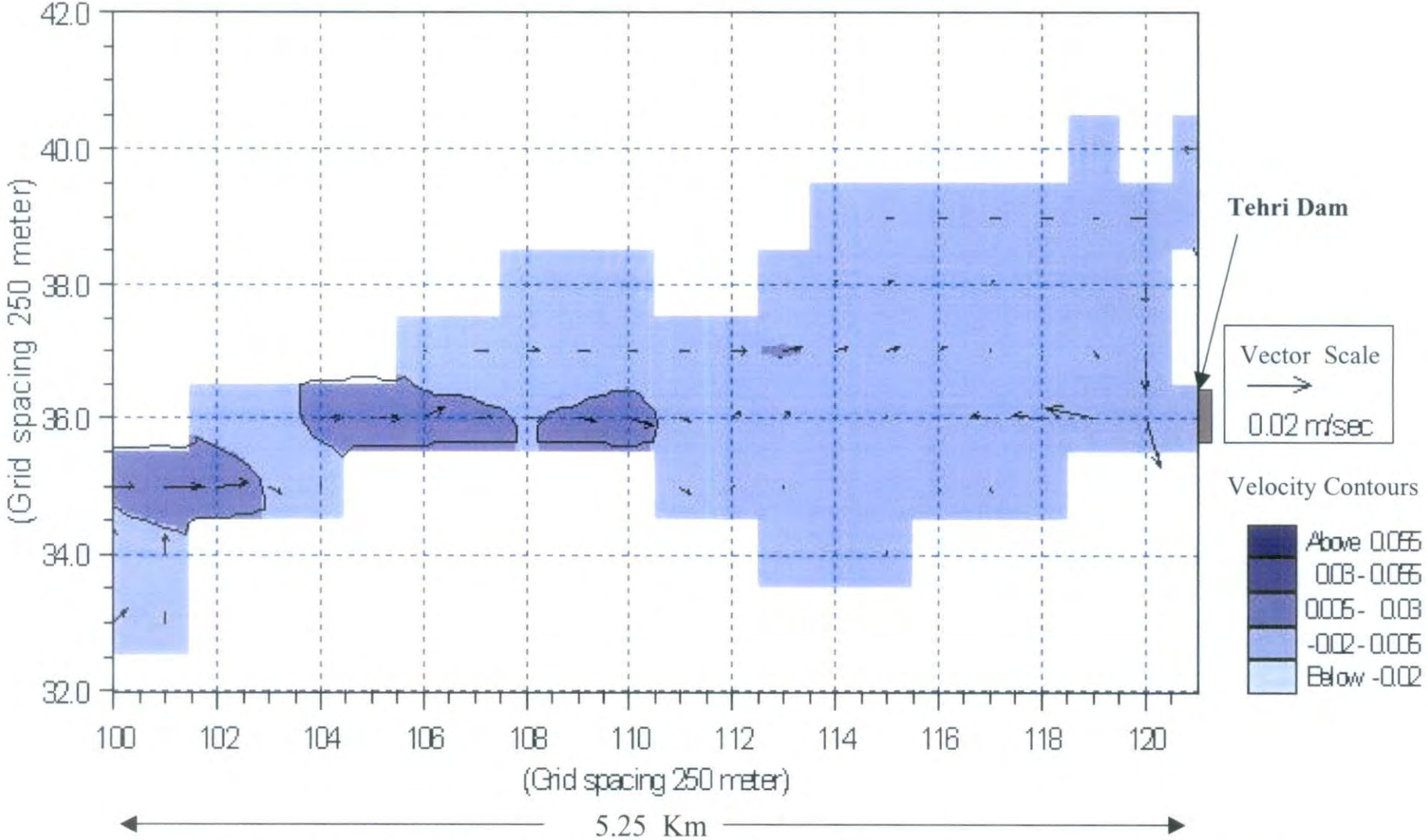
Horizontal Velocity Field at Level 720m (End of Monsoon : Power Outlet Closed)

Fig. 5.20



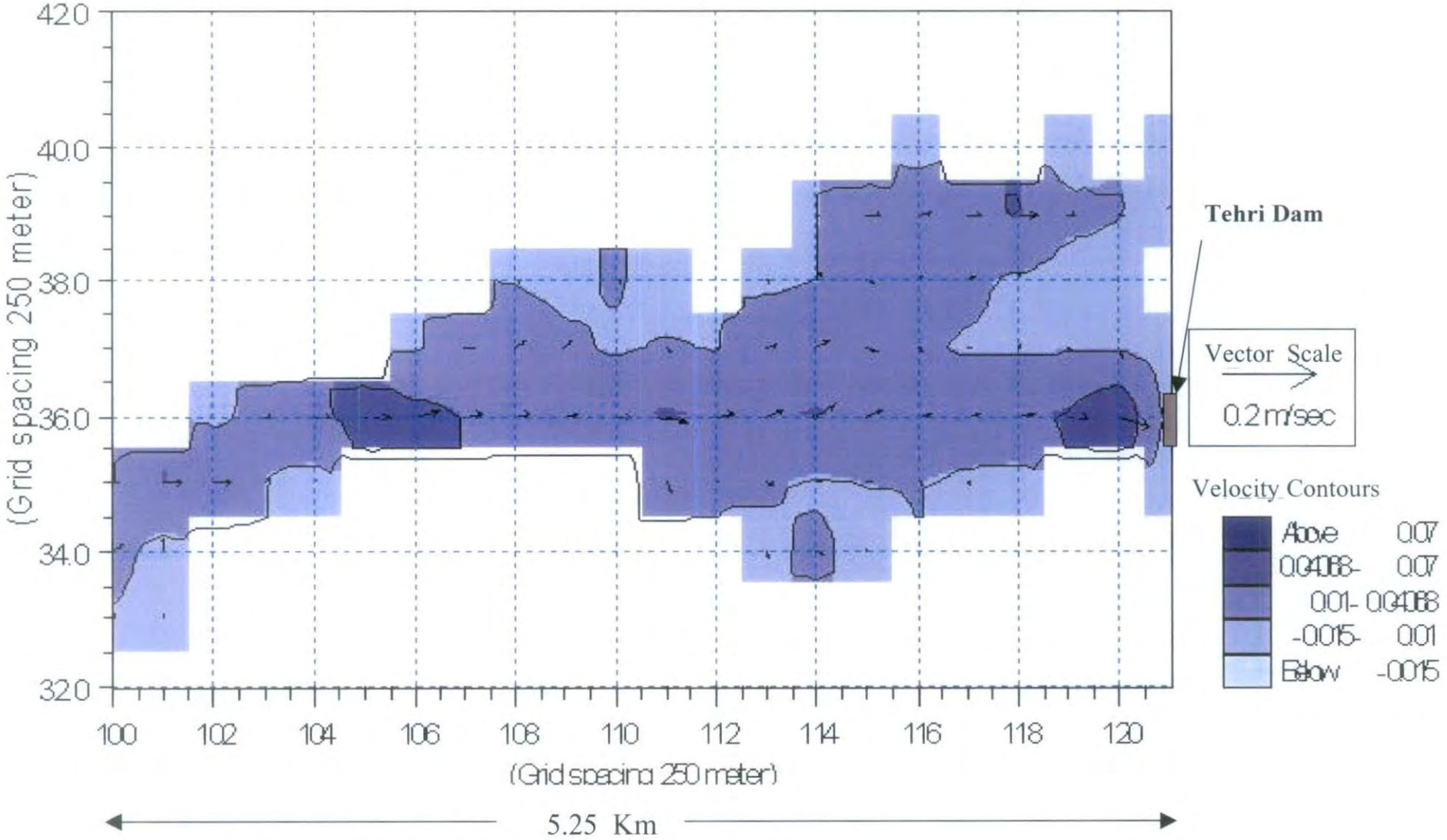
Horizontal Velocity Field at Level 720m (Winter : Power Outlet Open)

Fig. 5.21



Horizontal Velocity Field at Level 720m (Winter : Power Outlet Closed)

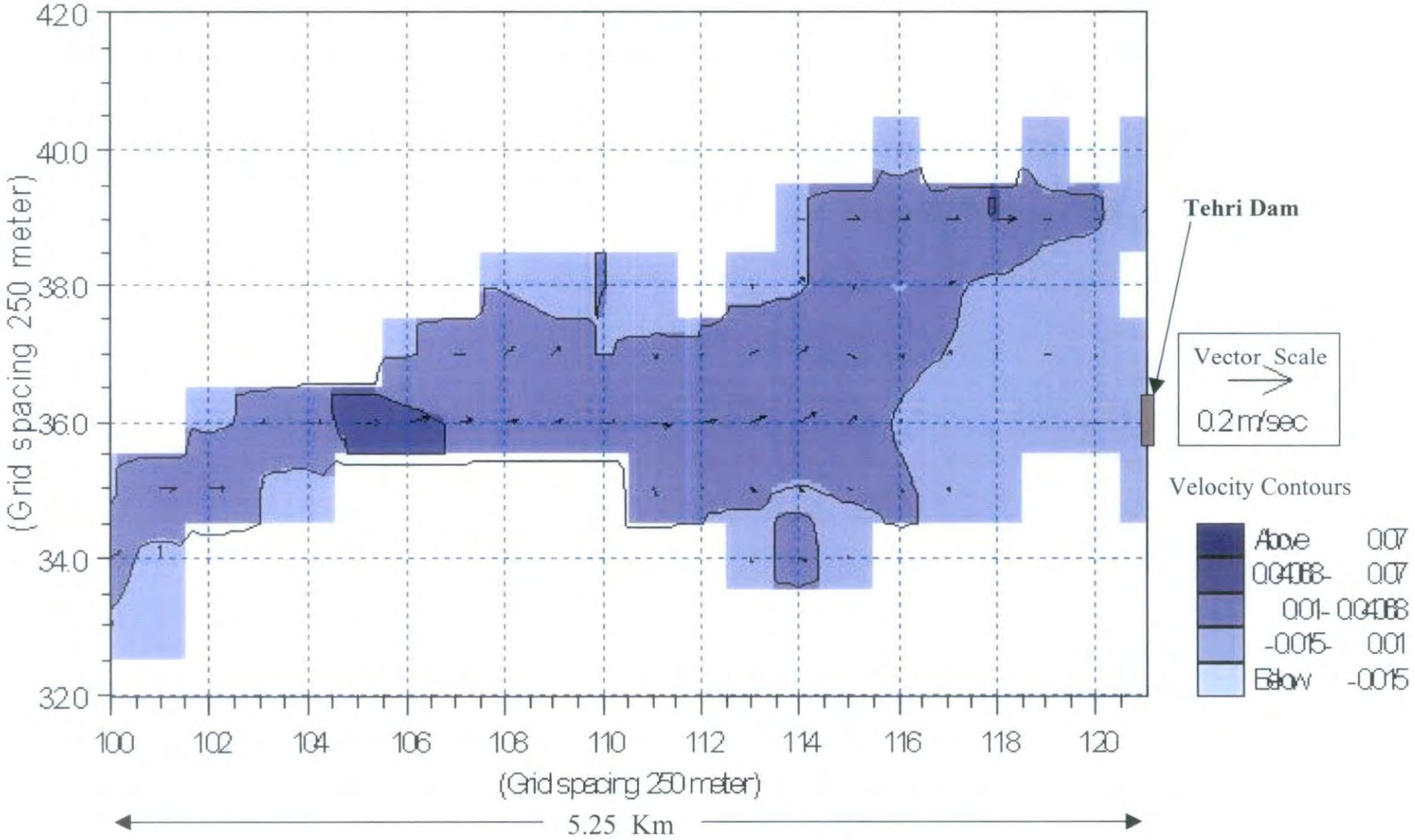
Fig. 5.22



Horizontal Velocity Field at Level 720m

(Interval Between Winter and Monsoon : Power Outlet Open)

Fig. 5.23



Horizontal Velocity Field at Level 720m
(Interval Between Winter and Monsoon : Power Outlet Closed)

Fig. 5.24

Annexure - I

10 DAILY DISCHARGE OF RIVER BHAGIRATHI AT TEHRI

YEAR	JUNE	JULY			AUG			SEPT			OCT			NOV			DEC			JAN			FEB			MAR			APR			MAY			JUN	
	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II
1963-64	325	584	610	801	854.3	1162	785.5	649.1	623.9	344.6	202.7	155	125.3	93.1	93.8	83.7	71.3	65.1	59.2	77	78	77	74	73	74	72	74	79	82	86	106	114	99	100	105	150
1964-65	325	584	610	801	727	1076	711	532	443	714	225	150	124	112	99	93	87	79	74	68	73	59	75	84	80	74	76	83	109	110	120	109	110	120	137	191
1965-66	344	468	533	537	595	380	461	312	200	144	117	100	92	85	80	75	75	73	71	71	67	63	68	61	68	68	69	69	70	71	73	110	97	87	156	249
1966-67	610	386	363	1110	1012	979	631	440	297	153	102	92	82	84	73	70	72	69	68	67	66	62	62	62	65	63	186	216	67	71	83	82	81	102	203	249
1967-68	304	453	468	744	1178	1011	1273	452	323	226	154	135	107	100	94	93	86	84	81	81	83	85	79	74	84	93	89	89	88	97	116	124	113	135	225	384
1968-69	484	465	696	619	683	993	585	323	294	228	150	113	91	83	78	76	72	70	69	70	67	66	69	69	65	65	71	74	69	79	76	105	131	178	300	261
1969-70	321	368	490	659	796	966	666	516	423	235	152	129	103	97	89	88	88	78	74	74	71	77	73	73	70	70	69	72	72	83	110	92	124	142	155	209
1970-71	285	401	433	511	811	1100	550	540	410	264	189	97	126	125	97	90	81	98	97	59	54	53	48	48	47	50	47	57	70	72	79	75	75	136	293	353
1971-72	571	835	663	659	1167	750	621	635	334	225	169	149	114	97	86	84	79	67	63	56	51	53	57	62	84	58	60	64	63	78	88	101	140	179	156	227
1972-73	307	576	516	476	495	579	493	494	456	235	173	138	106	87	76	67	68	66	59	56	58	64	57	56	63	69	78	99	102	124	190	309	182	209	285	532
1973-74	523	552	729	795	650	868	1000	645	484	325	237	131	100	83	78	78	71	68	58	54	56	56	54	54	51	47	47	59	65	69	82	105	93	80	123	224
1974-75	233	276	491	850	1110	723	522	387	279	211	158	160	109	93	78	69	65	64	61	58	56	60	63	83	62	66	72	104	148	132	150	144	196	187	215	385
1975-76	363	303	594	570	613	696	785	746	561	352	272	229	191	129	106	92	74	64	53	49	49	49	46	49	50	59	59	65	72	90	158	149	203	212	324	290
1976-77	258	423	900	777	675	706	682	582	418	322	210	136	94	81	78	72	63	54	52	51	49	46	45	38	39	35	31	33	44	45	43	46	69	87	134	101
1977-78	192	726	767	937	960	774	845	680	619	387	245	179	142	109	98	96	85	77	73	58	57	48	43	46	48	72	145	105	83	156	129	227	293	294	447	486
1978-79	734	1041	871	909	1265	1223	1178	1480	697	463	362	299	258	224	217	119	80	72	64	54	52	54	57	54	63	61	60	63	80	103	132	152	137	143	147	363
1979-80	1204	1209	1392	1369	1372	1424	1191	860	484	329	290	256	123	77	71	60	56	52	49	57	53	46	48	33	29	33	31	32	41	50	77	120	118	134	277	354
1980-81	524	816	1034	1090	1190	740	698	585	476	376	309	192	161	143	54	49	44	39	40	39	34	40	38	33	33	35	37	57	56	103	91	123	147	179	175	216
1981-82	419	481	646	886	1062	944	720	504	376	337	187	129	118	122	98	52	49	45	43	41	37	43	38	43	37	86	59	116	119	120	139	187	162	179	268	390
1982-83	370	479	586	394	477	628	338	350	294	232	150	136	123	120	125	139	57	50	53	45	39	49	44	42	41	51	54	68	65	124	134	183	223	248	337	245
1983-84	372	479	419	665	721	884	782	688	461	320	214	167	140	103	91	84	74	60	55	48	46	42	44	49	68	46	45	54	49	51	60	101	145	211	332	262
1984-85	393	531	413	683	495	604	564	563	424	200	130	92	84	65	55	50	45	41	37	36	31	30	30	27	28	27	26	33	31	50	50	67	71	148	199	248
1985-86	310	334	660	875	830	970	889	691	538	389	315	374	192	126	101	78	57	48	47	45	42	39	37	41	37	39	43	44	47	74	110	130	253	188	188	441
1986-87	856	755	1047	1198	1172	1286	842	520	319	244	165	157	112	82	70	63	57	59	55	50.7	51.6	50.1	47.8	57	63.1	62.6	61.2	73.7	87.3	81.1	102.2	135.8	122.3	141.8	278.5	245.6
1987-88	265.5	366.5	334.5	527.6	399.9	389.5	521.4	453.7	350.1	264.2	142.9	95.4	87.6	72.8	62.7	60.4	53.2	46.7	42	40.1	42.2	38.5	36.9	36	42.3	52.1	102	83.9	104.6	164.6	181.1	215.8	243	268.1	250	262.8
1988-89	445.3	500.1	800.2	1028	1188	1084	807.3	499.8	318.4	542.6	247.4	165.4	119.9	92.9	85.2	81.6	74.8	61.9	64.3	70.3	65.7	56.5	51.9	51	48.2	44.8	47.6	55.9	65.3	62.1	62.7	82.3	142	201.9	424.3	229.8
1989-90	304.7	342.9	529.2	674.7	447.6	659.3	803.3	687.9	408.9	286.6	171	142.1	147.1	101.4	79.8	65.1	45	49.6	50	40.7	39	40.3	37.2	35	38.8	57.7	61.2	110	91.7	117.7	125.3	134.2	288.6	282.9	279.8	266.5
1990-91	523.8	578.7	705.4	630.5	857.8	765.5	595.8	457.5	286.5	198.9	125.5	89.8	97.3	87.5	85	83.3	70.2	61.7	58.2	68.7	55.6	52.9	51.7	55	54.6	56.1	65.7	79.2	94	101.7	100.3	155	166.1	184.1	344.5	398.6
1991-92	420.2	543.1	579.1	665.8	721.1	533.3	618	534.4	403.4	229.4	167.2	116.7	113	102.4	92	76	69.4	69.2	70.6	60	53.6	63	66.1	59	52.9	58.4	58.8	66.4	37.7	67.3	71.6	98	123.3	164.3	171.1	172.8
1992-93	503	300.6	614.7	937.3	979.6	969	810.3	679.8	420.9	258.9	167.2	116.7	113	102.4	92	76	69.4	69.2	70.6	60.3	68.6	61.4	56.8	60	61	65.3	79.6	122.5	90.5	111.4	166	219.7	134.1	225.5	241.5	353.6
1993-94	328.3	457.8	865.5	654.6	556.6	459.9	462.1	685.7	519.6	264.5	199.1	140.3	125.7	100.1	83	76.3	69.8	52	53.9	51.3	52.8	50.4	49.4	50	54.1	53	57.4	53.7	72.3	57	63.2	109.6	118.1	229.2	259.4	265.7
1994-95	634.9	940	864.2	1025	963.8	638.1	718	681.7	344.7	240.9	204.4	148.6	128.2	102.3	94.9	89.7	84.4	74	70.8	64.7	59.8	61.2	55.8	66	61.3	60.5	61.1	102.5	83.7	93.1	130.1	153.9	335.2	251.6	390.3	475.6

Annexure - II

ANNUAL WATER YIELD

(Arranged in descending order)

Sl. No.	Year	Flow Volume (Mm^3)
1	1979-80	11830.32
2	1978-79	11737.70
3	1986-87	9509.43
4	1977-78	9463.22
5	1994-95	9313.28
6	1980-81	8826.54
7	1988-89	8807.02
8	1985-86	8503.49
9	1992-93	8424.14
10	1967-68	8335.87
11	1981-82	8195.13
12	1964-65	8143.37
13	1963-64	8124.88
14	1971-72	7872.68
15	1973-74	7774.79
16	1975-76	7735.82
17	1966-67	7516.89
18	1983-84	7447.77
19	1990-91	7432.54
20	1974-75	7168.52
21	1989-90	7124.53
22	1968-69	7034.86
23	1969-70	7032.36
24	1972-73	7031.23
25	1970-71	6967.82
26	1993-94	6872.45
27	1991-92	6687.45
28	1976-77	6642.69
29	1982-83	6231.26
30	1987-88	5922.20
31	1984-85	5834.85
32	1965-66	5520.44

Annexure - III

OBSERVED SILT DATA FOR RIVER BHAGIRATHI AT STFEL GIRDER BRIDGE, TEHRI

(in lakh tones)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Total Runoff (MHACM)
1973	-	-	0.10	0.21	5.9	42.47	101.47	99.01	10.55	0.14	0.02	0.01	259.07	0.88
1974	0.01	-	-	0.01	0.18	1.32	16.39	45.65	6.04	0.34	0.09	0.08	70.08	0.64
1975	0.08	0.41	0.76	0.33	0.58	14.30	15.71	17.90	18.90	3.09	0.35	0.17	72.58	0.79
1976	0.10	0.10	0.09	0.92	0.94	5.96	59.80	26.20	5.91	0.20	0.04	0.01	100.27	0.76
1977	-	-	0.01	0.01	0.03	1.34	56.84	78.62	43.69	6.12	0.84	0.05	187.55	0.79
1978	0.05	0.04	2.09	1.98	4.40	25.65	57.01	183.56	103.30	6.41	0.54	0.11	385.14	1.26
1979	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1980	0.10	0.41	0.02	0.05	0.35	13.51	70.11	63.99	30.32	1.70	0.02	-	180.58	0.89
1981	-	-	0.01	0.17	2.38	3.14	25.27	42.28	10.92	2.42	0.09	0.08	86.76	0.76
1982	0.04	0.02	0.17	0.31	7.13	26.47	37.02	29.25	11.33	1.18	0.86	0.29	114.05	0.63
1983	0.08	0.04	0.04	0.76	4.01	11.36	32.56	41.65	11.82	1.22	0.43	0.17	104.14	0.77
1984	0.02	0.06	0.03	0.05	2.05	13.32	32.23	35.08	13.71	0.85	0.07	0.02	97.49	0.63
1985	0.01	0.01	0.02	0.09	0.61	7.85	49.73	84.77	29.47	8.61	0.92	0.08	182.17	0.79
1986	0.24	0.43	0.58	1.70	3.10	29.85	44.01	22.45	9.30	4.96	2.62	1.86	121.10	0.96
1987	0.25	0.21	1.34	1.78	0.74	13.73	8.75	7.87	3.54	0.35	0.21	0.16	38.93	0.56
1988	0.09	0.08	0.90	1.80	4.31	10.40	60.17	92.75	21.48	4.79	0.81	0.54	198.12	0.92
1989	0.51	0.34	0.38	0.52	2.81	8.67	21.06	41.33	30.38	5.96	1.33	0.13	113.42	0.69
1990	0.15	0.10	0.93	0.68	7.39	19.94	63.13	66.99	4.84	0.14	0.07	0.04	164.40	0.74
1991	0.04	0.03	0.10	0.11	0.84	9.37	36.05	20.10	8.69	0.11	0.04	0.02	75.49	0.72
1992	0.02	0.02	0.11	0.19	0.51	2.49	20.16	27.52	7.08	0.68	0.15	0.07	59.00	0.81
1993	0.05	0.04	0.19	0.22	0.39	1.11	43.96	12.20	9.30	0.10	0.02	0.01	63.63	0.80

Total =	2673.98	15.79
Average =	133.70	0.79

1444

6/55

544

Central Water and Power Research Station (CWPRS), Pune, has grown from a humble beginning dealing with twin problems of irrigation and drainage in 1916 to an institution of international standing over the last EIGHT decades. CWPRS is one of the very few institutions of its kind in the world concerned with the entire life cycle of water, from its occurrence to its joining the ocean and dealing with the various uses of water on one hand and water-related disasters on the other. The global scenario of water use today is centered around sustainable development and associated environmental issues. The responsibility of CWPRS is to find and provide technical solutions to various problems associated with projects on water resources, energy and water-borne transport including coastal and harbour engineering. As the Regional Laboratroy of ESCAP since 1971, CWPRS has offered its services to a number of projects in the neighbourhood as well as countries in the Middle East and Africa. The activities of CWPRS encompass the studies undertaken in the following major disciplines :

- Hydrology and Water Resources Analysis
- River Engineering
- Reservoir and Appurtenant Structures
- Coastal and Offshore Engineering
- Ship Hydrodynamics
- Hydraulic Machinery
- Earth Sciences
- Mathematical Modelling
- Foundations and Structures
- Instrumentation and Control Engineering

With the capabilities of the Research Station, developed through multilateral and bilateral aid programmes, in-house developments, governmental support and the expertise gained during the course of last 8 decades, CWPRS is well equipped to meet the challenges ahead and contribute in the nation building endeavours.

Annexure R/7

Final Report

Self - Purification Capacity of River Bhagirathi : Impact of Tehri Dam

Sponsor : Tehri Hydro Development Corporation Ltd., Rishikesh

National Environmental Engineering Research Institute
Nehru Marg, Nagpur- 440 020

July, 2004

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Executive Summary

- Bhagirathi is one of the largest and important parent streams of the Ganga Fluvial system, which flows in the Garhwal Himalayan region of the Indian Subcontinent. The basins extend from Gangotri to Devprayag. The first observation of phage-activity was made in India in 1896 by Ernest Hanbury Hankin in the waters of Indian rivers Ganga (Ganges) and Yamuna. He noticed a marked anti-bacterial action in the waters of Indian rivers Ganga (Ganges) and Yamuna against Vibrio Cholorae. The activity destroyed cholera bacteria in cultures. He demonstrated that it could pass through fine porcelain filters and was destroyed by boiling. Twenty years later Frederick Twort in England, and Felix d'Herell from Canada, working at the Pasteur Institute in Paris, reported isolating similar filterable entities capable of destroying bacterial cultures. It was d'Herelle who named these ultra microbes, "bacteriophages" (http:/www.prajapati-samaj.ca/mainnews.asp?NewsID=723). Even today there is a belief amongst common people that water sample, collected from Ganga, has an inherent property that does not allow bacteria to survive for a longer period of time.

- The Tehri Dam project, conceived in 1949, was approved by the Planning Commission in 1972 and was accorded the administrative clearance in 1976 by the Uttar Pradesh government. This project envisages to capitalize on the 2328 Sq km snow bound area and the rainfall ranging from 1016-2630 mm, in the total catchment area of 7511 Sq km of river Bhagirathi upto Tehri. The Tehri Dam (under construction) shall have the capacity to store 2615 million cumecs, out of the total discharge of around 7400 million cumecs of the Ganga valley. The dam is also likely to capture around 65% of the total sediment carried by Ganga at present. Tehri Hydro Development Corporation Ltd., Rishikesh has retained National Environmental Engineering Research Institute, Nagpur to investigate the impact, if any, of the dam being constructed at Tehri, on the self purification capacity of the river Bhagirathi during post-commissioning phase.

- Studies conducted under the scope were targeted, to identify and quantify the water quality parameters influencing/indicating self purification; to model hydrodynamics and sediment transport in the study area before and after the construction of Tehri dam; to evaluate the biological parameters pertaining to river ecology; to identify and quantify chemical and biological agents and

processes which affect self purification; and to delineate the status of self-purification capacity of the study area

- Based on a reconnaissance survey conducted in September 2002, twenty sampling points were identified in the stretches from Gomukh to Rishikesh and from Badrinath to Devprayag. Maximum five sets of samples were collected from identified sampling points of the rivers (Bhagirathi, Bhilangana, Alaknanda, Mandakini and Ganga) during September 2002 to August 2003 for assessment of different abiotic, biotic and microbiological parameters. Considering the available facilities and expertise in the Institute, certain parameters of the sediment samples were analysed from National Bureau of Soil Survey and Land Use Planning (ICAR), Nagpur; Geological Survey of India, Government of India, Central Region, Nagpur; and Atomic Minerals Directorate, Government of India, Nagpur.

- In the entire study stretch, the pH, DO, total suspended solids, total dissolved solids, total nitrogen and total phosphorus varied between 6.4 and 8.0, 7.1 and 19.85 mg/l, 4.0 and 276.0 mg/l, 24 and 143 mg/l, 0.22 and 4.12 mg/l, and 0.001 and 0.070 mg/l respectively. The levels of BOD and COD were below 1.0 and 10.0 mg/l respectively in the water samples. The levels of physico-chemical parameters including the heavy metal (barring lead) concentrations did not indicate any adverse condition prevailing in the water samples. Higher value of lead (0.37 mg/l) was recorded once in summer (May 2003) at upstream of Gangotri. However, the value was drastically reduced to 0.004 mg/l during monsoon in the same year.

- Water samples were analysed for indicator bacteria, i.e. total coliforms, faecal coliforms, *E. coli* and fecal streptococci. Bhagirathi river water at Tapovan upstream of Gomukh and Gomukh was found to be free from contamination as evident from the absence of indicator bacteria. Total coliforms (TC) counts were found to be of increasing order from downstream of Gangotri (94, 127, 112, 64 and 22 CFU/100ml) to downstream of Rishikesh (10,000, 40,000, 40,000, 9,000 and 950 CFU/100ml) during all the five occasions of sampling. The increase of indicator bacteria towards downstream of the river might be attributed to increased anthropogenic activities.

- Four genetically different strains of *E. coli* were identified from the water/ sediment samples of the rivers Bhagirathi / Ganga and one more from Nagpur

sewage sample by using following Randomly Amplified Polymorphic DNA (RAPD) technique. These strains were used as host cultures for coliphage detection.

- Application of water quality index (WQI), which is based on nine parameters, viz. DO, pH, BOD, temperature, total solids, turbidity, total-P, NO_3 and fecal coliform, at various stretches of the river water samples revealed that water quality of the river between Tapovan and downstream of Uttarkashi was good (index value 70 – 90) throughout the period of study, while water samples of other areas were ranging medium and good during the same period. An exercise further revealed that WQI values would have been excellent (90 – 100) throughout the study area, if fecal coliform values were eliminated from the 9 parameters used for WQI calculations.

- Based on the irrigation water quality classification, water quality of all the sites of the entire stretch was determined and found to fall under the desired category of C_1S_1. The irrigation quality of water having C_1S_1 category is beneficial for growing plants like : *Eucalyptus robusta*, *Acacia nilotica*, *Casuarina* sp., *Prosopis tuliflora*, *Dalbergia sissoo*, *Azadirachta indica* etc.

- It has been observed that water samples from different rivers contained specific types of phages. Different types of hosts were required for their detection. Coliphages could not be detected in Alaknanda river water using the four host cells of *E. coli*, but possibility of the presence of phages could not be ruled out as phage specific hosts other than the tested four hosts might exist.

- Water samples from Gomukh, Gangotri and Tehri dam upstream were devoid of phytoplankton. Studies revealed that role of silt in removing the phytoplankton by settling is remote and nutrient levels may be the factor for absence of phytoplankton. The river samples from Tapovan to Gomukh were predominantly devoid of zooplankton during the study period. The most dominant group amongst the locations were Nematoda, followed by Copepoda and Plecoptera. The maximum Shannon Wiener diversity indices ranged from 0.00 to 2.25, which indicated oligotrophic nature of the Bhagirathi river water. Indicator invertebrates for oligotrophic freshwaters were found to be *Arcella* sp., *Philodina* sp., *Iron* sp., *Aliocapnia* sp. The benthic fauna of the river was negligible or near to zero throughout the stretch of the study area.

- The sediments have a great influence on the water quality of the river Bhagirathi. The metal ions, originally derived from the breaking of rocks, are controlled by several river valley conditions – physical as well as chemical. The volatile matters in successive sites were increased from 5.374 to 14.38 mg/kg in the sediments collected during October 2002 (except Gangotri downstream where 4.462 mg/kg value was recorded). The recorded range values of volatile matters were found to be between 1.493 and 11.89 mg/kg in sediment samples collected during May, 2003, while volatile matter in samples collected during August, 2003, showed variations from 3.27 to 8.71 mg/kg (respectively at sampling sites Gangotri upstream and Tehri upstream at Bhagirathi). The COD, PO_4-P and SO_4 ranges in the sediments varied from 1.10 to 29.6 mg/kg, 1.31 to 6.981 mg/kg, and 0.94 to 3.12 mg/kg respectively. In case of metals, highest concentration was observed for aluminium (9260 mg/kg) followed by iron (3896 mg/kg) and manganese (2036 mg/kg), which implies that the major geochemical phases (in addition to silica) in the rocks of the region are alumina, iron oxide and manganese oxide. It appears that the concentration of metals in sediments were fairly high.

- From the sediment Cu, Pb, Cr, Ni and Sr were released in static laboratory condition, when it was equilibrated with distilled water for 18 days (1:100 suspension). The Cu level increased from 0 to 3.93 mg/l during this period. The order of toxicity of metals for micro-organisms is $Ag^{+} >> Cu^{+2}$, $Ni^{+2} > Ba^{+2}$, Cr^{+6}, $Hg^{+2} > Zn^{+2}$, Na^{+}, Cd^{+2}, As_2O^{-}. The self preservative property of Bhagirathi water under static condition might be attributed to the release of these metal ions from the sediments and suspended solids. Since the interaction of Cr^{+6} and Cu^{+2} is known to be synergistic and both are released from the sediments, as evidenced from the present study, bactericidal impact of these metals can not be ruled out.

- The particle size analysis of sediments showed that the clay and silt fractions constituted around 15% of the total sediments. XRD technique identified smectite and vermiculite as major minerals in clay and silt fractions. Analysis of sediment sample from Gomukh revealed that the silt component is dominated by smectite (dioctahedral) followed by vermiculite, chlorite, mica, kaolinite, quartz and feldspar, whereas the total clay component is dominated by vermiculite (dioctahedral) followed by smectite, mica, kaolinite (trioctahedral), chlorite, quartz (trioctahedral) and feldspar (trioctahedral). Mineral composition varied marginally at other stations.

- Five sediment samples each from rivers Bhagirathi/ Ganga, and water bodies around Nagpur were collected in October 2002 and were subjected to Gamma Ray Spectrophotometric analysis. The analysis carried out by Atomic Mineral Directorate, Nagpur, revealed that the average levels of U_3O_8, ThO_2 and K are over 500, 275 and 150 percent respectively more in Bhagirathi/ Ganga sediments than those collected in Nagpur (Central India). Earlier, Ghosh and Sharma (1989) reported that short-lines isotopes of radium were present in higher concentration (80.5 pci) in the Ganga water than in the other rivers (65.5 pci).

- Sediment samples collected from Gomukh to Rishikesh were found to contain total coliforms (TC). The density of coliforms was found to increase as the river flows downwards to Devprayag. Alaknanda river sediment was found to contain the total coliform count in the range of 310 to 3130 CFU/g. TC count in sediments collected from Ganga river after confluence at Devprayag was observed to be in the range of 320 to 4400 CFU/g. Further downstream at Rishikesh, TC count of sediment was found to be in the range of 1125 to 4400 CFU/g.

- It has been observed that different types of coliphages were present in Ganga river sediment and could be detected by using five different types of susceptible host cells. Coliphages are inhabitant of human and warm blooded animals and are excreted alongwith faecal matter. Different types of phages have been detected in Ganga water and its sediments. It has been observed that 40% adsorption to the sediment occurred within 12 hours. The adsorption increased with increase in adsorption time. Complete adsorption of coliphages took place in 120 hrs as indicated by the absence of coliphages in the supernatant. The studies indicated that the sediment of the Ganga water has a potential to adsorb the phages which are likely to increase in number under static conditions and these phages may play an important role in preserving the Ganga water under static condition by reducing/ eliminating the coliforms. Studies further confirmed that phages require specific host cells for their growth. *E. coli*, isolated from the sediment at Rishikesh, was found to be susceptible to ten out of eleven phages identified in the rivers.

- The hydrodynamic modelling study of Tehri dam, carried out by CWPRS, Pune during 2001-02 using MIKE-3 (developed by Danish Hydraulic Institute)was found to be sufficient in accordance to the objectives. The study reveals that the possibility of algal bloom or eutrophication, which can cause population explosion of algae in the reservoir, is extremely remote. Based on their reported

hydrodynamic analysis and circulation pattern of the reservoir, it is also concluded that the sediments will tend to settle. For the Tehri dam, the highest reservoir level is 830 m while the lowest irrigation outlet level is at 700 m. Considering the simplest formulation for sedimentation following Stoke's law for a uniform horizontal velocity towards the outlet as 10 cm/s, particles will sink 130 m while travelling a distance of 25 km and will never escape from the reservoir. However, the circulation pattern in the reservoir is much more complex with reverse flow in the top layer. As a result, particles with diameters of the order of 0.01 mm or larger, i.e complete sand and most of the silt, will never escape from the reservoir and will be settled.

- The experimentation done at NEERI revealed that Ganga/ Bhagirathi sediment has the capability to adsorb coliphages and induce their proliferation. The coliphages adsorbed to the sediment appear to be responsible for predating coliforms in the overlying water column when the sediment and water co-exist in a container under static condition. The Bhagirathi water to be stored in a dam mimics such static condition and, therefore, shall in no way deteriorate the water quality of the river downstream of the Tehri dam.

- The release of copper and chromium under static condition and the synergistic effect of chromium on the bacteriostatic/ bactericidal property of copper appear to be the factors which keep the water free from coliforms and other bacteria responsible for putrification of water when left for a long time under static condition.

- Quantification of U_3O_8, ThO_2 and percent K in sediment samples and comparison of these parameters with those present in other river sediment samples and freshwater lake sediment samples show that Bhagirathi/ Ganga sediments collected between Gomukh and Rishikesh are more radioactive than others.

- It can be concluded now that the uniqueness of river Bhagirathi/ Ganga lies in its sediment content which is more radioactive compared to other river and lake water sediments, can release Cu and Cr which have bactericidal properties and can harbour and cause proliferation (under static condition) of coliphages that reduce and ultimately eliminate coliforms from the overlying water column. This is possible as the dam is going to retain about 90% of the sediment load of Bhagirathi as particles of size of >0.01 mm are likely to be retained in the dam. Thus, Tehri dam is not likely to affect the quality or self preservation property of

river Bhagirathi/ Ganga, as it mimics a static container which is conducive for conditions responsible to maintain the water quality.

- Since suspended particles play a major role towards self preservation of Ganga water, it is, thus, necessitated to have certain levels of suspended solid in the water, downstream of Tehri dam, particularly after confluence with the Alakhnanda river at Devprayag. Considering average annual flow of 258 and 467 cubic metre per second in Bhagirathi and Alakhnanda rivers respectively having average suspended solids of 73.75 and 53.25 mg/l in respective river waters, it is estimated that contribution of Alakhnanda at downstream of Devprayag is 69% of the existing suspended solids. Investigation further indicated that particulate matters of Alakhnanda river have identical antibacterial property as those of Bhagirathi river. Although about nine-tenth of the existing(31% at downstream of Tehri dam) sediment would be arrested at dam site, there would be ample sediment from the catchment in between Tehri and Devprayag, and also from Alakhnanda river to maintain the self preservation capacity of the Ganga river water during post construction phase of the dam.

Self - Purification Capacity of River Bhagirathi : Impact of Tehri Dam

1.0 Preamble

Bhagirathi is one of the largest and most important parent streams of the Ganga Fluvial system, which flows in the Garhwal Himalayan region of the Indian Subcontinent. Their basins extend from Gangotri to Devprayag. The source of the Bhagirathi is in the higher elevation of Garhwal Himalaya. The exact point of origin is the Gangotri glacier (Gomukh : 4000 m above m.s.l.) (**Plate 1**). The river initially has a north-western course and meets the stream Janhvi (Garganga) at the tip of Bhairon Ghati, where it has east-west course. The river has carved out deep gorges, and many smaller tributaries join it almost at right angle. From Harsil the river flows towards south-east, then towards south and suddenly has a wide valley upto some distance. The whole catchment area of Bhagirathi has a very scanty vegetation covered with morains.

The Tehri Dam project, conceived in 1949, was approved by the Planning Commission in 1972 and was accorded the administrative clearance in 1976 by the Government of Uttar Pradesh. The project involves construction of a 260.5 m high earth and rock-fill dam across river Bhagirathi at Tehri. The project envisages to capitalize on the run-off from the rainfall ranging from 1016-2630 mm over the total catchment area of 7511 Sq km out of which 2328 sq.km. is snow bound. The reservoir created by the Tehri dam (Under construction, **Plates 2** through **4**) shall have a total storage capacity of 3540 million cubic metre, out of which 2615 million cubic metre shall be live storage. The live storage shall be utilized for generating peaking power to the extent of 1000 MW in Stage-I, for which 4 turbines of 250 MW each shall be installed, besides providing irrigation facilities in the planes of Uttar Pradesh.

1.1 Bhagirathi as Rhithron

A river course can be divided into two principal zones – the rhithron and the potamon. The rhithron is defined as the region extending from the source to the point where the mean monthly temperatures rise to 20°C, oxygen concentrations are always high, flow is fast and turbulent, and the bed is composed of rocks, stones or gravel with occasional sandy or silty patches. The rhithron is subdivided into three zones – the epi, meta- and hyporhithron covering a range of watercourses from main streams to small rivers. The potamon is the region where monthly mean temperatures rise to over 20°C, oxygen deficits may occur, flow is slow and the bed

Plate 1 : The Location of Gomukh, the origin of the river Bhagirathi, at 4000 m above msl

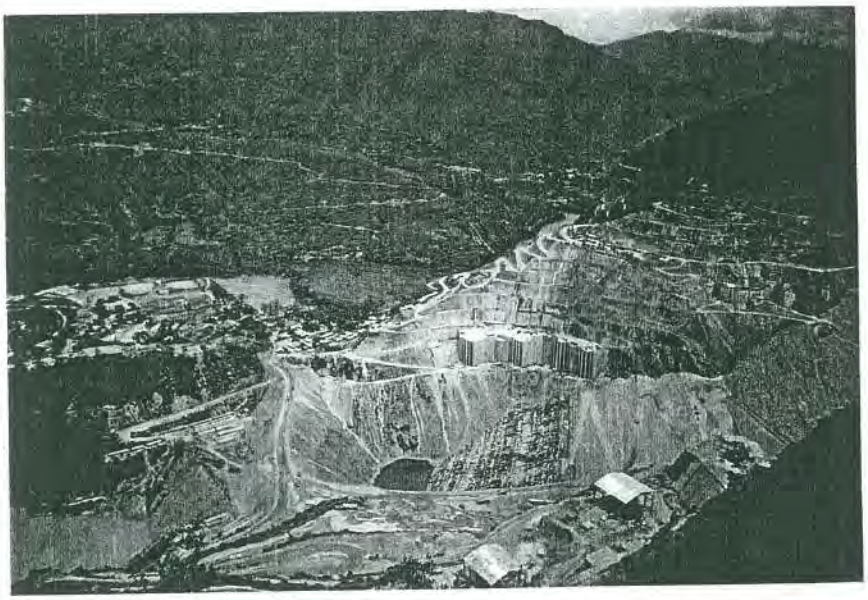


Plate 2 : The overview of the Tehri dam, under construction, in May 2003

Plate 3 : Upstream of Tehri dam showing submergence of the area and formation of reservoir (May 2003)

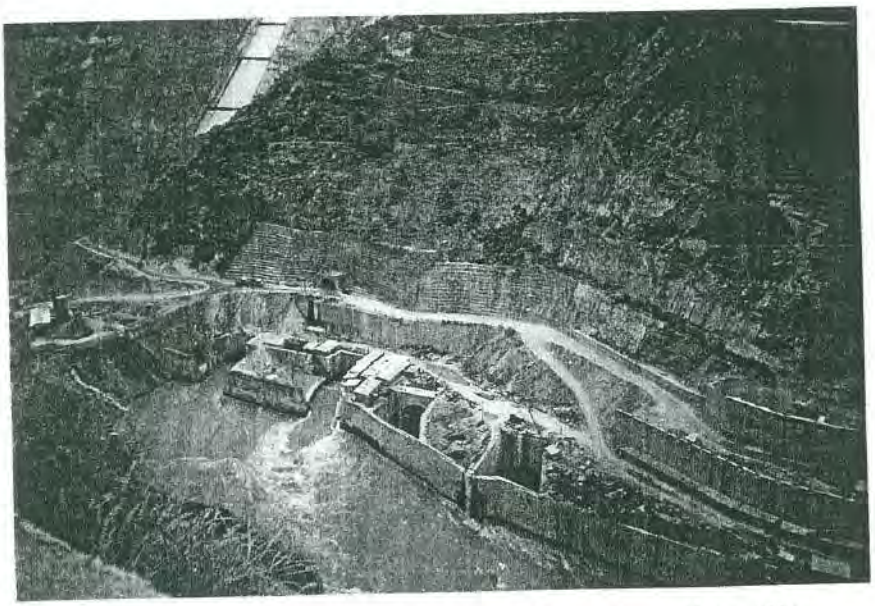


Plate 4 : Downstream of Tehri dam depicting release of water (May 2003)

is mainly sand or mud. On the basis of the in-depth observations on the morphology and lotic environment of the Bhagirathi, in addition to its animal and plant communities, the whole course of the upper Ganga from Gomukh to Rishikesh can aptly be categorized as Rhithron.

The main morphological characteristics of rhithron reaches of Bhagirathi are the alteration of pools and riffles which arise from the gradient. The whole course of rhithronic part of the Bhagirathi can be divided into three major sub zones:

1.1.1 ***Epi-rhithron:*** This sub-zone extends from Gomukh (4000 m m.s.l.) to Harsil (2620 m m.s.l.) with a sharp gradient of 1192 m in a zone of 44.0 km **(Table 1)**.

This zone is located in a narrow glaciated valley. Epi-rhithron of Bhagirathi is characterized by the dominance of riffles over the pools. The riffles, having steep reaches with variations in gradient, consist of alternating small waterfalls and shallow pools, and the subsurface consists of coarser large boulders. Swift flow of water in this sub-zone, which strikes with the big boulders, imparts a white foamy look. This zone is characterized by near-complete absence of biotic components in the water and has high dissolved oxygen (DO).

1.1.2 ***Meta-rhithron***: The meta-rhithron zone extends from Harsil (2620 m.s.l.) to Devprayag (460 m.s.l.) with a moderate difference of gradient of 2160 m in a zone of 224 km (Table 1). This zone is characterized by alternation of pools and riffles. Riffles are characterized by rapids, cascades and low gradient riffles at many places. Subsurface consists of small boulders, gravel, pebbles and cobble sized particles. Pools of the meta-rhithronic sub-zone have various types of habitats. Secondary channel pool and backwater pool habitats are common at the confluences; the prominent one being at Tehri (Ganesh Prayag) where Bhilangana, a major tributary of Bhagirathi, meets the main river. Some trench pools and dammed pools are also present, which are formed due to the construction activities of the Manner and Tehri dam projects. This sub-zone is vulnerable to anthropogenic influences and has been exposed to many ecological changes including excessive deforestation and soil erosion in the catchment area.

1.1.3 ***Hypo-rhithron:*** It extends from Devprayag (460 m.s.l.) to Rishikesh (325 m.s.l.) with an almost flattened gradient (Table 1). This sub-zone spreads over 67.0 km and characterized by the dominance of pools and glides, where the river runs

relatively straight at many places in the lower stretches. Presence of low gradient riffles with moderate water current is the characteristic of this sub-zone. Subsurface consists of sand, gravel and small pebbles. Secondary channel pools, backwater pools are also present in the sub-zone of hyporhithron of the Bhagirathi (Table 1).

Table 1 : Gradients of the Rhithronic Zone of Bhagirathi

Sub-zone	From	To	Distance (km)	Fall (m)	Rate of Fall (m/km)
Epi-rhithron	Gomukh Gangotri	Gangotri Harsil	19.0 25.0	764 428	40.2 10.7
Meta-rhithron	Harsil Uttarkashi Tehri	Uttarkashi Tehri Devprayag	79.0 75.0 70.0	1480 510 170	10.9 6.9 2.4
Hypo-rhithron	Devprayag	Rishikesh	67.0	135	2.0

(Source : Sharma, R.C. 1991)

1.2 Self-purification

The Ganga ecosystem presents such an excellent biologic fabric, that its self-purification capacity exceeds that of any other water. The self-purification of the lotic water of Ganga is its retrieving capacity from allochthonous and autochthonous pollution through phase transfer, assimilation and degradation. In other words, self-purification means the elimination of dissolved as well as particulate matter of polluting properties in river Bhagirathi. It is observed that water sample, collected from Ganga, has an inherent property that does not allow bacteria to survive for a longer period of time. In view of this, Tehri Hydro Development Corporation Ltd., Rishikesh has retained National Environmental Engineering Research Institute, Nagpur to investigate the impact, if any, of the dam, being constructed at Tehri, on the self purification capacity of the river Bhagirathi during post-commissioning phase.

Other than typical river water quality, Ganga water ecosystem exhibits high pH (7.8-8.4) and DO levels, finer sediments and radio active element such as Radon, all of which are likely to contribute to the self-purification and self-preservation.

Bacteriophages occur in high number in environment ecosystems and are thus significant mediators of microbial survival and activities. However, interactions between microbial populations and phages *in situ* have been largely ignored. One of the proposed objectives of this project is therefore to determine bacteriophage-host interactions under environmentally relevant conditions of nutrient limitation.

The agents of self-purification could, thus, be attributed to adsorption of coliphages and host microorganisms onto solid surfaces, transition between pseudolysogeny and true lysogeny depending upon the environmental condition and predation of coliphages on coliforms in the Ganga water.

1.3 Approach

The impact of Tehri Dam on self- purification capacity of River Bhagirathi has been taken up in the present investigation. The involved methodology essentially comprises of identification, prediction and evaluation steps. The tools employed in this study include field survey and sampling, data collection and collation, and appropriate prediction and evaluation methodologies. Pre-project studies and post-project predictions will constitute the instrument for determining the positive or negative impact of the Tehri dam on self- purification capacity of river Bhagirathi.

2.0 Objective of the Study

The objective of the study was to determine whether the construction of Tehri Dam will have any influence (positive/negative) on the self purification capacity of River Bhagirathi at epi. -meta – and hypo-rhithron zones.

Scope of the Work

- To identify and quantify the water quality parameters influencing/indicating self purification
- To examine hydrodynamics and sediment transport in the study area as reported by CWPRS before and after the construction of Tehri dam
- To evaluate the biological parameters pertaining to river ecology
- To identify and quantify chemical and biological agents and processes which affect self purification
- To delineate the status of self-purification capacity of the study area

3.0 Methodology

3.1 Sampling Sites

Based on a reconnaissance survey conducted in September 2002, twenty sampling points were identified from Gomukh to Rishikesh and also from Badrinath to Devprayag (**Fig. 1 & Table 2**).

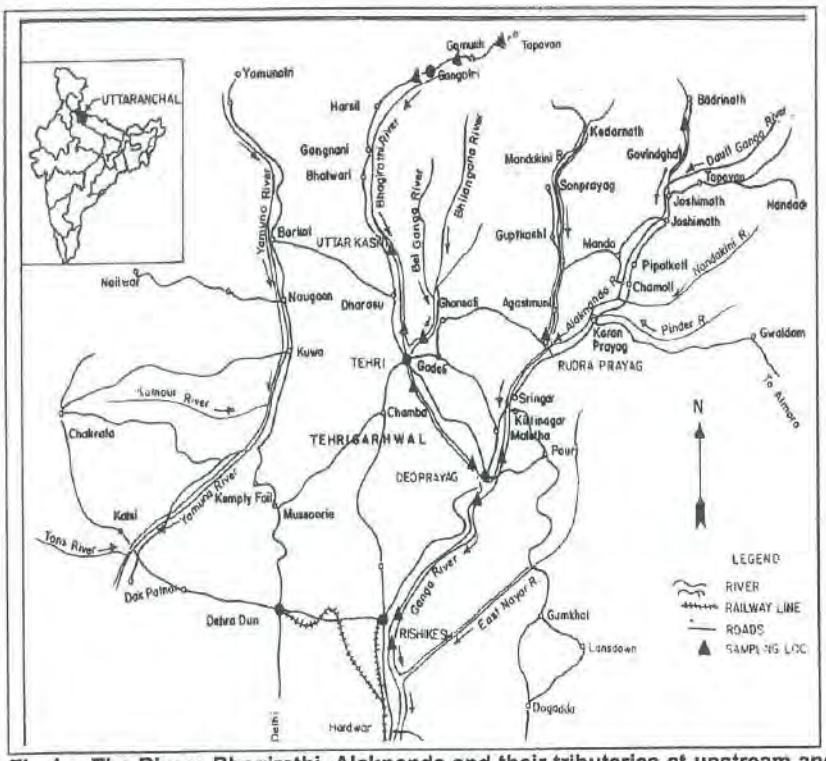


Fig 1 : The Rivers Bhagirathi, Alaknanda and their tributaries at upstream and downstream of Tehri Dam

Table 2 : Sampling Locations of the Study Area

Sampling points	Location	Sampling points	Location
1.	Tapovan	11.	Devprayag, before confluence (Alaknanda)
2.	Gomukh	12.	Devprayag, after confluence (Ganga), right bank
3.	Gangotri upstream (u.s.)	13.	Devprayag, after confluence (Ganga), midstream
4.	Gangotri downstream (d.s.)	14.	Devprayag, after confluence (Ganga), left bank
5.	Uttarkashi u.s.	15.	Rishikesh u.s.
6.	Uttarkashi d.s.	16.	Rishikesh d.s. (right bank)
7.	Tehri (u.s. of Bhagirathi)	17.	Rishikesh d.s. (midstream)
8.	Tehri (u.s. of Bhilangana)	18.	Rishikesh d.s (left bank)
9.	Tehri (d.s. of Bhagirathi)	19.	Alaknanda at Badrinath
10.	Devprayag, before confluence (Bhagirathi)	20.	Mandakini at Rudraprayag

3.2 Parameters Studied

Maximum five sets of samples were collected from various sampling points of different rivers (Bhagirathi, Bhilangana, Alaknanda, Mandakini and Ganga) during September 2002 to August 2003 for assessment of different abiotic, biotic and microbiological parameters (**Table 3**). Considering the available facilities and expertise, the analysis of the following parameters was done at the institutes indicated:

i)	Select sediment samples for pH, EC, particle size and mineral analysis by XRD method	:	National Bureau of Soil Survey and Land Use Planning (ICAR), Nagpur
ii)	Select sediment samples for certain heavy metal and heavy mineral analysis	:	Geological Survey of India, Government of India, Central Region, Nagpur
iii)	Select sediment samples for Gamma Ray Spectrometric analysis	:	Atomic Minerals Directorate, Government of India, Nagpur

Methodologies followed for specific parameters have been referred to in the concerned sections.

4.0 Results

4.1 Water Quality

4.1.1 Physico-chemical Characteristics of the River Water Samples

The stretch of the river Bhagirathi/ Ganga from Gomukh to Rishikesh was monitored at ten sampling points during September-October, 2002. During May and August, 2003 additional sampling points were selected in the stretch from Tapovan to Rishikesh and Badrinath to Rishikesh. Altogether twenty samples were collected each in May and August, 2003 from the study area.

The physico-chemical characteristics of the rivers Bhagirathi/ Ganga and their tributaries are presented in **Table 4**. Average values of the quantified parameters (except pH and temperature) are depicted in **Table 5**. The values have been compared with desired levels for normal growth and propagation of aquatic organisms as recommended by Environment Waikato (EW – Water Quality Glossary.htm dt. 11/30/02). Surface water temperatures of the water samples collected in August, 2003 were comparatively higher than those measured in May,

Table 3 : Predictors of Water Quality

Sr. No.	Parameters	Sr. No.	Parameters
Water			
Physico-chemical			
1	Temperature	***Biological***	
2	pH	1	Total coliforms
3	Conductivity	2	*E. coli*
4	Turbidity	3	F. Streptococci
5	Total dissolved solid	4	Coliphages
6	Total suspended solid	5	Phyto and Zoo plankton
8	DO		
9	BOD	**Sediments**	
10	COD	1.	Physico-chemical
11	Hardness	2.	Metals
12	Nitrite	3.	Particle size analysis
14	Ammonia	4.	Release of metal ions from sediments
15	Total Kjeldhal nitrogen	6.	Benthos
16	NH_3-N	7.	Coliphages
17	Nitrate nitrogen	*Mineral Analysis*	
18	Sulphate	1.	Smectite
19	Alkalinity	2.	Vermiculite
21	Chloride	3.	Chlorite
22	Fluoride	4.	Mica
23	Phosphate	5.	Kaolinite
24	Silica	6.	Quartz
Macro and Trace Elements		7.	Feldspar
1	Calcium	8.	Garnet
2	Magnesium	9.	Biotite
3	Sodium	10.	Magnetite
4	Potassium	11.	Zoisite
5	Iron	12.	Monazite
6	Manganese	13.	Hornblende
8	Cadmium	14.	Tourmaline
9	Chromium	15.	Epidote
10	Lead	16.	Apatite
11	Arsenic	17.	Clinoopyroxene
12	Aluminium	18.	Rutile
13	Strontium	*Gamma Ray Spectrophotometric Analysis*	
14	Nickel	1.	U_3O_8
		2.	ThO_2
		3.	% K

Table 4 : Physico-chemical characteristics at different Sampling Points of the Rivers/ Tributaries in the Study Area (September, 2002 to August, 2003)

Parameters	Sampling date	Sampling station									
		1	2	3	4	5	6	7	8	9	10
pH	24-25 Sept., 02	NS	6.4	NS	6.4	NS	6.7	7.2	NS	NS	7.9
	7-8 Oct., 02	NS	6.5	NS	6.8	NS	7.4	7.7	NS	7.9	NS
	23-24 Oct. 02	NS	6.8	NS	7.2	NS	7.5	7.6	7.7	7.6	7.9
	14-23 May, 03	7.70	7.50	7.78	7.80	7.59	7.59	7.52	7.80	7.56	7.55
	28-31 Aug., 03	7.3	7.2	7.5	7.35	7.27	7.29	7.20	7.31	7.15	7.08
DO (mg/l)	24-25 Sept., 02	NS	18.2	NS	16.1	NS	14.1	15.9	NS	NS	14.9
	7-8 Oct., 02	NS	19.6	NS	15.4	NS	12.2	16.2	NS	14.1	NS
	23-24 Oct. 02	NS	16.2	NS	14.2	NS	13.6	17.8	12.1	16.1	12.8
	14-23 May, 03	13.1	12.9	10.5	10.2	12.2	12.0	13.5	15.2	17.7	18.2
	28-31 Aug., 03	15	12.2	19.8	12.5	14.9	12.2	15.2	17.7	19.4	16.3
Temperature (^{o}C)	24-25 Sept., 02	NS	2	NS	6	NS	11	17	NS	NS	17
	7-8 Oct., 02	NS	1	NS	5	NS	15	17	NS	14	NS
	23-24 Oct. 02	NS	2	NS	4	NS	15	17	13	12	17
	14-23 May, 03	1	2	4	4	10	12	14	14	14.2	14
	28-31 Aug., 03	7	3	5	6	16	17	18	19	18	18
SS (mg/l)	24-25 Sept., 02	NS	98	NS	57	NS	32	37	NS	NS	29
	7-8 Oct., 02	NS	116	NS	68	NS	22	26	NS	42	NS
	23-24 Oct. 02	NS	56	NS	28	NS	2	4	4	4	8
	14-23 May, 03	4	6	33	60	14	2	14	10	4	18
	28-31 Aug., 03	92	344	472	456	252	272	147.5	108	245	516
TDS (mg/l)	24-25 Sept., 02	NS	120	NS	117	NS	91	120	NS	NS	117
	7-8 Oct., 02	NS	186	NS	128	NS	86	126	NS	94	NS
	23-24 Oct. 02	NS	128	NS	100	NS	20	106	50	64	52
	14-23 May, 03	32	96	80	74	182	130	60	90	104	100
	28-31 Aug., 03	82	98	76	68	80	48	84	100	112	112

NS : Not sampled; BDL : Below detectable limit

1. Tapovan; 2. Gomukh; 3. Gangotri upstream (u.s.); 4. Gangotri downstream (d.s.); 5. Uttarkashi u.s.; 6. Uttarkashi d.s.; 7. Tehri (u.s. of Bhagirathi); 8. Tehri (u.s. of Bhilangana); 9. Tehri (d.s. of Bhagirathi); 10. Devprayag, before confluence (Bhagirathi)

Table 4 (contd...)

Parameters	Date	Sampling station									
		1	2	3	4	5	6	7	8	9	10
COD (mg/l)	24-25 Sept., 02	NS	BDL	NS	BDL	NS	BDL	BDL	NS	NS	BDL
	7-8 Oct., 02	NS	BDL	NS	BDL	NS	BDL	BDL	NS	BDL	NS
	23-24 Oct. 02	NS	BDL	NS	BDL	NS	BDL	BDL	BDL	BDL	BDL
	14-23 May, 03	3	7	6	4	5	5	5	6	7	5
	28-31 Aug., 03	4	4	4	4	7	12	12	22	14	17
BOD (mg/l)	24-25 Sept., 02	NS	BDL	NS	BDL	NS	BDL	BDL	NS	NS	BDL
	7-8 Oct., 02	NS	BDL	NS	BDL	NS	BDL	BDL	NS	BDL	NS
	23-24 Oct. 02	NS	BDL	NS	BDL	NS	BDL	BDL	BDL	BDL	BDL
	14-23 May, 03	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	28-31 Aug., 03	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Kjeldahl nitrogen (mg/l)	24-25 Sept., 02	NS	3.1	NS	BDL	NS	1	1.1	NS	NS	0.5
	7-8 Oct., 02	NS	2.8	NS	4.1	NS	3.9	2.2	NS	2.8	NS
	23-24 Oct. 02	NS	0.1	NS	0.2	NS	0.8	0.3	0.4	0.3	0.2
	14-23 May, 03	2	0.8	1.7	1	1	1	0.9	0.9	BDL	0.5
	28-31 Aug., 03	2	0.8	1.2	1	0.2	1.2	1.0	1.0	0.6	0.5
NH_3-N (mg/l)	24-25 Sept., 02	NS	0.5	NS	0.6	NS	0.3	0.2	NS	NS	0.9
	7-8 Oct., 02	NS	0.8	NS	0.6	NS	0.2	0.2	NS	0.1	NS
	23-24 Oct. 02	NS	0.7	NS	0.12	NS	0.2	0.1	0.2	0.2	BDL
	14-23 May, 03	0.532	0.559	0.361	0.22	0.038	0.1	0.1	0.2	BDL	BDL
	28-31 Aug., 03	0.163	0.30	0.110	0.22	0.64	0.46	0.4	0.2	0.2	0.6
NO_2 (mg/l)	24-25 Sept., 02	NS	0.03	NS	0.01	NS	0.02	BDL	NS	NS	0.02
	7-8 Oct., 02	NS	0.03	NS	0.01	NS	0.01	0.02	NS	0.01	NS
	23-24 Oct. 02	NS	BDL	NS	BDL	NS	BDL	BDL	BDL	BDL	BDL
	14-23 May, 03	BDL	BDL	0.23	0.37	0.09	0.07	0.02	0.13	0.03	0.04
	28-31 Aug., 03	BDL	0.03	0.29	BDL	0.21	0.14	0.21	BDL	0.09	0.20
NO_3 (mg/l)	24-25 Sept., 02	NS	0.02	NS	0.06	NS	0.05	0.33	NS	NS	0.12
	7-8 Oct., 02	NS	0.15	NS	0.12	NS	0.13	0.53	NS	0.20	NS
	23-24 Oct. 02	NS	0.06	NS	0.06	NS	0.03	0.22	0.07	0.14	0.1
	14-23 May, 03	0.31	0.50	0.30	0.72	0.62	0.60	0.49	0.43	0.65	0.58
	28-31 Aug., 03	0.15	0.10	1.15	BDL	0.30	0.29	0.23	0.06	0.14	0.47

NS : Not sampled; BDL : Below detectable limit

1. Tapovan; 2. Gomukh; 3. Gangotri upstream (u.s.); 4. Gangotri downstream (d.s.); 5. Uttarkashi u.s.; 6. Uttarkashi d.s.; 7. Tehri (u.s. of Bhagirathi); 8. Tehri (u.s. of Bhilangana); 9. Tehri (d.s. of Bhagirathi); 10. Devprayag, before confluence (Bhagirathi)

Table 4 (contd...)

Parameters	Date	Sampling station									
		1	2	3	4	5	6	7	8	9	10
PO_4-P (mg/l)	24-25 Sept., 02	NS	0.019	NS	0.02	NS	0.014	0.07	NS	NS	0.01
	7-8 Oct., 02	NS	0.019	NS	0.03	NS	0.025	0.11	NS	0.04	NS
	23-24 Oct. 02	NS	0.012	NS	0.01	NS	0.007	0.007	0.002	0.001	0.002
	14-23 May, 03	0.005	0.070	0.02	0.04	0.03	0.03	0.03	0.07	0.03	0.03
	28-31 Aug., 03	0.04	0.04	0.05	0.03	0.004	0.005	0.04	0.053	0.04	0.04
SO_4 (mg/l)	24-25 Sept., 02	NS	41.94	NS	54.3	NS	68.0	57.0	NS	NS	48.0
	7-8 Oct., 02	NS	81.35	NS	68.8	NS	75	88	NS	72.7	NS
	23-24 Oct. 02	NS	19.4	NS	55.7	NS	15.9	21.9	8.5	17.5	17.3
	14-23 May, 03	8.27	52.0	59.61	61.73	16.05	10.38	11.92	10.67	10.38	12.88
	28-31 Aug., 03	54.42	32.67	19.03	17.11	16.92	11.7	11.15	0.76	7.5	10.57
Cl^- (mg/l)	24-25 Sept., 02	NS	2.7	NS	0.49	NS	2.9	3.7	NS	NS	0.9
	7-8 Oct., 02	NS	4.8	NS	2.0	NS	3.50	4.50	NS	3.00	NS
	23-24 Oct. 02	NS	0.48	NS	0.50	NS	1.0	2.4	1.0	1.0	1.4
	14-23 May, 03	2.0	2.0	2.0	BDL	1.0	1.0	2.0	3.0	3.0	4.0
	28-31 Aug., 03	8.00	4.00	10.0	4.00	8.00	4.00	2.00	4.00	2.0	2.0
Total hardness ($CaCO_3$) (mg/l)	24-25 Sept., 02	NS	76	NS	80	NS	56	61	NS	NS	67
	7-8 Oct., 02	NS	88	NS	98	NS	55	76	NS	80	NS
	23-24 Oct. 02	NS	75	NS	58	NS	42	62	48	62	56
	14-23 May, 03	12	40	36	36	68	72	56	44	56	72
	28-31 Aug., 03	40	40	34	42	56	56	48	34	42	48
Ca - Hardness ($CaCO_3$) (mg/l)	24-25 Sept., 02	NS	60	NS	57	NS	39	51	NS	NS	31
	7-8 Oct., 02	NS	60	NS	62	NS	31	54	NS	45	NS
	23-24 Oct. 02	NS	47.3	NS	38	NS	30	40	32	38	38
	14-23 May, 03	12	40	36	36	52	52	40	32	40	40
	28-31 Aug., 03	24	28	20	12	28	32	36	20	32	40
Mg - Hardness ($CaCO_3$) (mg/l)	24-25 Sept., 02	NS	16	NS	23	NS	17	10	NS	NS	36
	7-8 Oct., 02	NS	28	NS	36	NS	24	22	NS	35	NS
	23-24 Oct. 02	NS	27	NS	20	NS	12	22	16	24	18
	14-23 May, 03	BDL	BDL	BDL	BDL	16	20	16	12	16	32
	28-31 Aug., 03	16	12	14	30	28	24	12	14	10	8

NS : Not sampled; BDL : Below detectable limit

1. Tapovan; 2. Gomukh; 3. Gangotri upstream (u.s.); 4. Gangotri downstream (d.s.); 5. Uttarkashi u.s.; 6. Uttarkashi d.s.; 7. Tehri (u.s. of Bhagirathi); 8. Tehri (u.s. of Bhilangana); 9. Tehri (d.s. of Bhagirathi); 10. Devprayag, before confluence (Bhagirathi)

Table 4 (contd...)

Parameters	Date	Sampling station									
		1	2	3	4	5	6	7	8	9	10
Ca (mg/l)	24-25 Sept., 02	NS	21	NS	23	NS	17	21	NS	NS	21
	7-8 Oct., 02	NS	24	NS	25	NS	18	24	NS	18	NS
	23-24 Oct. 02	NS	19	NS	15	NS	12	16	13	13	16
	14-23 May, 03	4.8	16	14.4	14.4	20.8	20.8	16.0	12.8	16.0	16.0
	28-31 Aug., 03	9.6	11.2	8	4.8	11.2	12.8	14.4	8	12.8	16
Mg (mg/l)	24-25 Sept., 02	NS	7	NS	8	NS	6	4	NS	NS	11
	7-8 Oct., 02	NS	8	NS	9	NS	6	7	NS	8	NS
	23-24 Oct. 02	NS	7	NS	5	NS	3	5	3	4	4
	14-23 May, 03	BDL	BDL	BDL	BDL	3.9	4.9	3.9	2.9	3.9	7.8
	28-31 Aug., 03	3.8	2.916	3.402	7.29	6.8	5.83	2.916	3.402	2.43	1.94
Alkalinity ($CaCO_3$) (mg/l)	24-25 Sept., 02	NS	9	NS	17	NS	19	31	NS	NS	34
	7-8 Oct., 02	NS	13	NS	18	NS	42	64	NS	52	NS
	23-24 Oct. 02	NS	8.0	NS	14	NS	30	34	40	42	34
	14-23 May, 03	16	8	12	12	112	96	76	56	68	72
	28-31 Aug., 03	24	32	48	80	64	80	64	68	80	76
Na (mg/l)	24-25 Sept., 02	NS	3.1	NS	3.2	NS	3.9	5.6	NS	NS	4.81
	7-8 Oct., 02	NS	4.0	NS	4.5	NS	3.7	5.7	NS	5.0	NS
	23-24 Oct. 02	NS	2.2	NS	2.3	NS	2.2	3.1	2.3	2.8	2.9
	14-23 May, 03	0.5	2.5	3.0	3.0	2.2	2.5	3.0	3.5	2.8	3.0
	28-31 Aug., 03	1.25	1.75	1.25	1.50	2.75	4.75	2.75	2.75	3.0	2.5
K (mg/l)	24-25 Sept., 02	NS	2.7	NS	1.4	NS	0.8	1.4	NS	NS	2.7
	7-8 Oct., 02	NS	3.0	NS	2.9	NS	2.4	2.8	NS	2.7	NS
	23-24 Oct. 02	NS	1.4	NS	1.4	NS	1.5	1.0	0.8	1.0	1.0
	14-23 May, 03	2.5	2.7	3.0	3.2	2.4	2.5	1.8	2.0	1.1	2.0
	28-31 Aug., 03	1.6	2.7	1.0	1.1	2.5	2.8	2.8	1.9	3.2	3.2
Turbidity (NTU)	24-25 Sept., 02	NS	3.4	NS	3.80	NS	1.30	1.90	NS	NS	1.2
	7-8 Oct., 02	NS	1.2	NS	0.20	NS	0.30	0.70	NS	1.7	NS
	23-24 Oct. 02	NS	1.9	NS	1.10	NS	1.20	1.30	2.1	1.29	0.2
	14-23 May, 03	0.20	2.1	0.72	0.25	2.0	0.40	1.60	1.2	1.2	1.8
	28-31 Aug., 03	NS	1.9	NS	1.50	1.9	NS	1.10	1.1	1.1	1.7

NS : Not sampled; BDL : Below detectable limit

1. Tapovan; 2. Gomukh; 3. Gangotri upstream (u.s.); 4. Gangotri downstream (d.s.); 5. Uttarkashi u.s.; 6. Uttarkashi d.s.; 7. Tehri (u.s. of Bhagirathi); 8. Tehri (u.s. of Bhilangana); 9. Tehri (d.s. of Bhagirathi); 10. Devprayag, before confluence (Bhagirathi)

Table 4 (contd...)

Parameters	Date	Sampling station									
		1	2	3	4	5	6	7	8	9	10
F- (mg/l)	24-25 Sept., 02	NS	0.46	NS	0.675	NS	0.365	0.365	NS	NS	0.361
	7-8 Oct., 02	NS	0.4	NS	0.51	NS	0.49	0.45	NS	0.49	NS
	23-24 Oct. 02	NS	0.4	NS	0.39	NS	0.29	0.34	0.39	0.45	0.34
	14-23 May, 03	0.09	0.36	0.52	0.53	0.17	0.18	0.20	0.27	0.23	0.22
	28-31 Aug., 03	0.08	0.29	0.60	0.59	0.27	0.10	0.27	0.29	0.25	0.29
Conductivity (µs/cm)	24-25 Sept., 02	NS	132	NS	176	NS	152	113	NS	NS	111
	7-8 Oct., 02	NS	205	NS	141	NS	137	160	NS	142	NS
	23-24 Oct. 02	NS	191	NS	114	NS	121	141	132	161	154
	14-23 May, 03	28	69	74	75	101	104	92	75	88	66
	28-31 Aug., 03	101	71	48	47	65	74	66	48	63	95

NS : Not sampled; BDL : Below detectable limit

1. Tapovan; 2. Gomukh; 3. Gangotri upstream (u.s.); 4. Gangotri downstream (d.s.); 5. Uttarkashi u.s.; 6. Uttarkashi d.s.; 7. Tehri (u.s. of Bhagirathi); 8. Tehri (u.s. of Bhilangana); 9. Tehri (d.s. of Bhagirathi); 10. Devprayag, before confluence (Bhagirathi)

Table 4 (contd...)

Parameters	Date	Sampling station								
		11	12	13	14	15	16	17	18	19	20
pH	24-25 Sept., 02	NS	7.2	NS	NS	NS	8.0	NS	NS	NS	NS
	7-8 Oct., 02	7.2	8.0	NS	NS	NS	7.3	NS	NS	NS	NS
	23-24 Oct. 02	7.8	7.7	NS	NS	NS	7.9	NS	NS	NS	NS
	14-23 May, 03	7.37	7.28	7.62	7.69	7.80	7.73	7.95	7.73	6.8	7.0
	28-31 Aug., 03	7.26	7.21	7.38	7.41	7.63	7.64	NS	7.58	NS	NS
DO (mg/l)	24-25 Sept., 02	NS	16.9	NS	NS	NS	16.9	NS	NS	NS	NS
	7-8 Oct., 02	17.1	18.9	NS	NS	NS	12.9	NS	NS	NS	NS
	23-24 Oct. 02	13.5	15.1	NS	NS	NS	9.9	NS	NS	NS	NS
	14-23 May, 03	18.5	18.9	20.0	19.0	15.9	10.2	10.5	11.0	12.7	10.1
	28-31 Aug., 03	16.95	12.50	16.60	12.50	11.40	11.70	NS	12.25	NS	NS
Temperature (°C)	24-25 Sept., 02	NS	14.8	NS	NS	NS	20.7	NS	NS	NS	NS
	7-8 Oct., 02	15	18	NS	NS	NS	21	NS	NS	NS	NS
	23-24 Oct. 02	14.9	17.6	NS	NS	NS	20.1	NS	NS	NS	NS
	14-23 May, 03	13.8	14.1	14.2	14	17	16	15.8	16.0	3.5	12
	28-31 Aug., 03	20	20	21	20	21	22.5	NS	21.5	NS	NS
SS (mg/l)	24-25 Sept., 02	NS	31	NS	NS	NS	17	NS	NS	NS	NS
	7-8 Oct., 02	16	30	NS	NS	NS	16	NS	NS	NS	NS
	23-24 Oct. 02	8	6	NS	NS	NS	4	NS	NS	NS	NS
	14-23 May, 03	4	8	12	126	276	84	146	154	148	4
	28-31 Aug., 03	185	424	215	284	276	228	NS	300	NS	NS
TDS (mg/l)	24-25 Sept., 02	NS	128	NS	NS	NS	126	NS	NS	NS	NS
	7-8 Oct., 02	118	109	NS	NS	NS	136	NS	NS	NS	NS
	23-24 Oct. 02	48	40	NS	NS	NS	58	NS	NS	NS	NS
	14-23 May, 03	162	174	156	114	170	150	130	132	56	24
	28-31 Aug., 03	124	104	104	168	116	176	NS	71	NS	NS

NS : Not sampled; BDL : Below detectable limit

11. Devprayag, before confluence (Alaknanda); 12. Devprayag, after confluence (Ganga), right bank; 13. Devprayag, after confluence (Ganga), middle;
14. Devprayag, after confluence (Ganga), left bank; 15. Rishikesh u.s.; 16. Rishikesh d.s. (right bank); 17. Rishikesh d.s. (middle); 18. Rishikesh d.s (left bank);
19. Alaknanda at Badrinath; 20. Mandakini at Rudraprayag

Table 4 (contd...)

Parameters	Date	Sampling station									
		11	12	13	14	15	16	17	18	19	20
COD (mg/l)	24-25 Sept., 02	NS	BDL	NS	NS	NS	BDL	NS	NS	NS	NS
	7-8 Oct., 02	BDL	BDL	NS	NS	NS	BDL	NS	NS	NS	NS
	23-24 Oct. 02	BDL	BDL	NS	NS	NS	BDL	NS	NS	NS	NS
	14-23 May, 03	5	6	4	2	3	6	2	3	3	2
	28-31 Aug., 03	11	17	12	11	17	17	NS	12	NS	NS
BOD (mg/l)	24-25 Sept., 02	NS	BDL	NS	NS	NS	BDL	NS	NS	NS	NS
	7-8 Oct., 02	BDL	BDL	NS	NS	NS	BDL	NS	NS	NS	NS
	23-24 Oct. 02	BDL	BDL	NS	NS	NS	BDL	NS	NS	NS	NS
	14-23 May, 03	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	28-31 Aug., 03	<1	<1	<1	<1	<1	<1	<1	<1	NS	NS
Total nitrogen (mg/l)	24-25 Sept., 02	NS	0.71	NS	NS	NS	0.89	NS	NS	NS	NS
	7-8 Oct., 02	3.39	1.96	NS	NS	NS	1.4	NS	NS	NS	NS
	23-24 Oct. 02	0.35	0.3	NS	NS	NS	0.22	NS	NS	NS	NS
	14-23 May, 03	1.232	1.120	0.784	0.672	0.896	3.360	0.784	1.568	0.896	0.784
	28-31 Aug., 03	1.310	1.110	0.742	0.847	0.757	1.140	NS	0.7	NS	NS
NH_3-N (mg/l)	24-25 Sept., 02	NS	0.8	NS	NS	NS	0.8	NS	NS	NS	NS
	7-8 Oct., 02	0.42	0.6	NS	NS	NS	1.16	NS	NS	NS	NS
	23-24 Oct. 02	0.35	0.26	NS	NS	NS	0.06	NS	NS	NS	NS
	14-23 May, 03	0.157	0.176	0.091	0.104	0.104	0.87	0.1	0.2	0.48	BDL
	28-31 Aug., 03	0.315	0.2	0.3	0.1	0.2	0.011	NS	0.3	NS	NS
NO_2 (mg/l)	24-25 Sept., 02	NS	0.009	NS	NS	NS	0.031	NS	NS	NS	NS
	7-8 Oct., 02	0.009	0.024	NS	NS	NS	0.053	NS	NS	NS	NS
	23-24 Oct. 02	0.003	0.003	NS	NS	NS	0.031	NS	NS	NS	NS
	14-23 May, 03	BDL	BDL	0.131	BDL	BDL	BDL	BDL	BDL	0.102	BDL
	28-31 Aug., 03	0.005	0.106	0.095	0.112	BDL	BDL	NS	0.099	NS	NS
NO_3 (mg/l)	24-25 Sept., 02	NS	0.091	NS	NS	NS	0.078	NS	NS	NS	NS
	7-8 Oct., 02	0.212	0.31	NS	NS	NS	0.053	NS	NS	NS	NS
	23-24 Oct. 02	0.119	0.05	NS	NS	NS	0.005	NS	NS	NS	NS
	14-23 May, 03	0.509	0.595	0.645	0.606	0.699	0.743	0.602	0.540	0.743	0.462
	28-31 Aug., 03	0.075	0.238	0.246	0.360	0.212	0.249	NS	0.230	NS	NS

NS : Not sampled; BDL : Below detectable limit

11. Devprayag, before confluence (Alaknanda); 12. Devprayag, after confluence (Ganga), right bank; 13. Devprayag, after confluence (Ganga), middle; 14. Devprayag, after confluence (Ganga), left bank; 15. Rishikesh u.s.; 16. Rishikesh d.s. (right bank); 17. Rishikesh d.s. (middle); 18. Rishikesh d.s (left bank); 19. Alaknanda at Badrinath; 20. Mandakini at Rudraprayag

Table 4 (contd...)

Parameters	Date	Sampling station									
		11	12	13	14	15	16	17	18	19	20
PO_4-F (mg/l)	24-25 Sept., 02	NS	0.023	NS	NS	NS	0.011	NS	NS	NS	NS
	7-8 Oct., 02	0.028	0.015	NS	NS	NS	0.022	NS	NS	NS	NS
	23-24 Oct. 02	0.002	0.001	NS	NS	NS	0.001	NS	NS	NS	NS
	14-23 May, 03	0.020	0.025	0.030	0.040	0.040	0.060	0.030	0.040	0.040	0.001
	28-31 Aug., 03	0.030	0.030	0.008	0.006	0.006	0.023	NS	0.038	NS	NS
SO_4 (mg/l)	24-25 Sept., 02	NS	37.0	NS	NS	NS	71.9	NS	NS	NS	NS
	7-8 Oct., 02	48.7	50.5	NS	NS	NS	118.7	NS	NS	NS	NS
	23-24 Oct. 02	10.5	13.8	NS	NS	NS	21.5	NS	NS	NS	NS
	14-23 May, 03	11.05	10.28	25.57	21.34	10.19	13.27	9.80	8.65	13.27	11.92
	28-31 Aug., 03	5.38	5.76	8.26	5.57	8.26	10.76	NS	12.88	NS	NS
Cl (mg/l)	24-25 Sept., 02	NS	1.1	NS	NS	NS	0.5	NS	NS	NS	NS
	7-8 Oct., 02	2.0	3.0	NS	NS	NS	6.3	NS	NS	NS	NS
	23-24 Oct. 02	1.0	0.5	NS	NS	NS	2.9	NS	NS	NS	NS
	14-23 May, 03	2.0	3.0	2.0	2.0	1.0	3.0	1.0	1.0	2.0	2.0
	28-31 Aug., 03	2.0	4.0	4.00	4.0	4.0	4.0	NS	4.0	NS	NS
Total hardness ($CaCO_3$) (mg/l)	24-25 Sept., 02	NS	59	NS	NS	NS	88	NS	NS	NS	NS
	7-8 Oct., 02	92	92	NS	NS	NS	126	NS	NS	NS	NS
	23-24 Oct. 02	68	64	NS	NS	NS	112	NS	NS	NS	NS
	14-23 May, 03	88	76	68	72	92	80	88	80	38	46
	28-31 Aug., 03	108	78	56	68	64	88	NS	68	NS	NS
Ca - Hardness ($CaCO_3$) (mg/l)	24-25 Sept., 02	NS	29	NS	NS	NS	68	NS	NS	NS	NS
	7-8 Oct., 02	54	42	NS	NS	NS	76	NS	NS	NS	NS
	23-24 Oct. 02	44	38	NS	NS	NS	66	NS	NS	NS	NS
	14-23 May, 03	60	56	64	60	76	54	60	56	28	32
	28-31 Aug., 03	52	36	40	42	44	44	NS	44	NS	NS
Mg - Hardness ($CaCO_3$) (mg/l)	24-25 Sept., 02	NS	30	NS	NS	NS	20	NS	NS	NS	NS
	7-8 Oct., 02	38	50	NS	NS	NS	50	NS	NS	NS	NS
	23-24 Oct. 02	24	26	NS	NS	NS	46	NS	NS	NS	NS
	14-23 May, 03	28	20	04	12	24	16	28	24	9	16
	28-31 Aug., 03	56	42	16	26	20	44	NS	24	NS	NS

NS : Not sampled; BDL : Below detectable limit

11. Devprayag, before confluence (Alaknanda); 12. Devprayag, after confluence (Ganga), right bank; 13. Devprayag, after confluence (Ganga), middle; 14. Devprayag, after confluence (Ganga), left bank; 15. Rishikesh u.s.; 16. Rishikesh d.s. (right bank); 17. Rishikesh d.s. (middle); 18. Rishikesh d.s (left bank); 19. Alaknanda at Badrinath; 20. Mandakini at Rudraprayag

Table 4 (cotnd...)

Parameters	Date	Sampling station									
		11	12	13	14	15	16	17	18	19	20
Ca (mg/l)	24-25 Sept., 02	NS	20	NS	NS	NS	30	NS	NS	NS	NS
	7-8 Oct., 02	22	24	NS	NS	NS	31	NS	NS	NS	NS
	23-24 Oct. 02	18	15	NS	NS	NS	26	NS	NS	NS	NS
	14-23 May, 03	24.0	22.4	25.6	24	30.4	25.6	24.0	22.4	11.2	12.8
	28-31 Aug., 03	20.8	14.4	16	16.8	17.6	17.6	NS	17.6	NS	NS
Mg (mg/l)	24-25 Sept., 02	NS	16	NS	NS	NS	14	NS	NS	NS	NS
	7-8 Oct., 02	12	13	NS	NS	NS	12	NS	NS	NS	NS
	23-24 Oct. 02	4	6	NS	NS	NS	7	NS	NS	NS	NS
	14-23 May, 03	6.8	4.9	0.972	2.916	5.8	3.9	6.8	5.8	2.187	3.888
	28-31 Aug., 03	13.6	8.74	3.88	6.3	4.86	10.69	NS	5.83	NS	NS
Alkalinity ($CaCO_3$) (mg/l)	24-25 Sept., 02	NS	49	NS	NS	NS	70	NS	NS	NS	NS
	7-8 Oct., 02	64	72	NS	NS	NS	124	NS	NS	NS	NS
	23-24 Oct. 02	50	36	NS	NS	NS	106	NS	NS	NS	NS
	14-23 May, 03	104	96	72	76	104	108	96	100	24	28
	28-31 Aug., 03	116	124	104	108	104	100	NS	92	NS	NS
Na (mg/l)	24-25 Sept., 02	NS	3.6	NS	NS	NS	4.9	NS	NS	NS	NS
	7-8 Oct., 02	4.0	4.2	NS	NS	NS	9.0	NS	NS	NS	NS
	23-24 Oct. 02	2.1	2.2	NS	NS	NS	2.5	NS	NS	NS	NS
	14-23 May, 03	2.8	3.2	3.5	3.5	2.8	4.5	2.8	2.8	3.2	2.2
	28-31 Aug., 03	2.5	2.5	3.0	2.75	3.25	3.75	NS	3.25	NS	NS
K (mg/l)	24-25 Sept., 02	NS	3.1	NS	NS	NS	1.7	NS	NS	NS	NS
	7-8 Oct., 02	2.3	3.0	NS	NS	NS	3.2	NS	NS	NS	NS
	23-24 Oct. 02	1.0	0.9	NS	NS	NS	1.7	NS	NS	NS	NS
	14-23 May, 03	1.9	2.1	2.1	2.0	1.8	2.2	1.9	1.9	1.4	1.9
	28-31 Aug., 03	2.2	2.4	2.7	2.7	2.6	2.5	NS	2.5	NS	NS
Turbidity (NTU)	24-25 Sept., 02	NS	1.9	NS	NS	NS	3.1	NS	NS	NS	NS
	7-8 Oct., 02	1.3	1.9	NS	NS	NS	1.8	NS	NS	NS	NS
	23-24 Oct. 02	0.3	1.7	NS	NS	NS	0.6	NS	NS	NS	NS
	14-23 May, 03	1.2	2.7	1.9	1.1	1.8	1.1	1.2	1.1	1.0	2.0
	28-31 Aug., 03	0.2	1.1	1.6	1.7	1.1	1.0	NS	1.0	NS	NS

NS : Not sampled; BDL : Below detectable limit

11. Devprayag, before confluence (Alaknanda); 12. Devprayag, after confluence (Ganga), right bank; 13. Devprayag, after confluence (Ganga), middle; 14. Devprayag, after confluence (Ganga), left bank; 15. Rishikesh u.s.; 16. Rishikesh d.s. (right bank); 17. Rishikesh d.s. (middle); 18. Rishikesh d.s (left bank); 19. Alaknanda at Badrinath; 20. Mandakini at Rudraprayag

Table 4 (contd...)

Parameters	Date	Sampling station									
		11	12	13	14	15	16	17	18	19	20
F^- (mg/l)	24-25 Sept., 02	NS	0.29	NS	NS	NS	0.31	NS	NS	NS	NS
	7-8 Oct., 02	0.29	0.37	NS	NS	NS	0.615	NS	NS	NS	NS
	23-24 Oct. 02	0.52	0.46	NS	NS	NS	0.77	NS	NS	NS	NS
	14-23 May, 03	0.18	0.18	0.20	0.17	0.18	0.19	0.18	0.18	0.12	0.33
	28-31 Aug., 03	0.22	0.22	0.20	0.21	0.24	0.24	NS	0.38	NS	NS
Conductivity (µs/cm)	24-25 Sept., 02	NS	163	NS	NS	NS	129	NS	NS	NS	NS
	7-8 Oct., 02	108	130	NS	NS	NS	112	NS	NS	NS	NS
	23-24 Oct. 02	121	112	NS	NS	NS	112	NS	NS	NS	NS
	14-23 May, 03	84	80	75	80	81	83	114	80	123	124
	28-31 Aug., 03	111	108	117	114	118	125	NS	116	NS	NS

NS : Not sampled; BDL : Below detectable limit

11. Devprayag, before confluence (Alaknanda); 12. Devprayag, after confluence (Ganga), right bank; 13. Devprayag, after confluence (Ganga), middle;
14. Devprayag, after confluence (Ganga), left bank; 15. Rishikesh u.s.; 16. Rishikesh d.s. (right bank); 17. Rishikesh d.s. (middle); 18. Rishikesh d.s (left bank);
19. Alaknanda at Badrinath; 20. Mandakini at Rudraprayag

Table 5 : Average Physico-chemical characteristics at different Sampling Points of the Rivers/ Tributaries in the Study Area
(September, 2002 to August, 2003)

Parameters	Sampling station									
	1	2	3	4	5	6	7	8	9	10
DO (mg/l)	14.05	15.83 (±3.22)	15.18	13.69 (±2.37)	13.58	12.83 (±0.95)	15.73 (±1.56)	15.00	16.84	17.25
SS (mg/l)	48.00	124.00 (±130.08)	252.50	133.80 (±180.75)	133.00	66.00 (±115.89)	45.70 (±58.25)	40.67	73.75	180.67
TDS (mg/l)	57.00	125.60 (±36.48)	78.00	97.40 (±26.17)	131.00	75.00 (±42.30)	99.20 (±27.22)	80.00	93.50	106.00
COD (mg/l)	3.54	5.27 (±1.79)	4.88	4.11 (±0.16)	5.81	8.69 (±4.68)	8.31 (±5.23)	14.07	10.27	11.00
BOD (mg/l)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total nitrogen (mg/l)	2.06	1.52 (±1.34)	1.43	1.28 (±1.66)	0.58	1.58 (±1.31)	1.12 (±0.70)	0.75	0.93	0.50
NH_3-N (mg/l)	0.35	0.57 (±0.19)	0.24	0.36 (±0.24)	0.34	0.26 (±0.13)	0.19 (±0.15)	0.20	0.15	0.30
NO_2 (mg/l)	BDL	0.02 (±0.01)	0.26	0.10 (±0.18)	0.15	0.05 (±0.06)	0.05 (±0.09)	0.07	0.03	0.07
NO_3 (mg/l)	0.23	0.17 (±0.19)	0.72	0.19 (±0.30)	0.46	0.22 (±0.24)	0.36 (±0.14)	0.19	0.28	0.53
PO_4-P (mg/l)	0.02	0.03 (±0.02)	0.04	0.03 (±0.01)	0.02	0.02 (±0.01)	0.05 (±0.04)	0.04	0.03	0.04
SO_4 (mg/l)	31.35	45.47 (±23.38)	39.32	51.53 (±20.08)	16.49	36.20 (±32.39)	37.99 (±33.62)	8.64	27.02	11.73
Cl (mg/l)	5.00	2.80 (±1.69)	6.00	1.75 (±1.66)	4.50	2.48 (±1.41)	2.92 (±1.13)	2.67	2.25	3.00

BDL : Below detectable limit

Note : Values in parenthesis are standard deviation of minimum 5 sets of data

1. Tapovan; 2. Gomukh; 3. Gangotri upstream (u.s.); 4. Gangotri downstream (d.s.); 5. Uttarkashi u.s.; 6. Uttarkashi d.s.; 7. Tehri (u.s. of Bhagirathi); 8. Tehri (u.s. of Bhilangana); 9. Tehri (d.s. of Bhagirathi); 10. Devprayag, before confluence (Bhagirathi)

Table 5 (contd...)

Parameters	Sampling station									
	1	2	3	4	5	6	7	8	9	10
Total hardness ($CaCO_3$) (mg/l)	26.00	63.80 (±22.32)	35.00	62.80 (±26.02)	62.00	56.20 (±10.64)	60.60 (±10.24)	42.00	60.00	60.00
Ca - Hardness ($CaCO_3$) (mg/l)	18.00	47.06 (±13.68)	28.00	41.00 (±19.82)	40.00	36.80 (±9.20)	44.20 (±7.82)	28.00	38.75	40.00
Mg - Hardness ($CaCO_3$) (mg/l)	16.00	20.75 (±7.97)	14.00	27.25 (±7.18)	22.00	19.40 (±5.08)	16.40 (±5.55)	14.00	21.25	20.00
Ca (mg/l)	7.20	18.24 (±4.90)	11.20	16.44 (±8.03)	16.00	16.12 (±3.68)	18.28 (±4.05)	11.27	14.95	16.00
Mg (mg/l)	3.80	6.23 (±2.26)	3.40	7.32 (±1.70)	5.35	5.15 (±1.28)	4.56 (±1.55)	3.10	4.58	4.87
Alkalinity ($CaCO_3$) (mg/l)	20.00	14.00 (±10.27)	30.00	28.20 (±29.06)	88.00	53.40 (±33.10)	53.80 (±20.08)	54.67	60.50	74.00
Na (mg/l)	0.88	2.71 (±0.87)	2.13	2.90 (±1.12)	2.48	3.41 (±1.05)	4.03 (±1.48)	2.85	3.40	2.75
K (mg/l)	2.05	2.50 (±0.63)	2.00	2.00 (±0.97)	2.45	2.00 (±0.83)	1.96 (±0.82)	1.57	2.00	2.60
Turbidity (NTU)	0.20	2.10 (±0.80)	0.72	1.37 (±1.47)	1.95	0.80 (±0.52)	1.32 (±0.46)	1.47	1.32	1.23
F- (mg/l)	0.09	0.38 (±0.06)	0.56	0.54 (±0.11)	0.22	0.29 (±0.15)	0.33 (±0.10)	0.32	0.36	0.30
Conductivity (µs/cm)	64.50	133.60 (±64.20)	61.00	110.60 (±51.30)	83.00	117.60 (±30.24)	114.40 (±37.53)	85.00	113.50	106.50

Note : Values in parenthesis are standard deviation of minimum 5 sets of data

1. Tapovan; 2. Gomukh; 3. Gangotri upstream (u.s.); 4. Gangotri downstream (d.s.); 5. Uttarkashi u.s.; 6. Uttarkashi d.s.; 7. Tehri (u.s. of Bhagirathi); 8. Tehri (u.s. of Bhilangana); 9. Tehri (d.s. of Bhagirathi); 10. Devprayag, before confluence (Bhagirathi)

Table 5 (contd...)

Parameters	Sampling station									
	11	12	13	14	15	16	17	18	19	20
Total hardness ($CaCO_3$) (mg/l)	89.00	73.80 (±12.93)	62.00	70.00	78.00	96.80 (±19.37)	88.00	74.00	38.00	46.00
Ca - Hardness ($CaCO_3$) (mg/l)	52.50	40.20 (±10.01)	52.00	51.00	60.00	61.60 (±12.60)	60.00	50.00	28.00	32.00
Mg - Hardness ($CaCO_3$) (mg/l)	36.50	33.60 (±12.20)	10.00	19.00	22.00	35.20 (±15.91)	28.00	24.00	9.00	16.00
Ca (mg/l)	21.20	19.16 (±4.32)	20.80	20.40	24.00	26.04 (±5.28)	24.00	20.00	11.20	12.80
Mg (mg/l)	9.10	9.73 (±4.70)	2.43	4.61	5.33	9.52 (±4.05)	6.80	5.82	2.19	3.89
Alkallnity ($CaCO_3$) (mg/l)	83.50	75.40 (±35.52)	88.00	92.00	104.00	101.60 (±19.77)	96.00	96.00	24.00	28.00
Na (mg/l)	2.85	3.14 (±0.81)	3.25	3.13	3.03	4.93 (±2.45)	2.80	3.03	3.20	2.20
K (mg/l)	1.85	2.30 (±0.89)	2.40	2.35	2.20	2.26 (±0.63)	1.90	2.20	1.40	1.90
Turbidity (NTU)	0.75	1.86 (±0.57)	1.75	1.40	1.45	1.52 (±0.98)	1.20	1.05	1.00	2.00
F- (mg/l)	0.30	0.30 (±0.11)	0.20	0.19	0.21	0.43 (±0.25)	0.18	0.28	0.12	0.33
Conductivity (µs/cm)	106.00	118.60 (±30.61)	96.00	97.00	99.50	112.20 (±18.02)	114.00	98.00	123.00	124.00

Note : Values in parenthesis are standard deviation of minimum 5 sets of data

11. Devprayag, before confluence (Alaknanda); 12. Devprayag, after confluence (Ganga), right bank; 13. Devprayag, after confluence (Ganga), middle; 14. Devprayag, after confluence (Ganga), left bank; 15. Rishikesh u.s.; 16. Rishikesh d.s. (right bank); 17. Rishikesh d.s. (middle); 18. Rishikesh d.s (left bank); 19. Alaknanda at Badrinath; 20. Mandakini at Rudraprayag

Table 5 (contd...)

Parameters	Sampling station									
	11	12	13	14	15	16	17	18	19	20
DO (mg/l)	16.51	16.46 (±2.72)	18.30	15.75	13.65	12.32 (±2.83)	10.50	11.63	7.70	8.10
SS (mg/l)	53.25	99.80 (±181.62)	113.50	205.00	276.00	69.80 (±93.86)	146.00	227.00	148.00	4.00
TDS (mg/l)	113.00	111.00 (±48.35)	130.00	141.00	143.00	129.60 (±43.99)	130.00	101.50	56.00	24.00
COD (mg/l)	7.81	11.38 (±7.95)	8.11	6.46	10.04	11.38 (±7.95)	1.54	7.73	2.69	1.92
BOD (mg/l)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total nitrogen (mg/l)	1.57	1.04 (±0.62)	0.76	0.76	0.83	1.40 (±1.18)	0.78	1.13	0.90	0.78
NH_3-N (mg/l)	0.31	0.41 (±0.28)	0.20	0.10	0.15	0.58 (±0.51)	0.10	0.25	0.48	0
NO_2 (mg/l)	0.01	0.04 (±0.05)	0.11	0.11	0	0.04 (±0.01)	0	0.10	0.10	0
NO_3 (mg/l)	0.23	0.26 (±0.22)	0.45	0.48	0.46	0.23 (±0.30)	0.60	0.39	0.74	0.46
PO_4-P (mg/l)	0.02	0.02 (±0.01)	0.02	0.02	0.02	0.02 (±0.02)	0.03	0.04	0.04	0.00
SO_4 (mg/l)	18.91	23.47 (±19.33)	16.92	13.46	9.23	47.23 (±47.07)	9.80	10.77	13.27	11.92
Cl (mg/l)	1.75	2.32 (±1.46)	3.00	3.00	2.50	3.34 (±2.10)	1.00	2.50	2.00	2.00

Note : Values in parenthesis are standard deviation of minimum 5 sets of data

11. Devprayag, before confluence (Alaknanda); 12. Devprayag, after confluence (Ganga), right bank; 13. Devprayag, after confluence (Ganga), middle; 14. Devprayag, after confluence (Ganga), left bank; 15. Rishikesh u.s.; 16. Rishikesh d.s. (right bank); 17. Rishikesh d.s. (middle); 18. Rishikesh d.s (left bank); 19. Alaknanda at Badrinath; 20. Mandakini at Rudraprayag

2003. This is primarily due to melting of ice at upper stretches of the rivers during summer months (**Plates 5 and 6**).

Indian Standards/ Specification for Drinking Water IS 10500 – 1994 are given iin **Annexure I**.

Ecological Measures

Dissolved oxygen, pH, turbidity, total ammonia, temperature, total phosphorus and total nitrogen are ecological measures to assess whether water quality is good enough for plant and animal health and human recreational use. Since desirable levels of ecological measures are variable of different habitats, criteria followed widely by Environment Waikato (http://www.ew.govt.nz/ourenvironment/water/ healthyrivers/ glossaryhr.htm) for good health and propagation of living organisms in river ecosystem have been referred in this report.

Dissolved oxygen is required for respiration by fish and other aquatic life. Water should be greater than 80 percent saturated with dissolved oxygen for the survival of aquatic plants and animals. In rivers Bhagirathi/ Ganga and their tributaries the dissolved oxygen level ranged between 7.7 and 19.85 mg/l.

The pH is a measure of the acidity or alkalinity of water. A very high or very low pH means that water can be toxic for aquatic life. The pH range that is suitable for aquatic plants and animals is 6.5 to 9.0. In rivers Bhagirathi/ Ganga and their tributaries, the pH ranged between 6.4 and 8.0 with minimum at Gomukh and maximum at Devprayag (sampling point No. 12) and Rishikesh (sampling point No. 16). The pH measured during the study period does not indicate any adverse impact on river Bhagirathi.

Turbidity is a measure of the murkiness of water, reflecting the amount of sediment in the water. High turbidity reduces the amount of light available to the plants and animals living in the water and thereby reduces the ability of plants to photosynthesize and makes it difficult for fish and other animals to see their prey. Turbidity should be less than 5 NTU (turbidity measurement scale) for water to support the plant growth. At all sampling stations the turbidity ranged between 0.2 and 3.8 NTU. In general, turbidity appears to be more in river Bhagirathi. It is clearly

Plate 5 : The water flows through melted ice on the course of Alaknanda river at downstream of Badrinath on May 21, 2003

Plate 6 : A stream, carrying melted ice, joins the river Alaknanda at downstream of Badrinath (May 2003)

visible at confluence point in Rudraprayag that the river Alaknanda carries more sediment than Mandakini (**Plate 7**), while the turbidity of Bhagirathi is still higher than Alaknanda as seen at the confluence in Devprayag (**Plate 8**)

Ammonia at higher levels are known to be toxic to aquatic life, especially to the fish. The level of total ammonia in water should be less than 0.888 mg/l to be safe for fish. Ammonia in waterways comes from either wastewaters, agricultural run-off or animal wastes (dung and urine). In the entire stretch of the river Bhagirathi, the ammonia levels of the water samples varied between 0.011 and 0.87 mg/l which are within the desired level. In general, ammonia level was comparatively more in epi-rhithron region. This might be attributed to inadequate biological activity specially that of nitrifiers which oxidise ammonia to nitrite and nitrate.

Phosphorus is a nutrient that encourages the growth of nuisance aquatic plants. These plants can choke up waterways and out-compete native species. High levels of phosphorus in water can be a result of either wastewater or, more often, runoff from agricultural land. Ideally, total phosphorus level in water is desired to be less than 0.04 mg/l to prevent the excessive growth of aquatic weeds. The total phosphorus level in the entire stretch of the study area ranged between 0.001 and 0.07 mg/l. At two sampling sites, phosphorus (0.07 mg/l) was found to be above the limit of 0.04 mg/l. This might be attributed to dissolution of phosphorous from the rocks containing phosphate (**Plate 9**).

Total nitrogen is a nutrient that can encourage the growth of nuisance aquatic plants. High levels of nitrogen in water can be due to runoff and leaching from agricultural land. Ideally, total nitrogen levels in water desired to be less than 0.5 mg/l to prevent the excessive growth of aquatic weeds. In the study area, the total nitrogen level ranged between 0.22 and 4.12 mg/l.

Physico-chemical and bacteriological characteristics of Ganga water samples as analyzed by different agencies, are presented in **Table 6**. Levels of total nitrogen, ammonical nitrogen and phosphorus were observed to be on the higher side. Open defecation and discharge of untreated animal and human wastes are primarily responsible for the observed higher values. The comparative studies of various water bodies are presented in **Table 7**.

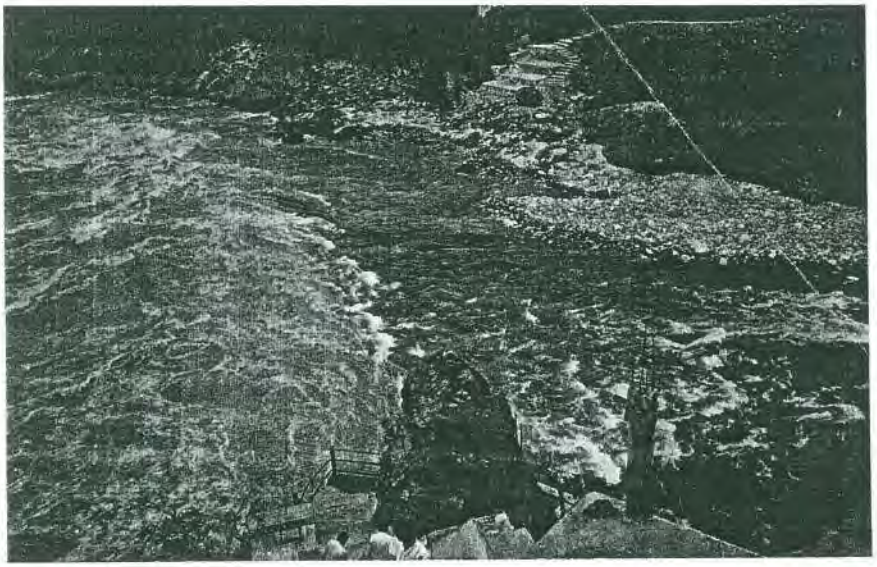


Plate 7 : Confluence of the rivers Alaknanda (turbid water) and Mandakini at Rudraprayag

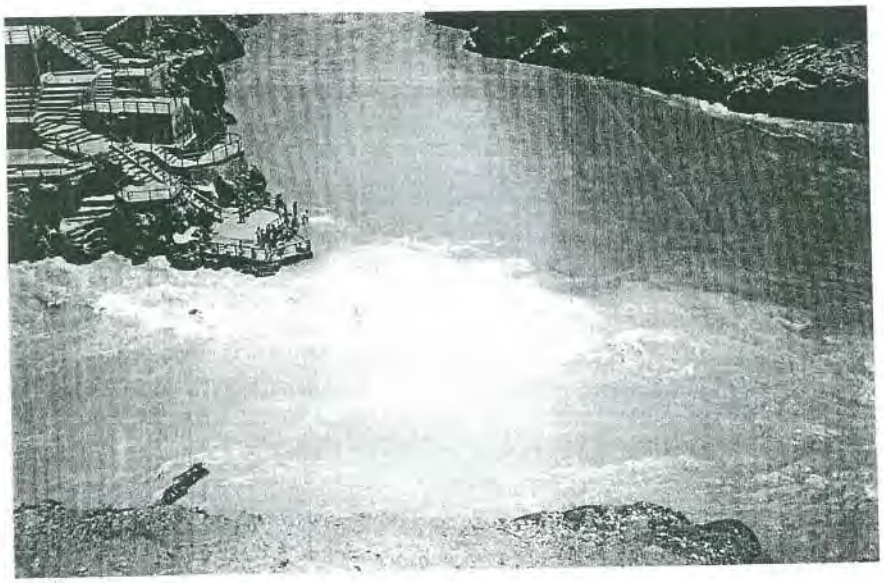


Plate 8 : Confluence of the rivers Alaknanda and Bhagirathi (higher turbidity) at Devprayag

Plate 9 : Construction of road leads to additional input of minerals and other pollutants to Ganga river

Table 6 : Select physico-chemical and bacteriological characteristics of Ganga water samples as reported by different agencies

(Data received from Tehri Hydro Development Corporation Limited, Rishikesh)

Parameters	CWC, Dehradun				BHEL, Haridwar				Present Study (NEERI)		
	Tehri (1995)	Tehri (1996)	Tehri (1997)	Tehri (1998)	Uttarkasi (D/S) Apr.98-Mar.99	Uttarkasi (U/S) Apr.98-Mar.99	Devprayag (D/S) Apr.98-Mar.99	Rishikesh (1999)	Tapovan to Tehri	Alaknanda to Devprayag	Rishikesh
pH	7.86-7.98	8.02-8.1	7.92-8.14	8.06-8.14	7.5-8.2	7.3-8.1	7.7-8.3	8.0	7.2-7.8	7.21-7.90	7.0-7.95
Conductivity (µS/cm)	102-182	124-182	118-172	142-148	75-167	80-171	90-177	173	61.00-133.60	97.0-118.0	98.0-114.0
Calcium (mg/l)	0.516-1.032	0.68-0.946	0.602-1.118	0.86-1.03	16-22.8	16-25.6	17-24	22.1	7.20-18.28	16.0-24.0	11.20-26.04
Magnesium (mg/l)	0.60-1.032	0.86-1.03	0.724-1.29	0.946-1.03	4-9	6.8-9	6-9	7.2	3.10-7.32	0.97-20.8	2.43-9.73
Potassium (mg/l)	ND	0.01-0.041	0.008-0.03	0.008-0.015	ND	ND	ND	ND	1.37-2.50	1.85-2.60	1.40-2.26
Chloride (mg/l)	0.085-0.169	0.141-0.225	0.141-0.23	0.169-0.225	1.5-4.7	3.0-4.5	3.0-4.2	2.6	1.75-5.00	1.75-3.00	1.0-3.34
Fluoride (mg/l)	0.007-0.011	0.013-0.017	0.009-0.011	0.011-0.013	ND	ND	ND	ND	0.09-0.56	0.19-0.30	98.0-124.0
Sulphate (mg/l)	0.094-0.156	0.08-0.135	0.047-0.156	0.135-0.167	13-24.5	13-25.3	13.3-21.0	21.5	16.49-51.53	11.73-23.47	9.23-47.23
Nitrate (mg/l)	0.006-0.019	0.01-0.02	0.01-0.02	0.011-0.013	0.17-1.4	0.2-1.4	0.4-1.05	0.69	0.17-0.46	0.23-0.53	0.23-0.74
Nitrite (mg/l)	ND	ND	0-0	ND	ND	ND	ND	ND	0.02-0.26	0.01-0.11	0.04-0.10
Phosphate (mg/l)	0.016-0.047	0.03-0.08	0.016-0.1	0.032-0.047	0.14-1.01	0.14-1.11	0.3-1.74	0.13	0.02-0.05	0.02-0.04	0.0-0.04
DO (mg/l)	7.82-8.15	8.05-8.82	8.2-9.02	8.49-8.72	8.3-10.6	8.1-10.3	8.3-10.4	8.5	12.83-16.84	13.65-17.25	7.70-12.32
BOD (mg/l)	1.12-1.24	1.08-1.26	1.04-1.2	1.03-1.06	0.5-1.2	0.6-1.3	0.9-1.5	1.1	<1	<1	<1
Total coliforms (Counts/100ml)	ND	ND	ND	ND	22-300	36-500	60-170	150	1 - 1730	700 - 23400	820 - 40000
Faecal coliforms (Counts/100ml)	ND	ND	ND	ND	11-220	16-300	22-90	70	2 – 500	182 - 6600	500 – 9000
Sodium (mg/l)	0.017-0.043	0.03-0.09	0.03-0.09	0.043-0.061	2.1-6	3.5-6	3.0-5.4	ND	0.34-0.88	2.75-3.25	2.20-4.93

ND : Not done

Table 7 : Comparative study of physicochemical characteristics of various water bodies

Parameters	Bhagirathi	Kaveri	Brahmini	Kadra reservoir	Antarctica		BBMB Project (University of Roorkee)		
					Zub lake	Glacier lake	Downstream of Bhakra	In the reservoir of Bhakra	Upstream of Bhakra
pH	7.2-7.8	8.17	7.44	7.0	5.1-6	4.6-6.0	7.46-7.59	8.0-8.32	7.4-7.57
DO (mg/l)	12.83-16.84	7.285	7.585	5.53	8.2-8.6	8.4-8.7	8.7-9.2	7.0-9.4	9.4-10.2
Temperature (^{0}C)	23.5	27.96	27.09	26.8	ND	ND	ND	ND	ND
Total solids	ND	1634.27	1610.7	72.6	ND	ND	ND	ND	ND
SS (mg/l)	24.6	287.2	331.46	ND	2.0-5.0	2.0-10.0	ND	ND	ND
Dissolved Solids (mg/l)	93.75	1206.74	ND	68.66	9.4-12.9	3.0-10.0	ND	ND	ND
COD (mg/l)	4.825	39.15	25.55	5.3	ND	ND	ND	ND	ND
BOD (mg/l)	<1	3.578	5.879	ND	ND	ND	ND	ND	ND
NO_2 (mg/l)	0.003-0.372	0.175	15.346	10.5	ND	ND	ND	ND	ND
NO_3 (mg/l)	0.002-0.653	8.52	21.30	ND	0.01-0.07	0.05-0.08	ND	ND	ND
PO_4-P (mg/l)	0.005-0.750	ND	ND	ND	ND	ND	0.20-0.26	0.46	ND
SO_4 (mg/l)	16.49-51.53	38.0157	ND	ND	1-4	8-9	20.0	11-17	18-35
Cl^- (mg/l)	ND	ND	ND	ND	ND	ND	10.7-14.2	10.2-14.4	16.0-17.8
Total hardness ($CaCO_3$) (mg/l)	74.7	850.88	83.769	36	ND	ND	ND	ND	ND
Total alkalinity	47.86	111.19	74.076	24	ND	ND	ND	ND	ND
Turbidity (NTU)	2.36	16.56	7.585	1.0	2.4-3.4	4.6	ND	ND	ND
Conductivity (µs/cm)	61.0-133.6	751.9	21.15	ND	18.6-24.04	8.2-10.6	177.8-178.5	151.8-178.5	121.3-262.0

ND : Not done

4.1.2 Metal composition of river water

Metals, such as cadmium, chromium, lead etc. were analysed from the water samples collected during the study period. All the heavy metal concentrations, except lead, are within the prescribed limits stipulated for drinking water standards (IS 10,500 - 1991). The range of values for lead are 0.002 and 0.37 mg/l. Occasionally lead concentrations were marginally exceeded the desired level at Gangotri and upstream of Uttarkashi (sampling stations 3,4 and 5). This might be attributed to higher levels of radioactive elements in epi-rhithron region. Lead is known to be daughter element of radioactive uranium. The levels of metal concentrations in the river water samples are presented in **Table 8**, while the average values are presented in **Table 9**.

4.1.3 Bacteriological Quality of River Water

Water samples from different rivers within the study area, were collected at different sampling points, i.e. at Tapovan (**Plate 10**), Gomukh (**Plate 11**), Gangotri, Uttarkashi, Tehri dam (**Plate 12**), Devprayag (**Plate 13**), Badrinath, Rudraprayag and Rishikesh. All these water samples were analysed for indicator bacteria i.e. total coliforms, faecal coliforms, *E. coli* and fecal streptococci and the results are reported in **Table 10**, while the average values are presented in **Table 11**. The Bhagirathi river, after confluence with Alaknanda river at Devprayag (Plate 8), flows further as a perennial River-Ganga.

Bhagirathi river water at Tapovan and Gomukh was found to be free from contamination as evident from the absence of indicator bacteria. The water samples collected from the upstream of Gangotri and further from Uttarkashi were found to be positive for indicator bacteria. The total coliforms were found to be less in upstream as compared to downstream water samples at these two sampling points indicating that the urban/ peri-urban stretch of the river became contaminated because of anthropogenic contribution and animal waste.

Bhagirathi river water samples at Gangotri, Uttarkashi, Tehri dam and other downstream locations were found to be positive for indicator bacteria. Total coliforms (TC) counts were found to be of increasing order from downstream of Gangotri (94, 127, 112, 64 and 22 CFU/100ml) to downstream of Rishikesh (10,000, 40,000, 40,000, 9,000 and 950 CFU/100ml) during all the five occasions of sampling. The

Table 8 : Metal Concentration at different Sampling Points of the Rivers/ Tributaries in the Study Area (September, 2002 to August, 2003)

Parameters	Date	Sampling station									
		1	2	3	4	5	6	7	8	9	10
Cadmium (mg/L)	24-25 Sept., 02	NS	BDL	NS	BDL	NS	BDL	BDL	NS	NS	BDL
	7-8 Oct., 02	NS	BDL	NS	BDL	NS	BDL	BDL	NS	BDL	NS
	23-24 Oct. 02	NS	BDL	NS	BDL	NS	BDL	BDL	BDL	BDL	BDL
	14-23 May, 03	0.001	0.002	BDL	0.007	0.005	0.003	0.004	0.003	0.008	0.009
	28-31 Aug., 03	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Chromium (mg/L)	24-25 Sept., 02	NS	0.001	NS	0.005	NS	0.023	0.005	NS	NS	BDL
	7-8 Oct., 02	NS	0.009	NS	BDL	NS	0.042	BDL	NS	BDL	NS
	23-24 Oct. 02	NS	0.045	NS	0.036	NS	BDL	BDL	BDL	BDL	BDL
	14-23 May, 03	0.004	0.032	BDL	0.02	0.016	0.037	0.012	0.004	0.005	0.029
	28-31 Aug., 03	BDL	0.010	BDL	BDL	BDL	0.005	0.002	0.005	0.005	0.023
Lead (mg/L)	24-25 Sept., 02	NS	0.004	NS	0.051	NS	0.025	BDL	NS	NS	0.003
	7-8 Oct., 02	NS	0.034	NS	BDL	NS	BDL	BDL	NS	0.008	NS
	23-24 Oct. 02	NS	BDL	NS	BDL	NS	0.05	0.009	0.048	BDL	0.04
	14-23 May, 03	0.030	0.013	0.370	0.156	0.111	0.037	BDL	0.104	0.092	0.016
	28-31 Aug., 03	BDL	0.025	0.004	BDL	BDL	0.015	0.049	0.026	0.035	0.022
Copper (mg/L)	24-25 Sept., 02	NS	0.012	NS	0.023	NS	0.006	BDL	NS	NS	0.040
	7-8 Oct., 02	NS	0.014	NS	BDL	NS	0.004	BDL	NS	0.09	NS
	23-24 Oct. 02	NS	BDL	NS	BDL	NS	BDL	0.002	BDL	BDL	BDL
	14-23 May, 03	BDL	BDL	BDL	0.028	BDL	BDL	BDL	BDL	BDL	BDL
	28-31 Aug., 03	0.035	BDL	BDL	BDL	BDL	BDL	BDL	0.006	BDL	0.006

NS : Not sampled; BDL : Below detectable limit

1. Tapovan; 2. Gomukh; 3. Gangotri upstream (u.s.); 4. Gangotri downstream (d.s.); 5. Uttarkashi u.s.; 6. Uttarkashi d.s.; 7. Tehri (u.s. of Bhagirathi); 8. Tehri (u.s. of Bhilangana); 9. Tehri (d.s. of Bhagirathi); 10. Devprayag, before confluence (Bhagirathi)

Table 8 (contd...)

Parameters	Date	Sampling station									
		1	2	3	4	5	6	7	8	9	10
Strontium (mg/L)	24-25 Sept., 02	NS	0.034	NS	0.00	NS	0.01	0.018	NS	NS	0.041
	7-8 Oct., 02	NS	0.009	NS	0.04	NS	0.020	BDL	NS	0.05	NS
	23-24 Oct. 02	NS	0.072	NS	BDL	NS	BDL	0.63	0.023	0.047	0.052
	14-23 May, 03	0.001	0.035	0.029	0.029	0.045	0.040	0.049	0.021	0.040	0.185
	28-31 Aug., 03	0.005	0.033	0.016	0.034	0.031	0.025	0.029	0.019	0.018	0.038
Cobalt (mg/L)	24-25 Sept., 02	NS	0.003	NS	0.001	NS	BDL	0.003	NS	NS	BDL
	7-8 Oct., 02	NS	0.025	NS	0.010	NS	0.002	0.001	NS	BDL	NS
	23-24 Oct. 02	NS	0.021	NS	0.003	NS	BDL	BDL	0.002	BDL	0.001
	14-23 May, 03	0.001	0.002	BDL	0.004	0.002	0.003	0.010	0.003	0.008	0.010
	28-31 Aug., 03	BDL	0.003	BDL	BDL	BDL	0.002	BDL	BDL	0.001	BDL
Manganese (mg/L)	24-25 Sept., 02	NS	0.031	NS	0.020	NS	BDL	0.080	NS	NS	BDL
	7-8 Oct., 02	NS	0.69	NS	BDL	NS	0.521	0.116	NS	0.018	NS
	23-24 Oct. 02	NS	0.006	NS	BDL	NS	BDL	BDL	BDL	BDL	0.069
	14-23 May, 03	0.008	0.235	0.208	0.189	0.005	0.014	0.019	0.004	0.005	0.017
	28-31 Aug., 03	0.079	0.094	0.057	0.031	BDL	BDL	0.042	0.049	0.006	0.034
Iron (mg/L)	24-25 Sept., 02	NS	0.028	NS	0.150	NS	0.200	0.080	NS	NS	0.080
	7-8 Oct., 02	NS	0.285	NS	BDL	NS	BDL	BDL	NS	0.048	NS
	23-24 Oct. 02	NS	0.821	NS	0.338	NS	BDL	0.08	0.0005	BDL	0.105
	14-23 May, 03	0.022	0.069	0.146	0.240	BDL	0.012	0.028	0.013	BDL	BDL
	28-31 Aug., 03	0.001	0.88	0.060	0.029	BDL	BDL	0.058	BDL	0.116	0.12
Aluminium (mg/L)	24-25 Sept., 02	NS	0.001	NS	0.021	NS	0.003	0.016	NS	NS	BDL
	7-8 Oct., 02	NS	2.97	NS	BDL	NS	1.196	BDL	NS	0.133	NS
	23-24 Oct. 02	NS	0.008	NS	BDL	NS	0.021	BDL	0.008	BDL	0.001
	14-23 May, 03	BDL	0.203	0.414	0.414	BDL	BDL	0.236	BDL	0.017	0.003
	28-31 Aug., 03	0.003	0.033	0.003	0.025	0.081	0.008	1.003	0.004	0.006	1.533

NS : Not sampled; BDL : Below detectable limit

1. Tapovan; 2. Gomukh; 3. Gangotri upstream (u.s.); 4. Gangotri downstream (d.s.); 5. Uttarkashi u.s.; 6. Uttarkashi d.s.; 7. Tehri (u.s. of Bhagirathi); 8. Tehri (u.s. of Bhilangana); 9. Tehri (d.s. of Bhagirathi); 10. Devprayag, before confluence (Bhagirathi)

Table 8 (contd...)

Parameters	Date	Sampling station									
		1	2	3	4	5	6	7	8	9	10
Nickel (mg/L)	24-25 Sept., 02	NS	0.007	NS	BDL	NS	0.024	BDL	NS	NS	0.011
	7-8 Oct., 02	NS	BDL	NS	0.054	NS	0.004	0.015	NS	0.003	NS
	23-24 Oct. 02	NS	0.057	NS	BDL	NS	0.01	0.006	BDL	0.007	0.025
	14-23 May, 03	0.006	0.023	0.051	0.023	BDL	0.006	0.004	0.008	0.008	0.031
	28-31 Aug., 03	0.013	0.007	0.013	0.005	0.007	BDL	0.015	0.005	0.011	0.042
Zinc (mg/L)	24-25 Sept., 02	NS	BDL	NS	BDL	NS	BDL	BDL	NS	NS	BDL
	7-8 Oct., 02	NS	0.003	NS	BDL	NS	0.001	BDL	NS	0.002	NS
	23-24 Oct. 02	NS	0.001	NS	0.005	NS	BDL	1.137	0.004	0.001	BDL
	14-23 May, 03	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	28-31 Aug., 03	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Arsenic (mg/L)	24-25 Sept., 02	NS	0.013	NS	BDL	NS	BDL	0.003	NS	NS	BDL
	7-8 Oct., 02	NS	0.0096	NS	BDL	NS	0.0041	BDL	NS	0.011	NS
	23-24 Oct. 02	NS	0.0018	NS	0.0092	NS	BDL	0.009	BDL	0.0043	0.092
	14-23 May, 03	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	28-31 Aug., 03	0.007	0.013	0.004	0.001	BDL	BDL	0.004	0.004	0.001	0.020

NS : Not sampled; BDL : Below detectable limit

1. Tapovan; 2. Gomukh; 3. Gangotri upstream (u.s.); 4. Gangotri downstream (d.s.); 5. Uttarkashi u.s.; 6. Uttarkashi d.s.; 7. Tehri (u.s. of Bhagirathi); 8. Tehri (u.s. of Bhilangana); 9. Tehri (d.s. of Bhagirathi); 10. Devprayag, before confluence (Bhagirathi)

Table 8 (contd...)

Parameters	Date	Sampling station									
		11	12	13	14	15	16	17	18	19	20
Cadmium (mg/L)	24-25 Sept., 02	NS	BDL	NS	NS	NS	BDL	NS	NS	NS	NS
	7-8 Oct., 02	BDL	BDL	NS	NS	NS	BDL	NS	NS	NS	NS
	23-24 Oct. 02	BDL	BDL	NS	NS	NS	BDL	NS	NS	NS	NS
	14-23 May, 03	0.005	0.002	0.005	0.001	BDL	0.009	0.019	0.009	0.003	0.007
	28-31 Aug., 03	BDL	BDL	BDL	BDL	BDL	BDL	NS	BDL	NS	NS
Chromium (mg/L)	24-25 Sept., 02	NS	0.006	NS	NS	NS	0.003	NS	NS	NS	NS
	7-8 Oct., 02	0.006	BDL	NS	NS	NS	0.034	NS	NS	NS	NS
	23-24 Oct. 02	BDL	0.02	NS	NS	NS	0.026	NS	NS	NS	NS
	14-23 May, 03	0.005	BDL	BDL	BDL	BDL	0.018	0.016	0.020	0.019	0.029
	28-31 Aug., 03	0.003	0.012	0.006	0.010	BDL	BDL	NS	0.003	NS	NS
Lead (mg/L)	24-25 Sept., 02	NS	0.023	NS	NS	NS	0.040	NS	NS	NS	NS
	7-8 Oct., 02	0.009	0.007	NS	NS	NS	BDL	NS	NS	NS	NS
	23-24 Oct. 02	0.002	BDL	NS	NS	NS	0.007	NS	NS	NS	NS
	14-23 May, 03	0.095	0.004	BDL	0.045	0.010	0.109	0.046	0.070	0.183	0.136
	28-31 Aug., 03	0.043	0.033	0.040	0.002	0.015	0.031	NS	0.025	NS	NS
Copper (mg/L)	24-25 Sept., 02	NS	0.032	NS	NS	NS	BDL	NS	NS	NS	NS
	7-8 Oct., 02	BDL	BDL	NS	NS	NS	0.006	NS	NS	NS	NS
	23-24 Oct. 02	BDL	BDL	NS	NS	NS	BDL	NS	NS	NS	NS
	14-23 May, 03	BDL	BDL	BDL	BDL	0.042	BDL	BDL	BDL	BDL	BDL
	28-31 Aug., 03	BDL	BDL	0.074	0.034	0.229	BDL	NS	BDL	NS	NS

NS : Not sampled; BDL : Below detectable limit

11. Devprayag, before confluence (Alaknanda); 12. Devprayag, after confluence (Ganga), right bank; 13. Devprayag, after confluence (Ganga), middle; 14. Devprayag, after confluence (Ganga), left bank; 15. Rishikesh u.s.; 16. Rishikesh d.s. (right bank); 17. Rishikesh d.s. (middle); 18. Rishikesh d.s (left bank); 19. Alaknanda at Badrinath; 20. Mandakini at Rudraprayag

Table 8 (contd...)

Parameters	Date	Sampling station										
		11	12	13	14	15	16	17	18	19	20	
Strontium (mg/L)	24-25 Sept., 02	NS	BDL	NS	NS	NS	0.007	NS	NS	NS	NS	
	7-8 Oct., 02	0.049	0.058	NS	NS	NS	BDL	NS	NS	NS	NS	
	23-24 Oct. 02	0.048	BDL	NS	NS	NS	0.04	NS	NS	NS	NS	
	14-23 May, 03	0.081	0.106	0.026	0.033	0.035	0.032	0.032	0.031	0.011	0.045	
	28-31 Aug., 03	0.045	0.041	0.026	0.038	0.044	0.029	NS	0.043	NS	NS	
Cobalt (mg/L)	24-25 Sept., 02	NS	0.001	NS	NS	NS	0.004	NS	NS	NS	NS	
	7-8 Oct., 02	0.003	BDL	NS	NS	NS	0.002	NS	NS	NS	NS	
	23-24 Oct. 02	0.003	0.005	NS	NS	NS	0.001	NS	NS	NS	NS	
	14-23 May, 03	0.004	0.006	0.003	BDL	BDL	BDL	BDL	BDL	0.076	BDL	
	28-31 Aug., 03	BDL	BDL	0.002	0.001	0.003	0.002	NS	BDL	NS	NS	
Manganese (mg/L)	24-25 Sept., 02	NS	0.020	NS	NS	NS	BDL	NS	NS	NS	NS	
	7-8 Oct., 02	0.001	0.001	NS	NS	NS	0.004	NS	NS	NS	NS	
	23-24 Oct. 02	BDL	BDL	NS	NS	NS	BDL	NS	NS	NS	NS	
	14-23 May, 03	0.007	0.003	BDL	BDL	BDL	BDL	0.006	BDL	0.119	BDL	
	28-31 Aug., 03	BDL	BDL	0.071	0.062	0.007	0.013	NS	BDL	NS	NS	
Iron (mg/L)	24-25 Sept., 02	NS	0.019	NS	NS	NS	0.002	NS	NS	NS	NS	
	7-8 Oct., 02	0.091	BDL	NS	NS	NS	0.08	NS	NS	NS	NS	
	23-24 Oct. 02	BDL	0.058	NS	NS	NS	BDL	NS	NS	NS	NS	
	14-23 May, 03	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.391	0.087	
	28-31 Aug., 03	0.051	BDL	0.128	0.150	0.268	0.019	NS	BDL	NS	NS	
Aluminium (mg/L)	24-25 Sept., 02	NS	BDL	NS	NS	NS	0.010	NS	NS	NS	NS	
	7-8 Oct., 02	0.053	0.055	NS	NS	NS	0.080	NS	NS	NS	NS	
	23-24 Oct. 02	BDL	0.002	NS	NS	NS	0.002	NS	NS	NS	NS	
	14-23 May, 03	BDL	1.21	BDL	BDL	BDL	BDL	BDL	BDL	0.998	BDL	
	28-31 Aug., 03	0.008	BDL	0.002	0.003	0.003	0.002	NS	BDL	NS	NS	

NS : Not sampled; BDL : Below detectable limit

11. Devprayag, before confluence (Alaknanda); 12. Devprayag, after confluence (Ganga), right bank; 13. Devprayag, after confluence (Ganga), middle; 14. Devprayag, after confluence (Ganga), left bank; 15. Rishikesh u.s.; 16. Rishikesh d.s. (right bank); 17. Rishikesh d.s. (middle); 18. Rishikesh d.s (left bank); 19. Alaknanda at Badrinath; 20. Mandakini at Rudraprayag

Table 8 (contd...)

Parameters	Date	Sampling station									
		11	12	13	14	15	16	17	18	19	20
Nickel (mg/L)	24-25 Sept., 02	NS	0.012	NS	NS	NS	0.006	NS	NS	NS	NS
	7-8 Oct., 02	0.046	0.063	NS	NS	NS	0.003	NS	NS	NS	NS
	23-24 Oct. 02	BDL	0.004	NS	NS	NS	0.111	NS	NS	NS	NS
	14-23 May, 03	0.016	0.009	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	28-31 Aug., 03	BDL	0.001	BDL	0.024	BDL	BDL	NS	BDL	NS	NS
Zinc (mg/L)	24-25 Sept., 02	NS	BDL	NS	NS	NS	BDL	NS	NS	NS	NS
	7-8 Oct., 02	0.005	BDL	NS	NS	NS	0.005	NS	NS	NS	NS
	23-24 Oct. 02	0.004	0.032	NS	NS	NS	BDL	NS	NS	NS	NS
	14-23 May, 03	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	28-31 Aug., 03	BDL	BDL	BDL	BDL	BDL	BDL	NS	BDL	NS	NS
Arsenic (mg/L)	24-25 Sept., 02	NS	0.019	NS	NS	NS	0.002	NS	NS	NS	NS
	7-8 Oct., 02	0.0198	0.012	NS	NS	NS	0.0083	NS	NS	NS	NS
	23-24 Oct. 02	BDL	BDL	NS	NS	NS	0.0083	NS	NS	NS	NS
	14-23 May, 03	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	28-31 Aug., 03	BDL	0.004	0.003	0.014	BDL	BDL	NS	BDL	NS	NS

NS : Not sampled; BDL : Below detectable limit

11. Devprayag, before confluence (Alaknanda); 12. Devprayag, after confluence (Ganga), right bank; 13. Devprayag, after confluence (Ganga), middle; 14. Devprayag, after confluence (Ganga), left bank; 15. Rishikesh u.s.; 16. Rishikesh d.s. (right bank); 17. Rishikesh d.s. (middle); 18. Rishikesh d.s (left bank); 19. Alaknanda at Badrinath; 20. Mandakini at Rudraprayag

Table 9 : Average Metal Concentration at different Sampling Points of the Rivers/ Tributaries in the Study Area (September, 2002 to August, 2003)

Parameters	Sampling station									
	1	2	3	4	5	6	7	8	9	10
Cadmium (mg/L)	0.001	0.002	BDL	0.007	0.005	0.003	0.004	0.003	0.008	0.009
Chromium (mg/L)	0.004	0.019 (±0.018)	BDL	0.020 (±0.015)	0.016	0.027 (±0.016)	0.006 (±0.005)	0.005	0.005	0.026
Lead (mg/L)	0.030	0.044 (±0.048)	0.187	0.104 (±0.074)	0.111	0.032 (±0.015)	0.029 (±0.028)	0.059	0.045	0.020
Copper (mg/L)	0.035	0.013 (±0.001)	BDL	0.025 (±0.003)	BDL	0.005 (±0.001)	0.002	0.006	0.090	0.023
Strontium (mg/L)	0.003	0.037 (±0.023)	0.022	0.026 (±0.018)	0.038	0.024 (±0.012)	0.181 (±0.299)	0.021	0.039	0.079
Cobalt (mg/L)	0.001	0.011 (±0.011)	BDL	0.004 (±0.003)	0.002	0.002 (±0.001)	0.005 (±0.004)	0.002	0.004	BDL
Manganese (mg/L)	0.043	0.211 (±0.282)	0.132	0.080 (±0.094)	0.005	0.267 (±0.358)	0.064 (±0.043)	0.026	0.009	0.040
Iron (mg/L)	0.011	0.417 (±0.408)	0.103	0.189 (±0.131)	BDL	0.106 (±0.133)	0.061 (±0.024)	0.007	0.082	0.102
Aluminium (mg/L)	0.003	0.643 (±1.303)	0.208	0.153 (±0.225)	0.081	0.307 (±0.592)	0.418 (±0.518)	0.006	0.052	0.512
Nickel (mg/L)	0.009	0.023 (±0.023)	0.032	0.027 (±0.025)	0.007	0.011 (±0.009)	0.010 (±0.005)	0.006	0.007	0.027
Zinc (mg/L)	BDL	0.002 (±0.001)	BDL	0.005	BDL	0.001	1.137	0.004	0.001	BDL
Arsenic (mg/L)	0.007	0.009 (±0.005)	0.004	0.005 (±0.005)	BDL	0.004	0.005 0.003	0.004	0.005 (±0.005)	BDL

BDL : Below detectable limit

Note : Values in parenthesis are standard deviation of minimum 5 sets of data

1. Tapovan; 2. Gomukh; 3. Gangotri upstream (u.s.); 4. Gangotri downstream (d.s.); 5. Uttarkashi u.s.; 6. Uttarkashi d.s.; 7. Tehri (u.s. of Bhagirathi); 8. Tehri (u.s. of Bhilangana); 9. Tehri (d.s. of Bhagirathi); 10. Devprayag, before confluence (Bhagirathi)

Table 9 (contd...)

Parameters	Sampling station									
	11	12	13	14	15	16	17	18	19	20
Cadmium (mg/L)	0.005	0.002	0.005	0.001	BDL	0.009	0.019	0.009	0.003	0.007
Chromium (mg/L)	0.005	0.013 (±0.007)	0.006	0.010	BDL	0.020 (±0.013)	0.016	0.011	0.019	0.029
Lead (mg/L)	0.037	0.017 (±0.014)	0.040	0.023	0.012	0.047 (±0.044)	0.046	0.047	0.183	0.136
Copper (mg/L)	BDL	0.032	0.074	0.034	0.135	0.006	BDL	BDL	BDL	BDL
Strontium (mg/L)	0.056	0.068 (±0.034)	0.026	0.035	0.039	0.027 0.014	0.032	0.037	0.011	0.045
Cobalt (mg/L)	0.003	0.004 (±0.003)	0.002	0.001	0.003	0.002 (±0.001)	BDL	BDL	0.076	BDL
Manganese (mg/L)	0.004	0.008 (±0.010)	0.071	0.062	0.007	0.008 (±0.006)	0.006	BDL	0.119	BDL
Iron (mg/L)	0.071	0.038 (±0.027)	0.128	0.150	0.268	0.033 (±0.041)	BDL	BDL	0.391	0.087
Aluminium (mg/L)	0.030	0.422 (±0.683)	0.002	0.003	0.003	0.023 (±0.037)	BDL	BDL	0.998	BDL
Nickel (mg/L)	0.031	0.017 (±0.025)	BDL	0.024	BDL	0.040 (±0.061)	BDL	BDL	BDL	BDL
Zinc (mg/L)	0.004	0.032	BDL	BDL	BDL	0.005	BDL	BDL	BDL	BDL
Arsenic (mg/L)	0.019	0.012 (±0.007)	0.003	0.014	BDL	0.006 (±0.004)	BDL	BDL	BDL	BDL

BDL : Below detectable limit

Note : Values in parenthesis are standard deviation of minimum 5 sets of data

11. Devprayag, before confluence (Alaknanda); 12. Devprayag, after confluence (Ganga), right bank; 13. Devprayag, after confluence (Ganga), middle; 14. Devprayag, after confluence (Ganga), left bank; 15. Rishikesh u.s.; 16. Rishikesh d.s. (right bank); 17. Rishikesh d.s. (middle); 18. Rishikesh d.s (left bank); 19. Alaknanda at Badrinath; 20. Mandakini at Rudraprayag

Table 10 : Bacteriological Quality of Ganga River Water

CFU/100 ml

Sr. no.	Sampling location	24-25 Sept 02				7-8 Oct., 2002				23-24 Oct., 2002				14-23 May, 2003				28-31 August, 2003			
		TC	FC	EC	FS	TC	FC	EC	FS	TC	FC	EC	FS	TC	FC	EC	FS	TC	FC	EC	FS
1	Tapovan	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0	0	0	0	0	0	0	0
2	Gomukh	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
3	Gangotri u.s.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	7	6	2	9	9	2	0	2
4	Gangotri d.s.	94	21	0	18	127	70	1	20	112	32	0	22	64	32	0	11	22	13	1	4
5	Uttarkashi u.s.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	600	200	40	60	100	40	20	10
6	Uttarkashi d.s.	530	63	47	128	1060	383	210	310	1730	283	34	125	1000	320	200	130	240	90	30	30
7	Tehri u.s. (Bhagirathi)	1370	110	68	318	1590	420	360	320	870	350	100	350	1700	500	340	100	700	200	80	50
8	Tehri u.s. (Bhilangana)	NS	NS	NS	NS	NS	NS	NS	NS	200	106	13	66	800	300	240	120	450	300	60	40
9	Tehri d.s. (Bhagirathi)	NS	NS	NS	NS	736	244	109	300	690	290	77	180	1200	360	280	60	600	300	70	50
10	Devprayag before confluence (Bhagirathi)	1200	182	110	640	5400	2850	490	1900	2000	850	180	804	2200	600	200	300	700	250	140	70
11	Devprayag before confluence (Alaknanda)	NS	NS	NS	NS	23400	6600	3700	2550	4930	3530	840	2180	2000	1000	340	200	850	280	210	120
12	Devprayag after confluence (Ganga) right bank	6200	3150	890	1570	8400	3550	290	1420	7300	2650	239	1270	1000	800	300	140	700	430	200	110

TC : Total coliforms; FC : Faecal coliforms; EC : *E. coli*; FS : Faecal streptococci
NS : Not sampled

Table 10 (contd...)

3

Sr. no.	Sampling locations	24-25 Sept 02				7-8 Oct., 2002				23-24 Oct., 2002				14-23 May, 2003				28-31 August, 2003			
		TC	FC	EC	FS	TC	FC	EC	FS	TC	FC	EC	FS	TC	FC	EC	FS	TC	FC	EC	FS
13	Devprayag after confluence (Ganga) Midstream	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1100	940	280	120	850	480	280	100
14	Devprayag after confluence (Ganga) left bank	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	2100	720	300	260	800	560	320	120
15	Rishikesh u.s.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1600	500	420	100	820	510	270	120
16	Rishikesh d.s. (right bank)	10000	800	530	2900	40000	7300	4200	3020	40000	9000	3100	2810	9000	1000	900	500	950	550	320	240
17	Rishikesh d.s. (midstream)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	4000	1200	600	400	NS	NS	NS	NS
18	Rishikesh d.s. (left bank)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	7000	1400	800	400	1200	800	300	200
19.	Alaknanda (Badrinath)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	600	300	240	200	NS	NS	NS	NS
20.	Mandakini (Rudraprayag)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	800	400	320	300	NS	NS	NS	NS

TC : Total coliforms; FC : Faecal coliforms; EC : *E. coli*; FS : Faecal streptococci

NS : Not sampled

Table 11 : Average Bacteriological quality of Ganga river water

(CFU/100 ml)

Sr. no.	Sampling locations	Total coliforms	Faecal coliforms	*E. coli*	Faecal streptococci
1	Tapovan	Nil	Nil	Nil	Nil
2	Gomukh	0.20 (±0.45)	Nil	Nil	Nil
3	Gangotri u.s.	8.00	3.00	2.00	5.50
4	Gangotri d.s.	83.80 (±41.76)	33.60 (±21.87)	1.00	15.00 (±7.42)
5	Uttarkashi u.s.	350.00	120.00	30.00	35.00
6	Uttarkashi d.s.	912.00 (±569.27)	227.80 (±142.98)	104.20 (±92.29)	144.60 (±101.68)
7	Tehri u.s. (Bhagirathi)	1246.00 (±441.39)	316.00 (±159.46)	189.60 (±147.04)	227.60 (±140.99)
8	Tehri u.s. (Bhilangana)	483.33	235.33	104.33	75.33
9	Tehri d.s. (Bhagirathi)	806.50	298.50	134.00	147.50
10	Devprayag before confluence (Bhagirathi)	2300.00 (±1835.76)	946.40 (±1097.98)	224.00 (±152.74)	742.80 (±707.48)
11	Devprayag before confluence (Alaknanda)	7796.00	2852.50	1272.50	1262.50
12	Devprayag after confluence (Ganga) right bank	4720.00 (±3618.98)	2116.00 (±1412.89)	383.80	902.00 (±717.26)
13	Devprayag after confluence (Ganga) midstream	975.00	710.00	280.00	110.00
14	Devprayag after confluence (Ganga) left bank	1450.00	640.00	310.00	190.00
15	Rishikesh u.s.	1210.00	505.00	345.00	110.00
16	Rishikesh d.s. (right bank)	19990.00 (±18600.42)	3730.00 (±4082.54)	1810.00 (±1736.57)	1894.00 (±1396.23)
17	Rishikesh d.s. (midstream)	4000.00	1200.00	600.00	400.00
18	Rishikesh d.s. (left bank)	4100.00	1100.00	550.00	300.00
19.	Alaknanda (Badrinath)	600.00	300.00	240.00	200.00
20.	Mandakini (Rudraprayag)	800.00	400.00	320.00	300.00

Note : Values in parenthesis are standard deviation of minimum 5 sets of data

Plate 10 : NEERI team members on way to Tapovan, as visible at a distant place, for sample collection in August 2003

Plate 11: Bhagirathi river water is being filtered through specific net for collection of zooplankton at Gomukh

Plate 12 : Collection of water samples from Bhilangana river at Tehri, prior to confluence with Bhagirathi

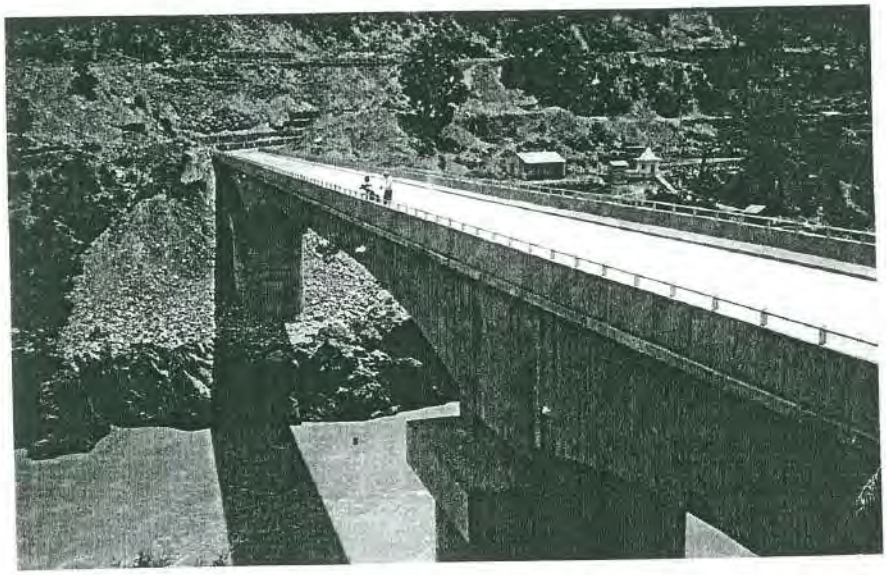


Plate 13 : Sampling of water from the river Ganga at downstream (middle) of Devprayag (May 2003)

Bhilangana river joins the Bhagirathi river at Tehri (**Plate 14**). The average TC count of Bhilangana river water samples was 484 CFU/100 ml and the water sample collected at downstream of the confluence with Bhagirathi showed an average TC count of 807 CFU/100 ml. Total coliform count of Ganga river increases as it flows downwards. The Alaknanda river water was found to be highly contaminated. The total coliform, fecal coliform, *E. coli*, and fecal streptococci counts ranged from 850 to 23400, 280 to 6600, 210 to 3700 and 120 to 2550 CFU/100 ml respectively. This might be due to the fact that the river water was getting contaminated with sewage generated from the towns situated on the banks of this river. The water samples of Ganga river at Rishikesh were also found to be contaminated due to anthropogenic activities (**Plate 15**) and the total coliform, fecal coliform, *E. coli*, and fecal streptococci counts ranged from 950 to 40,000, 550 to 9,000, 320 to 4200 and 240 to 3020 CFU/100 ml respectively during the period of study.

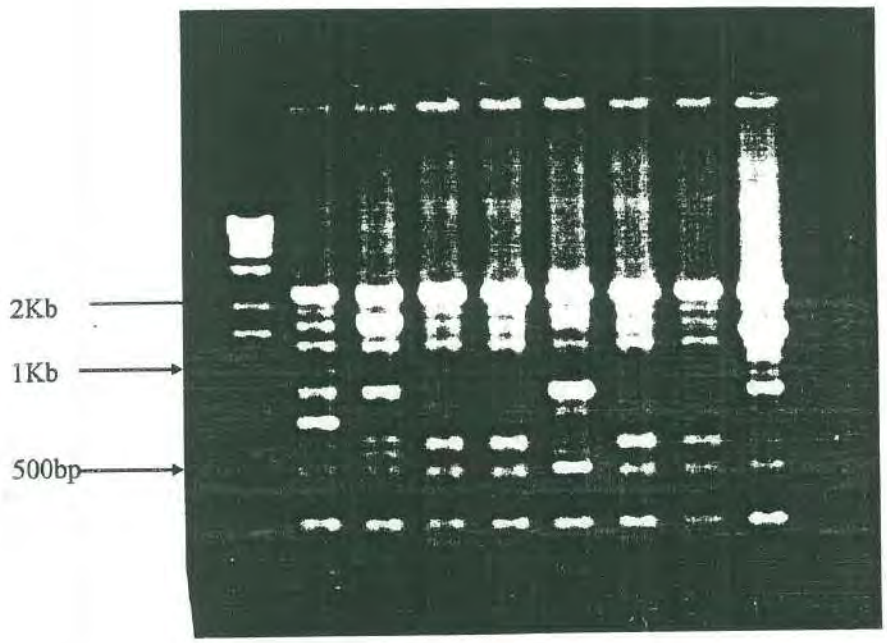
Bacteriological quality of river water in terms of coliform bacteria (indicators of faecal pollution) was studied and it was found that the river water was free from faecal coliform in Tapovan, Gomukh and at upstream of Gangotri. The river water from these three locations can be used as such for unpiped water supplies (WHO, 1984).The bacteriological standard by WHO, for drinking water is referred in Annexures II.

RAPD Analysis of *E. coli* strains

Different strains of *E. coli* were randomly isolated from water and sediment samples collected from different rivers in the study area. Additionally, one *E. coli* strain was isolated from a sewage sample collected at Nagpur. These isolates were analysed to identify the genetically different strains of *E. coli* by using the technique of Randomly Amplified Polymorphic DNA (RAPD). RAPD was performed on 8 isolated *E. coli* cultures. Polymerase Chain Reaction (PCR) primer was used randomly to give a chance for amplifying several different regions of the genome. The result was a set of different sized amplified bands of DNA. All samples were electrophoresed on 2% agarose gel. The gel was observed under U.V. transilluminator by using ethidium bromide stain. The obtained RAPD pattern is shown in **Plate 16** which depicts Lane 1 as the standard for 1 kb ladder, while lanes 2 through 9 show the amplified patterns of various *E. coli* strains. **RAPD pattern shown in the plate depicts five genetically different strains of *E. coli*. Lane Nos. 2, 3, 6, and 9 are genetically different *E. coli* strains, while 4, 5, 7 and 8**

Plate 14 : A broad view of the confluence of the rivers Bhilangana and Bhagirathi at upstream of Tehri dam (May 2003)

Plate 15 : Anthropogenic activities and sampling of water from right bank of the river Ganga at Rishikesh



Lane 1, standard 1kb ladder; Lanes 2 to 9 show amplification pattern of various E.coli strains using RAPD primer. The strains were collected from Uttarkashi sediment, Tehri Dam- upstream, Tehri Dam- downstream, Devprayag, Uttarkashi, Nagpur sewage, Rishikesh, and Tehri Dam Bhilangana river respectively.

Plate 16 : RAPD Analysis of *E.coli* Strains Collected at Different Sources

lane samples are similar, but belong to another strain. The genetically different strains were used as host cultures for coliphage detection.

4.1.4 Water Quality Index Study

Water Quality Index (WQI) study of Bhagirathi water samples was carried out using the protocol of National Sanitation Foundation (1970). WQI was used to compare the water quality between different stretches of the river Bhagirathi (**Table 12**). WQI is based on 9 parameters, viz. DO, pH, BOD, temperature, total phosphorus (as P), nitrate (NO_3-), turbidity, total solids and fecal coliforms.

According to the WQI, the water quality at Tapovan was found to be the best with an index value of 81.29, followed by Gomukh (80.01), both of which fall under good index range. At Gangotri u.s., Gangotri d.s., Uttarkashi u.s., and Uttarkashi d.s. the WQI was found to be good. The WQI was found to be as medium at Tehri u.s. (Bhagirathi), Tehri u.s. (Bhilangana), Devprayag before confluence (Alaknanda), Devprayag after confluence with Bhagirathi, i.e. in Ganga (right bank), Devprayag after confluence Ganga (Midstream), Devprayag after confluence Ganga (left bank), Rishikesh u.s., Rishikesh d.s. (right bank) and Alaknanda at Badrinath. The sampling sites viz. Tehri (d.s. of Bhagirathi), Devprayag before confluence (Bhagirathi), Rishikesh d.s. (left bank) and Mandakini at Rudraprayag were all found to have good index range of water quality indices (Table 12).

An exercise was conducted by eliminating fecal coliforms and redetermining WQI after necessary normalization. It could be seen that fecal coliforms counts in the river water sample have a profound influence on WQI. The coliform density can be reduced by controlling allochthonous addition of coliforms to the river water through animal and human wastes and thereby WQI could be substantially improved.

Based on the irrigation water quality classification, water quality of all the sites of the entire stretch was determined and found to fall under category C_1S_1. The category C_1 specifies low salinity water and can be used for irrigating most of the crops in all soil types. The electrical conductivity was observed to be 250 μmhos/cm which indicates lesser chance of development of saline conditions.

Table 12 : Water Quality Index of River Water Samples

Sampling station	Description	WQI*	Interpretation	No. of sets
1	Tapovan	81.29	Good	Two
2	Gomukh	80.01	Good	Five
3	Gangotri upstream (u.s.)	76.72	Good	Two
4	Gangotri downstream (d.s.)	77.91	Good	Five
5	Uttarkashi u.s.	71.93	Good	Two
6	Uttarkashi d.s.	72.73	Good	Five
7	Tehri (u.s. of Bhagirathi)	69.42	Medium	Five
8	Tehri (u.s. of Bhilangana)	68.8	Medium	Three
9	Tehri (d.s. of Bhagirathi)	70.93	Good	Four
10	Devprayag, before confluence (Bhagirathi)	70.03	Good	Four
11	Devprayag, before confluence (Alaknanda)	69.79	Medium	Four
12	Devprayag, after confluence (Ganga), right bank	67.38	Medium	Five
13	Devprayag, after confluence (Ganga), midstream	69.19	Medium	Two
14	Devprayag, after confluence (Ganga), left bank	68.21	Medium	Two
15	Rishikesh u.s.	67.07	Medium	Two
16	Rishikesh d.s. (right bank)	69.51	Medium	One
17	Rishikesh d.s. (midstream)	72.09	Good	One
18	Rishikesh d.s (left bank)	70.62	Good	Two
19	Alaknanda at Badrinath	66.83	Medium	One
20	Mandakini at Rudraprayag	77.99	Good	One

Indices : 90-100 excellent; 70-90 good; 50-70 medium; 25-50 bad; and 0-25 very bad

* Results are based on average values

The category S_1 specifies low sodium adsorption ratio of 0-10 (**Table 13**). The water quality at all the stretches of river was found to fall under S_1 which suggests little danger of sodium hazard i.e. sodium sensitive crops accumulating injurious amount of sodium in leaves. The irrigation quality of water having C_1S_1 category is beneficial for growing plants like : *Eucalyptus robusta, Acacia nilotica, Casuarina* sp., *Prosopis tuliflora, Dalbergia sissoo, Azadirachta indica*.

The major ion chemistry of river Bhagirathi and its tributaries was studied and the percentage of major cations and anions was quantified (**Table 14**). The observed major cations and anions in the river Bhagirathi and its tributaries are Ca, Mg, HCO_3 and sulphate. Considering that (Ca + Mg) and HCO_3 make up the bulk of cations and anions respectively and that carbonates are abundant in the drainage basis, it is likely that the major fraction of the (Ca + Mg) is derived from the weathering of carbonates. The source of weathering sulphate could be both anthropogenic and natural. The abundance of anions in river water samples coupled with regional lithology shows that both carbonic and sulphuric acids provide the protons for the weathering.

4.1.5 Detection of Coliphages in River Waters

Since concentration of coliphages in river water samples might be low, it was felt necessary to concentrate the phages from large volumes of water for detection. Since phage recovery was not above 40 percent by membrane filter adsorption-elution method, the modified bituminous coal method, developed in NEERI for concentrating enteroviruses from water, was used in the present studies. In this method, the river water was adjusted to pH 6.0 with 1 N HCl, followed by addition of aluminium trichloride to a final concentration of 0.00005 M. The conditioned water sample was passed through a coal bed of 32 mm diameter prepared from 1.5 g of sterilized coal powder (120 mesh size) and fitted to a millipore membrane filter holder of 47 mm dia. Phages adsorbed onto the coal bed were eluted with 10 ml of 3% Beef Extract in McIlvaine Buffer (BEMB) solution of pH 7.1.

It has been observed that water samples from different rivers contained specific types of phages, all of which could not be detected by using single host. In view of this, different types of hosts were required for their detection. Coliphages could not be detected in Alaknanda river water using the four host cells of *E. coli*, but possibility of the presence of phages could not be ruled out as phage specific hosts other than the tested four hosts might exist which are required to detect them

Table 13 : Classification of Irrigation Water based on EC and SAR

The irrigation water, classified on the basis of electrical conductivity and sodium absorption ratio is as follows :

Electrical conductivity (EC) of the water μ mhos/cm @ 25°C	**Class**
100 to 250	C1
250 to 750	C2
750 to 2250	C3
2250 to 5000	C4
5000 to 20,000	C5
Sodium Absorption ratio of the water (SAR)	**Class**
Less than 10	S1
10 to 18	S2
18 to 26	S3
Greater than 26	S4

Source : Indian Standard Guidelines for the Quality of Irrigation Water

The Ganga water samples showed EC range of 61 – 133.6 (μ mhos/cm) and SAR range of 0.14 – 0.24. The water is, therefore, classified as C_1S_1.

Table 14 : Percentage of Cations and Anions in River Water Samples

Sr. No.	Sample site	SAR	Ca	Mg	$SO^{=}_{4}$	CO^{-}_{3}
1	Tapovan	0.025	51.68	27.27	64.53	24.70
2	Gomukh	0.058	61.45	20.99	82.50	12.92
3	Gangotri upstream (u.s.)	0.052	59.79	18.15	61.39	28.107
4	Gangotri downstream (d.s.)	0.053	57.36	25.54	73.20	23.85
5	Uttarkashi u.s.	0.047	60.88	20.35	22.20	71.11
6	Uttarkashi d.s.	0.062	60.41	19.30	51.02	45.16
7	Tehri (u.s. of Bhagirathi)	0.073	24.85	15.81	51.65	43.88
8	Tehri (u.s. of Bhilangana)	0.053	59.97	16.4	15.69	77.54
9	Tehri (d.s. of Bhagirathi)	0.057	59.96	18.37	41.03	55.12
10	Devprayag, before confluence (Bhagirathi)	0.050	59.54	21.36	38.93	56.85
11	Devprayag, before confluence (Alaknanda)	0.039	60.57	26.0	26.67	70.57
12	Devprayag, after confluence (Ganga), right bank	0.041	55.81	28.35	32.83	63.55
13	Devprayag, after confluence (Ganga), Midstream	0.051	72.22	8.43	23.12	72.16
14	Devprayag, after confluence (Ganga), left bank	0.044	66.90	15.11	18.65	76.51
15	Rishikesh u.s.	0.041	69.4	15.42	12.37	83.65
16	Rishikesh d.s. (right bank)	0.060	55.11	20.14	51.65	44.44
17	Rishikesh d.s. (Midstream)	0.035	67.60	19.15	19.67	77.10
18	Rishikesh d.s (left bank)	0.038	64.41	18.74	20.68	73.76
19	Alaknanda at Badrinath	0.043	62.25	12.17	43.63	47.35
20	Mandakini at Rudraprayag	0.028	61.15	18.71	38.22	53.88

$$\text{SAR}\ (\sqrt{\text{millimoles/liter}}) = \frac{Na^{+}}{\left(\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}\right)}$$

Where Na, Ca & Mg are expressed in milliequivalent/litre

(Table 15). However, experimentally it was found that when 3 months old Alaknanda river water sample (28-31 Aug., 2003) of 1 litre volume was taken from a container and after thorough shaking and mixing the water sample allowed to stand for 4 days at room temperature, an appreciable number of coliphages (10^3 PFU against *E. coli* host R9) were detected in settled solids. Further, but it was interesting to note that total coliforms were not detected either in the supernatant water or in the settled solids.

4.1.6 Biological Quality

Biotic component comprises of both plant and animal communities, which interact not only within them, but also with abiotic components of the environment. Generally, a biological community, being dependent on the environmental conditions and resources of its surrounding, may change if there are any alterations in the environment. A number of variables like temperature, pH, DO, nutrients, hardness etc. are responsible for maintaining the homeostasis of the environment and a change in any of these variables may lead to stress on the ecosystem. Plants and animals often become susceptible to anthropogenic or nature-induced influences, and as a result, a change in the distribution pattern, diversity and dominance of natural species is evident in the ecosystem. Studies were undertaken to evaluate the states of the biota in the river waters between Gomukh and Rishikesh, and also at different sampling points of two rivers viz. Alaknanda and Mandakini.

4.1.6.1 Phytoplankton

Five sets of surface water samples were collected during September-October, 2002 and May-August, 2003 for biological analysis. For phytoplankton, the water was collected as such in 100 ml polyethylene bottles and was preserved with Lugol's iodine. The microscopic analysis was undertaken and the phytoplankton counts were enumerated using Lackey's drop method. The data were analyzed for pollution indices, viz. Palmer's Pollution Index, & Shannon Wiener Diversity Index using following formulae.

Shannon Wiener Diversity Index: $SWI = -\sum \frac{ni}{N} \log_2 \frac{ni}{N}$

Where, SWI = Shannon Wiener Diversity Index
N = number of species of individuals in all the samples
n = number of species of individuals in each sample

Table 15 : Detection of Coliphages in River water samples between Tapovan and Rishikesh

(PFU/l)

Sr. no.	Sampling locations	24-25 Sept., 2002	7-8 Oct., 2002	23-24 Oct., 2002				14-23 May, 2003					28-31 Aug., 2003				
		Host EC1	Host EC1	Host EC1	Host U3	Host T4	Host R9	Host EC1	Host U3	Host T4	Host EC6	Host R9	Host EC1	Host U3	Host T4	Host EC6	Host R9
1	Tapovan	NS	NS	NS	NS	NS	NS	-	-	-	-	-	-	-	-	-	-
2	Gomukh	-	-	-	-	-	16	-	-	-	-	-	-	-	-	-	-
3	Gangotri u.s.	NS	NS	NS	NS	NS	NS	-	-	80	80	-	-	-	-	-	-
4	Gangotri d.s.	-	-	-	96	-	-	-	20	120	-	-	-	-	-	-	-
5	Uttarkashi u.s.	NS	NS	NS	NS	NS	NS	-	-	400	-	-	-	-	-	-	-
6	Uttarkashi d.s.	-	-	32	-	-	32	40	-	-	160	20	-	-	-	-	-
7	Tehri u.s. (Bhagirathi)	-	4	-	-	6	36	-	-	-	-	30	-	-	-	-	-
8	Tehri u.s. (Bhilangana)	NS	NS	NS	NS	NS	NS	-	-	-	-	25	-	-	-	-	-
9	Tehri d.s. (Bhagirathi)	NS	-	8	-	24	16	-	-	-	90	10	-	-	-	-	-
10	Devprayag before confluence (Bhagirathi)	-	8	40	-	-	-	-	-	-	-	-	-	-	-	-	-
11	Devprayag before confluence (Alaknanda)	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	Devprayag after confluence (Ganga) right bank	20	-	-	12	374	24	-	-	-	-	-	-	-	-	-	-
13	Devprayag after confluence (Ganga) midstream	NS	NS	NS	NS	NS	NS	-	-	-	-	-	-	-	-	-	-
14	Devprayag after confluence (Ganga) left bank	NS	NS	NS	NS	NS	NS	-	25	-	-	20	-	-	-	-	-
15	Rishikesh u.s.	NS	NS	NS	NS	NS	NS	-	-	-	-	8	-	-	-	-	-
16	Rishikesh d.s. (right bank)	10	12	-	-	8	16	-	-	-	90	40	-	-	-	-	-
17	Rishikesh d.s. (midstream)	NS	NS	NS	NS	NS	NS	-	-	-	40	-	-	-	-	-	-
18	Rishikesh d.s. (left bank)	NS	NS	NS	NS	NS	NS	15	-	-	-	30	-	-	-	-	-
19.	Alaknanda (Badrinath)	NS	NS	NS	NS	NS	NS	-	-	-	-	-	NS	NS	NS	NS	NS
20.	Mandakini (Rudraprayag)	NS	NS	NS	NS	NS	NS	-	-	-	-	-	NS	NS	NS	NS	NS

NS : Not sampled

- : Not detected

Palmer's Index

Palmer Pollution index employs the taxa of algae. The most tolerant genera and species were given ratings which are used to calculate the index. An alga is recorded as 'present', if there are more than 50 organisms /ml. The sum of the ratings of the recorded algae is then calculated (Hellawell, 1978). If the index value is above 20, the surface water appears to be organically polluted, while a score less than 15 is an evidence of probable oligotrophic state.

The data analysis reveals the following salient observations during three seasons September-October, 2002, April-May, 2003 and July-August, 2003 :

. The water samples from Tapovan, Gomukh, Gangotri, and Tehri dam (u/s) were mostly devoid of phytoplankton. Phytoplankton was sparsely present at nearly all sampling locations and density ranged from 2 to 22 organisms/ml and maximum 30 to 56/ml at Rishikesh during the study period. Higher values for phytoplankton density (83 -124/ml) and diversity indices (SWI-1.22-2.53) were recorded at Tehri in May, 2003. The density and diversity of phytoplankton at different sampling locations are presented in **Table 16**, while the average values are presented in **Table 17**.

In general, phytoplankton was present throughout from locations Devprayag to Rishikesh. In August, 2003, maximum diversity indices (SWI – 1) were recorded at Devprayag and Rishikesh. Palmer's index values (below 15) indicated highly oligotrophic condition (i.e. presence of organic matter is very negligible) starting from Gomukh to Rishikesh during September-Oct, 2002, May and August, 2003. Bacillariophyceae group comprised of 16, 10 and 3 genera respectively in three above mentioned sampling periods **(Table 18)**. Chlorophyceae and Cyanophyceae were observed only during May and August, 2003.

Elimination or reduction in number of phytoplankton might be attributed to water currents due to hilly terrain and high level of silt in the river water. In order to assess the role of silt, if any, towards agglomerating & settling of phytoplankton, an experiment was carried out using laboratory grown phytoplankter *Scenedesmus*. The silt, collected from the study area, was mixed (at various concentrations ranging from 25, 50, 100 & 150 mg/l) with a known density of algal culture, and then mechanically stirred and allowed to settle after 1, 3, 6, 24 hrs. of contact period. The counts of algae in the supernatant after settling revealed that the role of silt in removing the

Table 16 : Density, Diversity and Composition of Phytoplankton at different Sampling Points of the Rivers/ Tributaries in the Study Area (September, 2002 to August, 2003)

Sr. No.	Sampling Location	Sampling Dates	Counts /ml	SWI	Palmer's Index	Percent composition in groups		
						Cyano-phyceae	Chloro-phyceae	Bacillario-phyceae
1.	Tapovan	24-25 Sept. 02	NS	NS	NS	NS	NS	NS
		7-8 Oct. 02	NS	NS	NS	NS	NS	NS
		23-24 Oct. 02	NS	NS	NS	NS	NS	NS
		14-23 May, 03	0	0	0	0	0	0
		28-31 Aug., 03	2	0	1	100	0	0
2.	Gomukh	24-25 Sept. 02	0	0	0	0	0	0
		7-8 Oct. 02	0	0	0	0	0	0
		23-24 Oct. 02	0	0	0	0	0	0
		14-23 May, 03	0	0	0	0	0	0
		28-31 Aug., 03	0	0	0	0	0	0
3.	Gangotri upstream	24-25 Sept. 02	NS	NS	NS	NS	NS	NS
		7-8 Oct. 02	NS	NS	NS	NS	NS	NS
		23-24 Oct. 02	NS	NS	NS	NS	NS	NS
		14-23 May, 03	0	0	0	0	0	0
		28-31 Aug., 03	0	0	0	0	0	0
4.	Gangotri downstream	24-25 Sept. 02	0	0	0	0	0	0
		7-8 Oct. 02	0	0	0	0	0	0
		23-24 Oct. 02	0	0	0	0	0	0
		14-23 May, 03	0	0	0	0	0	0
		28-31 Aug., 03	0	0	0	0	0	0
5.	Uttarkashi upstream	24-25 Sept. 02	NS	NS	NS	NS	NS	NS
		7-8 Oct. 02	NS	NS	NS	NS	NS	NS
		23-24 Oct. 02	NS	NS	NS	NS	NS	NS
		14-23 May, 03	28	0.921	3	0	0	100
		28-31 Aug., 03	0	0	0	0	0	0
6.	Uttarkashi downstream	24-25 Sept. 02	14	2.79	0	0	0	100
		7-8 Oct. 02	14	2.48	0	0	0	100
		23-24 Oct. 02	22	2.90	0	0	0	100
		14-23 May, 03	0	0	0	0	0	0
		28-31 Aug., 03	0	0	0	0	0	0
7.	Tehri upstream (Bhagirathi)	24-25 Sept. 02	0	0	0	0	0	0
		7-8 Oct. 02	0	0	0	0	0	0
		23-24 Oct. 02	0	0	0	0	0	0
		14-23 May, 03	0	0	0	0	0	0
		28-31 Aug., 03	0	0	0	0	0	0

NS : Not sampled

Table 16 (contd...)

Sr. No.	Sampling Location	Date	Counts /ml	SWI	Palmer's Index	Percent composition in groups		
						Cyano-phyceae	Chloro-phyceae	Bacillario-phyceae
8.	Tehri upstream (Bhilangana)	24-25 Sept. 02	NS	NS	NS	NS	NS	NS
		7-8 Oct. 02	NS	NS	NS	NS	NS	NS
		23-24 Oct. 02	14	2.12	0			100
		14-23 May, 03	124	2.53	6	0	0	100
		28-31 Aug., 03	0	0	0	0	0	0
9.	Tehri downstream (Bhagirathi)	24-25 Sept. 02	NS	NS	NS	NS	NS	NS
		7-8 Oct. 02	6	1.5	0	0	0	100
		23-24 Oct. 02	2	0	0	0	0	100
		14-23 May, 03	83	1.22	3	0	0	100
		28-31 Aug., 03	0	0	0	0	0	0
10.	Devprayag before confluence (Bhagirathi)	24-25 Sept. 02	2	0	0	0	0	100
		7-8 Oct. 02	NS	NS	NS	NS	NS	NS
		23-24 Oct. 02	8	1.50	0	0	0	100
		14-23 May, 03	66	2.03	9	0	0	100
		28-31 Aug., 03	3	1.0	1	50	0	50
11.	Devprayag before confluence (Alaknanda)	24-25 Sept. 02	NS	NS	NS	NS	NS	NS
		7-8 Oct. 02	2	NA	0	0	0	100
		23-24 Oct. 02	12	2.22	0	0	0	100
		14-23 May, 03	46	1.52	6	0	0	100
		28-31 Aug., 03	0	0	0	0	0	0
12.	Devprayag after confluence (Ganga right bank)	24-25 Sept. 02	2	0	0	0	0	100
		7-8 Oct. 02	0	0	0	0	0	0
		23-24 Oct. 02	16	2.56	0	0	0	100
		14-23 May, 03	28	0.88	3	0	0	100
		28-31 Aug., 03	2	0	1	100	0	0
13.	Devprayag after confluence (Ganga middle)	24-25 Sept. 02	NS	NS	NS	NS	NS	NS
		7-8 Oct. 02	NS	NS	NS	NS	NS	NS
		23-24 Oct. 02	NS	NS	NS	NS	NS	NS
		14-23 May, 03	18	1.00	0	0	0	100
		28-31 Aug., 03	0	0	0	0	0	0
14.	Devprayag after confluence (Ganga left bank)	24-25 Sept. 02	NS	NS	NS	NS	NS	NS
		7-8 Oct. 02	NS	NS	NS	NS	NS	NS
		23-24 Oct. 02	NS	NS	NS	NS	NS	NS
		14-23 May, 03	9	0	3	0	0	100
		28-31 Aug., 03	0	0	0	0	0	0
15.	Rishikesh upstream	24-25 Sept. 02	NS	NS	NS	NS	NS	NS
		7-8 Oct. 02	NS	NS	NS	NS	NS	NS
		23-24 Oct. 02	NS	NS	NS	NS	NS	NS
		14-23 May, 03	6	2.00	6	0	0	100
		28-31 Aug., 03	2	0	0	100	0	0

NS : Not sampled

Table 16 (contd...)

Sr. No.	Sampling Location	Date	Counts /ml	SWI	Palmer's Index	Percent composition in groups		
						Cyano-phyceae	Chloro-phyceae	Bacillario-phyceae
16.	Rishikesh downstream (right bank)	24-25 Sept. 02	30	2.77	0	0	0	100
		7-8 Oct. 02	56	2.64	0	0	0	100
		23-24 Oct. 02	30	3.50	0	0	0	100
		14-23 May, 03	9	0	0	0	0	100
		28-31 Aug., 03	3	1.0	3	0	0	100
17.	Rishikesh downstream (middle)	24-25 Sept. 02	NS	NS	NS	NS	NS	NS
		7-8 Oct. 02	NS	NS	NS	NS	NS	NS
		23-24 Oct. 02	NS	NS	NS	NS	NS	NS
		14-23 May, 03	5	1.58	3	0	0	100
		28-31 Aug., 03	NS	NS	NS	NS	NS	NS
18.	Rishikesh downstream (left bank)	24-25 Sept. 02	NS	NS	NS	NS	NS	NS
		7-8 Oct. 02	NS	NS	NS	NS	NS	NS
		23-24 Oct. 02	NS	NS	NS	NS	NS	NS
		14-23 May, 03	14	1.87	3	0	0	100
		28-31 Aug., 03	0	0	0	0	0	0
19.	Alaknanda (Badrinath)	24-25 Sept. 02	NS	NS	NS	NS	NS	NS
		7-8 Oct. 02	NS	NS	NS	NS	NS	NS
		23-24 Oct. 02	NS	NS	NS	NS	NS	NS
		14-23 May, 03	3	1.00	4	50	0	50
		28-31 Aug., 03	NS	NS	NS	NS	NS	NS
20.	Mandakini (Rudraprayag)	24-25 Sept. 02	NS	NS	NS	NS	NS	NS
		7-8 Oct. 02	NS	NS	NS	NS	NS	NS
		23-24 Oct. 02	NS	NS	NS	NS	NS	NS
		14-23 May, 03	9	2.22	6	0	16	84
		28-31 Aug., 03	NS	NS	NS	NS	NS	NS

NS : Not sampled

Table 17 : Average Density, Diversity and Composition of Phytoplankton at different Sampling Points of the Rivers/ Tributaries in the Study Area (September, 2002 to August, 2003)

Sr. No.	Sampling Location	Counts /ml	SWI	Palmer's Index	Percent composition in groups		
					Cyano-phyceae	Chloro-phyceae	Bacillario-phyceae
1.	Tapovan	1	0	0.5	50	0	0
2.	Gomukh	0	0	0	0	0	0
3.	Gangotri upstream	0	0	0	0	0	0
4.	Gangotri downstream	0	0	0	0	0	0
5.	Uttarkashi upstream	14	0.46	1.5	0	0	50
6.	Uttarkashi downstream	10 (±9.69)	1.63 (±1.50)	0	0	0	60 (±54.77)
7.	Tehri upstream (Bhagirathi)	0	0	0	0	0	0
8.	Tehri upstream (Bhilangana)	46	1.55	2.0	0	0	66.67
9.	Tehri downstream (Bhagirathi)	22.75	0.68	0.75	0	0	75
10.	Devprayag before confluence (Bhagirathi)	19.75	1.13	2.5	12.5	0	87.5
11.	Devprayag before confluence (Alaknanda)	15.00	1.25	1.50	0	0	75
12.	Devprayag after confluence (Ganga right bank)	9.6 (±12.12)	0.69 (±1.11)	0.80 (±1.30)	20 (±44.72)	0	60 (±54.77)
13.	Devprayag after confluence (Ganga middle)	9	0.5	0	0	0	50

Note : Values in parenthesis are standard deviation of minimum 5 sets of data

Table 17 (contd...)

Sr. No.	Sampling Location	Counts /ml	SWI	Palmer's Index	Percent composition in groups		
					Cyano-phyceae	Chloro-phyceae	Bacillario-phyceae
14.	Devprayag after confluence (Ganga left bank)	4.5	0	1.5	0	0	50
15.	Rishikesh upstream	4	1	3	50	0	50
16.	Rishikesh downstream (right bank)	25.6 (± 0.91)	1.982 (± 1.44)	0.6 (±1.34)	0	0	100
17.	Rishikesh downstream (middle)	5	1.58	3	0	0	100
18.	Rishikesh downstream (left bank)	7	0.93	1.5	0	0	50
19.	Alaknanda (Badrinath)	3	1	4	50	0	50
20.	Mandakini (Rudraprayag)	9	2.22	6	0	16	84

Note : Values in parenthesis are standard deviation of minimum 5 sets of data

Table 18 : List of Phytoplankton Genera Recorded in the Study Area

Sr. No.	Identified groups and genera	Sept. – Oct. 2002	May 2003	August 2003
	Cyanophyceae			
1.	*Phormidium* sp.	-	-	-
	Chlorophyceae			
2.	*Chlorella* sp.	-	+	+
	Bacillariophyceae			
3.	*Achananthes* sp.	+	+	-
4.	*Amphora* sp.	+	-	-
5.	*Cocconeis* sp.	+	-	+
6.	*Cyclotella* sp.	+	-	-
7.	*Cymbella* sp.	+	+	-
8.	*Diatoma* sp.	+	+	-
9.	*Fragilaria* sp.	+	-	-
10.	*Mastogloia* sp.	+	-	-
11.	*Melosira* sp.	+	-	-
12.	*Meridion* sp.	+	+	-
13.	*Navicula* sp.	+	+	+
14.	*Nitzchia* sp.	+	+	-
15.	*Stauroneis* sp.	+	+	-
16.	*Synedra* sp.	+	+	-
17.	*Tabellaria* sp.	+	+	-
18.	*Caloneis* sp.	-	+	-
19.	*Rhicosphemia* sp.	+	-	-
20.	*Neidium* sp.	-	-	+

+ : Available
- : Not available

phytoplankton by settling is remote. It appears that reduction in light penetration due to enhanced silt concentrations arrests the photosynthesis of primary producers. This, in addition to poor nutrient levels of the river Bhagirathi, might be the factors for poor growth of phytoplankton.

Algae play a very important role in aquatic ecosystems by supplying oxygen in the purification process. Organic waste entering in the receiving river is broken down by bacterial decomposition to form simple nutrients which are taken up by the algae and used to synthesize new algal cell material in presence of light. CO_2 produced during the oxidation of organic matter enhances the photosynthesis of algae while the oxygen produced by algae during photosynthesis promotes the aerobic degradation process of bacteria and other microorganisms (Fogg, 1953). Renn (1954) refers that algae, viz., *Chlorella, Scenedesmus* etc. are able to take up nitrogen and phosphorus in excess when these are present in medium and high concentration as ammonia, nitrate and phosphate. Algae may also play an indirect part by altering the physico-chemical environment. The utilization of carbon dioxide during active photosynthesis causes a shift in the carbonate-bicarbonate equilibrium with a resultant increase in pH due to hydroxyl ion formation (Pipes, 1961).

High densities of algae may produce toxins that are lethal to animals. The fresh water algal genera, commonly reported as toxic, are *Microcystis, Nodularia, Nostoc, Oscillatoria, Aphanizomenon* etc.(Sangolkar et al., 1999). Large populations of cells are necessary to produce sufficient toxins to kill fish and high toxin activity occurs when phosphorus becomes limiting, because the formation of phospho lipids in cell membranes is disrupted, allowing leakage of the toxin. Toxin produced by cyanobacteria may also pose risks to human health, livestock and wild animals. Certain species of the genera *Microcystis, Anabaena* etc. can produce potent poisons, which can induce rapid and fatal liver damage at low concentrations and may also be neurotoxic, causing paralysis and death (Mason, 2002). The algal genera, recorded during the investigation period, are devoid of the abovementioned genera.

4.1.6.2 Zooplankton

A measured quantity of surface water from each sampling point was passed through a plankton net made of Nylonbolt cloth no. 20 (mesh size 75 μ). The filtered water comprising of plankters was transferred into a sampling bottle and preserved

immediately with 5% formalin. The analysis of zooplankton was done microscopically using Sedgwick Rafter Cell Method and enumerated as counts per meter cube of water.

Microscopic analysis of the zooplankton revealed the following salient features:

- During the study period, the locations Tapovan and Gomukh were totally devoid of zooplankton as the climate was extremely cold throughout the year and there was no prey (phytoplankton) in this region.
- In the months of September and October, 2002 a total of eight groups, comprising of 13 genera were recorded. The group *Plecoptera* was the most dominant and this was followed by *Nematoda* (**Table 19**). The average values of the density and diversity of zooplankton are presented in **Table 20**.
- The indicator invertebrates from fresh water bodies, as recorded elsewhere, have been presented in **Table 21** and classified according to the saprobicity of river water as clean, medium and heavily polluted. Studies indicate the presence of certain invertebrates which are known to be indicators of clean water.
- Shannon Wiener Index or biotic index takes account of the sensitivity or tolerance of individual species / groups to pollution and assign them a value, the sum of which gives an index of pollution for site. The index value is ranging from 0.00 to 2.25 exhibiting mild organic pollution along the river stretch.
- In the months of May and August, 2003 (summer and monsoon period) the zooplankton comprised of 7 genera belonging to 3 groups, viz. Nematoda, Copepoda and Herpecticoida. Nematoda was the most dominant and frequently occurring group noticed at all the stations. Nematodes, which are prevalent in soil, might have been washed away along with surface run off. However, at extreme upstream (Tapovan to Gangotri) zooplankters were absent.
- Total count ranged from nil to 30 per cubic metre from Uttarkashi to Rishikesh (Table 19), the highest being at Rishikesh (left bank).

Table 19 : Density and Diversity of Zooplankton at different Sampling Points of the Rivers/ Tributaries in the Study Area (September, 2002 to August, 2003)

Sr. No.	Sampling stations	Date	Total Zooplankton (per m^3)	Percentage composition in groups						Shannon Wiener Index
				Protozoa	Rotifera	Nematoda	Copepoda	Plecop-tera	Ephemero ptera	
1	Tapovan	24-25 Sept., 02	NS	NS	NS	NS	NS	NS	NS	NS
		7-8 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		23-24 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		14-23 May, 03	14	85.72	14.28	0	0	0	0	1.14
		28-31 Aug., 03	0	0	0	0	0	0	0	0
2	Gomukh	24-25 Sept., 02	0	0	0	0	0	0	0	0
		7-8 Oct., 02	0	0	0	0	0	0	0	0
		23-24 Oct., 02	0	0	0	0	0	0	0	0
		14-23 May, 03	6	0	0	0	0	50	50	1.0
		28-31 Aug., 03	0	0	0	0	0	0	0	0
3	Gangotri upstream	24-25 Sept., 02	NS	NS	NS	NS	NS	NS	NS	NS
		7-8 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		23-24 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		14-23 May, 03	0	0	0	0	0	0	0	0
		28-31 Aug., 03	0	0	0	0	0	0	0	0
4	Gangotri downstream	24-25 Sept., 02	3	0	0	0	0	100.00	0	0.00
		7-8 Oct., 02	0	0	0	0	0	0	0	0
		23-24 Oct., 02	0	0	0	0	0	0	0	0
		14-23 May, 03	0	0	0	0	0	0	0	0
		28-31 Aug., 03	0	0	0	0	0	0	0	0
5	Uttarkashi upstream	24-25 Sept., 02	NS	NS	NS	NS	NS	NS	NS	NS
		7-8 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		23-24 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		14-23 May, 03	18	0	0	100	0	0	0	0.99
		28-31 Aug., 03	2	0	0	0	100	0	0	0.00

NS : Not sampled

Table 19 (contd...)

Sr. No.	Sampling stations	Date	Total Zooplankton (per m^3)	Percentage composition in groups						Shannon Wiener Index
				Protozoa	Rotifera	Nematoda	Copepoda	Plecop-tera	Ephemer-optera	
6	Uttarkashi downstream	24-25 Sept., 02	6	0	0	0	0	50.00	50.00	1.00
		7-8 Oct., 02	0	0	0	0	0	0	0	0
		23-24 Oct., 02	3	0	0	0	0	100.00	0	0.00
		14-23 May, 03	10	0	0	100.00	0	0	0	0.72
		28-31 Aug., 03	2	0	0	0	0	0	0	0.00
7	Tehri upstream (Bhagirathi)	24-25 Sept., 02	0	0	0	0	0	0	0	0
		7-8 Oct., 02	10	0	0	0	0	0	0	0.00
		23-24 Oct., 02	3	0	0	0	50.00	50.00	0	0.00
		14-23 May, 03	2	0	0	0	100.00	0	0	0
		28-31 Aug., 03	0	0	0	0	0	0	0	0
8	Tehri upstream (Bhilangana)	24-25 Sept., 02	NS	NS	NS	NS	NS	NS	NS	NS
		7-8 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		23-24 Oct., 02	6	0	0	0	0	100.00	0	0.00
		14-23 May, 03	2	0	0	0	100.00	0	0	0.00
		28-31 Aug., 03	2	0	0	100.00	0	0	0	0.00
9	Tehri downstream (Bhagirathi)	24-25 Sept., 02	NS	NS	NS	NS	NS	NS	NS	NS
		7-8 Oct., 02	0	0	0	0	0	0	0	0
		23-24 Oct., 02	0	0	0	0	0	0	0	0
		14-23 May, 03	6	0	0	66.66	33.34	0	0	0.92
		28-31 Aug., 03	0	0	0	0	0	0	0	0
10	Devprayag before confluence (Bhagirathi)	24-25 Sept., 02	0	0	0	0	0	0	0	0
		7-8 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		23-24 Oct., 02	13	0	0	76.93	0	23.07	0	0.78
		14-23 May, 03	0	0	0	0	0	0	0	0
		28-31 Aug., 03	6	0	0	100.00	0	0	0	0.00
11	Devprayag before confluence (Alaknanda)	24-25 Sept., 02	NS	NS	NS	NS	NS	NS	NS	NS
		7-8 Oct., 02	0	0	0	0	0	0	0	0
		23-24 Oct., 02	12	0	0	50.00	0	50.00	0	1.00
		14-23 May, 03	10	0	0	60.00	40.00	0	0	1.52
		28-31 Aug., 03	6	0	0	100.00	0	0	0	0

NS : Not sampled

Table 19 (contd..)

Sr. No.	Sampling stations	Date	Total Zooplankton (per m³)	Percentage composition in groups						Shannon Wiener Index
				Protozoa	Rotifera	Nematoda	Copepoda	Plecop-tera	Ephemeropt era	
12	Devprayag after confluence (Ganga right bank)	24-25 Sept., 02	3	0	0	0	0	100.00	0	0
		7-8 Oct., 02	0	0	0	0	0	0	0	0
		23-24 Oct., 02	23	0	0	100	0	0	0	0
		14-23 May, 03	0	0	0	0	0	0	0	0
		28-31 Aug., 03	0	0	0	0	0	0	0	0
13	Devprayag after confluence (Ganga middle)	24-25 Sept., 02	NS	NS	NS	NS	NS	NS	NS	NS
		7-8 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		23-24 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		14-23 May, 03	0	0	0	0	0	0	0	0
		28-31 Aug., 03	0	0	0	0	0	0	0	0
14	Devprayag after confluence (Ganga left bank)	24-25 Sept., 02	NS	NS	NS	NS	NS	NS	NS	NS
		7-8 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		23-24 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		14-23 May, 03	0	0	0	0	0	0	0	0
		28-31 Aug., 03	4	0	0	100.00	0	0	0	0.00
15	Rishikesh upstream	24-25 Sept., 02	NS	NS	NS	NS	NS	NS	NS	NS
		7-8 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		23-24 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		14-23 May, 03	2	0	0	100.00	0	0	0	0.00
		28-31 Aug., 03	8	0	0	100.00	0	0	0	2.00
16	Rishikesh downstream (right bank)	24-25 Sept., 02	23	43.47	13.04	30.43	0	13.06	0	2.25
		7-8 Oct., 02	0	0	0	0	0	0	0	0
		23-24 Oct., 02	3	0	0	0	0	100..00	0	0.00
		14-23 May, 03	2	0	0	100.00	0	0	0	0
		28-31 Aug., 03	0	0	0	0	0	0	0	0.00
17	Rishikesh downstream (middle)	24-25 Sept., 02	NS	NS	NS	NS	NS	NS	NS	NS
		7-8 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		23-24 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		14-23 May, 03	14	0	0	85.72	14.28	0	0	1.14
		28-31 Aug., 03	NS	NS	NS	NS	NS	NS	NS	NS

NS : Not sampled

Table 19 (contd...)

Sr. No.	Sampling stations	Date	Total Zooplankton (per m^3)	Percentage composition in groups						Shannon Wiener Index
				Protozoa	Rotifera	Nematoda	Copepoda	Plecop-tera	Ephemero ptera	
18	Rishikesh downstream (left bank)	24-25 Sept., 02	NS	NS	NS	NS	NS	NS	NS	NS
		7-8 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		23-24 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		14-23 May, 03	30	0	6.66	93.34	0	0	0	1.29
		28-31 Aug., 03	4	0	0	50	50	0	0	1.0
19	Alaknanda (Badrinath)	24-25 Sept., 02	NS	NS	NS	NS	NS	NS	NS	NS
		7-8 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		23-24 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		14-23 May, 03	4	0	0	50	50	0	0	1.0
		28-31 Aug., 03	NS	NS	NS	NS	NS	NS	NS	NS
20	Mandakini (Rudraprayag)	24-25 Sept., 02	NS	NS	NS	NS	NS	NS	NS	NS
		7-8 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		23-24 Oct., 02	NS	NS	NS	NS	NS	NS	NS	NS
		14-23 May, 03	2	0	0	100	0	0	0	0.00
		28-31 Aug., 03	NS	NS	NS	NS	NS	NS	NS	NS

NS : Not sampled

Table 20 : Average Density and Diversity of Zooplankton at different Sampling Points of the Rivers/ Tributaries in the Study Area (September, 2002 to August, 2003)

Sr. No.	Sampling stations	Total Zooplankton (per m^3)	Percentage composition in groups						Shannon Wiener index
			Protozoa	Rotifera	Nematoda	Copepoda	Plecoptera	Ephemeroptera	
1	Tapovan	7	0	0	85.42	14.28	0	0	0.57
2	Gomukh	1.2 (± 2.68)	0	0	0	0	50 (± 22.36)	50 (±22.36)	0.2 (±0.45)
3	Gangotri upstream	0	0	0	0	0	0	0	0
4	Gangotri downstream	0.6 (±1.34)	0	0	0	0	100 (±44.72)	0	0
5	Uttarkashi upstream	10	0	0	50	50	0	0	0.49
6	Uttarkashi downstream	4.2 (±3.89)	0	0	33.33 (±44.72)	0	50 (±44.72)	21.77 (±22.36)	0.34 (±0.48)
7	Tehri upstream (Bhagirathi)	3 (±4.12)	0	0	0	75 (±54.77)	25 (±44.72)	0	0
8	Tehri upstream (Bhilangana)	3.33	0	0	33.33	33.33	33.34	0	0
9	Tehri downstream (Bhagirathi)	1.5	0	0	66.66	33.34	0	0	0.23
10	Devprayag before confluence (Bhagirathi)	4.75	0	0	88.46	0	11.54	0	0.19
11	Devprayag before confluence (Alaknanda)	7	0	0	70	13.33	16.67	0	0.63
12	Devprayag after confluence (Ganga right bank)	5.2 (±10.03)	0	0	50 (±44.72)	0	50 (±44.72)	0	0
13	Devprayag after confluence (Ganga midstream)	0	0	0	0	0	0	0	0

Note : Values in parenthesis are standard deviation of minimum 5 sets of data

Table 20 (contd...)

Sr. No.	Sampling stations	Total Zooplankton (per m^3)	Percentage composition in groups						Shannon Wiener Index
			Protozoa	Rotifera	Nematoda	Copepoda	Plecoptera	Ephemeroptera	
14	Devprayag after confluence (Ganga left bank)	2	0	0	0	100	0	0	0
15	Rishikesh upstream	5	0	0	100	0	0	0	1
16	Rishikesh downstream (right bank)	5.6 (±9.81)	14.49 (±19.44)	4.34 (±5.83)	43.48 (±43.37)	0	37.69 (±43.63)	0	0.45 (±1.01)
17	Rishikesh downstream (midstream)	14	0	0	85.72	14.28	0	0	1.14
18	Rishikesh downstream (left bank)	17	0	3.33	71.67	25	0	0	1.15
19	Alaknanda (Badrinath)	4	0	0	50	50	0	0	1
20	Mandakini (Rudraprayag)	2	0	0	100	0	0	0	0

Note : Values in parenthesis are standard deviation of minimum 5 sets of data

Table 21 : Indicator Invertebrates in different Grades of Freshwaters

Clean water (Oligosaprobic)		
1	Protozoa	*Dileptus* sp, *Prorodon* sp, ***Arcella*** sp, ***Epistylis*** sp
2	Rotifera	*Brachionus falcatus*, *Brachionus forficula*, *Brachionus quadridentatus*, *Tetramastix* sp., *Hexarthra* sp., ***Philodina*** sp.
3	Cladocera	*Holopedium* sp.
4.	Copepoda	*Diaptomus* sp., *Neodiaptomus* sp., *Heliodiaptomus* sp., *Paradiaptomus* sp., *Phyllodiaptomus* sp.
5.	Ephemeroptera	***Iron*** sp.
6.	Plecoptera	***Allocapnia*** sp.
Medium Polluted (Mesosaprobic)		
1.	Protozoa	*Chilomonas* sp., *Aspidisca* sp., *Carchesium* sp., *Chilodonella* sp., *Cyclidium* sp. *Lionotus* sp., *Paramecium* sp., *Spirostomum* sp., *Stentor* sp., *Amoeba* sp., *Euglypha* sp., *Colpoda* sp., *Halteria* sp., *Didinium* sp., *Leucophrys* sp.
2.	Rotifera	*Brachionus angularis*, *Brachionus calyciflorus*, *Keratella tropica*, *Filinia longiseta*, *Filinia terminalis*, *Polyarthra* sp.
3.	Cladocera	*Alona* sp., *Chydorus* sp.
4.	Copepoda	***Cyclops*** sp., *Mesocyclops* sp., *Nauplius*
Heavily Polluted (Polysaprobic)		
1	Protozoa	*Caenomorpha* sp., *Colpidium* sp., *Glaucoma* sp., *Metopus* sp., *Paramecium* sp., *Tetrahymena* sp., *Codosiga* sp., *Gonostomum* sp., *Frontonia* sp., *Vorticella* sp.
2	Rotifera	*Epiphanes macrourus*, *Rotaria rotatoria*, ***Philodina*** sp.
3	Cladocera	*Diaphanosoma* sp., *Simocephalus* sp., *Ceriodaphnia* sp., *Moina* sp.
4.	Copepoda	***Cyclops*** sp.

Source : (Krishnamoorthi et al., 1978; Arora, 1966; Mahajan, 1981; Radhakrishna, 1976)

Note : Organisms recorded in study area are shown in bold

- Shannon Wiener Diversity indices varied from 0.00 to 2.00, exhibiting poor to semi-productive nature of the surface waters.

The biota of the rhithrons Bhagirathi is of mixed assemblage of a wide variety of micro fauna and flora. The composite picture in rhithronic ecosystem is interesting and exhibits a series of trophic levels. Amongst the zooplankton, the most commonly occurring groups like small crustacea, larval forms of insects, in addition to some protozoans and rotifers constitute the secondary trophic level. It has been recorded that the cold water streams are inherently poor in biological productivity, resulting in limitation of available quantity of food, and hence a keen competition. The indicator value of plankton is well established (Kolkwitz, 1908; Marsson, 1909; Nygaard, 1949; Palmer, 1969). Except for disturbed sites, the plankton density (quanta) and diversity (spectra) profile showed a general tendency to increase as the current velocity decreased. Current velocity is known to be a factor detrimental to plankton density in the hilly streams (Nautiyal, 1984, 1986). The discharge of organic load imposes a natural restriction on diversity, but the current velocity rapidly minimizes the discharge load by carrying it downstream and with subsequent dilution. The water quality of river Ganga was monitored using certain physical, chemical and biological characteristics and the study indicated an oligotrophic state of the river during the year 1994 (Gautam, 1994).

The animal communities are fairly common in the meta-rhithronic zone (i.e. Uttarkashi to Devprayag) and hypo (Devprayag to Rishikesh) rhithronic subzones of the Bhagirathi river, whereas, the epi-rithronic subzone (Gomukh to Gangotri) is not able to support a wide variety of animal life.

The effect of zooplankton on river ecology is primarily dependent on their population densities and the specific rates of feeding, respiration and growth. However, the major influence of nematodes is probably on decomposition processes by their metabolism and on bacteria by their grazing activities. Meiofauna, in general, and nematodes, in particular, may have important effects on bacterial activity, but that the direct role of nematodes in used-water decomposition is likely to be negligible (Curds and Hawkes, 1975).

The dominant rotifers feed mainly on primary producers and play only a secondary role in the removal of organic wastes. Their contribution to the overall balance of the ecosystem cannot be overlooked.

It is evident from literature that the dominant types of protozoa, found in organically riched water, feed mainly on bacteria and so it has often been suggested that the predatory activities of the protozoa might be responsible for bacterial removal (Sandon, 1932). Zooplankters of higher groups maintain ecological balance of the water bodies.

4.2 Sediment Quality

The transport of sediment within a river system is a complex phenomenon. Weathering of pre-existing rocks results in disintegrated and decomposed material (sediment), transported by the river, with its deposited material downstream away from their place of formation. Sediment, in general, is a term used to describe both suspended and deposited materials. Different fractions of sediment are of great importance, according to their nature.

The sediments have a great influence on the water quality of the river Bhagirathi. The metal ions, originally derived from the breaking of rocks, are controlled by several river valley conditions – physical as well as chemical. Many metals which are not derived from these rock-fragments are also affected by sediment concentration and composition. Earlier studies carried out by Golterman et al. (1983) on the qualitative observations of minerals in sediments (by Bromoform treatment) of the river Bhagirathi at different locations, viz. Uttarkashi, Tehri and Devprayag have been presented in **Table 22**.

Table 22 : Qualitative observations of minerals in sediments of the river Bhagirathi at different locations

Station	Silli-manite	Musco-vite	Chlo-rite	Biotite	Quarrtz	Phy-llite	Felds-par
Uttarkashi	-	-	X	*	*	X	*
Tehri	-	-	-	-	*	*	*
Devprayag	X	-	*	-	*	-	*

(Source : Gautam, 1990)

* Abundance; - Medium; X not present

4.2.1 Physico-chemical Characteristics

The physico-chemical characteristics of the sediments of the rivers in the study area are shown in **Table 23,** while the average values are presented in **Table 24**. The volatile matters in successive sites were increased from 5.374 to 14.38 mg/kg in the sediments collected during October 2002 (except Gangotri downstream where 4.462 mg/kg value was recorded). The recorded range values of volatile matters were found to be between 1.493 and 11.89 mg/kg in sediment samples collected during May, 2003, while volatile matter in samples collected during August, 2003, showed variations from 3.27 to 8.71 mg/kg (respectively at sampling sites Gangotri upstream and Tehri upstream at Bhagirathi).

The COD, PO_4-P and SO_4 ranges in the sediments varied from 1.10 to 29.6 mg/kg, 1.31 to 6.981 mg/kg, and 0.94 to 3.12 mg/kg respectively.

Calcium content of the sediments showed a variation with a minimum of 0.08 mg/kg and maximum of 10.861 mg/kg, while magnesium content showed a variation between 1.201 and 11.153 mg/kg.

4.2.2 Metals in Sediments

The levels of metal concentrations in sediments are presented in **Table 25,** while the average values are depicted in **Table 26**. In case of metals, highest concentration was observed for aluminium (9260 mg/kg) followed by iron (3896 mg/kg) and manganese (2036 mg/kg), which implies that the major geochemical phases (in addition to silica) in the rocks of the region are alumina, iron oxide and manganese oxide. This interpretation is found to be in close agreement with the

Table 23 : Physico-chemical characteristics of Sediments at different Sampling Points in the Study Area (September, 2002 to August, 2003)

Parameters	Date of sampling	Sampling station									
		1	2	3	4	5	6	7	8	9	10
Volatile matter (g/kg)	23-24 Oct. 02	NS	5.374	NS	4.462	NS	5.658	8.728	7.86	13.32	14.48
	14-23 May, 03	7.26	3.2	1.493	11.89	4.74	5.54	5.61	6.3	5.7	7.2
	28-31 Aug., 03	6.10	5.14	3.27	7.90	7.34	6.90	8.71	7.2	7.6	7.1
COD (g/kg)	23-24 Oct. 02	NS	9.257	NS	9.814	NS	13.773	12.762	12.904	7.072	8.008
	14-23 May, 03	10.45	9.062	6.76	2.65	14.74	11.70	12.70	6.33	10.26	8.03
	28-31 Aug., 03	9.18	9.10	7.07	5.22	9.22	13.0	11.12	7.28	9.40	11.12
Sulphate (g/kg)	23-24 Oct. 02	NS	0.874	NS	0.2968	NS	3.531	1.710	1.332	0.884	1.273
	14-23 May, 03	1.102	0.984	1.987	2.420	2.310	1.4011	1.110	2.060	1.984	1.32
	28-31 Aug., 03	0.911	0.794	1.999	1.310	1.740	3.120	2.700	1.920	1.414	2.180
Phosphate as P (g/kg)	23-24 Oct. 02	NS	3.415	NS	3.338	NS	3.479	4.654	1.438	2.136	3.069
	14-23 May, 03	3.792	4.953	6.981	5.52	7.63	4.66	1.3935	1.31	1.5116	3.030
	28-31 Aug., 03	3.120	4.101	3.789	4.920	3.390	2.110	1.991	2.792	3.122	4.120
Calcium (g/kg)	23-24 Oct. 02	NS	0.428	NS	0.221	NS	1.252	3.217	0.917	1.618	1.165
	14-23 May, 03	0.145	0.145	0.119	0.118	0.302	0.408	0.470	1.53	0.093	0.080
	28-31 Aug., 03	0.121	0.217	0.198	0.157	0.242	0.302	0.218	0.428	0.401	0.398
Magnesium (g/kg)	23-24 Oct. 02	NS	0.521	NS	2.552	NS	3.297	4.467	1.076	3.195	2.123
	14-23 May, 03	1.73	3.175	1.205	2.195	2.493	3.318	4.713	6.613	3.213	3.002
	28-31 Aug., 03	1.201	2.10	1.912	2.11	2.145	3.106	1.989	2.019	3.141	3.01

NS : Not sampled; BDL : Below detectable limit

*The value are obtained for 1:20 suspension of sediments

1. Tapovan; 2. Gomukh; 3. Gangotri upstream (u.s.); 4. Gangotri downstream (d.s.); 5. Uttarkashi u.s.; 6. Uttarkashi d.s.; 7. Tehri (u.s. of Bhagirathi); 8. Tehri (u.s. of Bhilangana); 9. Tehri (d.s. of Bhagirathi); 10. Devprayag, before confluence (Bhagirathi)

Table 23 (contd...)

Parameters	Date of sampling	Sampling station									
		11	12	13	14	15	16	17	18	19	20
Volatile matter (g/kg)	23-24 Oct. 02	10.78	NS	NS	7.06	NS	18.379	NS	NS	NS	NS
	14-23 May, 03	7.07	NS	NS	13.78	9.85	16.37	NS	13.84	NS	NS
	28-31 Aug., 03	8.10	NS	NS	9.12	7.98	12.0	NS	11.0	9.99	BDL
COD (g/kg)	23-24 Oct. 02	5.5147	NS	NS	6.636	NS	7.167	NS	NS	NS	NS
	14-23 May, 03	10.28	NS	NS	29.6	7.768	7.21	NS	23.29	NS	NS
	28-31 Aug., 03	12.13	NS	NS	1.10	13.10	10.92	NS	13.91	14.22	BDL
Sulphate (g/kg)	23-24 Oct. 02	2.062	NS	NS	1.980	NS	2.320	NS	NS	NS	NS
	14-23 May, 03	2.420	NS	NS	3.130	2.941	3.131	NS	2.887	NS	NS
	28-31 Aug., 03	2.221	NS	NS	2.110	2.830	1.920	NS	2.348	2.442	BDL
Phosphate as P (g/kg)	23-24 Oct. 02	1.854	NS	NS	1.781	NS	4.685	NS	NS	NS	NS
	14-23 May, 03	1.7896	NS	NS	1.7896	2.55	1.479	NS	2.021	NS	NS
	28-31 Aug., 03	4.120	NS	NS	4.102	3.140	4.90	NS	3.12	4.831	BDL
Calcium (g/kg)	23-24 Oct. 02	5.53	NS	NS	10.861	NS	10.486	NS	NS	NS	NS
	14-23 May, 03	1.54	NS	NS	1.18	1.58	1.41	NS	1.08	1.06	1.03
	28-31 Aug., 03	1.412	NS	NS	0.878	1.21	1.02	NS	1.04	1.44	1.27
Magnesium (g/kg)	23-24 Oct. 02	1.922	NS	NS	2.199	NS	2.635	NS	NS	NS	NS
	14-23 May, 03	5.53	NS	NS	6.153	11.153	6.946	NS	3.124	3.262	4.032
	28-31 Aug., 03	3.450	NS	NS	4.980	3.190	2.120	NS	4.198	4.110	4.002

NS : Not sampled; BDL : Below detectable limit

*The value are obtained for 1:20 suspension of sediments

11. Devprayag, before confluence (Alaknanda); 12. Devprayag, after confluence (Ganga), right bank; 13. Devprayag, after confluence (Ganga), middle; 14. Devprayag, after confluence (Ganga), left bank; 15. Rishikesh u.s.; 16. Rishikesh d.s. (right bank); 17. Rishikesh d.s. (middle); 18. Rishikesh d.s (left bank); 19. Alaknanda at Badrinath; 20. Mandakini at Rudraprayag

Table 24 : Average Physicochemical characteristics of Sediment at different Sampling Points in the Study Area (September, 2002 to August, 2003)

Parameters	Sampling station									
	1	2	3	4	5	6	7	8	9	10
Volatile matter (g/kg)	6.680	4.571 (±1.193)	2.382	8.084 (±3.717)	6.040	6.033 (±0.753)	7.683 (±1.795)	7.120 (±0.783)	8.873 (±3.966)	9.593 (±4.232)
COD (g/kg)	9.815	9.140 (±0.103)	6.915	5.895 (±3.629)	11.980	12.824 (±1.048)	12.194 (±0.931)	8.838 (±3.553)	8.911 (±1.649)	9.053 (±1.790)
Sulphate (g/kg)	1.007	0.884 (±0.095)	1.993	1.342 (±1.062)	2.025	2.684 (±1.130)	1.840 (±0.803)	1.771 (±0.386)	1.427 (±0.550	1.591 (±0.511)
Phosphate as P (g/kg)	3.456	4.156 (±0.770)	5.385	4.593 (±1.127)	5.510	3.416 (±1.276)	2.680 (±1.736)	1.847 (±0.821)	2.257 (±0.812)	3.406 (±0.618)
Calcium (g/kg)	0.133	0.263 (±0.147)	0.159	0.165 (±0.052)	0.272	0.654 (±0.521)	1.302 (±1.664)	0.958 (±0.552)	0.704 (±0.806)	0.548 (±0.558)
Magnesium (g/kg)	1.466	1.932 (±1.335)	1.559	2.286 (±0.235)	2.319	3.240 (±0.117)	3.723 (±1.507)	3.236 (±2.962)	3.183 (±0.037)	2.712 (±0.510)

NS : Not sampled

Note : Values in parenthesis are standard deviation of minimum 5 sets of data

*The value are obtained for 1:20 suspension of sediments

1. Tapovan; 2. Gomukh; 3. Gangotri upstream (u.s.); 4. Gangotri downstream (d.s.); 5. Uttarkashi u.s.; 6. Uttarkashi d.s.; 7. Tehri (u.s. of Bhagirathi); 8. Tehri (u.s. of Bhilangana); 9. Tehri (d.s. of Bhagirathi); 10. Devprayag, before confluence (Bhagirathi)

Table 24 (contd...)

Parameters	Sampling station									
	11	12	13	14	15	16	17	18	19	20
Volatile matter (g/kg)	8.650 (±1.915)	NS	NS	9.987 (±3.443)	8.915	15.583 (±3.262)	NS	12.420 (±2.008)	9.990	NS
COD (g/kg)	9.308 (±3.413)	NS	NS	12.445 (±15.112)	10.434	8.432 (±2.154)	NS	18.600 (±6.633)	14.220	NS
Sulphate (g/kg)	2.234 (±0.179)	NS	NS	2.407 (±0.630)	2.886	2.457 (±0.617)	NS	2.618 (±0.381)	2.442	NS
Phosphate as P (g/kg)	2.588 (±1.327)	NS	NS	2.558 (±1.338)	2.845	3.688 (±1.916)	NS	2.571 (±0.777)	4.831	NS
Calcium (g/kg)	2.827 (±2.341)	NS	NS	4.306 (±5.679)	1.395	4.305 (±5.356)	NS	1.060 (±0.028)	1.250	NS
Magnesium (g/kg)	3.634 (±1.811)	NS	NS	4.444 (±2.031)	7.172	3.900 (±2.650)	NS	3.661 (±0.759)	3.686	NS

NS : Not sampled

Note : Values in parenthesis are standard deviation of minimum 5 sets of data

*The value are obtained for 1:20 suspension of sediments

11. Devprayag, before confluence (Alaknanda); 12. Devprayag, after confluence (Ganga), right bank; 13. Devprayag, after confluence (Ganga), middle; 14. Devprayag, after confluence (Ganga), left bank; 15. Rishikesh u.s.; 16. Rishikesh d.s. (right bank); 17. Rishikesh d.s. (middle); 18. Rishikesh d.s (left bank); 19. Alaknanda at Badrinath; 20. Mandakini at Rudraprayag

Table 25 : Metal characteristics of the Sediments at different Sampling Points in the Study Area (September, 2002 to August, 2003)

Parameters	Date of sampling	Sampling station									
		1	2	3	4	5	6	7	8	9	10
Cadmium	23-24 Oct., 02	NS	3.71	NS	2.3	NS	11.05	8.61	3.14	10.22	8.01
	14-23 May, 03	NS	BDL	BLD	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	28-31 Aug., 03	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Chromium	23-24 Oct., 02	NS	23.44	NS	15.48	NS	32.47	61.46	16.5	40.16	22.7
	14-23 May, 03	NS	5.132	1.678	3.718	3.11	BDL	4.601	4.792	6.039	BDL
	28-31 Aug., 03	NS	6.901	3.204	4.812	6.325	5.200	4.80	9.25	5.699	7.00
Lead	23-24 Oct., 02	NS	BDL	NS	100.5	NS	13.67	28.14	8.55	31.86	41.55
	14-23 May, 03	NS	26.49	13.78	24.75	49.54	BDL	34.63	28.643	18.289	BDL
	28-31 Aug., 03	NS	20.00	15.29	29.03	49.60	34.60	11.06	13.08	46.00	20.00
Copper	23-24 Oct., 02	NS	5.21	NS	3.65	NS	29.12	20.22	11.11	31.45	14.62
	14-23 May, 03	NS	10.26	4.674	5.926	40.21	BDL	1.332	10.38	4.60	BDL
	28-31 Aug., 03	NS	10.26	13.80	1.32	2.89	6.05	3.08	4.09	1.11	2.30
Strontium	23-24 Oct., 02	NS	0.7	NS	1.20	NS	6.63	0.75	0.98	3.24	15.08
	14-23 May, 03	NS	1.671	0.359	0.813	0.359	BDL	0.329	6.961	0.383	BDL
	28-31 Aug., 03	NS	1.89	3.42	4.12	3.15	8.19	5.00	4.00	2.18	2.00
Manganese	23-24 Oct., 02	NS	148.377	NS	636.63	NS	2036	323	125	612	272
	14-23 May, 03	NS	121.74	57.41	88.088	1111.7	BDL	244.16	166.60	89.914	BDL
	28-31 Aug., 03	NS	61.02	71.06	48.09	244.16	389.0	416.0	166.5	172.8	148.0
Iron	23-24 Oct., 02	NS	1028	NS	6.2	NS	904	1800	788	2212	1133
	14-23 May, 03	NS	1062.3	480.64	746.07	1460.0	BDL	1161.29	1063.56	1172.84	BDL
	28-31 Aug., 03	NS	512.08	814.0	1250.0	1289	1120	196	546	112.46	1120

All the values are expressed in mg/kg dry weight
NS – Not sampled; BDL – Below detectable limit

1. Tapovan; 2. Gomukh; 3. Gangotri upstream (u.s.); 4. Gangotri downstream (d.s.); 5. Uttarkashi u.s.; 6. Uttarkashi d.s.; 7. Tehri (u.s. of Bhagirathi); 8. Tehri (u.s. of Bhilangana); 9. Tehri (d.s. of Bhagirathi); 10. Devprayag, before confluence (Bhagirathi)

Table 25 (contd...)

Parameters	Date of sampling	Sampling station									
		1	2	3	4	5	6	7	8	9	10
Aluminium	23-24 Oct., 02	NS	3732	NS	4000	NS	3766	9260	3403	7009	2964
	14-23 May, 03	NS	4770.9	1842.38	3273.49	2466.85	BDL	3632.8	182.62	4247.9	BDL
	28-31 Aug., 03	NS	2289	2246	3120	1189	1168	3240	4480	5120	3860
Nickel	23-24 Oct., 02	NS	5.945	NS	3.21	NS	15.55	20.91	6.39	20.53	10.52
	14-23 May, 03	NS	8.235	2.756	6.624	18.66	BDL	14.046	10.042	6.395	BDL
	28-31 Aug., 03	NS	2.09	1.03	0.04	0.006	6.39	4.04	3.08	10.04	6.00
Zinc	23-24 Oct., 02	NS	2.22	NS	12.42	NS	25.63	4.63	1.77	4.45	3.62
	14-23 May, 03	NS	BDL	BDL	BDL	0.359	BDL	0.726	4.792	1.279	BDL
	28-31 Aug., 03	NS	BDL	0.120	1.129	BDL	1.240	0.805	BDL	1.308	1.04
Arsenic	23-24 Oct., 02	NS	8.55	NS	3.24	NS	10.84	19.9	6.58	15.07	13.61
	14-23 May, 03	NS	7.16	4.31	4.99	3.634	BDL	8.525	10.38	6.907	BDL
	28-31 Aug., 03	NS	2.32	3.4	2.4	BDL	2.49	0.802	BDL	9.62	BDL

All the values are expressed in mg/kg dry weight
NS – Not sampled; BDL – Below detectable limit

1. Tapovan; 2. Gomukh; 3. Gangotri upstream (u.s.); 4. Gangotri downstream (d.s.); 5. Uttarkashi u.s.; 6. Uttarkashi d.s.; 7. Tehri (u.s. of Bhagirathi); 8. Tehri (u.s. of Bhilangana); 9. Tehri (d.s. of Bhagirathi); 10. Devprayag, before confluence (Bhagirathi)

Table 25 (contd...)

Parameters	Date of sampling	Sampling station									
		11	12	13	14	15	16	17	18	19	20
Cadmium	23-24 Oct., 02	4.84	NS	NS	12.07	NS	9.43	NS	NS	NS	NS
	14-23 May, 03	BDL	NS	NS	BDL	NS	1.806	NS	BDL	NS	NS
	28-31 Aug., 03	BDL	NS	NS	BDL	NS	BDL	NS	BDL	BDL	
Chromium	23-24 Oct., 02	32.81	NS	NS	22.73	NS	44.41	NS	NS	NS	NS
	14-23 May, 03	6.866	NS	NS	5.659	NS	6.322	NS	BDL	NS	NS
	28-31 Aug., 03	6.35	NS	NS	2.60	NS	7.29	NS	1.06	2.89	
Lead	23-24 Oct., 02	16.13	NS	NS	32.86	NS	70.62	NS	NS	NS	NS
	14-23 May, 03	31.446	NS	NS	25.46	NS	38.133	NS	BDL	NS	NS
	28-31 Aug., 03	18.00	NS	NS	42.04	NS	28.09	NS	24.00	36.08.	
Copper	23-24 Oct., 02	5.331	NS	NS	16.38	NS	95.8	NS	NS	NS	NS
	14-23 May, 03	23.69	NS	NS	6.224	NS	14.24	NS	BDL	NS	NS
	28-31 Aug., 03	0.35	NS	NS	6.08	NS	13.2	NS	4.03	2.89	
Strontium	23-24 Oct., 02	3.36	NS	NS	6.97	NS	29.7	NS	NS	NS	NS
	14-23 May, 03	12.08	NS	NS	14.26	NS	13.848	NS	BDL	NS	NS
	28-31 Aug., 03	0.36	NS	NS	17.06	NS	16.08	NS	11.00	2.69	
Manganese	23-24 Oct., 02	183.7	NS	NS	413	NS	1714	NS	NS	NS	NS
	14-23 May, 03	166.15	NS	NS	167.50	NS	462.6	NS	BDL	NS	NS
	28-31 Aug., 03	246.0	NS	NS	43.08	NS	92.05	NS	112	246	
Iron	23-24 Oct., 02	971	NS	NS	2299	NS	1538	NS	NS	NS	NS
	14-23 May, 03	1098.56	NS	NS	1048.0	NS	2187.45	NS	BDL	NS	NS
	28-31 Aug., 03	1180	NS	NS	3896	NS	3400	NS	360	1450	

All the values are expressed in mg/kg dry weight
NS – Not sampled; BDL – Below detectable limit

11. Devprayag, before confluence (Alaknanda); 12. Devprayag, after confluence (Ganga), right bank; 13. Devprayag, after confluence (Ganga), middle; 14. Devprayag, after confluence (Ganga), left bank; 15. Rishikesh u.s.; 16. Rishikesh d.s. (right bank); 17. Rishikesh d.s. (middle); 18. Rishikesh d.s (left bank); 19. Alaknanda at Badrinath; 20. Mandakini at Rudraprayag

Table 25 (contd...)

Parameters	Date of sampling	Sampling station									
		11	12	13	14	15	16	17	18	19	20
Aluminium	23-24 Oct., 02	4151	NS	NS	7707	NS	4689	NS	NS	NS	NS
	14-23 May, 03	3860.47	NS	NS	3581.69	NS	4921.76	NS	BDL	NS	NS
	28-31 Aug., 03	4700	NS	NS	396	NS	1159	NS	3400	1150	
Nickel	23-24 Oct., 02	7.61	NS	NS	16.55	NS	121.7	NS	NS	NS	NS
	14-23 May, 03	11.26	NS	NS	10.29	NS	16.35	NS	BDL	NS	NS
	28-31 Aug., 03	8.29	NS	NS	8.04	NS	1.20	NS	11.00	2.08	
Zinc	23-24 Oct., 02	1.97	NS	NS	4.35	NS	21.05	NS	NS	NS	NS
	14-23 May, 03	BDL	NS	NS	BDL	NS	1.304	NS	BDL	NS	NS
	28-31 Aug., 03	BDL	NS	NS	4.04	NS	4.08	NS	4.29	BDL	
Arsenic	23-24 Oct., 02	10.67	NS	NS	20.16	NS	11.97	NS	NS	NS	NS
	14-23 May, 03	9.063	NS	NS	9.054	NS	9.33	NS	BDL	NS	NS
	28-31 Aug., 03	4.89	NS	NS	2.92	NS	6.03	NS	1.02	4.08	

All the values are expressed in mg/kg dry weight
NS – Not sampled; BDL – Below detectable limit

11. Devprayag, before confluence (Alaknanda); 12. Devprayag, after confluence (Ganga), right bank; 13. Devprayag, after confluence (Ganga), middle; 14. Devprayag, after confluence (Ganga), left bank; 15. Rishikesh u.s.; 16. Rishikesh d.s. (right bank); 17. Rishikesh d.s. (middle); 18. Rishikesh d.s (left bank); 19. Alaknanda at Badrinath; 20. Mandakini at Rudraprayag

Table 26 : Average Metal characteristics of the Sediments at different Sampling Points in the Study Area (September, 2002 to August, 2003)

Parameters	Sampling station									
	1	2	3	4	5	6	7	8	9	10
Cadmium	NS	3.71	-	2.30	-	11.05	8.61	3.14	10.22	8.01
Chromium	NS	11.82 (±10.09)	2.44	8.00 (±6.49)	4.71	18.83	23.62 (±32.77)	10.18 (±5.90)	17.29 (±19.79)	14.85
Lead	NS	23.24 (±4.59)	14.53	51.43 (±42.55)	49.57	24.13	24.61 (±12.17)	16.76 (±10.54)	32.05 (±13.86)	30.77
Copper	NS	8.58 (±2.91)	9.24	3.63 (±2.30)	21.55	17.58	8.21 (±10.44)	8.53 (±3.86)	12.38 (±16.60)	8.46
Strontium	NS	1.42 (±0.63)	1.88	2.04 (±1.81)	1.75	7.41	2.03 (±2.58	3.98 (±2.99)	1.93 (±1.44)	8.54
Manganese	NS	110.38 (±44.77)	64.235	257.60 (±328.85)	677.93	1212.50	327.72 (±86.02)	152.70 (±23.99)	291.57 (±280.58)	210.00
Iron	NS	867.46 (±308.24)	647.32	667.42 (±625.62)	1374.50	1012.00	1052.43 (±807.52)	799.19 (±258.96)	1165.77 (±1049.79)	1126.50
Aluminium	NS	3597.30 (±1246.42)	2044.19	3464.50 (±470.07)	1827.93	2467.00	5377.60 (±3367.98)	2688.54 (±2236.00)	5458.97 (±1411.41)	3412.00
Nickel	NS	5.42 (±3.11)	1.89	3.29 (±3.29)	9.33	10.97	12.99 (±8.48)	6.50 (±3.48)	12.32 (±7.34)	8.26
Zinc	NS	2.22	0.12	6.77	0.36	13.43	2.05 (±2.23)	3.28 (±2.14)	2.34 (±1.82)	2.33
Arsenic	NS	6.01 (±3.27)	3.85	3.54 (±1.32)	3.63	6.66	9.74 (±9.61)	8.48	10.53 (±4.15)	13.61

All the values are expressed in mg/kg dry weight
NS – Not sampled
Note : Values in parenthesis are standard deviation of minimum 5 sets of data

1. Tapovan; 2. Gomukh; 3. Gangotri upstream (u.s.); 4. Gangotri downstream (d.s.); 5. Uttarkashi u.s.; 6. Uttarkashi d.s.; 7. Tehri (u.s. of Bhagirathi); 8. Tehri (u.s. of Bhilangana); 9. Tehri (d.s. of Bhagirathi); 10. Devprayag, before confluence (Bhagirathi)

Table 26 (contd...)

Parameters	Sampling station									
	11	12	13	14	15	16	17	18	19	20
Cadmium	4.84	NS	NS	12.07	NS	5.62	NS			NS
Chromium	15.34 (±15.13)	NS	NS	10.33 (±10.85)	NS	19.34	NS	1.06	2.89	NS
Lead	21.86 (±8.35)	NS	NS	33.45 (±8.31)	NS	45.61	NS	24.00	36.08	NS
Copper	9.79 (±12.29)	NS	NS	9.56 (±5.91)	NS	41.08 (±47.39)	NS	4.03	2.89	NS
Strontium	5.27 (±6.08)	NS	NS	12.76 (±5.21)	NS	19.88 (±8.58)	NS	11.00	2.69	NS
Manganese	198.62 (±41.96)	NS	NS	207.86 (±188.23)	NS	756.22 (±849.90)	NS	112.00	246.00	NS
Iron	1083.19 (±105.34)	NS	NS	2414.33 (±1427.49)	NS	2375.15 (±945.08)	NS	360.00	1450.00	NS
Aluminium	4237.16 (±426.34)	NS	NS	3894.90 (±3665.55)	NS	3589.92 (±2108.45)	NS	3400.00	1150	NS
Nickel	9.05 (±1.94)	NS	NS	11.63 (±4.41)	NS	46.42 (±65.63)	NS	11.00	2.08	NS
Zinc	1.97	NS	NS	4.19	NS	8.81 (±10.68)	NS	4.29		NS
Arsenic	8.21 (±2.98)	NS	NS	10.71 (±8.74)	NS	9.11 (±2.97)	NS	1.02	4.08	NS

All the values are expressed in mg/kg dry weight
NS – Not sampled
Note : Values in parenthesis are standard deviation of minimum 5 sets of data

11. Devprayag, before confluence (Alaknanda); 12. Devprayag, after confluence (Ganga), right bank; 13. Devprayag, after confluence (Ganga), middle; 14. Devprayag, after confluence (Ganga), left bank; 15. Rishikesh u.s.; 16. Rishikesh d.s. (right bank); 17. Rishikesh d.s. (middle); 18. Rishikesh d.s (left bank); 19. Alaknanda at Badrinath; 20. Mandakini at Rudraprayag

mineral analysis of sediments followed by XRD technique (**Table 27**) which identified smectite and vermiculite as major minerals in clay and silt fractions. The metal ions present in the bed sediments are not expected to present any deleterious effect as long as they are not released completely from the sediments. The levels of heavy metals, viz. cadmium, copper, zinc, nickel, chromium and arsenic in river water were very low and within the limits stipulated in drinking water standards (IS10500 : 1994). However, the concentrations of these metals in sediments were fairly high.

Literature reveals that heavy metal levels in Ganga sediments are comparatively higher than crustal average. For example, the concentration of Cd in Ganga sediment (15 mg/kg) is alarmingly high as compared to crustal average of 0.22 mg/kg (Ghose and Sharma, 1989). Suspended sediments of Ganga and Brahmaputra rivers were found (Subramanian, et.al., 1987) to be 5 to 10 times richer in heavy metals than the bed sediments.

The metal ions available in the bed sediments were not expected to exhibit any deleterious effect as long as these are not released completely from the sediments. In view of this, it was felt necessary to evaluate whether construction of dam on the river will have any impact on the natural conditions of river water. If the levels of various parameters like pH, ionic strength, Eh etc. in river water vary in course of time, then it may result in remobilization of metal ions, the extent of which depends upon the speciation of metals. Also in case of Bhagirathi river, the rate of siltation is extremely high. **So, in order to quantify its self purification capacity, a comprehensive study of the sediments was needed.**

4.2.3 Release of Metal Ions from Sediments

From the sediment, Cu, Pb, Cr, Ni and Sr were released (**Table 28**) in laboratory condition, when it was equilibrated with distilled water for 18 days (1:100 suspension). The Cu level increased from 0 to 3.93 mg/l during this period. The order of toxicity of metals for micro-organisms is $Ag^{+} >> Cu^{+2}$, $Ni^{+2} > Ba^{+2}$, Cr^{+6}, $Hg^{+2} > Zn^{+2}$, Na^{+}, Cd^{+3}, $As_2O^{-}s$). The self preservative property of Bhagirathi water might be attributed to the release of these metal ions from the sediments and suspended solids. Since the interaction of Cr^{+6} and Cu^{+2} is known to be synergistic (Dirilgen,

Table 27 : Mineral Analysis of Sediments of River Bhagirathi followed by XRD Techniques (October 2002)
(Analysed by National Bureau of Soil Survey and Land Use Planning)
(refer Annexure – III)

Sample Station	Silt (50-2 μm)	Clay (<2 μm)
Gomukh	Sm(D), Vm, Ch, M, K, Q, F	Vm(D),Sm, Ch, M, K (Tr), Q
Gangotri	M (D) Sm,Vm, M, K, Q, F	Vm(D),Sm,M, K (Tr), Q(Tr) ,F(Tr)
Uttarkashi	Sm(D), Vm, Ch, M, K (Tr), Q, F	Sm(D), Vm, Ch, M,Q(Tr), F(Tr)
Tehri (d/s of Bhagirathi)	Sm(D), Vm, Ch, M, K (Tr), Q, F	Sm(D), Vm, Ch, M,Q(Tr), F(Tr), K(Tr)
Rishikesh	Sm(D), Vm, Ch, M, K (Tr), Q, F	Sm(D), Vm, Ch, M,Q(Tr), F(Tr)

Sm =Smectite; Vm = vermiculite; Ch= chlorite; M= mica; K= kaolinite; Q= quartz; F= feldspar; D= dominant; Tr= trace

Table 28 : Release of Metal Ions from the Sediments of River Bhagirathi (Tehri up-stream) with Time

Metal	Time of contact (days)							
	0	1	2	5	6	11	15	18
Cu	BDL	0.009	0.045	0.143	0.2	0.384	0.54	3.93
Pb	BDL	1.91	2.16	2.57	2.76	2.82	2.99	4.18
Cr	BDL	0.016	0.024	0.032	0.040	0.049	0.063	0.068
Ni	BDL	0.023	0.026	0.032	0.035	0.039	0.04	0.042
Sr	BDL	0.007	0.007	0.020	0.021	0.018	0.019	0.024

Metal concentration is expressed as ppm

2002) and both are released from the sediments, as evidenced from the present study, bactericidal impact of these metals can not be ruled out.

It was observed that Ganga river water was stored in a copper container had shown a significant reduction of coliforms and *Streptococcus fecalis* after a storage period of 5 days (Simon et al., 2002). Laboratory studies indicated a tolerance limit (16%) of total coliforms to copper (200 μg/ml) and cadmium (50 μg/ml) in the leaves and roots of radish (Parihar and Ramteke, 2002).

4.2.4 Mineral Composition

4.2.4.1 Mineralogical Properties of the Soils

The inorganic fraction of soils is composed of rock fragments and minerals of varying size and composition. These are sometimes distinguished as primary and secondary minerals. Primary minerals are rock - forming minerals that are present in soils and are chemically unchanged, whereas secondary minerals are formed by weathering of primary minerals. Sometimes, secondary minerals may well be regarded as primary on a pedological basis. Both the physical and chemical properties of any soil are controlled to a large extent by the minerals of the soil and especially by those constituting the clay fraction. Identification, characterization and understanding of properties of the different minerals materially aid in evaluation of soils in relation to classification, agronomic practices and engineering properties.

X-ray diffraction technique is used for mineral identification and mineralogical composition in clay and silt components in soils of the study area. Total clay and silt samples prepared for analysis were examined in the following order for most efficient identification and differentiation of mineral species: (1) K-saturated heated sample (550^0 C), (2) K-saturated heated sample (300^0 C), (3) K-saturated heated sample (110^0 C) (4) K-saturated air dried sample(25^0 C), (5) Ca-saturated, ethylene glycol – solvated sample, (6) Ca- saturated, air dried sample.

4.2.4.2 Identification of Minerals

Primary minerals:

Quartz: The framework of quartz is very densely packed and occurs in a high degree of purity. It is strongly resistant to physical and chemical weathering as the structure is densely packed, electrically neutral and prevents any form of substitution. With time it gets accumulated in soil as the other susceptible minerals decompose to form

clay and decrease in their respective amounts. As such, the abundance of quartz more in soils is next only to feldspar. With X-ray analysis quartz yields a d (100) spacing of 4.28 A° and d (101) spacing of 3.34 A°. Frequently the d (100) diffraction peak at 4.28 A° is very weak in intensity, leaving the usually strong 3.34 A° X-ray diffraction peak for use in diagnosis of quartz.

Feldspar: Feldspars are most abundant among rock forming minerals and constitute nearly 61% of the minerals that are found in the earth's crust. These are non-ferromagnesian minerals and act as storehouse for sodium, calcium, potassium and many trace elements in soil. With X-ray analysis, feldspar can be identified by a (001) d spacing of 3.2 A°. This peak does not shift or collapse after heating salvation to 500° C or solvation with ethylene glycol.

Secondary minerals

Smectite: The minerals are generally very fine grained, whereas the component layers are not bonded strongly. In contact with water, the mineral exhibits interlayer swelling, causing the volume of the clay to double. Indications are available that the basal spacing of smectite increases uniformly with absorption of water. Several authors noted that the increase in basal spacing could occur stepwise, suggesting formation of hydration shells around interlayer cations. The high swell-shrink potential is why the mineral can admit and fix metal ions and organic compounds. The absorption of organic compounds leads to the formation organo-mineral compounds. Organic ions are believed to be able to replace inorganic cations in the interlayer position. Monolayers, sometimes double layers, of organic molecules are adsorbed, depending on the size of the cations and the charge deficit of the layers. Among the several species of clays in soils, the mineral smectite is perhaps the most widely distributed member. Most soil smectite (montmorillonites) are dioctahedral.

Adsorption of organic compounds such as glycerol and ethylene glycol, is diagnostic in identification of smectite by x-ray diffraction analysis. Oven dry (105° C) smectite is usually characterized by a basal (001) d spacing diffraction peak at 10 A°. In air dry condition, the mineral has some interlayer water and the characteristic spacing is approximately 12.4 – 14 A°. After solvation or intercalation with ethylene glycol, the basal (001) spacing expands to 17.0 A°.

Vermiculite: The common occurrence of vermiculite is mixed layers with smectite, chlorite, illite and biotite yields many difficulties in the positive identification of vermiculite. Many clay vermiculite may have been identified in the past as smectite. The vermiculite group of minerals also form mica like flakes as illites. It is also a mica alteration product. Vermiculite can be divided into two categories: *true vermiculite* and *clay vermiculite*. True vermiculite is not considered a clay mineral, but a rock forming mineral. The clay-sized vermiculite found in soils is considered clay vermiculite or soil vermiculite.

The detection of vermiculite in soils is based on its x-ray diffraction peak at 14 A° at the basal spacing of (001) d. This is why it is often called 14 A° mineral. Clay vermiculite is a magnesium aluminium silicate with Mg occupying the octahedral position between two silica tetrahedral sheets. Some iron may also be present.

Chlorites: Chlorites are hydrated magnesium and aluminum silicates, which are related to mica minerals in appearance. Depending on the species, the characteristic of the basal spacing (001) d of chlorite is 14.0 A°, as determined by X-ray diffraction analysis using oriented specimens. This peak does not shift or collapse by treatments of the sample with ethylene glycol or by heating to 500 –550° C. Swelling chlorite may have a basal spacing of 28A°, which increases to 32 A ° by solvation.

Abundance and frequency of occurrence of chlorite are considered low. Isomorphous substitution of magnesium by aluminium (in brucite) creates positive charge practically neutralizes the negative charge of mica layer. Therefore, chlorite has only a very small negative charge, and consequently small CEC. The hydroxy interlayers are sites for anion retention. Phosphorous is reported to be fixed by interlayer hydroxides of chlorites. On the other hand, the presence of these interlayers reduces fixation of K^+ or NH_4 ions.

Mica: Mica (biotite, muscovite) mineral belongs to phyllosilicates, which have sheet structure of honeycomb like tetrahedral structure. In biotite, the positive charged ions holding inner surface are iron and magnesium. In muscovite, each pair of tetrahedral sheets is tightly connected together by ions of aluminium rather than iron and magnesium. In view of perfect cleavage along surfaces of these weak K+ bonds, micas can be peeled off easily. For oriented samples, the basal (001) d X-ray

diffraction peak is at 10A°. This peak will not shift or collapse upon solvation with ethylene glycol or heating the mineral at 500° C.

Kaolinite: Kaolinite is known for low plasticity and shrinkage and swelling properties. Its restricted surface area limits the adsorption capacity for cations. The specific surface area is approximately 7-30 m^2/g. The presence of kaolinite can be identified by a basal (001) d spacing of 7.14 A° X-ray diffraction, and by a second order 3.57 A° diffraction in oriented samples. These diffraction peaks will disappear after heating the kaolinite mineral to 500-550 ° C.

4.2.4.3 Mineral Composition of the Sediments of Study Area

Analysis of sediment sample from Gomukh revealed that the silt component is dominated by smectite (dioctahedral) followed by vermiculite, chlorite, mica, kaolinite, quartz and feldspar, whereas the total clay component is dominated by vermiculite (dioctahedral) followed by smectite, mica, kaolinite (trioctahedral), chlorite, quartz (trioctahedral) and feldspar (trioctahedral).

Samples collected from Gangotri showed mica (dioctahedral) as the dominant mineral in silt followed by smectite, vermiculite, kaolinite, quartz and feldspar, whereas clay components are dominated by vermiculite (dioctahedral) followed by smectite, mica, kaolinite, quartz (trioctahedral) and feldspar (trioctahedral).

Silt component from Uttarkashi is dominated by smectite (dioctahedral) followed by chlorite, vermiculite, kaolinite (trioctahedral), mica, quartz and feldspar, whereas the clay component is dominated by smectite (dioctahedral), followed by vermiculite, chlorite, mica, quartz (trioctahedral) and feldspar (trioctahedral).

Tehri (d/s of Bhagirathi) sample showed smectite (dioctahedral) as the dominant mineral followed by vermiculite, chlorite, mica, kaolinite (trioctahedral), quartz and feldspar in silt components, whereas the clay portion is dominated by smectite (dioctahedral), followed by vermiculite, mica, kaolinite (trioctahedral), quartz (trioctahedral) and feldspar (trioctahedral).

Sample collected from Rishikesh is dominated by smectite (dioctahedral) followed by vermiculite, chlorite, mica, kaolinite (trioctahedral), quartz and feldspar silt components where as the total clay components is dominated by smectite

(dioctahedral), followed by vermiculite, mica, chlorite, quartz (trioctahedral) and feldspar (trioctahedral).

Subramanian (1979) studied the chemical and suspended characteristics of most of the major Indian rivers including that of Ganga. He observed that the kaolinite, illite and chlorite are the main constituents carried in suspension particulate of the Ganga and Brahmaputra, while the Peninsular rivers eg. Krishna and Godavari carry high amount of montmorillonite alongwith very insignificant amount of mixed clays. Literature reveals that cation exchange capacity (CEC) for Sm and Vm is very high and lies in the range of 60-100 meq/100gm and 80-150 meq/100gm respectively. For kaolinite and chlorite, the values are 2-8meq/100gm and 10-40meq/100gm respectively. The cation exchange property is due to displacement of Si^{4+} by Al^{3+} and Al^{3+} by Mg^{2+} in their lattice, which causes charge deficiency in the lattice, that finally results in migration of cations from water to sediments. **Therefore it is necessary to confirm whether the lower levels of hardness and metal concentrations in water samples were due to the result of adsorption or ion exchange.** It is also necessary to study the metal release from the sediment through various biogeochemical cycles operating in the sediment. Mineral analysis by isodynamic separation and identification has been presented in **Table 29.**

4.3 Particle Size Analysis

The particle size analysis of sediments (**Table 30**) showed that the clay and silt fractions constituted around 15% of the total sediments. It was thus, necessary to evaluate whether sand also got adsorption or ion exchange property.

Table 30 : Particle Size Distribution of Sediments of River Bhagirathi/ Ganga

Sampling Station	Sand (2000-50 μm)	Silt (50-2 μm)	Clay (<2 μm)
Gomukh	84.5	12.6	2.8
Gangotri (downstream)	94.8	3.8	1.4
Uttarkashi (downstream)	88.5	9.1	2.4
Tehri (downstream) Bhagirathi	90.9	1.8	7.3
Rishikesh (downstream)	88.4	9.6	2.0

Table 29 : Mineral Analysis of the Sediments from the river Bhagirathi by Isodynamic Separation and Identification

(October, 2002)

(Analysed by Geological Survey of India, Petrology Division, Central Region, Nagpur

(Refer Annexure IV)

Sr. No.	Location	Mineral assemblage	Texture
1.	Gomukh	Garnet + Biotite + Magnetite + Zoisite + Monazite + Epidote + Tourmaline	Heavy mineral grains are mainly sub-rounded to rounded, average size of the grains vary from 0.001 mm to 0.003 mm
2.	Gangotri	Garnet + Biotite + Magnetite + Zoisite + Monazite + Hornblende + Tourmaline	Heavy mineral grains are mainly sub-rounded to rounded, average size of grains vary from 0.002 mm to 0.0007 mm
3.	Uttarkashi	Biotite + Apatite + Epidote	Heavy mineral grains are mainly sub-rounded to rounded, average size of the grains vary from 0.001 mm to 0.003 mm.
4.	Tehri (d/s of Bhagirathi)	Garnet + Biotite + Zoisite + Epidote + Clinopyroxene + Rutile	Heavy mineral grains are mainly sub-rounded to rounded. Some angular grains are also recorded. Average size of the grains vary from 0.001 mm to 0.003 mm.
5.	Rishikesh	Biotite + Epidote + Magnetite + Rutile	Heavy mineral grains are mainly sub-angular to rounded. Average size of the grains vary from 0.002 to 0.0008 mm.

4.4 Radium Equivalent Analysis

Five sediment samples each from rivers Bhagirathi/ Ganga, and water bodies around Nagpur were analysed through Atomic Minerals Directorate for Exploration and Research, Department of Atomic Energy, Central Region, Nagpur. The concentrations of U_3O_8 (ppm), ThO_2 (ppm) and %K are shown in **Table 31**. It appears that the average levels of U_3O_8, ThO_2 and K are over 500, 275 and 150 percent respectively more in Bhagirathi/ Ganga sediments than those collected in Nagpur (Central India).

Based on a comprehensive study on the isotopes in the Ganga-Brahmaputra river system, Sarin et al. (1996) reported that the dissolved ^{238}U concentration in these river waters ranges between 0.44 and 8.32 µg/l, and it exhibits a positive correlation with major cations (Na + K + Mg + Ca). The $^{238}U/\Sigma$Cations ratio in waters is very similar to that measured in the suspended sediments indicating congruent weathering of uranium and major cations. The regional variations observed in the $[^{234}U/^{238}U]$ activity ratio are consistent with the lithology of the drainage basins. The lowland tributaries (Chambal, Betwa, Ken, and Son), draining through the igneous and metamorphic rocks of the Deccan Traps and the Vindhyan-Bundelkhand Plateau, have $[^{234}U/^{238}U]$ ratio in the range 1.16 to 1.84. This range is significantly higher than the near equilibrium ratio (~1.05) observed in the highland rivers which drain through sedimentary terrains. The dissolved ^{226}Ra concentration ranges between 0.03 and 0.22 dpm/l. The striking feature of the radium isotopes data is the distinct difference in the ^{228}Ra and ^{226}Ra abundances between the highland and lowland rivers. The lowland waters are enriched in ^{228}Ra, while the highland waters contain more ^{226}Ra. This difference mainly results from the differences in their weathering regimes. The discharge-weighted mean concentration ^{238}U in the Ganga (at Patna) and in the Brahmaputra (at Goalpara) are 1.81 and 0.3 µg/l, respectively. The Ganga-Brahmaputra river system contributes the major source of dissolved uranium to the Bay of Bengal. These rivers transport annually about 1000 tons of uranium to their estuaries, about 10% of the estimated global supply of dissolved uranium to the oceans via rivers. The transport of uranium by these rivers far exceeds that of the Amazon although their water discharge is only about 20% of that of the Amazon. The high intensity of weathering of uranium in the Ganga-Brahmaputra River system can also be deduced from the $[^{232}Th/^{238}U]$ and $[^{230Th}/^{238}U]$ activity ratios measured in the suspended sediments. ^{230Th} is enriched by about 19% in the suspended sediments relative to its parent ^{238}U. The flux of excess ^{230Th} supplied to the Bay of Bengal via these river sediments is 980 x 10^{12} dpm/a and is

about six times more than its *in situ* production from seawater in the entire Bay of Bengal.

Literature (Ghosh and Sharma, 1989) reveals that short-lived isotopes of radium are present in higher concentration (80.5 pci) in the Ganga water than other river (65.5 pci). High concentration of radium might play an important role in rapid killing of bacteria, possibly through the interaction of radiation with biological materials present in the Gang water, resulting in the formation of ionized host species (such as H^+, H_2O^-, e^-, e^+ etc.). These ionized particles react with protein and deactivate the enzymes, leading to inhibition of cell multiplication or otherwise damage the cell performance.

Table 31 : Gamma Ray Spectrophotometric Analysis of Sediment Samples [Analysed by Atomic Minerals Directorate (AMD) (Refer Annexure V)]

Sr. No.	Sampling Locations	U_3O_8 (ppm)*	ThO_2 (ppm)	%K
	From Study Area			
1.	Gomukh	7.0	17.8	2.5
2.	Gangotri (d.s.)	7.5	10.3	2.7
3.	Uttarkashi (d.s.)	6.2	20.1	2.2
4.	Tehri (d.s.of Bhagirathi)	6.8	22.4	1.8
5.	Rishikesh (d.s.)	5.5	17.6	1.9
	From Central India			
6.	Telankhedi reservoir, Nagpur	<1.0	4.8	0.8
7.	Kanhan river, Nagpur	1.7	5.7	2.3
8.	Pili river, Nagpur	1.2	3.9	0.3
9.	Kollar river, near Nagpur	1.5	4.6	0.2
10.	Ambazari reservoir, Nagpur	<1.0	4.4	0.7

* Radium equivalent

4.5 Bacteriological Quality of Sediments of the Rivers

Sediment samples from Bhagirathi river were collected from Gomukh, Gangotri, Uttarkashi, Upstream of Tehri dam, downstream of Tehri dam, Devprayag before confluence with Alaknanda river. Ganga river sediments were collected at Devprayag after confluence with Alaknanda river and also at Rishikesh. All collected samples were analyzed for indicator bacteria, i.e. total coliforms, faecal coliforms, *E. coli* and faecal streptococci.

Sediment samples collected from Gomukh to Rishikesh were found to contain total coliforms. The density of coliforms was found to increase as the river flows downwards to Devprayag. Alaknanda river sediment was found to contain the total coliform count in the range of 310 to 3130 CFU/g. TC count in sediments collected from Ganga river after confluence at Devprayag was observed to be in the range of 320 to 4400 CFU/g (**Table 32**). Further downstream at Rishikesh, TC count of sediment was found to be in the range of 1125 to 4400 CFU/g. The average counts of five sets samples are presented in **Table 33**.

4.6 Detection of Coliphages in River Sediments

Sediment samples were collected from Ganga river at different locations i.e. Gomukh, Gangotri, Uttarkashi, upstream and downstream of Tehri dam, Devprayag before & after confluence with Alaknanda river and also at Rishikesh. Twenty percent suspension of the sediment was prepared in 3% BEMB solution of pH 7.1 and stirred for 30 minutes. Supernatant was collected after centrifugation at 3000 rpm and made free from bacterial contamination by filtering through 0.45µm membrane filter and was assayed for coliphages by plaque assay method using different types of *E. coli* host cells. The counts of coliphages detected in Ganga river sediment samples at different locations are presented in **Table 34**. It has been observed that different types of coliphages are present in Ganga river sediment and could be detected by using different types of susceptible host cells. Four different host of *E. coli*, isolated from water and sediment samples of rivers in the study area, were used to detect coliphages. One more host of *E. coli* was isolated from sewage sample collected at Nagpur and was also used for detection of coliphages.

Since coliphages were not detected in both water samples and river sediment samples collected during August, 2003, two experiments were conducted. In the first experiment, the coliphages concentrated from the river sediment samples were assayed by incubating at a lower temperature of 20°C (in contrast to incubation at temperature of 37°C as done in earlier occasions) as given in the review paper on Bacteriophages as model viruses in water quality control, IAWPRC Study Group on Health Related Water Microbiology, 1991. But coliphages were not detected.

In the second experiment, the coliphages concentrated from the river sediment were subjected to a treatment of a hypertonic solution of NaCl so as to

Table 32 : Bacteriological Quality of Ganga River Sediment

CFU/g

Sr. no.	Sampling locations	24-25 Sept 02				7-8 Oct., 2002				23-24 Oct., 2002				14-23 May, 2003				28-31 August, 2003			
		TC	FC	EC	FS	TC	FC	EC	FS	TC	FC	EC	FS	TC	FC	EC	FS	TC	FC	EC	FS
1	Tapovan	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0	0	0	0	0	0	0	0
2	Gomukh	9	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
3	Gangotri u.s	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	6	2	0	0	5	1	0	0
4	Gangotri d.s.	20	0	0	1	13	3	0	0	0	3	0	1	10	3	1	1	25	9	2	10
5	Uttarkashi u.s.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	64	41	20	9	120	25	11	5
6	Uttarkashi d.s.	63	47	29	15	15	8	4	22	195	77	60	20	172	55	32	21	135	27	14	12
7	Tehri u.s. (Bhagirathi)	NS	NS	NS	NS	20	08	6	3	160	82	48	1	110	80	40	28	190	31	16	24
8	Tehri u.s. (Bhilangana)	NS	NS	NS	NS	NS	NS	NS	NS	150	70	38	10	170	90	50	42	90	14	12	29
9	Tehri d.s. (Bhagirathi)	NS	NS	NS	Ns	82	26	19	14	590	320	141	22	320	210	130	40	130	22	15	26
10	Devprayag before confluence (Bhagirathi)	180	96	42	131	77	44	31	189	2610	1075	332	241	982	610	210	55	150	16	11	31
11	Devprayag before confluence (Alaknanda)	NS	NS	NS	NS	1200	186	32	110	3130	380	58	116	1210	700	340	40	310	18	35	51
12	Devprayag after confluence (Ganga) right bank	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

TC : Total coliforms; FC : Faecal coliforms; EC : *E. coli*; FS : Faecal streptococci
NS : Not sampled

Table contd...

Table 32 (contd...)

Sr. no.	Sampling locations	24-25 Sept 02				7-8 Oct., 2002				23-24 Oct., 2002				14-23 May, 2003				28-31 August, 2003			
		TC	FC	EC	FS	TC	FC	EC	FS	TC	FC	EC	FS	TC	FC	EC	FS	TC	FC	EC	FS
13	Devprayag after confluence (Ganga) midstream	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
14	Devprayag after confluence (Ganga) left bank	NS	NS	NS	NS	1140	110	52	87	4400	450	98	133	1160	820	330	70	320	79	33	50
15	Rishikesh u.s.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1690	950	210	82	1125	162	48	62
16	Rishikesh d.s. (right bank)	2980	390	112	154	3200	405	128	190	4400	420	165	166	3500	2000	1500	100	2450	960	660	180
17	Rishikesh d.s. (midstream)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
18	Rishikesh d.s. (left bank)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	2900	1900	1200	120	2100	880	524	190
19.	Alaknanda (Badrinath)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
20.	Mandakini (Rudreprayag)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

TC : Total coliforms; FC : Faecal coliforms; EC : *E. coli*; FS : Faecal streptococci
NS : Not sampled

Table 33 : Average Bacteriological quality of Ganga river Sediment

(CFU/g)

Sr. no.	Sampling locations	Total coliforms	Faecal coliform	*E. coli*	Faecal streptococci
1	Tapovan	Nil	Nil	Nil	Nil
2	Gomukh	2.00 (±4.93)	Nil	Nil	Nil
3	Gangotri u.s.	8.80 (±6.97)	1.80 (±0.95)	Nil	0.40
4	Gangotri d.s.	17.50	6.00	1.50	5.50
5	Uttarkashi u.s.	92.00	33.00	15.50	7.00
6	Uttarkashi d.s.	116.00 (±75.41)	42.80 (±26.44)	27.80 (±21.28)	18.00 (±4.30)
7	Tehri u.s. (Bhagirathi)	120.00	50.25	27.50	14.00
8	Tehri u.s. (Bhilsngana)	136.66	58.00	33.33	27.00
9	Tehri d.s. (Bhagirathi)	280.50	144.50	76.25	25.50
10	Devprayag before confluence (Bhagirathi)	799.80 (±1076.90)	368.20 (±464.02)	125.20 (±140.35)	129.40 (±88.35)
11	Devprayag before confluence (Alaknanda)	1462.50	321.00	116.25	79.25
12	Devprayag after confluence (Ganga) right bank	2770.00	280.00	75.00	110.00
13	Devprayag after confluence (Ganga) middle	NS	NS	NS	NS
14	Devprayag after confluence (Ganga) left bank	740.00	449.50	181.50	60.00
15	Rishikesh u.s.	2679.00 (±1295.85)	465.40 (±290.81)	132.60 (±60.50)	130.80 (±55.67)
16	Rishikesh d.s. (right bank)	2975.00	1480.00	1080.00	140.00
17	Rishikesh d.s. (middle)	NS	NS	NS	NS
18	Rishikesh d.s. (left bank)	2500.00	1390.00	862.00	155.00
19.	Alaknanda (Badrinath)	NS	NS	NS	NS
20.	Mandakini (Rudraprayag)	NS	NS	NS	NS

NS : Not sampled

Note : Values in parenthesis are standard deviation of minimum 5 sets of data

Table 34 : Detection of Coliphages in Ganga sediment between Tapovan and Rishikesh

(PFU/g)

Sr. No.	Sampling locations	24-25 Sept., 2002	7-8 Oct., 2002	23-24 Oct., 2002				14-23 May, 2003					28-31 Aug., 2003				
		Host EC1	Host EC1	Host EC1	Host U3	Host T4	Host R9	Host EC1	Host U3	Host T4	Host EC6	Host R9	Host EC1	Host U3	Host T4	Host EC6	Host R9
1	Tapovan	NS	NS	NS	NS	NS	NS	-	-	-	-	-	-	-	-	-	-
2	Gomukh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	Gangotri u.s.	NS	NS	NS	NS	NS	NS	-	-	-	-	4	-	-	-	-	-
4	Gangotri d.s.	-	-	-	-	-	-	-	-	75	30	-	-	-	-	-	-
5	Uttarkashi u.s.	NS	NS	NS	NS	NS	NS	4	-	-	-	10	-	-	-	-	-
6	Uttarkashi d.s.	2	2	4	-	-	-	10	-	12	-	20	-	-	-	-	-
7	Tehri u.s. (Bhagirathi)	NS	4	-	-	-	-	-	-	-	-	1	-	-	-	-	-
8	Tehri u.s. (Bhilangana)	NS	NS	NS	NS	NS	NS	64	-	-	-	-	-	-	-	-	-
9	Tehri d.s. (Bhagirathi)	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	Devprayag before confluence (Bhagirathi)	16	-	-	-	3	-	7	5	-	-	-	-	-	-	-	-
11	Devprayag before confluence (Alaknanda)	NS	-	6	-	-	22	-	-	-	20	12	-	-	-	-	-
12	Devprayag after confluence (Ganga) right bank	NS	2	1	-	-	-	NS	NS	NS	NS	NS	-	-	-	-	-
13	Devprayag after confluence (Ganga) midstream	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
14	Devprayag after confluence (Ganga) left bank	NS	NS	NS	NS	NS	NS	6	-	-	-	-	-	-	-	-	-
15	Rishikesh u.s.	NS	NS	NS	NS	NS	NS	5	-	-	-	10	-	-	-	-	-
16	Rishikesh d.s. (right bank)	8	-	12	-	-	3	10	-	-	-	30	-	-	-	-	-
17	Rishikesh d.s. (midstream)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
18	Rishikesh d.s. (left bank)	NS	NS	NS	NS	NS	NS	15	-	-	-	30	-	-	-	-	-
19.	Alaknanda (Badrinath)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
20.	Mandakini (Rudraprayag)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS : Not sampled

- : Not detected

disrupt the cell wall of the bacteria lodging the phages inside the cell and then the phage sample was assayed, but this procedure also did not show any coliphages.

Bacteriological quality of the sediment from Alaknanda river was assessed by analyzing various parameters including may bacteriophages. In the study, coliphages (Bacteriophages specific to *E. coli*) were detected in river water and sediment samples from Tapovan (upstream) to Rishikesh (downstream) including Alaknanda river at Devprayag. It was found that the sediment of Alaknanda river contained coliphages against *E. coli* hosts used in this study (Table 34).

4.7 Adsorption of Coliphages to Sediment

. Coliphages are inhabitant of human and warm blooded animals and are excreted alongwith faecal matter. Detection of coliphages in water is one of the tests, considered for water pollution. Different types of phages have been detected in Ganga water and its sediments. The coliphages might be adhering to the sediment suspended in Ganga water and settling to the bottom along with silt.

An experiment was conducted to evaluate the trend of adsorption of coliphages in Ganga water. In this experiment, Ganga water (100 ml) was taken in a conical flask, warmed upto 65°C and cooled to room temperature, and contaminated with known number of coliphages and *E. coli*. Initial sample was collected to find out the coliphage content. The sample was kept on shaker at 70 rpm and samples were collected at 12, 24, 48, 72, 120, 144 and 168 hrs. These samples were made free of bacteria by passing through 0.45µm MF and assayed for coliphages. Result is presented in **Table 35**. It has been observed that 40% adsorption to the sediment occurred within 12 hours. The adsorption increased with increase in adsorption time. Complete adsorption of coliphages took place in 120 hrs as indicated by the absence of coliphages in the supernatant.

Table 35 : Adsorption of Coliphages on Sediment

Time in Hrs	Coliphages in the sediment (PFU/g)	% adsorption of coliphages
0	6000	-
12	3600	40
24	2300	62
48	2200	64
72	1300	78
120	00	100
144	00	100
168	00	100

100 ml Ganga water + *E. coli* + Phage + 1% Sediment

Elution of Adsorbed Coliphages

The coliphages adsorbed onto the Ganga/ Bhagirathi river sediments were detected as follows. Water sample of 100 ml was centrifuged at 1800 g for 30 minutes. Supernatant was decanted and assayed for the coliphages. The settled sediment was suspended in 5 ml of 3% BE in McIlvaine buffer (BEMB) and stirred for 15 minutes. The eluate was centrifuged to remove the sediment and the supernatant was collected and assayed for the coliphages. Result is presented in **Table 36**.

Table 36 : Coliphage in Sediment

Initial concentration of added phages	Phages in filtrate	Phages in sediment after 168 hours
6000 PFU/100ml	1000 PFU/100ml	20200 PFU/g of sediment

It has been seen that the sediment contained 20200 PFU of phages after the conclusion of the experiment. The adsorbed phage concentration was much more than the initial count. This study reveals that added phages might have infected *E. coli* resulting in the multiplication of the phages which in turn were adsorbed onto the sediment. This indicates that the sediment of the Ganga water has a potential to adsorb the phages which are likely to increase in number under static conditions and these phages may play an important role in preserving the Ganga water under static condition by reducing/ eliminating the coliforms.

Different types of phages are present in Ganga water. Detection of these phages requires different types of *E. coli* hosts. Therefore, host cells of *E. coli* were

isolated from sewage collected from Nagpur and also from sediment samples collected at the bank of Ganga river at different places, i.e. Rishikesh, downstream & upstream of Tehri dam, Devprayag and Uttarkashi. *E. coli* hosts were also isolated from Bhilangana river water. All these *E. coli* hosts were used for detection of phages from Ganga river water samples. Phages isolated from Ganga water samples were tested for their susceptibility to different *E coli* host strains. **Table 37** shows diverse coliform-coliphage response.

It has been observed that phages No. 1, 2, and 4 could be cultivated on *E. coli* host cells NS_1, R_9 and D_6. Phages 4 & 5 could be grown on *E. coli* NS_1, R_9, D_6 and U(1)3. Phage 9 could be grown only on R_9, whereas Phage No. 10 was found to grow on NS_1 and U(1)3. This indicates that Phages require specific host cells for their growth. *E. coli*, isolated from the sediment at Rishikesh (R_9), was found to be susceptible for all of the Phages (Table 37) except Phage 10.

Table 37 : Diversity of Coliform-Coliphage Response

Host/ Phage	Host NS1	Host R9	Host T5	Host D6	Host B4	Host T4	Host U(1)3	Host U(2)3
Phage 1	+	+		+	-	-	-	-
Phage 2	+	+	-	+	-	-	-	-
Phage 3	-	+	-	-	-	-	-	-
Phage 4	+	+	-	+	-	-	+	-
Phage 5	+	+	-	+	-	-	+	-
Phage 6	-	+	-	-	-	-	-	+
Phage 7	-	+	+	+	-	-	+	-
Phage 8	-	+	-	+	-	-	+	-
Phage 9	-	+	-	-	-	-	-	-
Phage 10	+	-	-	-	-	-	+	-
Phage 11	+	+	-	+	-	-	+	-

Note : Host NS1 – Isolated from Nagpur sewage
Host R9 – Isolated from Rishikesh sediment
Host T5 – Isolated from Tehri Dam Down stream sediment
Host D6 – Isolated from Bhilangana River
Host B4 – Isolated from Bhilangana River
Host T4 – Isolated from Tehri Dam Upstream sediment
Host U(1)3 – Isolated from Uttarkashi sediment
Host U(2)3 – Isolated from Uttarkashi sediment

4.8 Benthic Fauna

These are the organisms inhabited in the bottom sediments of water bodies. The quantity and quality of benthic fauna depend mainly on certain variables such as the altitude, current velocity, temperature, type of substratum and dissolved substances. Literature reveals that sandy stretches support poor benthic invertebrates, while rocky beds, gravels, rubbles etc. support increasing benthic biomass (Sehgal, 1984).

The sediment from each sampling point was collected by Van Veen grab and passed through 500 and 45 micron mesh sieves for isolation of macro and meiobenthos respectively. Benthic fauna could not be recorded during the months of September and October, 2002. Analysis of macrobenthos revealed 2 Diptera larva viz. *Tabanus* sp. and *Megistocera* sp. in an area of 0.0929 per m^2 at sampling points viz. Rishikesh upstream and Rishikesh downstream (right bank) respectively in the month of August, 2003. However, meiobenthos could not be recorded **(Table 38)** in any of the samples during this period.

In May, 2003 only meiobenthos were observed at Tehri downstream (Bhagirathi) alongwith the presence of one variety of nematoda (*Bathyonchus* sp.).

5.0 Modelling for Tehri Dam to Study Self Purification Capacity of Bhagirathi River

The hydrodynamic modelling of Tehri dam was carried out by CWPRS, Pune during 2001. Two reports documented the findings. Careful studies of these reports revealed that CWPRS modeling studies were found to be sufficient for the required purpose. NEERI agrees with the methodology adopted by CWPRS, Pune for the study. The findings of CWPRS and our comments are as follows :

1. "There is no possibility of permanent stagnation of water in the reservoir. The 2-Dimensional circulation prevails in the reservoir at all the times of the year". (Ref: synopsis Report No. 3821). This could be the general situation since the inflowing river water is colder than the top or middle level water of the reservoir which will induce lateral and vertical flows. But during the passage through the upper layers, considerable mixing will take place and this water may remain warmer than the bottom layers. As a result, the deepest layer and some pockets in the

Table 38 : Density and Diversity of Benthic Fauna at different sampling points in the Study Area (September, 2002 to August, 2003)

Sr. No.	Sampling stations	Date of sampling	Benthos (per square meter)		Percentage of organisms in groups		Shannon Wiener Index
			Macro	Meio	Nematoda	Diptera	
1	Tapovan	14-23 May, 03	Nil	Nil	Nil	Nil	Nil
		28-31 Aug., 03	Nil	Nil	Nil	Nil	Nil
2	Gomukh	14-23 May, 03	Nil	Nil	Nil	Nil	Nil
		28-31 Aug., 03	Nil	Nil	Nil	Nil	Nil
3	Gangotri upstream	14-23 May, 03	Nil	Nil	Nil	Nil	Nil
		28-31 Aug., 03	Nil	Nil	Nil	Nil	Nil
4	Gangotri downstream	14-23 May, 03	Nil	Nil	Nil	Nil	Nil
		28-31 Aug., 03	Nil	Nil	Nil	Nil	Nil
5	Uttarkashi upstream	14-23 May, 03	Nil	Nil	Nil	Nil	Nil
		28-31 Aug., 03	Nil	Nil	Nil	Nil	Nil
6	Uttarkashi downstream	14-23 May, 03	Nil	Nil	Nil	Nil	Nil
		28-31 Aug., 03	Nil	Nil	Nil	Nil	Nil
7	Tehri upstream (Bhagirathi)	14-23 May, 03	Nil	Nil	Nil	Nil	Nil
		28-31 Aug., 03	Nil	Nil	Nil	Nil	Nil
8	Tehri upstream (Bhilangana)	14-23 May, 03	Nil	Nil	Nil	Nil	Nil
		28-31 Aug., 03	Nil	Nil	Nil	Nil	Nil
9	Tehri downstream (Bhagirathi)	14-23 May, 03	Nil	2153	100.00	Nil	0.00
		28-31 Aug., 03	Nil	Nil	Nil	Nil	Nil
10	Devprayag before confluence (Bhagirathi)	14-23 May, 03	Nil	Nil	Nil	Nil	Nil
		28-31 Aug., 03	Nil	Nil	Nil	Nil	Nil
11	Devprayag before confluence (Alaknanda)	14-23 May, 03	Nil	Nil	Nil	Nil	Nil
		28-31 Aug., 03	Nil	Nil	Nil	Nil	Nil
12	Devprayag after confluence (Ganga right bank)	14-23 May, 03	Nil	Nil	Nil	Nil	Nil
		28-31 Aug., 03	Nil	Nil	Nil	Nil	Nil
13	Devprayag after confluence (Ganga Midstream)	14-23 May, 03	Nil	Nil	Nil	Nil	Nil
		28-31 Aug., 03	Nil	Nil	Nil	Nil	Nil
14	Devprayag after confluence (Ganga left bank)	14-23 May, 03	Nil	Nil	Nil	Nil	Nil
		28-31 Aug., 03	Nil	Nil	Nil	Nil	Nil
15	Rishikesh upstream	14-23 May, 03	Nil	Nil	Nil	Nil	Nil
		28-31 Aug., 03	3229	Nil	Nil	100.00	0.00
16	Rishikesh downstream (right bank)	14-23 May, 03	Nil	Nil	Nil	Nil	Nil
		28-31 Aug., 03	2691	Nil	Nil	100.00	0.00
17	Rishikesh downstream (Midstream)	14-23 May, 03	Nil	Nil	Nil	Nil	Nil
		28-31 Aug., 03	Nil	Nil	Nil	Nil	Nil
18	Rishikesh downstream (left bank)	14-23 May, 03	Nil	Nil	Nil	Nil	Nil
		28-31 Aug., 03	Nil	Nil	Nil	Nil	Nil
19	Alaknanda (Badrinath)	14-23 May, 03	Nil	Nil	Nil	Nil	Nil
		28-31 Aug., 03	Nil	Nil	Nil	Nil	Nil
20	Mandakini (Rudraprayag)	14-23 May, 03	Nil	Nil	Nil	Nil	Nil
		28-31 Aug., 03	Nil	Nil	Nil	Nil	Nil

periphery towards the downstream side may remain stagnant. In absence of significant biological activities at large depths, water quality, however, may not get deteriorated.

2. The circulation patterns and velocity profiles in the spatial and temporal domains are given in the report. However, these do not change the reservoir water quality class in terms of DO and BOD significantly as per these predictions, since the variations are very marginal and at such low BOD values the model parameter estimation and modelling scheme may become insignificant. In fact BOD less than 1mg/l experimentally is treated as non-detectable and model estimates BOD in some cases in the range 0.001 mg/l which has no significance. Accordingly, the question of algal bloom or eutrophication which can cause population explosion of algae in the reservoir is just not possible.

3. Self-purification property is not associated with DO-BOD parameters. Dissolved materials will also be pushed out on yearly cycle basis as the CWPRS suggests. If it is associated with discrete particles in water sediments, as many researchers feel, then sediment transport due to hydrodynamics is an important aspect. Sediment, being considerably heavier than water, will tend to settle. Considering sediment density and kinematic viscosity as 1.7 and 1.14 centistokes, the computed settling velocity, Reynolds Number and drag coefficient would be 0.0528 cm/s, 0.0185 and 1313 respectively for particle size of 0.004 cm following Stokes Law. For a horizontal velocity towards the outlet as 10 cm/s, as suggested in the CWPRS report, it will sink 130 m while travelling a distance of 25 km. However, the circulation pattern in the reservoir is very complex with reverse flow in the top layer. Horizontal velocity of 10 cm/s may be on the higher side. As a result, particles with diameters of the order of 0.01 mm or larger will not escape from the reservoir and settle. Scouring velocity for resuspension of settled matter simply does not exist anywhere.

6.0 Self Preservation Capacity of River Bhagirathi/ Ganga

For times immemorial, it is observed that Bhagirathi/ Ganga water possesses an unique self preservation capacity. A century ago, Hankin (1896) reported that the waters of the Ganges and Jamuna rivers in India had marked antibacterial action. Edward Twort (1915) and Felix d'Herelle (1917) independently reported isolating filterable entities capable of destroying bacterial cultures and of producing small cleared areas on bacterial lawns seemingly implying that discrete particles were

involved. They were jointly given credit for the discovery. It was d'Herelle, a Canadian working at the Pasteur Institute in Paris, who gave them the name "bacteriophages". Several explanations for self purification were put forward, though none of those could justify this unique observation.

The investigations carried out by NEERI had led to the following observations which might provide a credible explanation to the observed self preservation capacity of river Bhagirathi/ Ganga.

- Experiments carried out revealed that Ganga/ Bhagirathi sediment has the capability to adsorb coliphages (Table 35) and induce their proliferation (Table 36). The coliphages adsorbed to the sediment appear to be responsible for predating coliforms in the overlying water column when the sediment and water co-exist in a container under static condition. The Bhagirathi water stored in dam mimics such static condition and, therefore, shall in no way deteriorate the water quality of the river downstream of the Tehri dam.
- The release of copper and chromium under static condition (Table 28) and the synergistic effect of chromium on the bacteriostatic/ bactericidal property of copper (Dirilgen, 2002) is one of the factors which keeps the water free from coliforms and other bacteria responsible for putrification of water, when left for a long time under static condition.
- Quantification of U_3O_8, ThO_2 and percent K in sediment samples and comparison of these parameters with those present in other river sediment samples and freshwater lake sediment samples show that Bhagirathi/ Ganga sediments collected between Gomukh and Rishikesh are more radioactive than others.
- It can be concluded now that the uniqueness of river Bhagirathi/ Ganga lies in its sediment content which is comparatively more radioactive compared to other river and lake water sediments investigated, and can release Cu and Cr which have bactericidal property and can harbour and cause proliferation (under static condition) of coliphages which reduce and ultimately eliminate coliforms from the overlying water column. Thus Tehri dam is not likely affect the quality or self preservation property of river Bhagirathi/ Ganga as it mimics a static container which is conducive for conditions responsible for maintaining water quality.
- Since suspended particles play a major role towards self preservation of Ganga water, it is, thus, necessitated to have certain levels of suspended

solid in the water, downstream of Tehri dam, particularly after confluence with the Alakhnanda river at Devprayag. Considering average annual flow of 258 and 467 cubic metre per second in Bhagirathi and Alakhnanda rivers respectively having average suspended solids of 73.75 and 53.25 mg/l in respective river waters, it is estimated that contribution of Alakhnanda at downstream of Devprayag is 69% of the existing suspended solids. Investigation further indicated that particulate matters of Alakhnanda river have identical antibacterial property as those of Bhagirathi river. While the modelling studies suggest that the sediment particles above 10μ will settle in the dam site, the contribution of sediment in Bhagirathi through dam discharge would be about 10% comprising clay and portion of silt (Ref. Table 30). Although about nine-tenth of the existing(31% at downstream of Tehri dam) sediment would be arrested at dam site, there would be ample sediment from the catchment in between Tehri and Devprayag, and also from Alakhnanda river to maintain the self preservation capacity of the Ganga river water during post construction phase of the dam.

7.0 Summary of Experimental Results

Physico-Chemical

- In the entire study area, the pH varied between 6.4 and 8.0
- In the study area, the DO varied between 7.1 and 19.85 mg/L
- The total suspended solids varied between 4.0 and 276.0 mg/L
- The total dissolved solids concentration varied between 24 and 143 mg/L
- The COD was found to be below 10 mg/L along the whole stretch of the study area.
- BOD was less than 1.0 mg/l
- Total nitrogen in the study area varied between 0.22 and 4.12 mg/L
- Total phosphorus varied between 0.001 and 0.070 mg/L
- Heavy metal concentration was within the desirable limits of drinking water standards
- All the above physico-chemical parameters do not indicate any adverse condition prevailing in the rivers Bhagirathi/ Alaknanda/ Ganga.

Biological

- Water samples from Gomukh, Gangotri and Tehri dam upstream were devoid of phytoplankton
- Studies revealed that role of silt in removing the phytoplankton by settling is remote and nutrient levels may be the factor for absence of phytoplankton
- The river samples from Tapovan to Gomukh were predominantly devoid of zooplankton during the study period. The most dominant group amongst the locations were Nematoda, followed by Copepoda and Plecoptera
- The maximum Shannon Wiener diversity indices ranged from 0.00 to 2.25 at which indicated oligotrophic nature of the Bhagirathi river water
- Indicator invertebrates for oligotrophic freshwaters were found to be *Arcella* sp., *Philodina* sp., *Iron* sp., *Allocapnia* sp.
- The benthic fauna of the river was negligible or near to zero throughout the stretch of the study area.

Microbiological

- Water samples for bacteriological analyses were collected from Bhagirathi, Bhilangana and Alaknanda rivers
- Indicator bacteria were not detected from the water samples collected from Tapovan and Gomukh almost on all occasions
- The load of bacterial indicators was showing an increasing trend from upstream to downstream which is attributed to increased anthropogenic activities as one moves downstream to Gangotri
- The lowest concentration of indicator bacteria in river water samples was observed during August 2003, which may be due to the dilution of river water during monsoon
- Indicator bacteria were detected from the samples of river sediments also.
- Coliphages were detected in water samples of river Bhagirathi and Ganga. Similarly, coliphages were detected in sediment samples of River Bhagirathi and Ganga. *E. coli* R9 appeared to be an universal host for the isolated bacteriophages (phages 1-9 and 11,).

Self purification aspects

- The experimentation revealed that Ganga/ Bhagirathi sediment has the capability to adsorb coliphages and induce their proliferation. The coliphages adsorbed to the sediment appear to be responsible for predating coliforms in the overlying water column when the sediment and water co-exist in a container under static condition. The Bhagirathi water to be stored in a dam mimics such static condition and, therefore, shall in no way deteriorate the water quality of the river downstream of the Tehri dam.
- The release of copper and chromium under static condition and the synergistic effect of chromium on the bacteriostatic/ bactericidal property of copper (Dirilgen, 2002) is one of the factors which keeps the water free from coliforms and other bacteria responsible for putrification of water when left for a long time under static condition.
- Quantification of U_3O_8, ThO_2 and percent K in sediment samples and comparison of these parameters with those present in other river sediment samples and freshwater lake sediment samples show that Bhagirathi/ Ganga sediments collected between Gomukh and Rishikesh are more radioactive than others.

8.0 Conclusion

It is concluded that the uniqueness of river Bhagirathi/ Ganga lies in its sediment content which is more radioactive compared to other river and lake water sediments and can release Cu and Cr which have bactericidal properties and can harbour and cause proliferation (under static condition) of coliphages that reduce and ultimately eliminate coliforms from the overlying water column. Thus, Tehri dam is not likely to affect the quality or self preservation property of river Bhagirathi/ Ganga, as it mimics a static container which is conducive for conditions responsible to maintain the water quality.

Since suspended particles play a major role towards self preservation of Ganga water, it is, thus, necessitated to have certain levels of suspended solid in the water, downstream of Tehri dam, particularly after confluence with the Alakhnanda river at Devprayag. Considering average annual flow of 258 and 467 cubic metre per second in Bhagirathi and Alakhnanda rivers respectively having average suspended solids of 73.75 and 53.25 mg/l in respective river waters, it is estimated that contribution of Alakhnanda at downstream of Devprayag is 69% of the existing suspended solids. Investigation further indicated that particulate matters of Alakhnanda river have identical antibacterial property as those of Bhagirathi river. Although about nine-tenth of the existing(31% at downstream of Tehri dam) sediment would be arrested at dam site, there would be ample sediment from the catchment in between Tehri and Devprayag, and also from Alakhnanda river to maintain the self preservation capacity of the Ganga river water during post construction phase of the dam.

Pipes, W.C. (1961) Water & Sewage Works, Vol. 108, 176-181.

Radhakrishna, Y. and Rangareddy, Y. (1976) Habitat preferences in ome common freshwater calanoid species in the lower deltai region of the river Krishna Memoir, Society of Zoologists, Guntur, India, pp. 66-69.

Renn, C.E. (1954) *Am. J. Publ. Hlth.*, 44, pp. 631-634.

Rudolfs et al., (1926) Bull. Newjers. Argric.. Ext. Stn., 403, 60-81.

Sandon, H. (1932) The Food of Protozoa, Egyptian Univ. Cairo Publ. Fac. Sci. No. 1

Sangolkar,L.N., Choudhary,P.R., Shivaraman,N.(1999) Cyanobacterial toxins in water environment-A review Journal IAEM, Vol. 26, 18-29.

Sarin, M.M., Krishnaswami, S., Dilli, K., Somayajulu, B.L.K., and Moore, W.S. (1989), Major ion chemistry of the Ganga-Brahmaputra river system: Weathering processes and fluxes to the Bay of Bengal, *Geochimica et Cosmochimica Acta*, Vol. 53, pp. 997-1009.

Sarin, M.M., Krishnaswami, S., Somayajulu, B.L.K., and Moore, W.S., (1996) Chemistry of uranium, thorium, and radium isotopes in the Ganga-Brahmaputra river system : Weathering processes and fluxes to the Bay of Bengal, *Geochimica et Cosmochimica Acta*, Vol. 54, pp. 1387-1396

Sharma, R.C., (1991) Rhithronology of Bhagirathi, Garhwal Himalaya (India), In : Ecology of Mountain Waters, (ed.) Bhatt, P.K. and Pande, R.K., p. 198, Ashish Publishing House, New Delhi

Simon, S., Hussain M.G. and Sharma, M. (2002) Effect of *Trichoderma viride*, *Pseudomonas fluorescens* and plant growth stimulated (cytozyme) on the diseases of sunflower (*Helianthus annus* L.), In the proceedings of The National Academy of Sciences, India, Seventy Second Annual Session, 25-27 October, 2002, pp. 110.

Twort, E.W. (1915) An investigation on the nature of ultramicroscopic viruses. Lancet 1915 II:1241.

Woodruff, (1912) J. Exp. Zool., 12, 205-264.

Annexure I
(11 pages)

IS 10500 : 1991

भारतीय मानक

पीने का पानी — विशिष्टि

(पहला पुनरीक्षण)

Indian Standard

DRINKING WATER — SPECIFICATION

(First Revision)

Second Reprint AUGUST 1995

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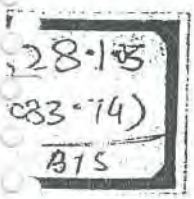

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

September 1991

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FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Water Sectional Committee had been approved by the Chemical Division Council.

This standard was originally published in 1983. The current revision has been undertaken to take into account the uptodate information available about the nature and effect of various contaminants as also the new techniques for identifying and determining their concentration. In this revision based on experience gained additional requirements for alkalinity, aluminium and boron have been incorporated and the permissible limits for dissolved solids, nitrate and pesticides residues have been modified.

A report prepared by the World Health Organization in cooperation with the World Bank showed that in 1975, some 1 230 million people were without safe water supplies. These appalling facts were central to the United Nations decision to declare an International Drinking Water Supply and Sanitation decade, beginning in 1981. Further, the VI Five-Year Plan of India had made a special provision for availability of safe drinking water for the masses. Therefore, this standard was prepared with the following objectives:

a) To assess the quality of water resources, and

b) To check the effectiveness of water treatment and supply by the concerned authorities.

During VII Five-Year Plan, 55 mini mission districts were identified with a view to meet supply of water to all the problem villages. The VIII Five-Year Plan intends to provide safe drinking water to the rural mass. It also propose to ensure supply of desired quality and required quantity of drinking water.

While preparing this standard, the Committee had taken note of the limited testing facilities available in the country. This standard, therefore, categories various characteristics as essential or desirable. The standard also mentions the desirable limit and indicates its background so that the implementing authorities may exercise their discretion, keeping in view the health of the people, adequacy of treatment, etc. All essential characteristics should be examined in routine. Besides, all desirable characteristics should be examined either when a doubt arises or the potability of water from a new source is to be established.

It has been recognised that often it is necessary to relax the specifications, especially when no alternate resources are available and therefore, to enable the experts to exercise their discretion a maximum permissible limit has also been given.

In the case of virological examination, if not even one plaque-forming unit (PFU) of virus can be found in 1 litre of water, it can reasonably be assumed that the water is safe to drink. It would, however, be necessary to examine a sample of the order of 10 litres to obtain a proper estimation of the PFUs at this level. Such examinations cannot be made in ordinary control laboratories but there should be at least one laboratory in the country or region capable of carrying out virus examinations and also of pursuing further research on this subject.

The methods of test for various characteristics mentioned in this standard are currently under revision and their latest revision shall be used in testing.

In the formulation of this standard, assistance has been derived from the following publications:

a) International Standards for Drinking Water issued by World Health Organization, 1984 Geneva;

b) Manual of Standards of Quality for Drinking Water Supplies. Indian Council of Medical Research, 1971, New Delhi; and

c) Manual on Water Supply and Treatment (*third revision*), Ministry of Urban Development, 1989, New Delhi.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

IS 10500 : 1991

Indian Standard

DRINKING WATER — SPECIFICATION

(First Revision)

1 SCOPE

The standard prescribes the requirements for the essential and desirable characteristics required to be tested for ascertaining the suitability of water for drinking purpose.

2 REFERENCES

The Indian Standard listed in Annex A are necessary adjuncts to this standard.

3 CHARACTERISTICS

3.1 The test characteristics are given in Table 1.

3.2 Bacteriological Examination

3.2.1 *Water in Distribution System*

Ideally, all samples taken from the distribution system including consumers' premises, should be free from coliform organisms. In practice, this is not always attainable, and the following standard for water collected in the distribution system is therefore recommended when tested in accordance with IS 1622 : 1981.

a) Throughout any year, 95 percent of samples should not contain any coliform organisms in 100 ml;

b) No sample should contain E. Coli in 100 ml;

c) No sample should contain more than 10 coliform organisms per 100 ml; and

d) Coliform organisms should not be detectable in 100 ml of any two consecutive samples.

3.2.1.1 If any coliform organisms are found the minimum action required is immediate resampling. The repeated finding of 1 to 10 coliform organisms is 100 ml or the appearance of higher numbers in individual samples suggests that undesirable material is gaining access to the water and measures should at once be taken to discover and remove the source of the pollution.

3.2.2 *Unpiped Water Supplies*

Where it is impracticable to supply water to consumers through a piped distribution network and where untreated sources, such as wells, boreholes and springs which may not be naturally pure, have to be used, the requirements for piped supplies may not be attainable. In such circumstances, disinfection although desirable is not always practicable, and considerable reliance has to be placed on sanitary inspection and not exclusively on the results of bacteriological examination. Everything possible should be done to prevent pollution of the water. Obvious sources of contamination should be removed from the immediate catchment area, special attention being given to the safe disposal of excrement. Wells and storage tanks should be protected by lining and covering, surface drainage should be diverted, erosion prevented and the surrounding area paved. Access of man and animals should be restricted by fencing, and should be so designed that fouling is prevented when drawing water. Although not supplied through pipes, water from such sources is likely to undergo further deterioration in quality during transport or storage before drinking. Containers used for water should be kept clean, covered and clear of the floor. The most important factor in achieving these objectives is to ensure the cooperation of the local community, and the importance of education in simple sanitary hygiene should be strongly stressed. In hospitals or medical clinics with such supplies, the value of some form of treatment is stressed.

3.2.2.1 Bacteriologically, the objective should be to reduce the coliform count to less than 10 per 100 ml, but more importantly, to ensure the absence of faecal coliform organisms. If these organisms are repeatedly found, or if sanitary inspection reveals obvious sources of pollution which cannot be avoided, then an alternative source of drinking water would be sought, whenever possible. Greater use should be made of protected ground-water sources and rain-water catchment which are more likely to meet requirements for potable water quality.

3.2.2.2 Although private sources of drinking water may be outside the jurisdiction of public health and water supply authorities, such supplies should still be of potable quality. The results of bacteriological tests and those of sanitary surveys should therefore be used to encourage improvement. Partial treatment may be necessary to remove turbidity even when coliform counts are low; and other quality criteria may dictate the need for treatment processes.

3.3 Virological Examination

3.3.1 It is theoretically possible that virus disease can be transmitted by water free from coliform organisms, but conclusive evidence, that this has occurred, is lacking.

Table 1 Test Characteristics For Drinking Water

(*Clause* 3.1)

Sl No.	Substance or Characteristic	Requirement (Desirable Limit)	Undesirable Effect Outside the Desirable Limit	Permissible Limit in the Absence of Alternate Source	Methods of Test (Ref to IS)	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Essential Characteristics						
i)	Colour, Hazen units, *Max*	5	Above 5, consumer acceptance decreases	25	3025 (Part 4) : 1983	Extended to 25 only if toxic substances are not suspected, in absence of alternate sources
ii)	Odour	Unobjectionable	—	—	3025 (Part 5) : 1983	a) Test cold and when heated b) Test at several dilutions
iii)	Taste	Agreeable	—	—	3025 (Parts 7 and 8) : 1984	Test to be conducted only after safety has been established
iv)	Turbidity, NTU, *Max*	5	Above 5, consumer acceptance decreases	10	3025 (Part 10) : 1984	—
v)	pH value	6·5 to 8·5	Beyond this range the water will affect the mucous membrane and/ or water supply system	No relaxation	3025 (Part 11) : 1984	—
vi)	Total hardness (as $CaCO_3$) mg/l, *Max*	300	Encrustation in water supply structure and adverse effects on domestic use	600	3025 (Part 21) : 1983	—
vii)	Iron (as Fe) mg/l, *Max*	0·3	Beyond this limit taste/appearance are affected, has adverse effect on domestic uses and water supply structures, and promotes iron bacteria	1·0	32 of 3025 : 1964	—
viii)	Chlorides (as Cl) mg/l, *Max*	250	Beyond this limit, taste, corrosion and palatibility are affected	1 000	3025 (Part 32) : 1988	—
ix)	Residual, free chlorine, mg/l, *Min*	0·2	—	—	3025 (Part 26) : 1986	To be applicable only when water is chlorinated. Tested at consumer end. When protection against viral infection is required, it should be *Min* 0·5 mg/l.
Desirable Characteristics						
x)	Dissolved solids mg/l, *Max*	500	Beyond this palatability decreases and may cause gastro intestinal irritation	2 000	3025 (Part 16) : 1984	—
xi)	Calcium (as Ca) mg/l, *Max*	75	Encrustation in water supply structure and adverse effects on domestic use	200	3025 (Part 40) : 1991	—

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TO
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(First Revision)

[*Page* 2, *Table* 1, *Sl No.* (xi)] — Insert the following new matter under respective columns after Sl No. (xi) and renumber subsequent rows:

(1)	(2)	(3)	(4)	(5)	(6)	(7)
xii)	Magnesium (as Mg), mg/l, Max	30	Encrustation to water supply structure and adverse effects on domestic use	100	16, 33, 34 of IS 3025 : 1964	—

[*Page* 3, *Table* 1, *Sl No.* (xvi)] — Shift the matter under respective columns and put after Sl No. (ix) under essential characteristics and renumber the subsequent rows.

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Table 1 Test Characteristics for Drinking Water (*Contd*)

Sl No.	Substance or Characteristic	Requirement (Desirable Limit)	Undesirable Effect Outside the Desirable Limit	Permissible Limit in the Absence of Alternate Source	Methods of Test (Ref to IS)	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
xii)	Copper (as Cu) mg/l, *Max*	0·05	Astringent taste, discoloration and corrosion of pipes, fitting and utensils will be caused beyond this	1·5	36 of 3025 : 1964	—
xiii)	Manganese (as Mn) mg/l, *Max*	0·1	Beyond this limit taste/appearance are affected, has adverse effect on domestic uses and water supply structures	0·3	35 of 3025 : 1964	—
xiv)	Sulphate (as SO_4) mg/l, *Max*	200	Beyond this causes gastro intenstinal irritation when magnesium or sodium are persent	400 (*see* col 7)	3025 (Part 24) : 1986	May be extended up to 400 provided (as Mg) does not exceed 30
xv)	Nitrate (as NO_3) mg/l, *Max*	45	Beyond this methaemoglobinemia takes place	100	3025 (Part 34) : 1988	—
xvi)	Fluoride (as F) mg/l, *Max*	1·0	Fluoride may be kept as low as possible. High fluoride may cause fluorosis	1·5	23 of 3025 : 1964	—
xvii)	Phenolic compounds (as C_6H_5OH) mg/l, *Max*	0·001	Beyond this, it may cause objectionable taste and odour	0·002	54 of 3025 : 1964	—
xviii)	Mercury (as Hg) mg/l, *Max*	0·001	Beyond this, the water becomes toxic	No relaxation	(*see* Note) Mercury ion analyser	To be tested when pollution is suspected
xix)	Cadmium (as Cd), mg/l, *Max*	0·01	Beyond this, the water becomes toxic	No relaxation	(*see* Note)	To be tested when pollution is suspected
xx)	Selenium (as Se), mg/l, *Max*	0·01	Beyond this, the water becomes toxic	No relaxation	28 of 3025 : 1964	To be tested when pollution is suspected
xxi)	Arsenic (as As), mg/l, *Max*	0·05	Beyond this, the water becomes toxic	No relaxation	3025 (Part 37) : 1988	To be tested when pollution is suspected
xxii)	Cyanide (as CN), mg/l, *Max*	0·05	Beyond this limit, the water becomes toxic	No relaxation	3025 (Part 27) : 1986	To be tested when pollution is suspected
xxiii)	Lead (as Pb), mg/l, *Max*	0·05	Beyond this limit, the water becomes toxic	No relaxation	(*see* Note)	To be tested when pollution/plumbosolvency is suspected
xxiv)	Zinc (as Zn), mg/l, *Max*	5	Beyond this limit it can cause astringent taste and an opalescence in water	15	39 of 3025 : 1964	To be tested when pollution is suspected
xxv)	Anianic detergents (as MBAS) mg/l, *Max*	0·2	Beyond this limit it can cause a light froth in water	1·0	Methylene-blue extraction method	To be tested when pollution is suspected
xxvi)	Chromium (as Cr^{6+}) mg/l, *Max*	0·05	May be carcinogenic above this limit	No relaxation	38 of 3025 : 1964	To be tested when pollution is suspected

(*continued*)

Table 1 Test Characteristics for Drinking Water (*concluded*)

Sl No.	Substance or Characteristic	Requirement (Desirable Limit)	Undesirable Effect Outside the Desirable Limit	Permissible Limit in the Absence of Alternate Source	Methods of Test (Ref to IS)	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
xxvii)	Polynuclear aromatic hydrocarbons (as PAH) g/l, *Max*	—	May be carcinogenic	—	—	—
xxviii)	Mineral oil mg/l, *Max*	0·01	Beyond this limit undesirable taste and odour after chlorination take place	0·03	Gas chromatographic method	To be tested when pollution is suspected
xxix)	Pesticides mg/l, *Max*	Absent	Toxic	0·001	—	—
xxx)	Radioactive materials:				58 of 3025 : 1964	
	a) Alpha emitters Bq/l, *Max*	—	—	0·1	—	—
	b) Beta emitters pci/l, *Max*	—	—	1	—	—
xxxi)	Alkalinity mg/l, *Max*	200	Beyond this limit taste becomes unpleasant	600	13 of 3025 : 1964	—
xxxii)	Aluminium (as Al), mg/l, *Max*	0·03	Cumulative effect is reported to cause dementia	0·2	31 of 3025 : 1964	—
xxxiii)	Boron, mg/l, *Max*	1	—	5	29 of 3025 : 1964	—

NOTE — Atomic absorption spectrophotometric method may be used.

3.3.2 None of the generally accepted sewage treatment methods yield virus-free effluent. Although a number of investigators have found activated sludge treatment to be superior to trickling filters from this point of view, it seems possible that chemical precipitation methods will prove to be the most effective.

3.3.3 Virus can be isolated from raw water and from springs. Enterovirus, reovirus, and adenovirus have been found in water, the first named being the most resistant to chlorination. If enterovirus are absent from chlorinated water, it can be assumed that the water is safe to drink. Some uncertainty still remains about the virus of infectious hepatitis, since it has not so far been isolated but in view of the morphology and resistance of enterovirus it is likely that, if they have been inactivated hepatitis virus will have been inactivated also.

3.3.4 An exponential relationship exists between the rate of virus inactivation and the redox potential. A redox potential of 650 mV (measured between platinum and calomel electrodes) will cause almost instantaneous inactivation of even high concentrations of virus. Such a potential can be obtained with even a low concentration of free chlorine, but only with an extremely high concentration of combined chlorine. This oxidative inactivation may be achieved with a number of other oxidants also, for example, iodine, ozone, and potassium permanganate, but the effect of the oxidants will always be counteracted if reducing components, which are mainly organic, are present. As a consequence, the sensitivity of virus towards desinfectants will depend on the *milieu* just as much as on the particular disinfectant used.

3.3.5 Thus, in a water in which free chlorine is present, active virus will generally be absent if coliform organisms are absent. In contrast, because the difference between the resistance of coliform organisms and of virus to disinfection by oxidants increases with increasing concentration of reducing components, for example, organic matter, it cannot be assumed that the absence of viable coliform organisms implies freedom from active virus under circumstances where a free chlorine residual cannot be maintained. Sedimentation and slow sand filtration in themselves may contribute to the removal of virus from water.

3.3.6 In practice, 0·5 mg/l of free chlorine for one hour is sufficient to inactivate virus, even in water that was originally polluted.

3.4 Biological Examination

3.4.1 Biological examination is of value in determining the causes of objectionable tastes and odours in water and controlling remedial treatments, in helping to interpret the results of various chemical analysis, and in explaining the causes of clogging in distribution pipes and filters. In some instances, it may be of use in demonstrating that water from one source has been mixed with that from another.

3.4.2 The biological qualities of a water are of greater importance when the supply has not undergone the conventional flocculation and filtration processes, since increased growth of methane-utilizing bacteria on biological slimes in pipes may then be expected, and the development of bryozoal growths such as *Plumatella* may cause operational difficulties.

3.4.3 Some of the animalcules found in water mains may be free-living in the water, but others such as *Dreissena* and *Asellus* are more or less firmly attached to the inside of the mains. Although these animalcules are not themselves pathogenic, they may harbour pathogenic organisms or virus in their intestines, thus protecting theses pathogens from destruction by chlorine.

3.4.4 Chlorination, at the dosages normally employed in waterworks, is ineffective against certain parasites, including amoebic cysts; they can be excluded only by effective filtration or by higher chlorine doses than can be tolerated without subsequent dechlorination. *Amoebiasis* can be conveyed by water completely free from enteric bacteria; microscopic examination after concentration is, therefore, the only safe methods of identification.

3.4.5 Strict precautions against back-syphonage and cross-connections are required if amoebic cysts are found in a distribution system containing tested water.

3.4.6 The *cercariae of schistosomiasis* can be detected by similar microscopic examination, but there is, in any case, no evidence to suggest that this disease is normally spread through piped water supplies.

3.4.7 The cyclops vector of the embroys of *Dracunculus medinensis* which causes dracontiasis or Guinea-worm disease can be found in open wells in a number of tropical areas. They are identifiable by microscopic examination. Such well supplies are frequently used untreated, but the parasite can be relatively easily excluded by simple physical improvements in the form of curbs, drainage, and apron surrounds and other measures which prevent physical contact with the water source.

3.4.8 The drinking water shall be free from microscopic organisms such as algae, zooplanktons, flagillates, parasites and toxin-producing organisms. An illustrative (and not exhaustive) list is given in Annex B for guidance.

4 SAMPLING

Representative samples of water shall be drawn as prescribed in IS 1622 : 1981 and IS 3025 (Part 1) : 1987.

ANNEX A

(Clause 2.2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*	*IS No.*	*Title*
1622 : 1981	Methods of sampling and microbiological examination of water (*first revision*)	3025 (Part 5) : 1983	Methods of sampling and test (physical and chemical) for water and waste water : Part 5 Odour (*first revision*)
3025 : 1964	Methods of sampling and test (physical and chemical) for water used in industry	3025 (Part 7) : 1984	Methods of sampling and test (physical and chemical) for water aad waste water : Part 7 Taste threshold (*first revision*)
3025 (Part 1) : 1987	Methods of sampling and test (physical and chemical) for water and waste water : Part 1 Sampling (*first revision*)		
3025 (Part 4) : 1983	Methods of sampling and test (physical and chemical) for water and waste water : Part 4 Colour (*first revision*)	3025 (Part 8) : 1984	Methods of sampling and test (physical and chemical) for water and waste water : Part 8 Taste rating (*first revision*)

IS No.	*Title*	*IS No.*	*Title*
3025 (Part 10) : 1984	Methods of sampling and test (physical and chemical) for water and waste water : Part 10 Turbidity (*first revision*)	3025 (Part 26) : 1986	Methods of sampling and test (physical and chemical) for water and waste water : Part 26 Chlorine residual (*first revision*)
3025 (Part 11) : 1983	Methods of sampling and test (physical and chemical) for water and waste water : Part 11 *p*H value (*first revision*)	3025 (Part 27) : 1986	Methods of sampling and test (physical and chemical) for water and waste water : Part 27 Cyanide (*first revision*)
3025 (Part 16) : 1984	Methods of sampling and test (physical and chemical) for water and waste water : Part 16 Filterable residue (total dissolved solids) (*first revision*)	3025 (Part 32) : 1988	Methods of sampling and test (physical and chemical) for water and waste water : Part 32 Chloride (*first revision*)
3025 (Part 21) : 1983	Methods of sampling and test (physical and chemical) for water and waste water : Part 21 Total hardness (*first revision*)	3025 (Part 34) : 1988	Methods of sampling and test (physical and chemical) for water and waste water : Part 34 Nitrogen (*first revision*)
3025 (Part 24) : 1986	Methods of sampling and test (physical and chemical) for water and waste water : Part 24 Sulphates (*first revision*)	3025 (Part 37) : 1988	Methods of sampling and test (physical and chemical) for water and waste water : Part 37 Arsenic (*first revision*)

ANNEX B

(*Clause* 3.4.8)

ILLUSTRATIVE LIST OF MICROSCOPIC ORGANISMS WHICH MAY BE PRESENT IN WATER

Classification of Microscopic Organism	*Group and Name of the Organism*	*Habitat*	*Effect of the Organisms and Significance*
(1)	(2)	(3)	(4)
1. *ALGAE*	a) *Chlorophyceae*		
	Species of *Coelastrum, Gomphospherium, Micractinium, Mougeotia,* oocystis, *Euastrum, Scenedesmus, Actinastrum, Gonium, Eudorina Pandorina, Pediastrum, Zygnema, Chlamydomonas, Careteria, Chlorella, Chroococcus, Spirogyra, Tetraedron, Chlorogonium, Stigeoclonium*	Polluted water, impounded sources	Impart colouration
	Species of *Pandorina, Volvox, Gomphospherium, Staurastrum, Hydrodictyon, Nitella*	Polluted waters	Produce taste and odour
	Species of *Rhizoclonium, Cladothrix, Ankistrodesmus, Ulothrix, Micrasterias, Chromulina*	Clean water	Indicate clean condition
	Species of *Chlorella, Tribonema, Closterium, Spirogyra, Palmella*	Polluted waters, impounded sources	Clog filters and create operational difficulties

Classification of Microscopic Organism	Group and Name of the Organism	Habitat	Effect of the Organisms and Significance
(1)	(2)	(3)	(4)
	b) *Cyanophyceae*		
	Species of *Anacystis and Cylindrospermum*	Polluted waters	Cause water bloom and impart colour
	Species of *Anabena, Phormidium, Lyngbya, Arthrospira, Oscillatoria*	Polluted waters	Impart colour
	Species of *Anabena, Anacystis, Aphanizomenon*	Polluted waters, impounded sources	Produce taste and odour
	Species of *Anacystis, Anabena, Coelospherium, Gleotrichina, Aphanizomenon*	Polluted waters	Toxin producing
	Species of *Anacystis, Rivularia, Oscillatoria, Anabena*	Polluted waters	Clog filters
	Species of *Rivularia*	Calcareous waters and also rocks	Bores rocks and calcareous strata and causes matted growth
	Species of *Agmenellum, Microcoleus, Lemanea*	Clean waters	Indicators of purification
	c) *Diatoms (Bacillariophyceae)*		
	Species of *Fragillaria, Stephanodiscus, Stauroneis*	—	Cause discoloration
	Species of *Asterionella, Tabellaria*	Hill streams high altitude, torrential and temperate waters	Taste and odour producing clog filters
	Species of *Synedra* and *Fragillavia*	Polluted waters	Taste and odour producing
	Species of *Nitzchia, Gomphonema*	Moderately polluted waters	Cause discoloration
	Species of *Cymbela, Synedra, Melosira, Navicula, Cyclotella, Fragillaria, Diatoma, Pleurogsigma*	Rivers and streams impounded sources	Clog filters and cause operational difficulties
	Species of *Pinnularia, Surinella, Cyclotella, Meridion, Cocconeis*	Clean waters	Indicators of purification
	d) *Xanthophyceae*		
	Species of *Botryococcus*	Hill streams, high altitudes and temperate waters	Produces coloration
2. *ZOOPLANKTON*	a) *Protozoa*		
	Amoeba, Giardia Lamblia Arcella, Difflugia, Actinophrys	Polluted waters	Pollution indicators
	Endamoeba, Histolytica	Sewage and activated sludge	Parasitic and pathogenic
	b) *Ciliates*		
	Paramoccium, Vorticella, Carchesium, Stentor, Colpidium, Coleps, Euplotes, Colopoda, Bodo	Highly polluted waters, sewage and activated sludge	Bacteria eaters
	c) *Crustacea*		
	Bosmina, Daphnia	Stagnant polluted waters	Indicators of pollution

Classification of Microscope Organism	*Group and Name of the Organism*	*Habitat*	*Effect of the Organisms and Significance*
(1)	(2)	(3)	(4)
	Cyclops	Step wells in tropical climate	Carrier host of guinea worm
3. *ROTIFERS*	a) *Rotifers*		
	Anurea, Rotaria, Philodina	Polluted and algae laden waters	Feed on algae
	b) *Flagellates*		
	Ceratium, Glenodinium, Peridinium Dinobryon	Rocky strata, iron bearing and acidic waters	Impart colour and fishy taste
	Euglena, Phacus	Polluted waters	Impart colour
	c) *Miscellaneous Organisms Sponges, Hydra*	Fresh water	Clog filters and affect purification systems
	Tubifex, Eristalis, Chironomids	Highly polluted waters, sewage and activated sludge and bottom deposits	Clog filters and render water unaesthetic
	d) *Plumatella*	Polluted waters	Produces biological slimes and causes filter operational difficulties
	Dreissena, Asellus	Polluted waters	Harbour pathogenic organisms

Annexure – II

Table 1 : Microbiological and Biological Quality

Organism	Guideline value (Unit Number/100ml)	Remarks
Microbiological Quality *A. Piped water supplies* *A1 Treated water* entering the distribution system Faecal coliforms Coliform organisms	 0 0	 Turbidity 1 NTU for disinfection with chlorine, pH preferably <8.0, free chlorine residual 0.2 mg/litre following 30 minutes (minimum) contact
A2. Untreated water entering the distribution system Faecal coliforms Coliform organisms Coliform organisms	 0 0 3	 In 98% of samples examined throughout the year in the case of large supplies when sufficient samples are examined In an occasional sample, but not in consecutive samples
A3 Water in the distribution system Faecal coliforms Coliform organisms Coliform organisms	 0 0 3	 In 95% of samples examined throughout the year – in the case of large supplies when sufficient samples are examined In an occasional sample, but not in consecutive samples
B. Unpiped water supplies Faecal coliforms Coliform organisms	 0 10	 Should not occur repeatedly if occurrence is frequent and if sanitary protection cannot improve, an alternative source must be found it possible
C. Bottled drinking-water Faecal coliforms Coliform organisms	 0 0	 Source should be free from faecal contamination
D. Emergency water supplies Faecal coliforms Coliform organisms Enteroviruses	 0 0 no guideline value set	 Advise public to boil water in case of failure to meet guideline values
II. Biological quality Protozoa (pathogenic) Helminths (pathogenic) Free-living organisms (algae, others)	 No guideline value set No guideline value set No guideline value set	

(WHO-1984)

Annexure III

(61 pages)

Report on the analysis done on the five samples received from Dr. T. Chakraborty, NEERI, Nagpur

pH, EC and particle size distribution

Serial No.	pH (1:2) water	EC dS m^{-1}	Sand (2000-50 µm)	Silt (50-2 µm)	Clay (<2 µm)
			%		
NEERI 1	5.7	0.10	84.5	12.6	2.8
NEERI 2	6.7	008	94.8	3.8	1.4
NEERI 3	7.7	0.26	88.5	9.1	2.4
NEERI 5	8.3	0.10	90.9	1.8	7.3
NEERI 9	8.2	0.23	88.4	9.6	2.0

Minerals identified by XRD

Serial No.	Silt	Clay
NEERI 1	Sm (D), Vm, Ch, M, K, Q, F	Vm (D), Sm, M, K(Tr), Ch, Q (Tr), F (Tr)
NEERI 2	M (D), Sm, Vm, K, Q, F	Vm (D), Sm, M, K(Tr), Q (Tr), F (Tr)
NEERI 3	Sm(D), Ch, Vm, K(Tr), M, Q, F	Sm (D), Vm, Ch, M, Q(Tr), F(Tr)
NEERI 5	Sm (D), Vm, Ch, M, K (Tr), Q, F	Sm(D), Vm, M, K(Tr), Q(Tr), F(Tr)
NEERI 9	Sm (D), Vm, Ch, M, K (Tr), Q, F	Sm (D), Vm, M, Ch, Q(Tr), F(Tr)

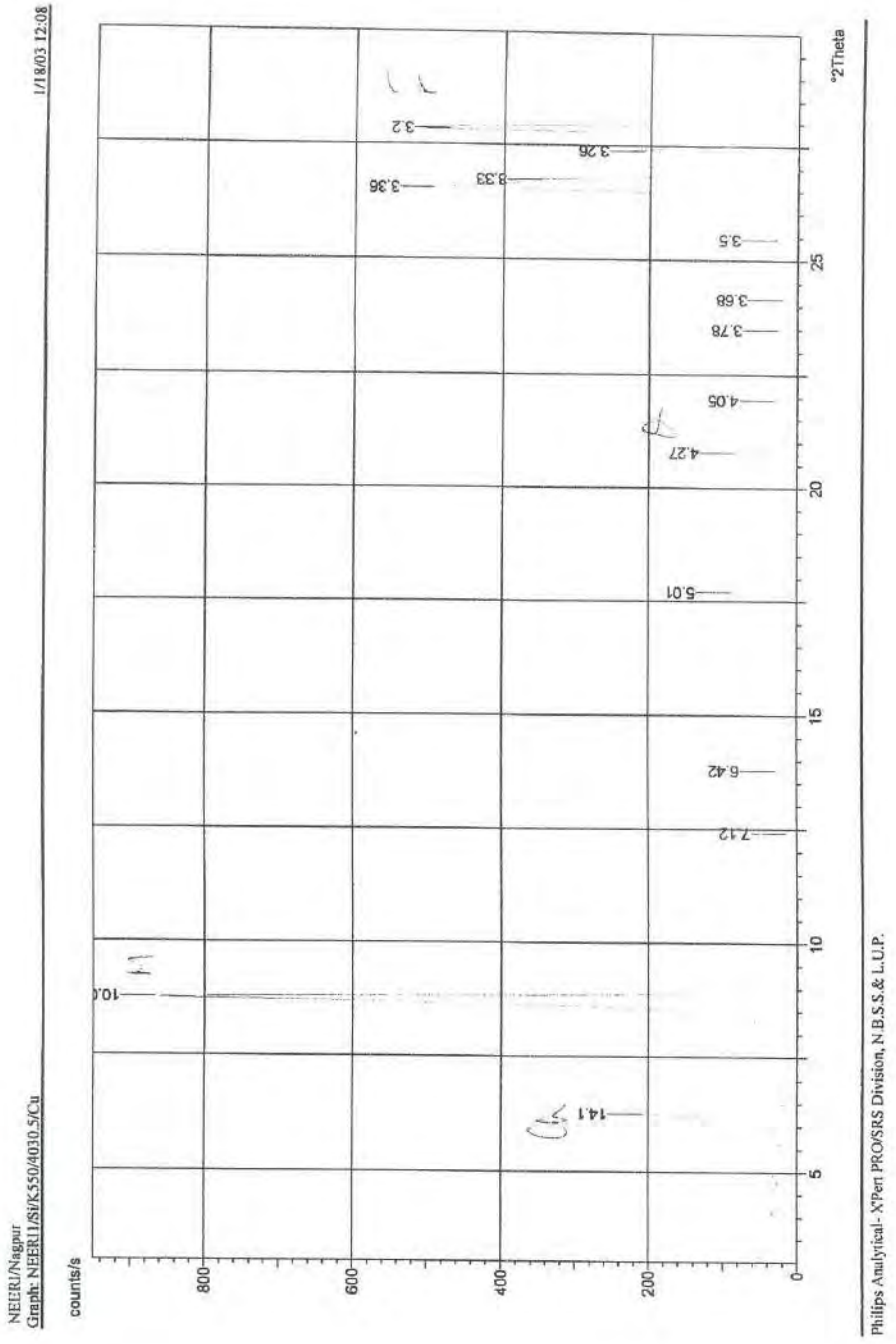
Sm = smectite; Vm = vermiculite; Ch = chlorite; M = mica, K kaolinite; Q = quartz, F = feldspars; D = Dominant; Tr = Trace

All the materials are neither strongly acidic nor alkaline and contain very less amounts of silt and clay. The silt and clay fractions contain minerals like Sm and Vm that have very high surface area. Higher surface area minerals adsorb and absorb more amount of water and cations. If these materials are alluvia, then these will favour growing crops because Sm, Vm and M minerals are known for better crop growth and productivity in terms of retention of water and nutrient. On the other hand these minerals provide a favourable surface for the retention of heavy metals and pesticides.

These results along with the XRD diagrams are being handed over to the concerned scientist of the NEERI, Nagpur.

(D.K. PAL)
Principal Scientist
&
Head, Division of Soil Resource Studies

Copy to: The Director, NBSSLUP, Nagpur for his kind information.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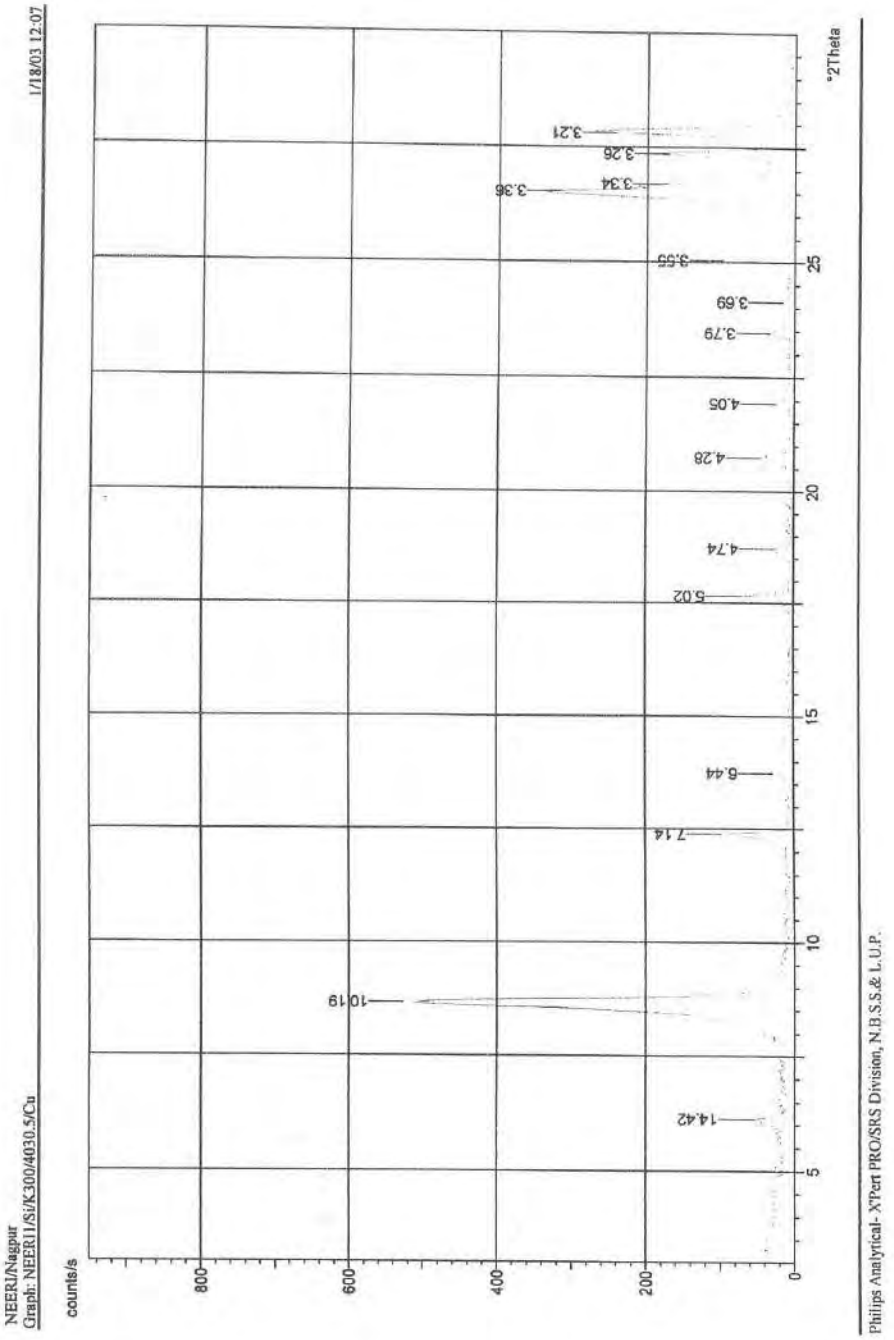
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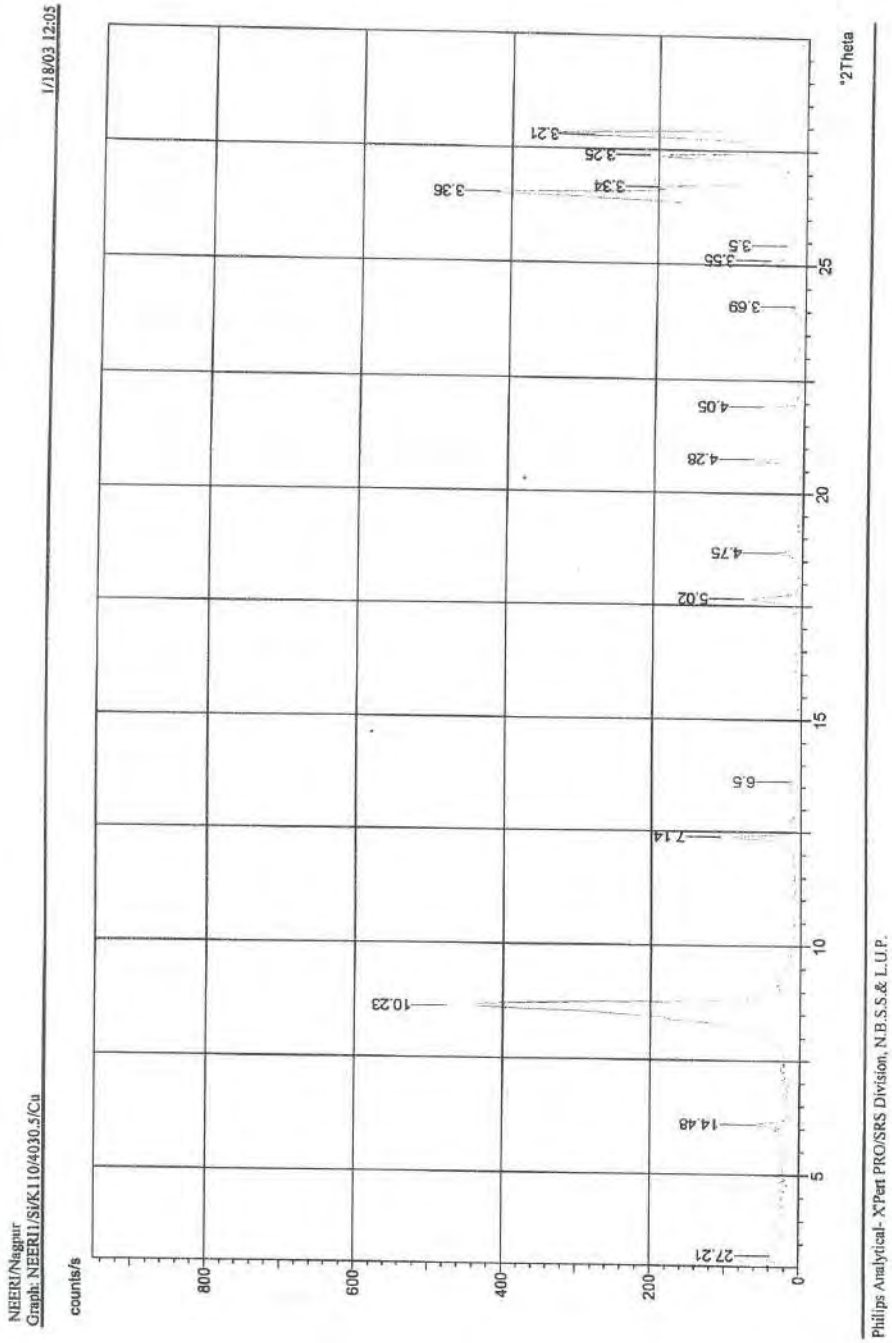
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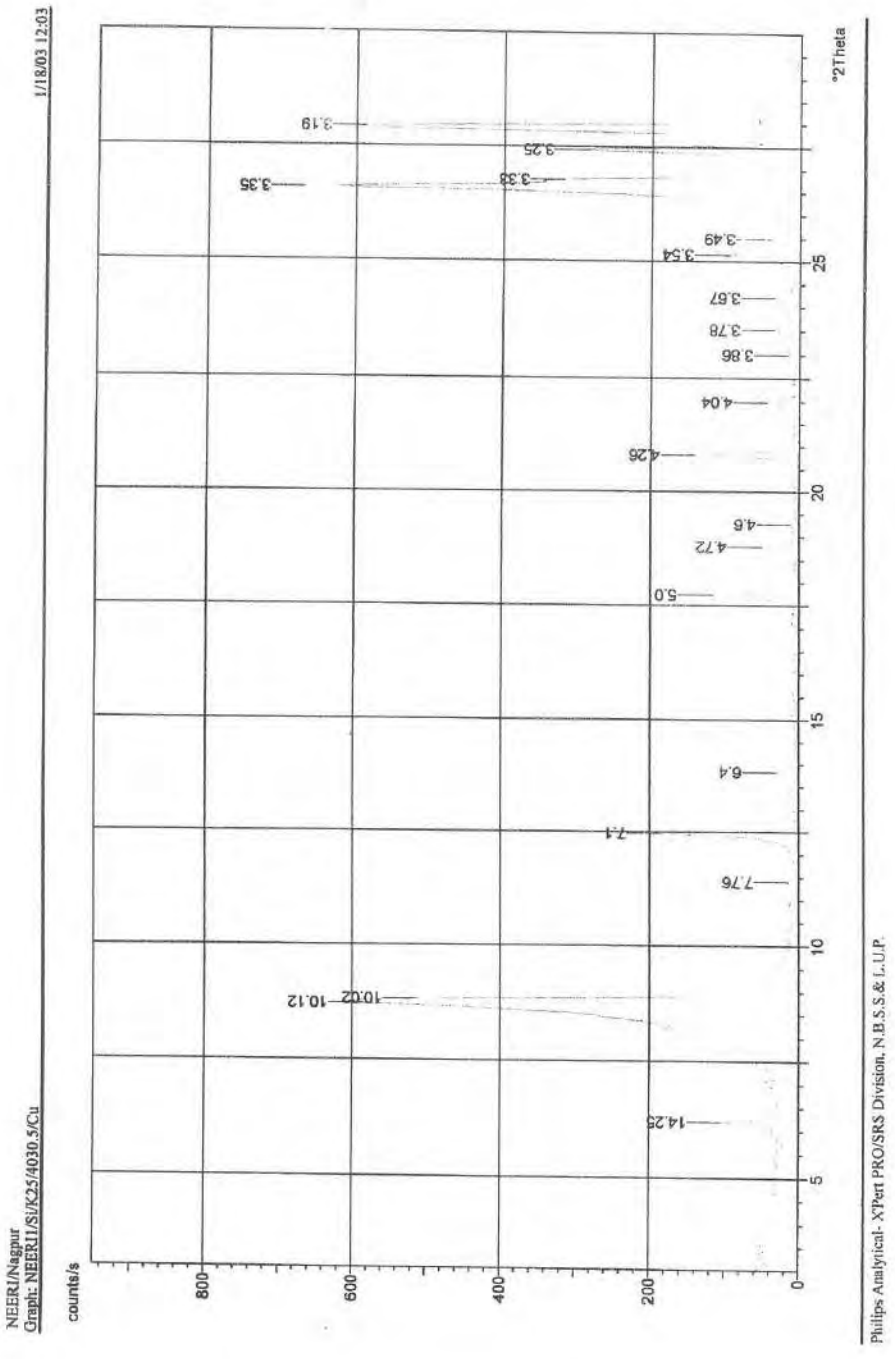
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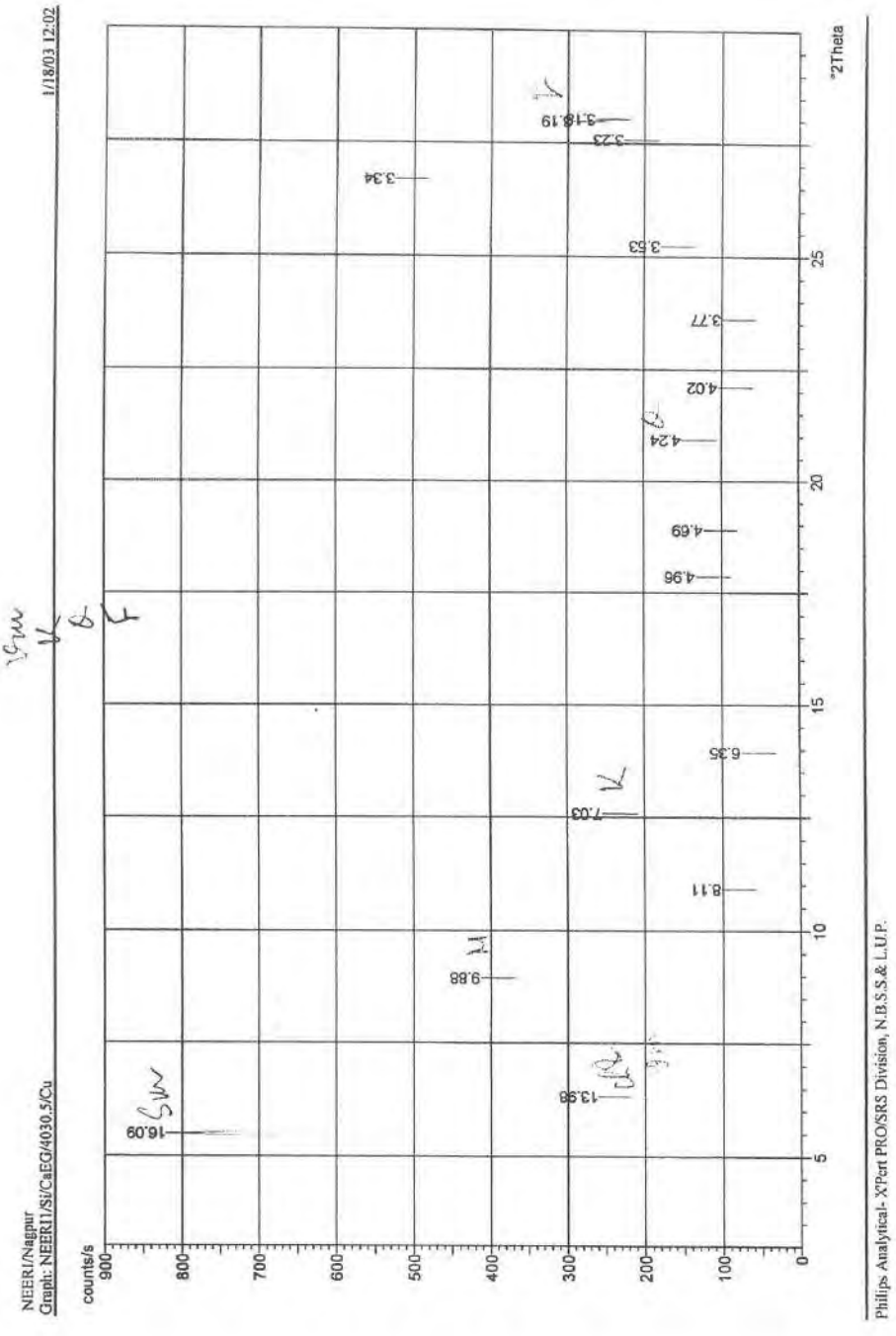
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Philips Analytical- X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.

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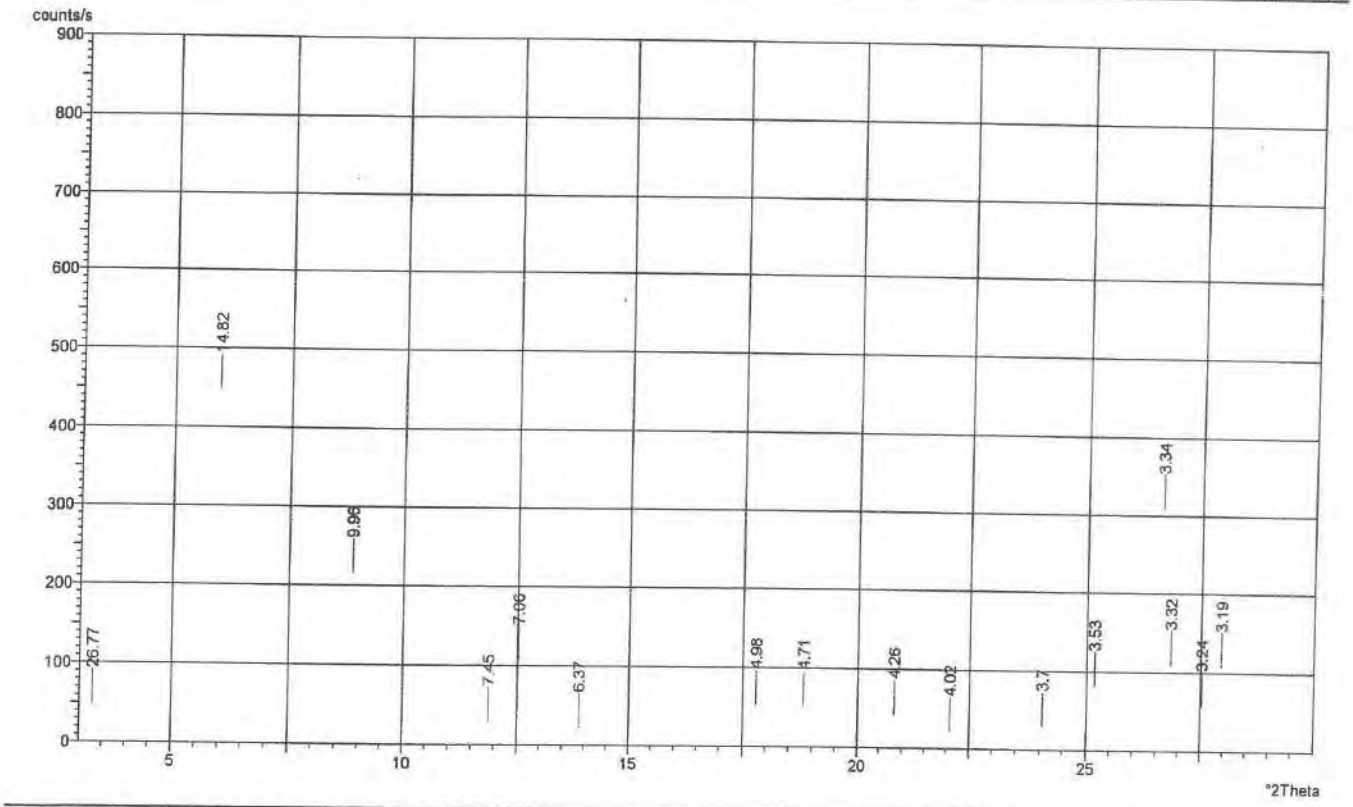

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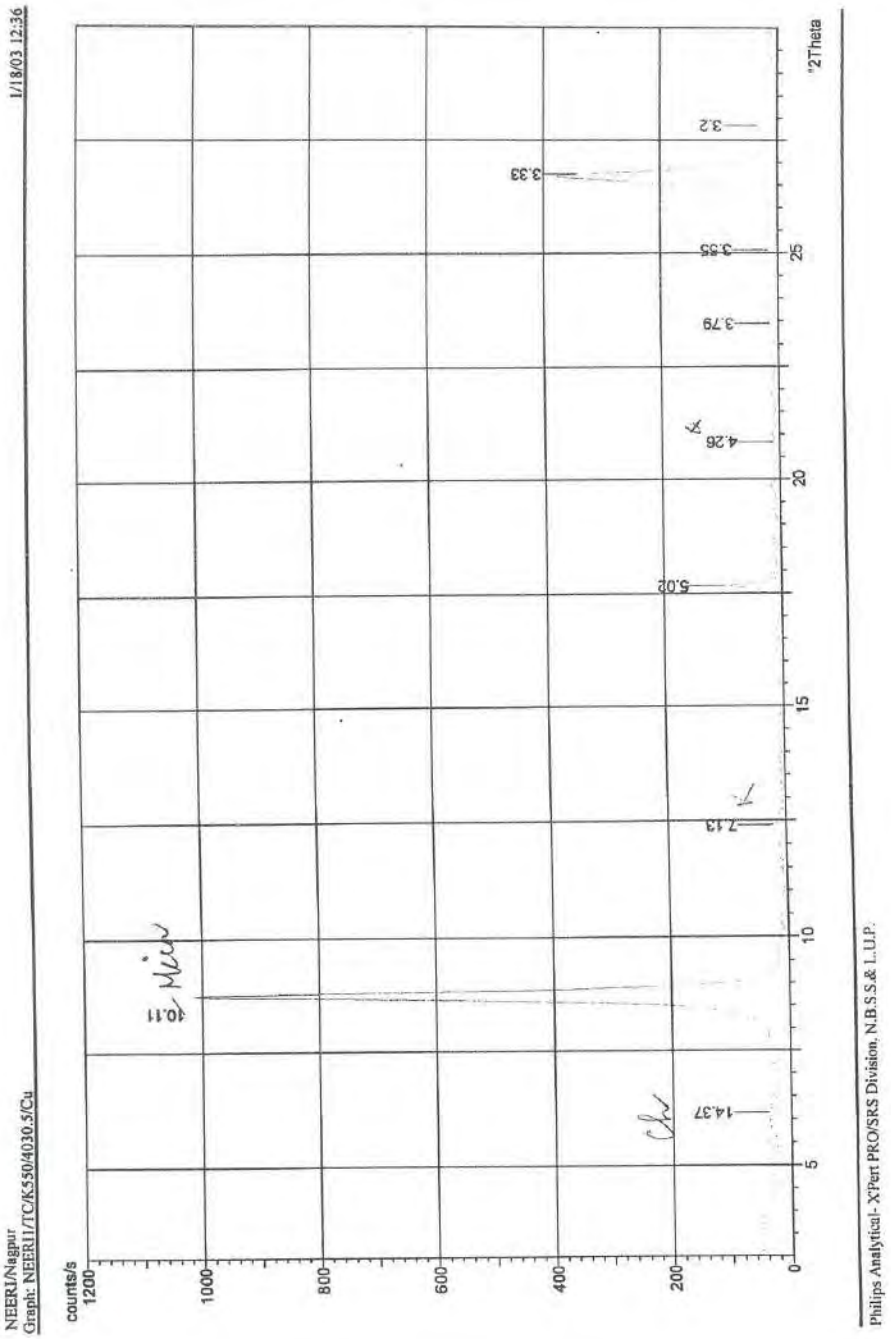
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°2Theta
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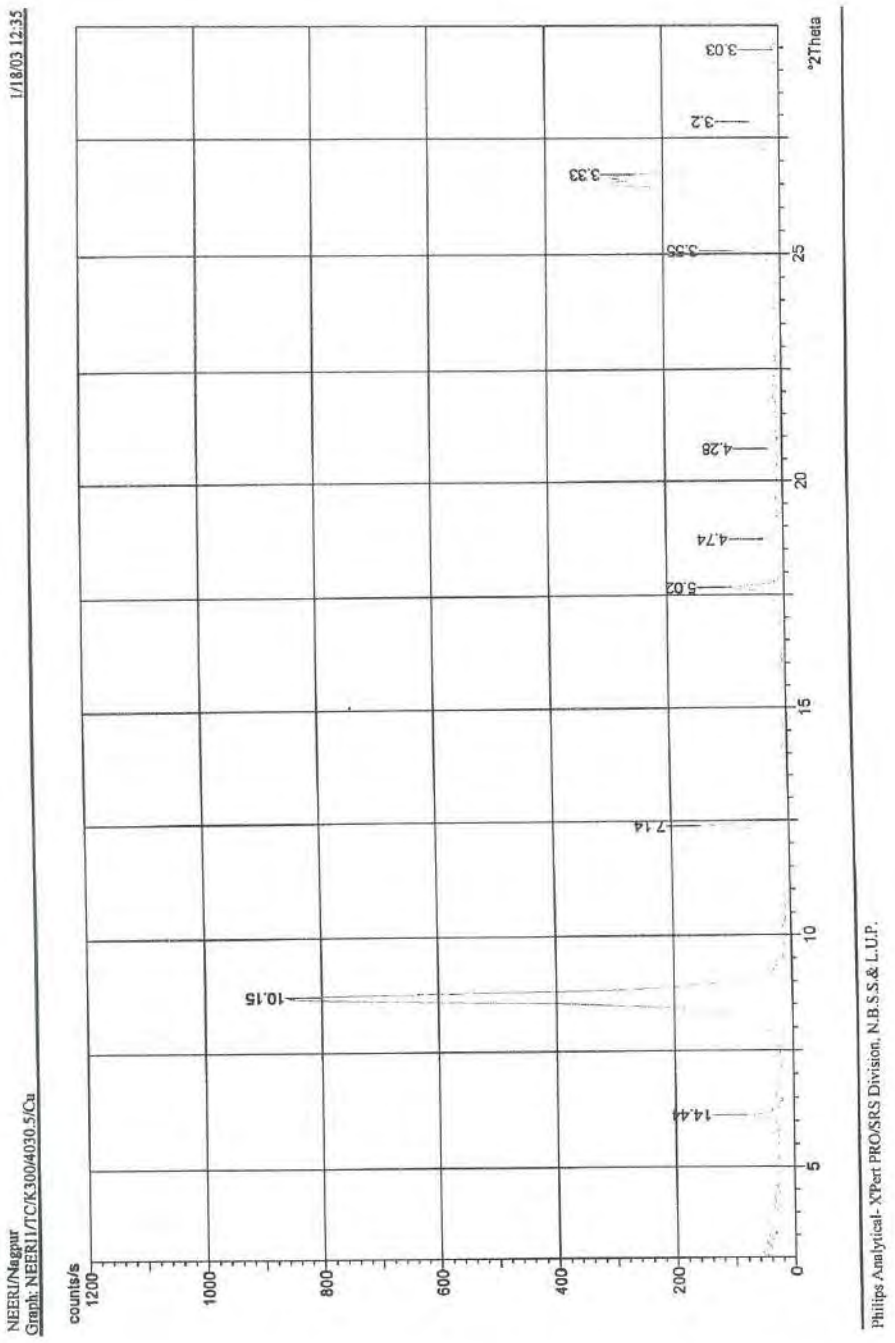
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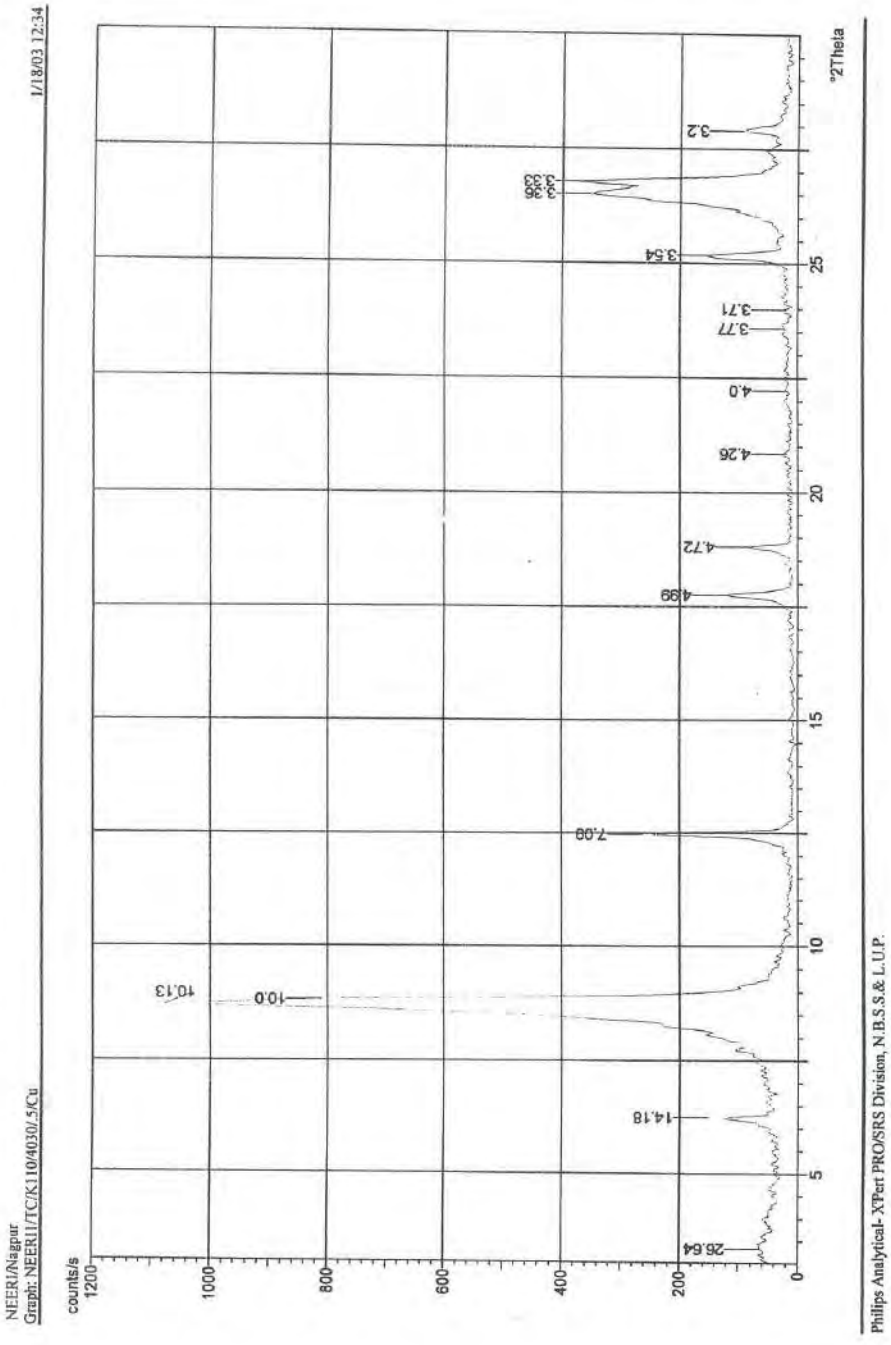
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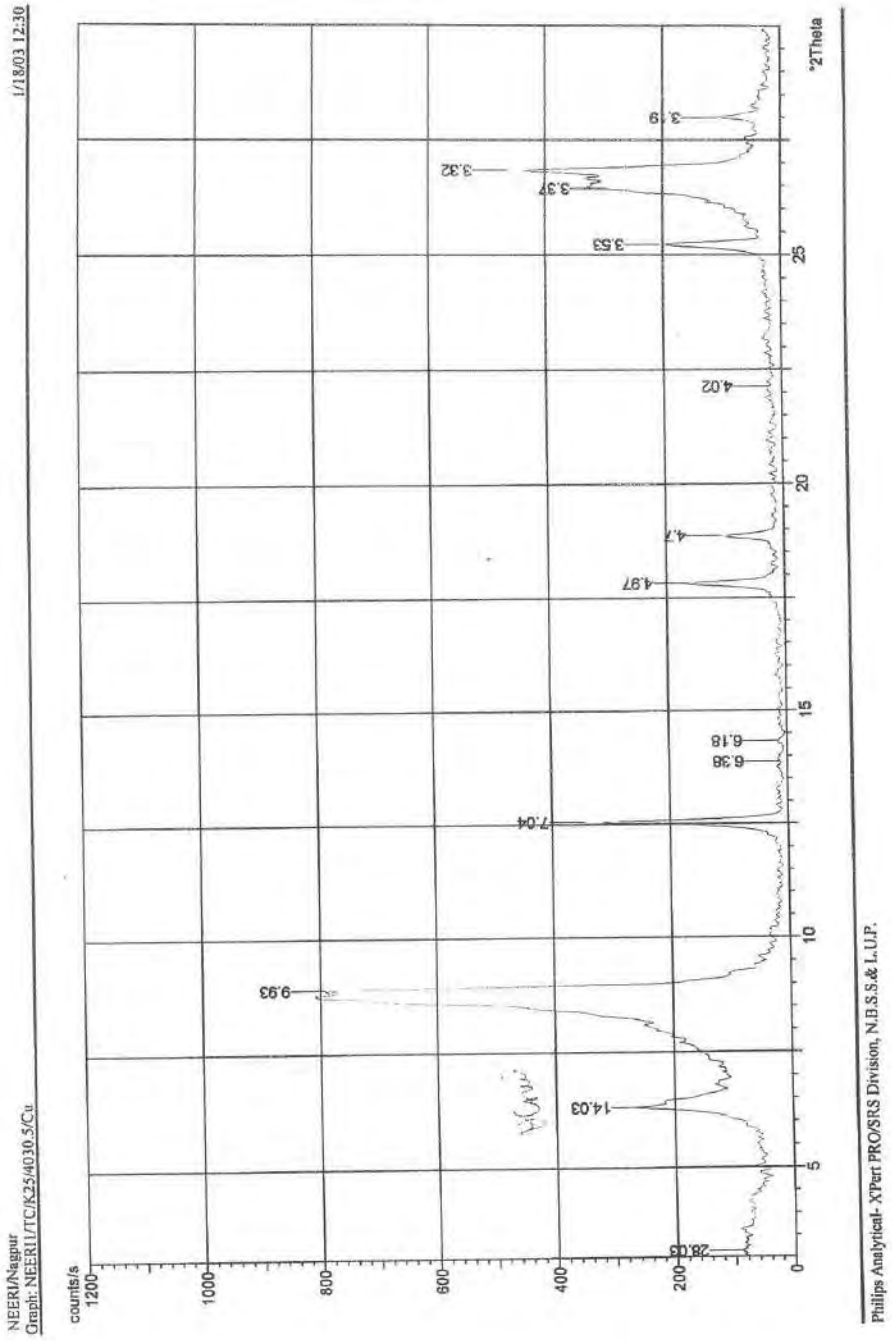
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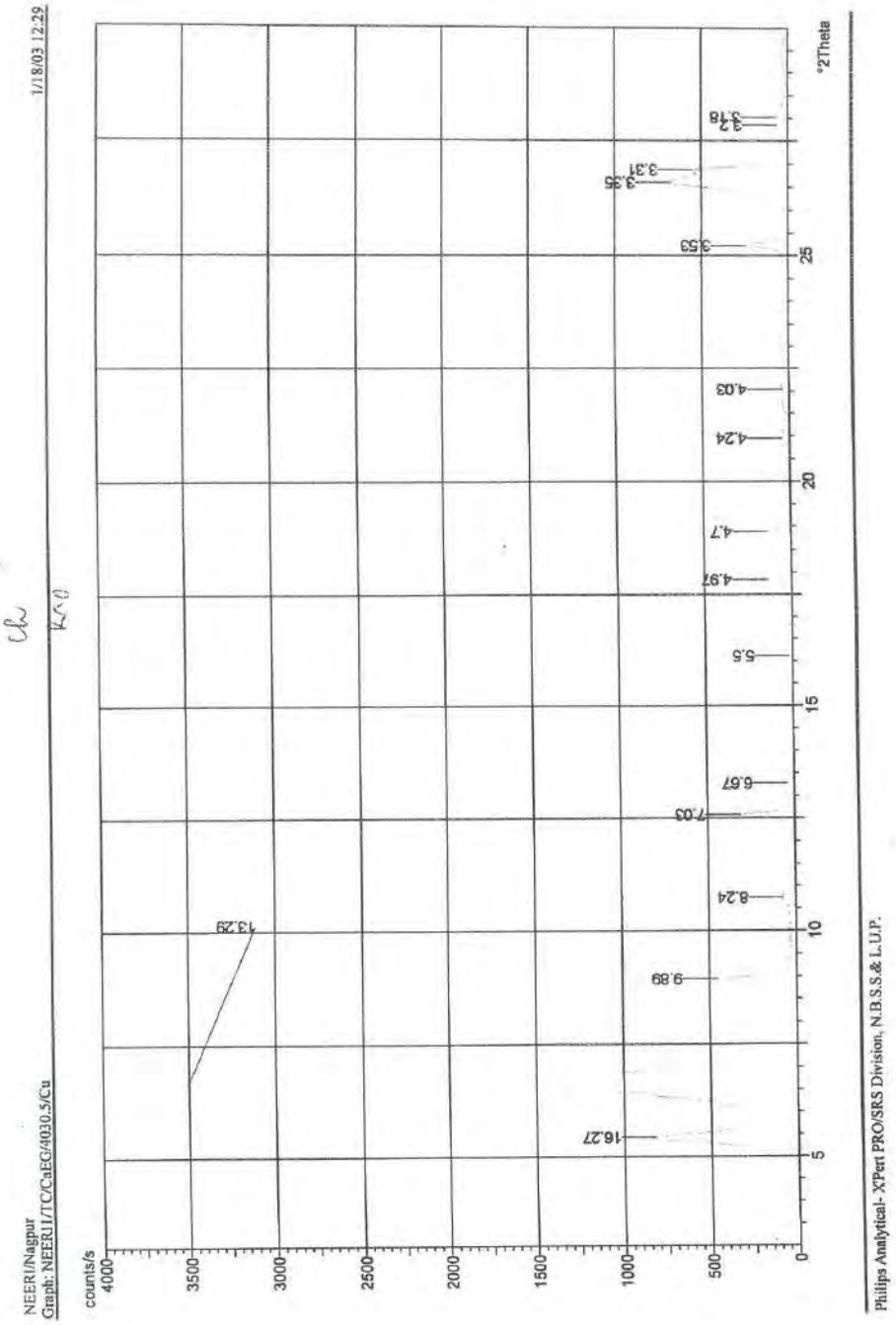
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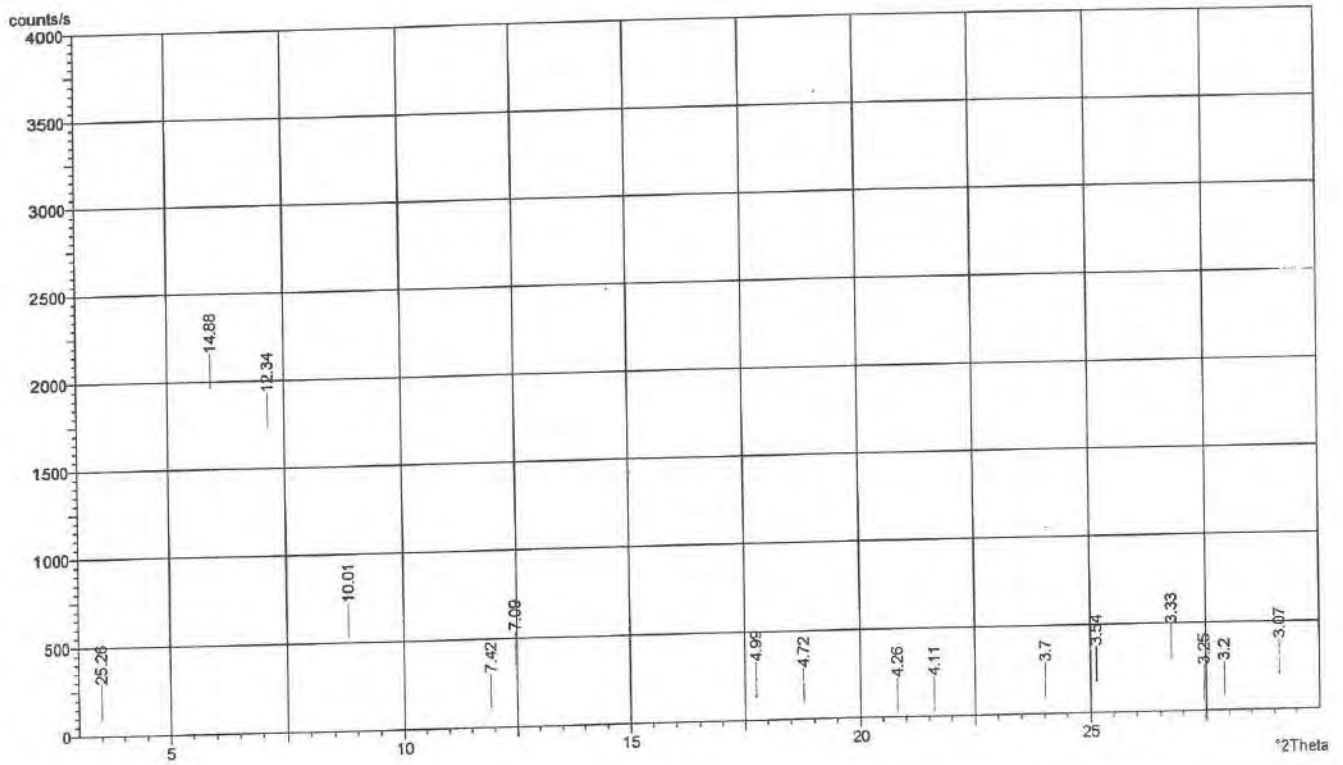

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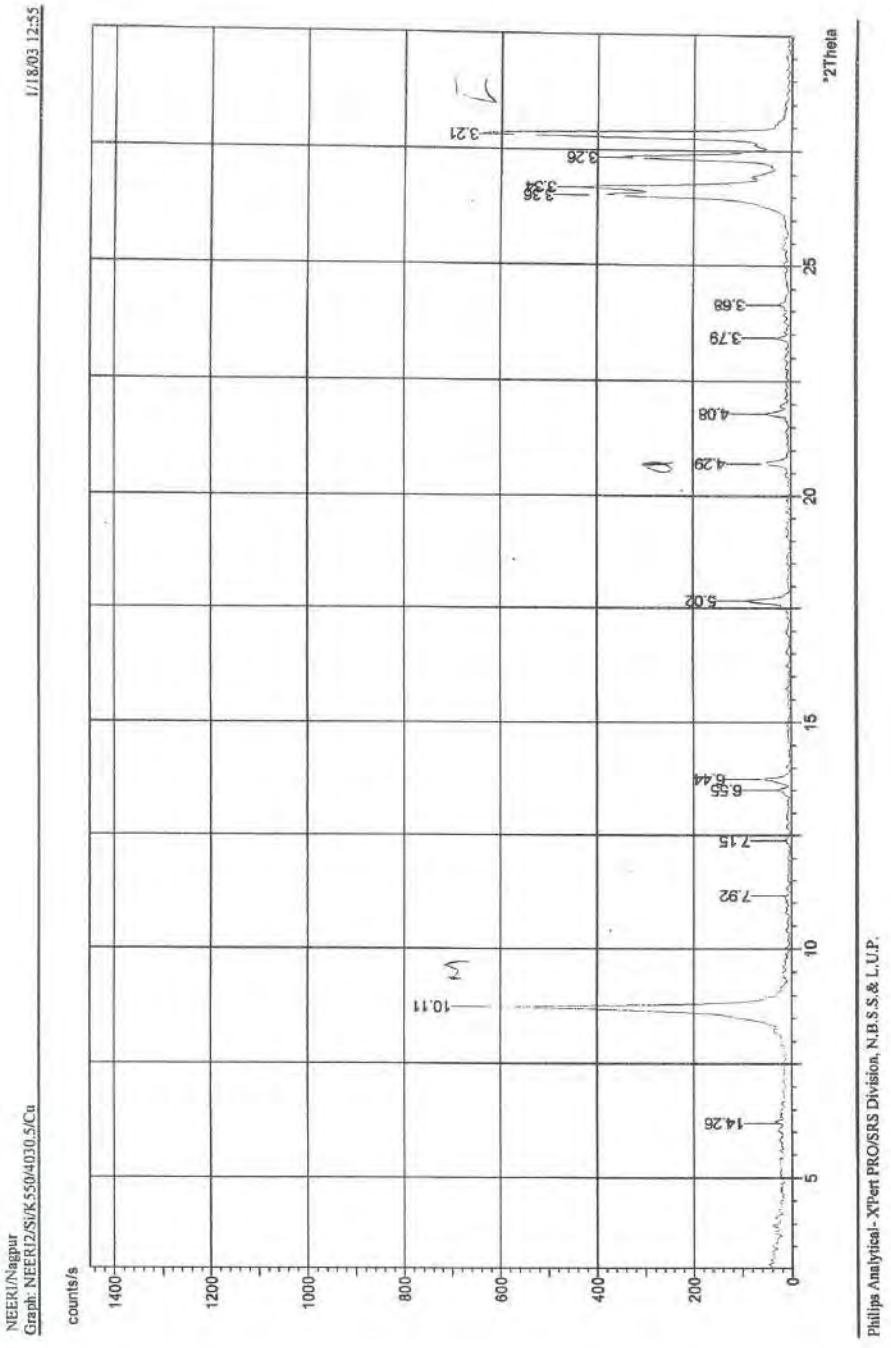
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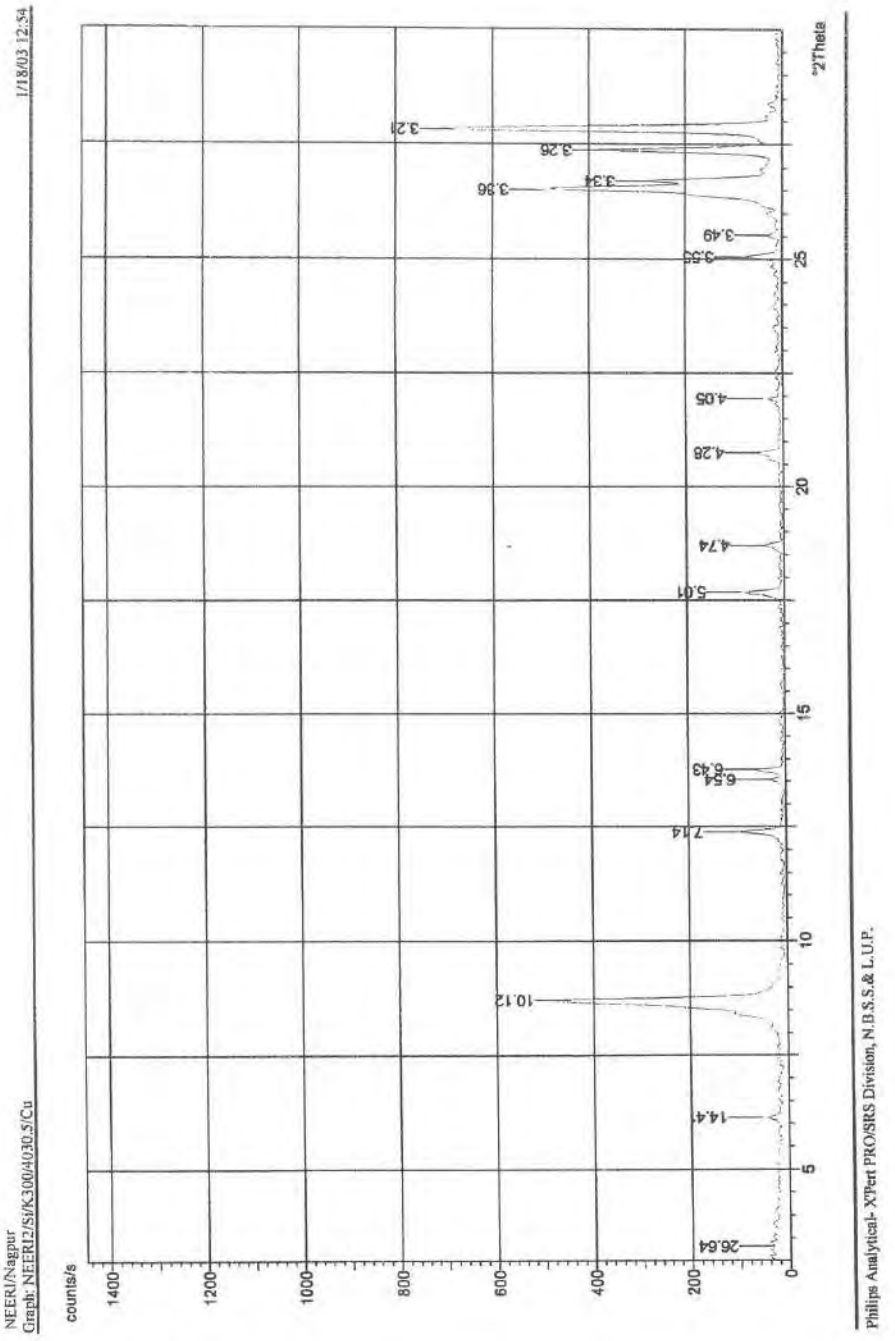
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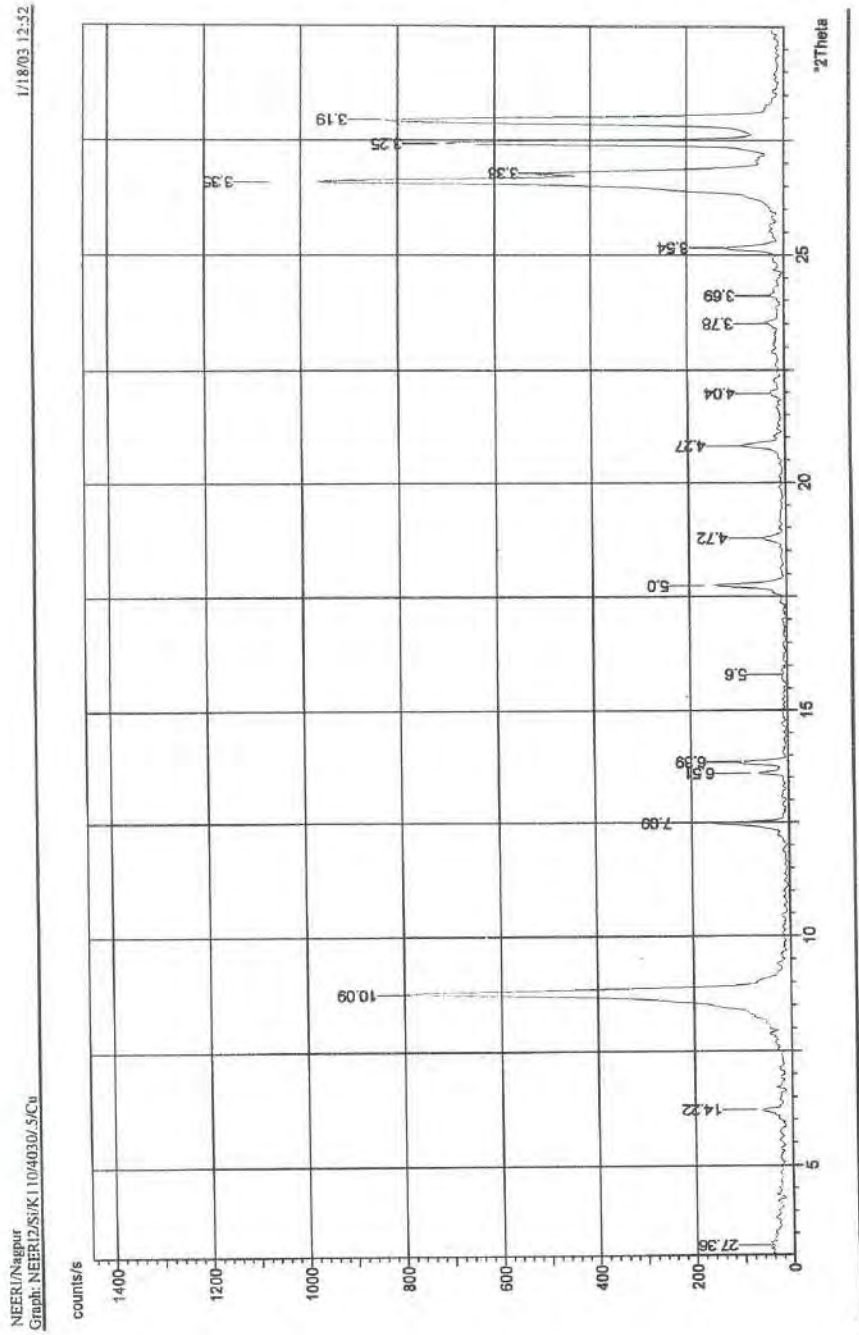
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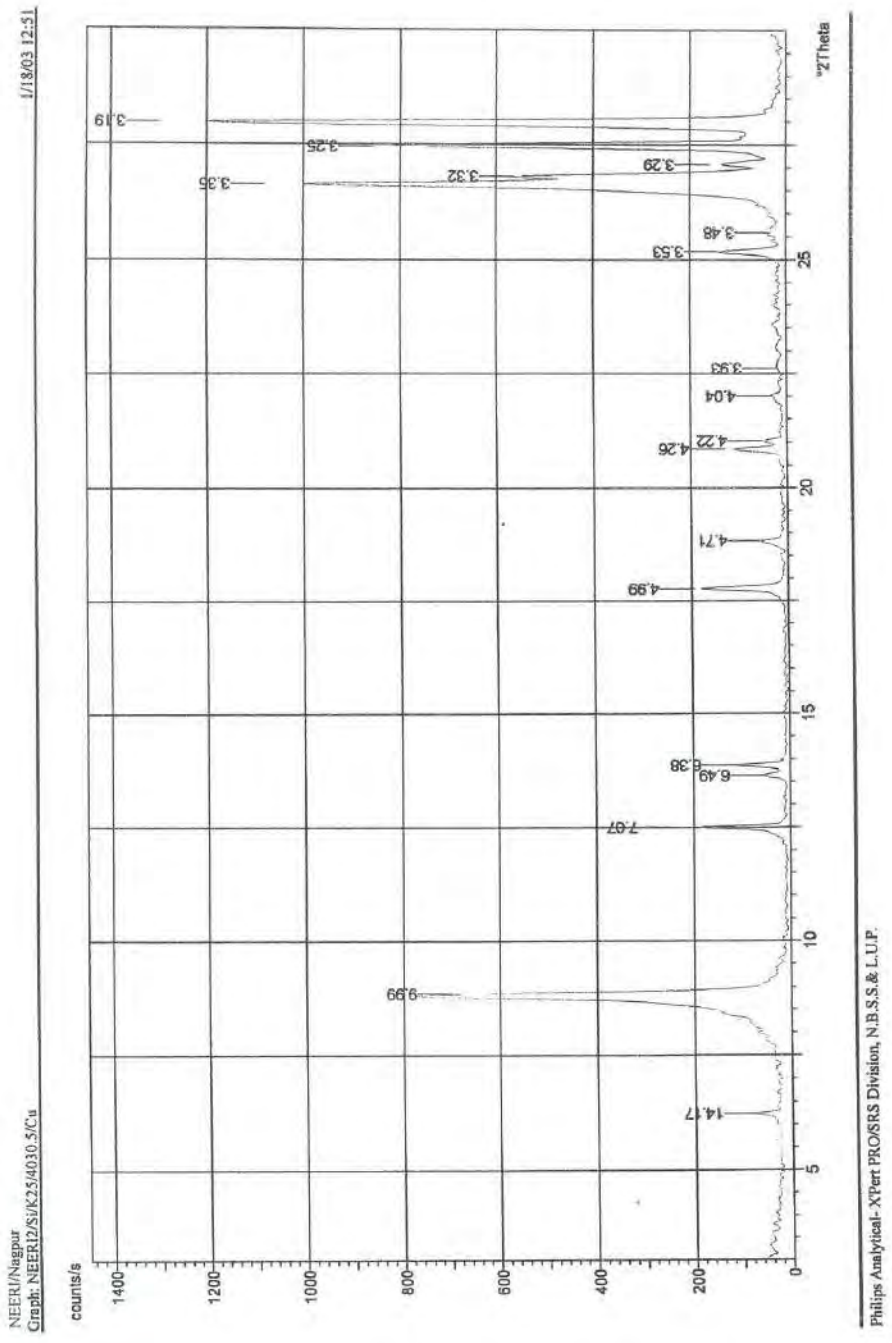
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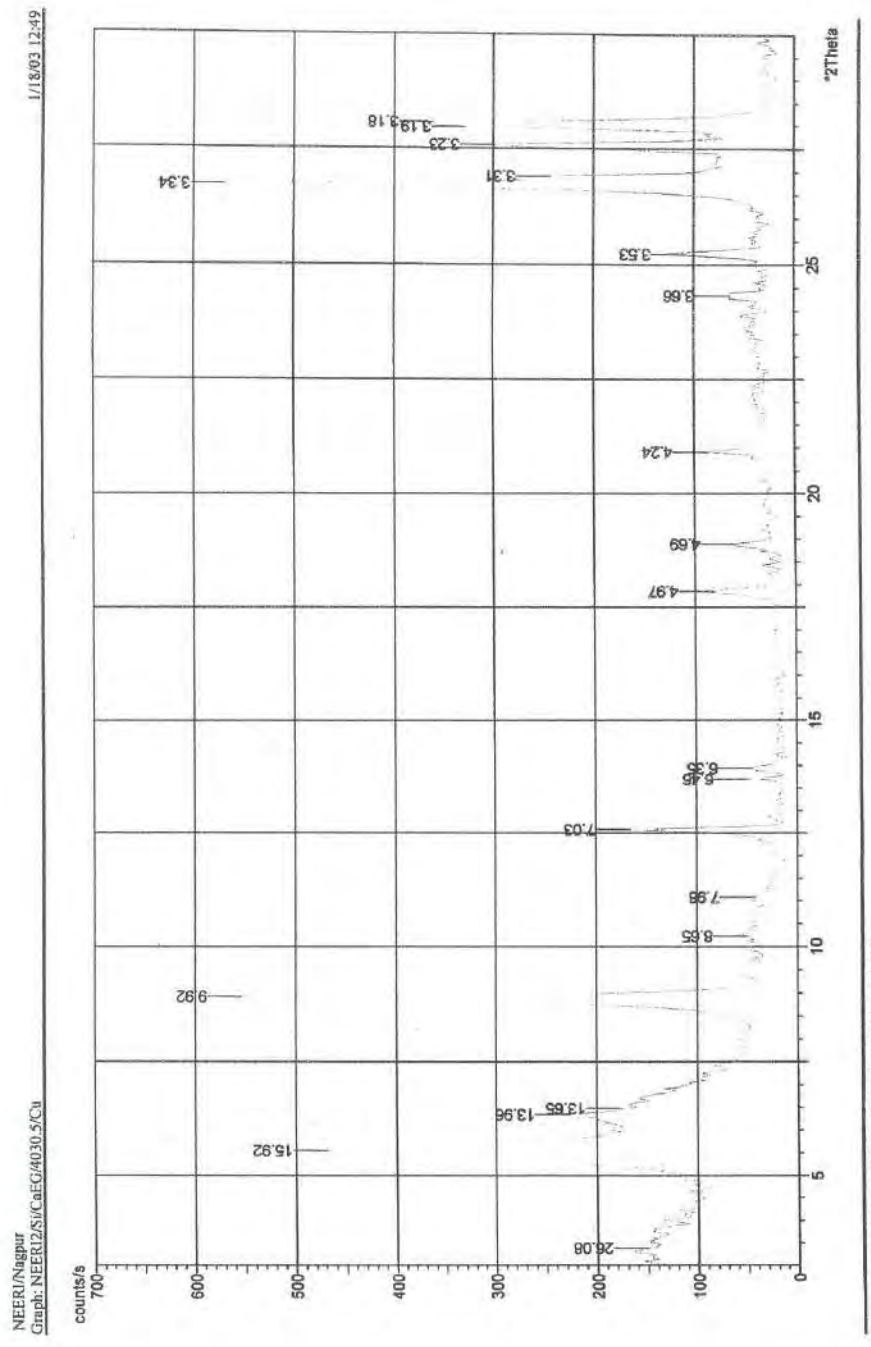
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20
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°2Theta
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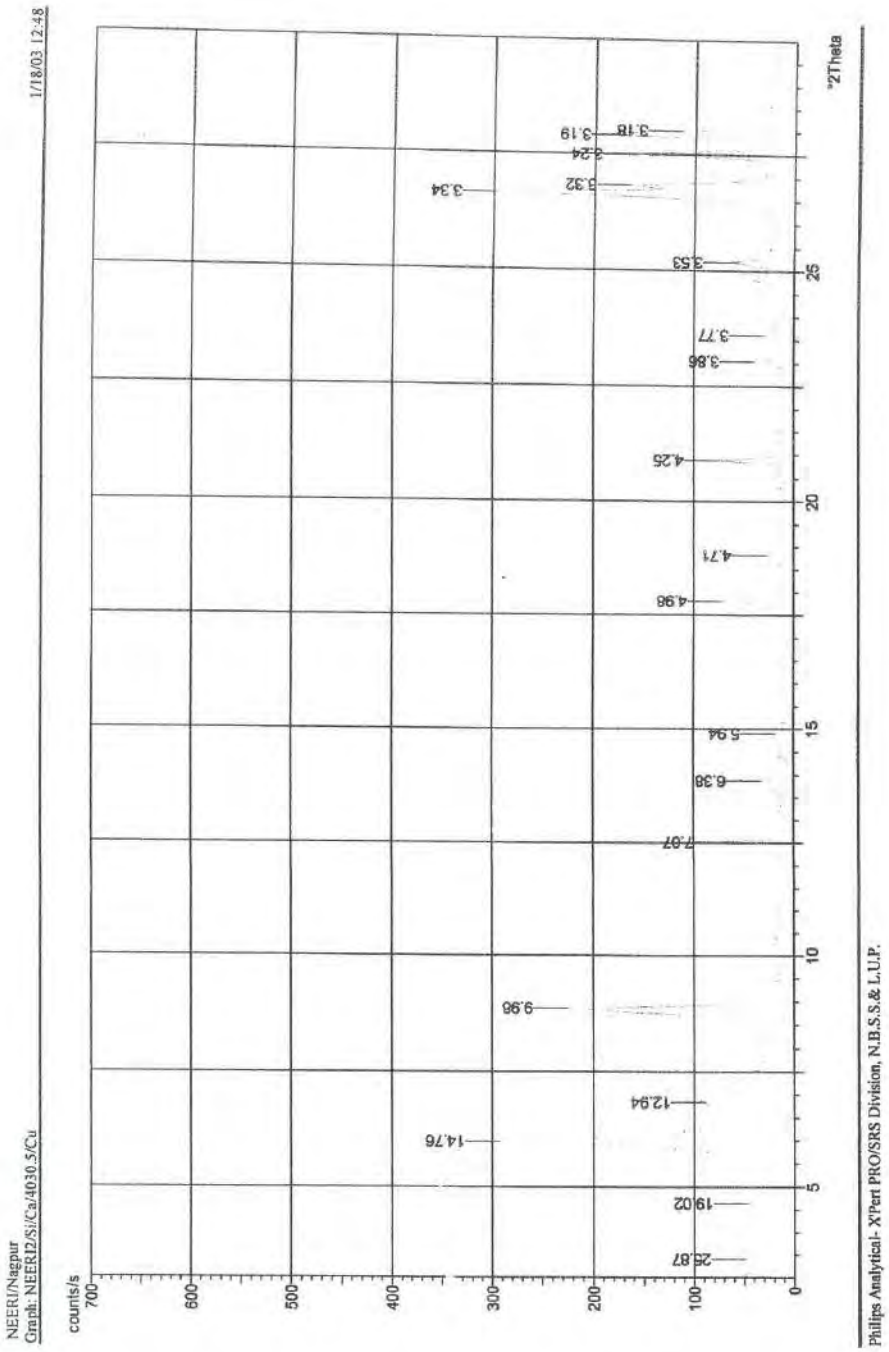
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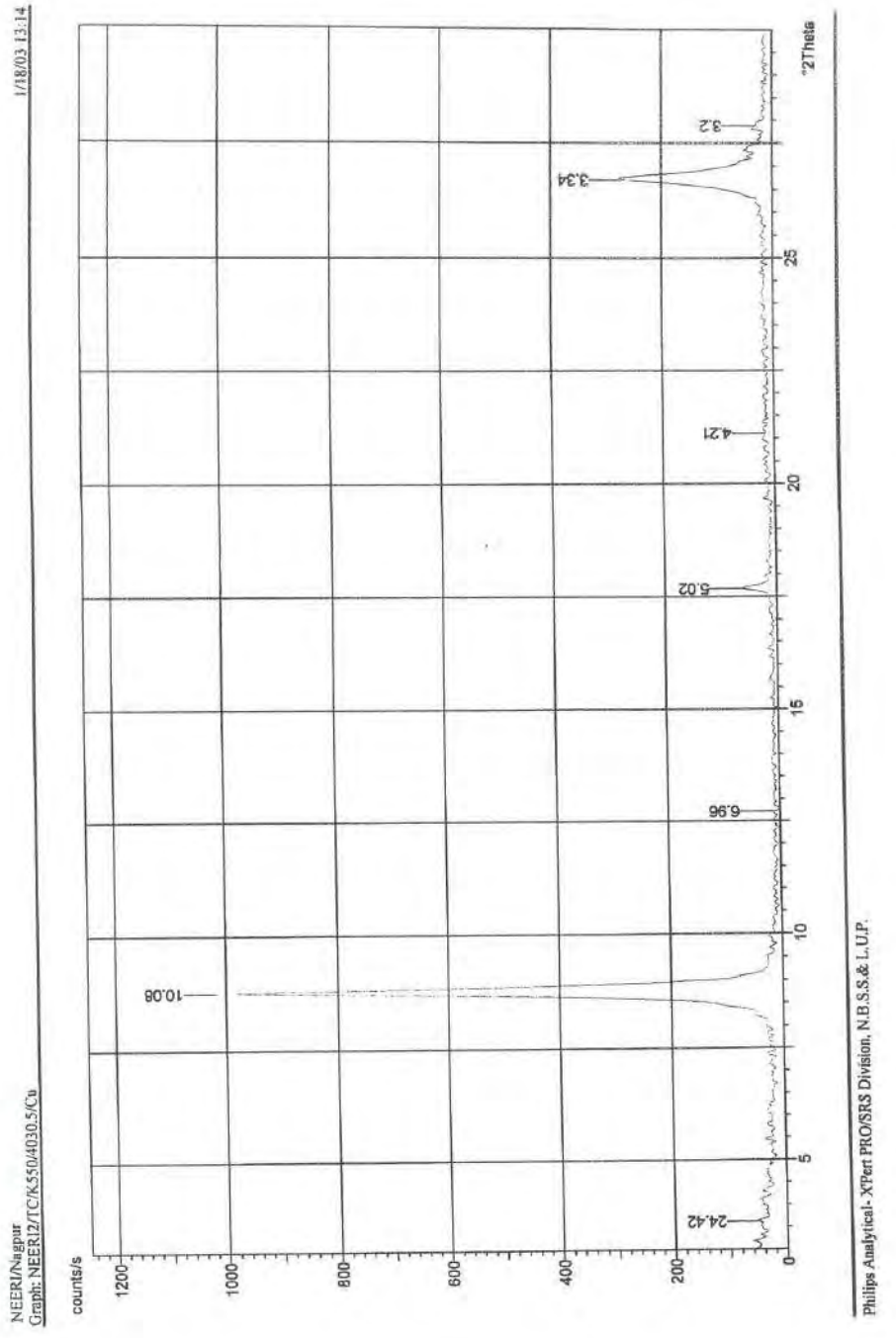
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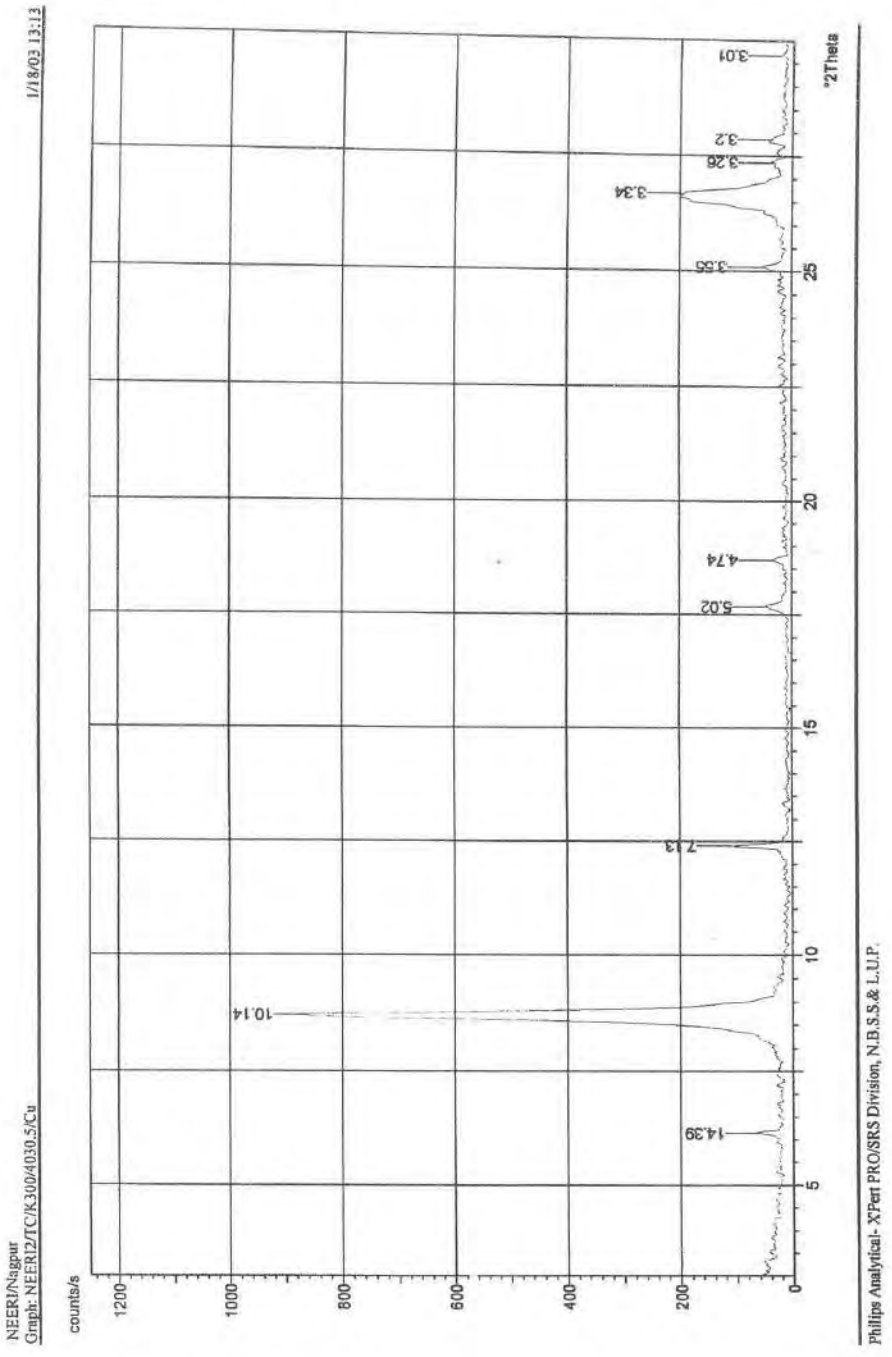
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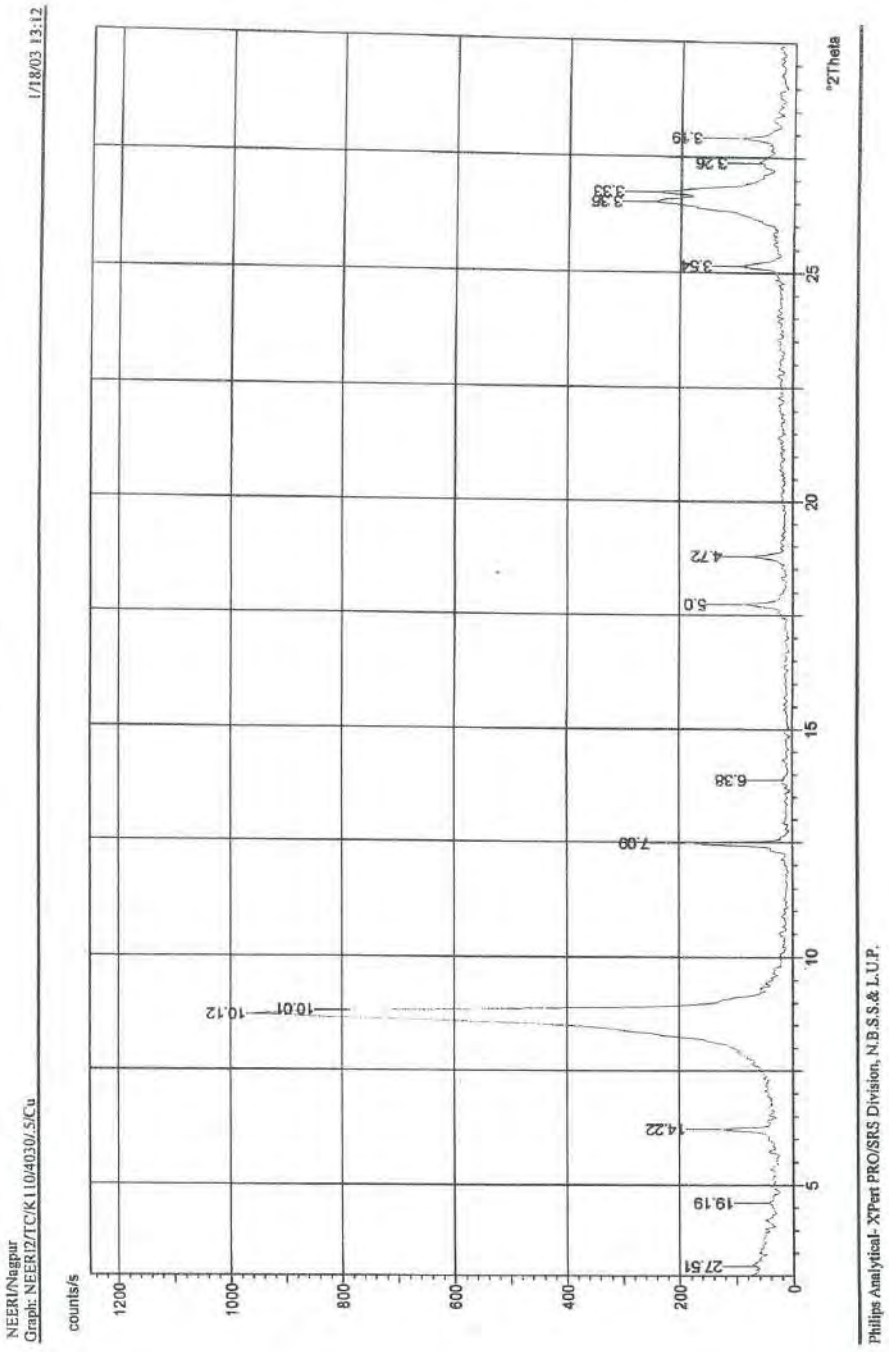
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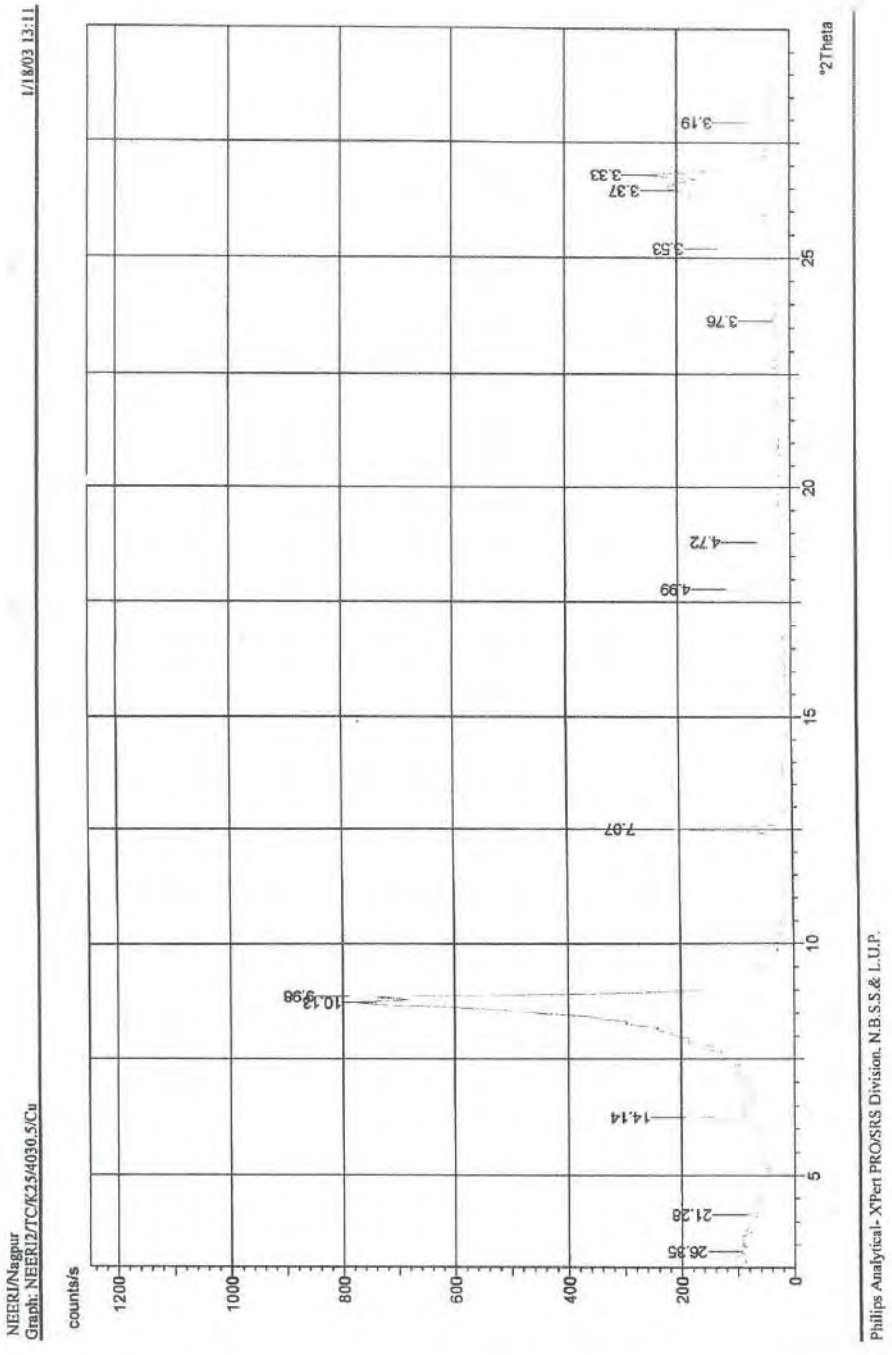
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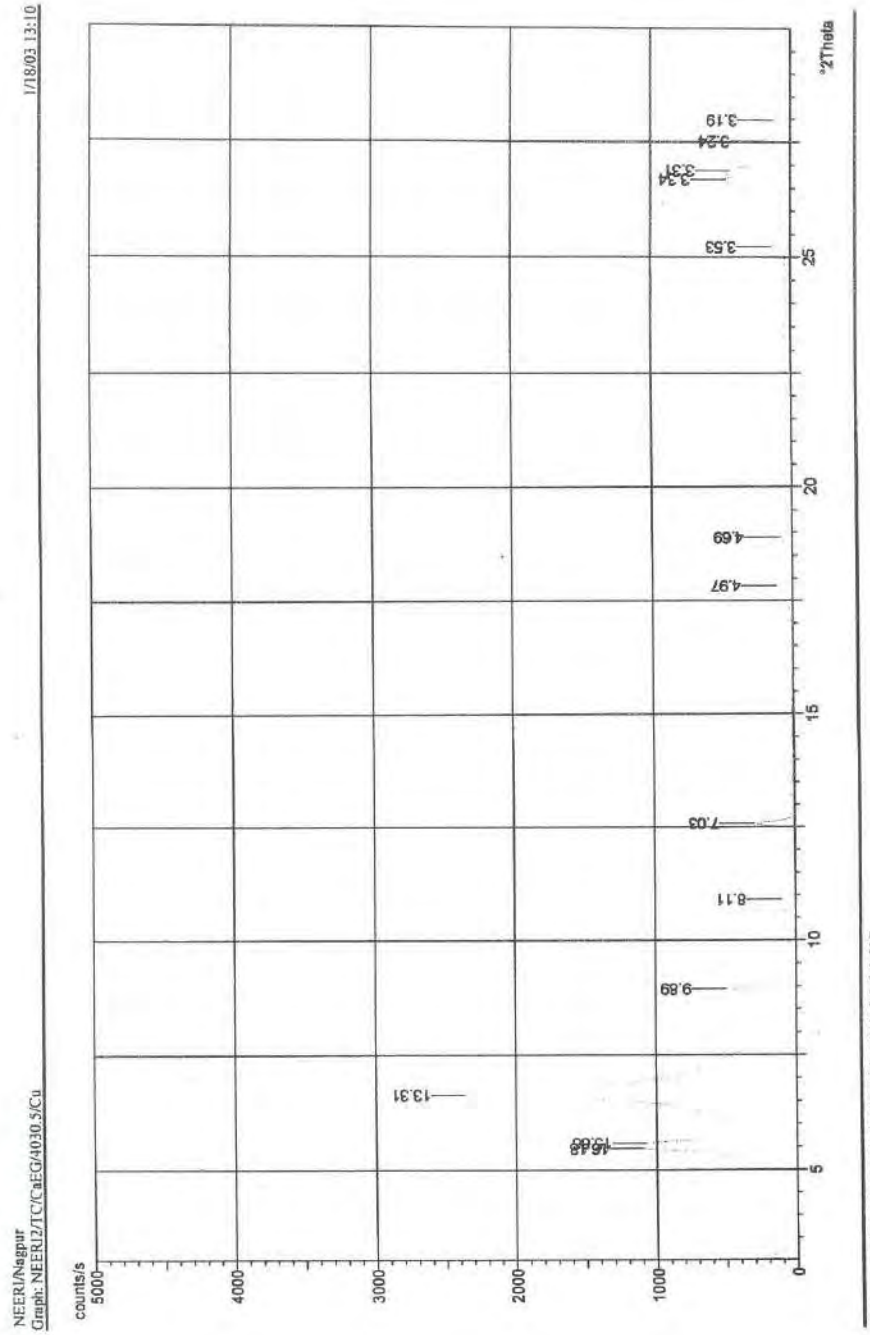
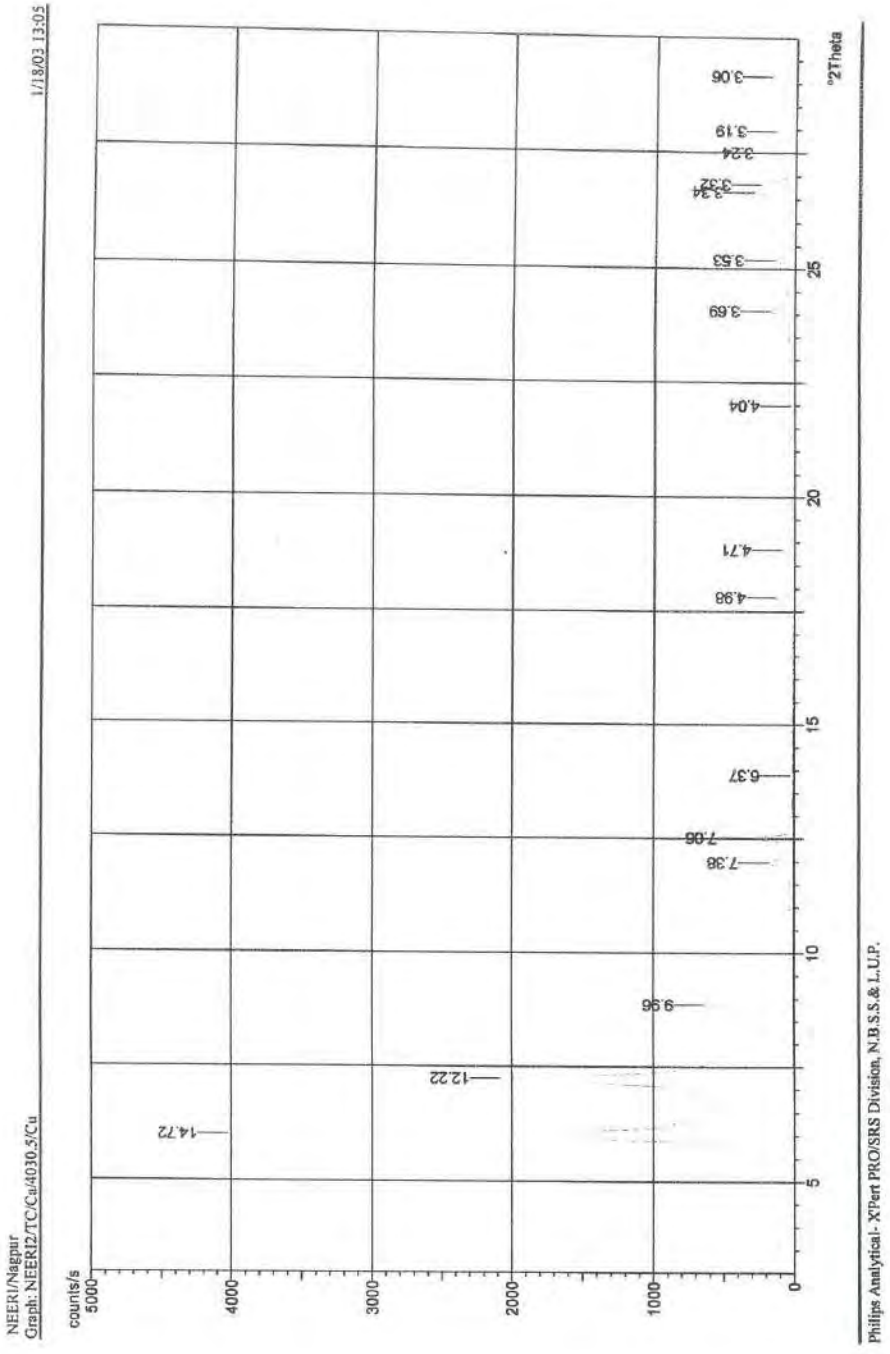
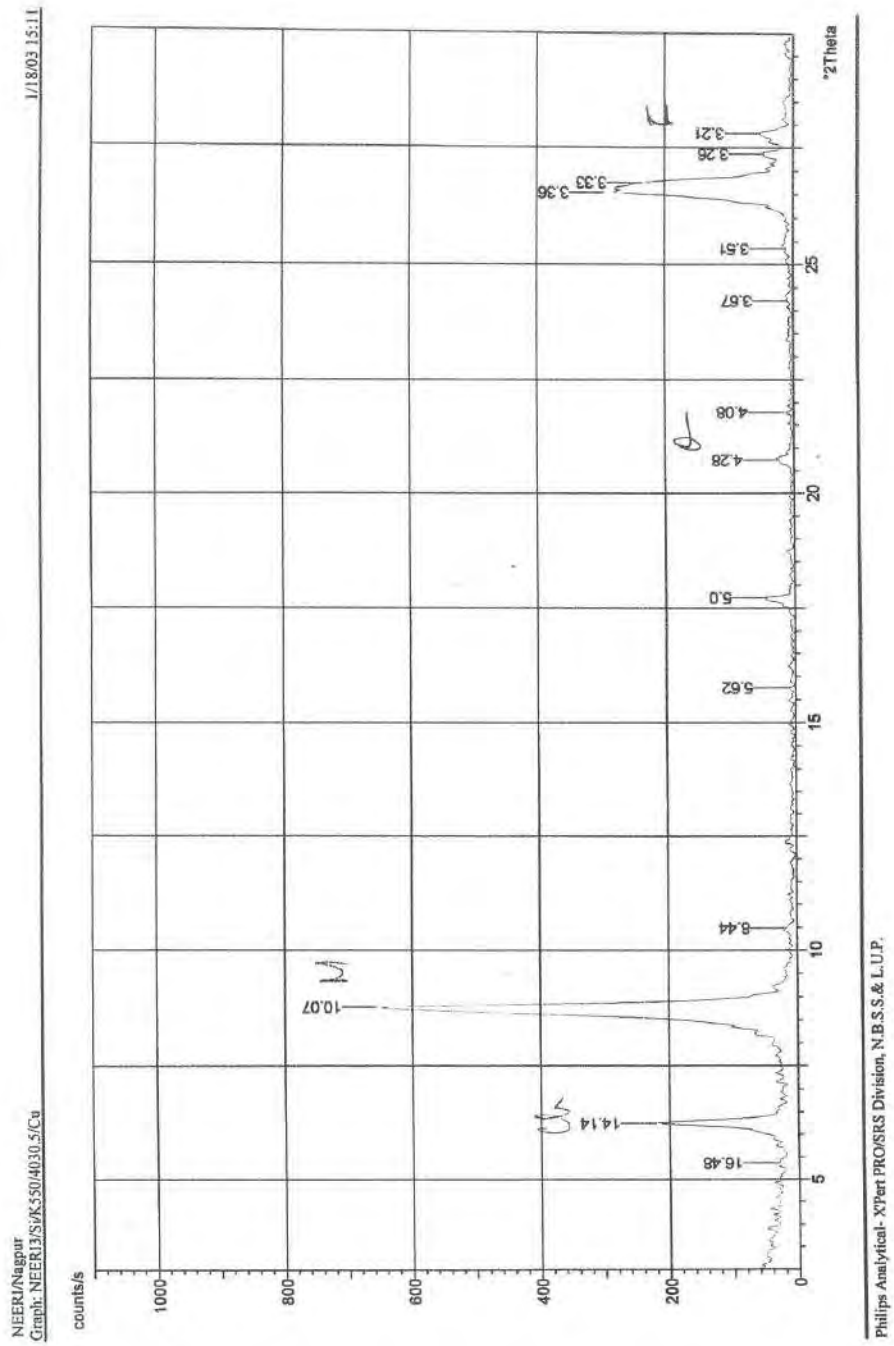
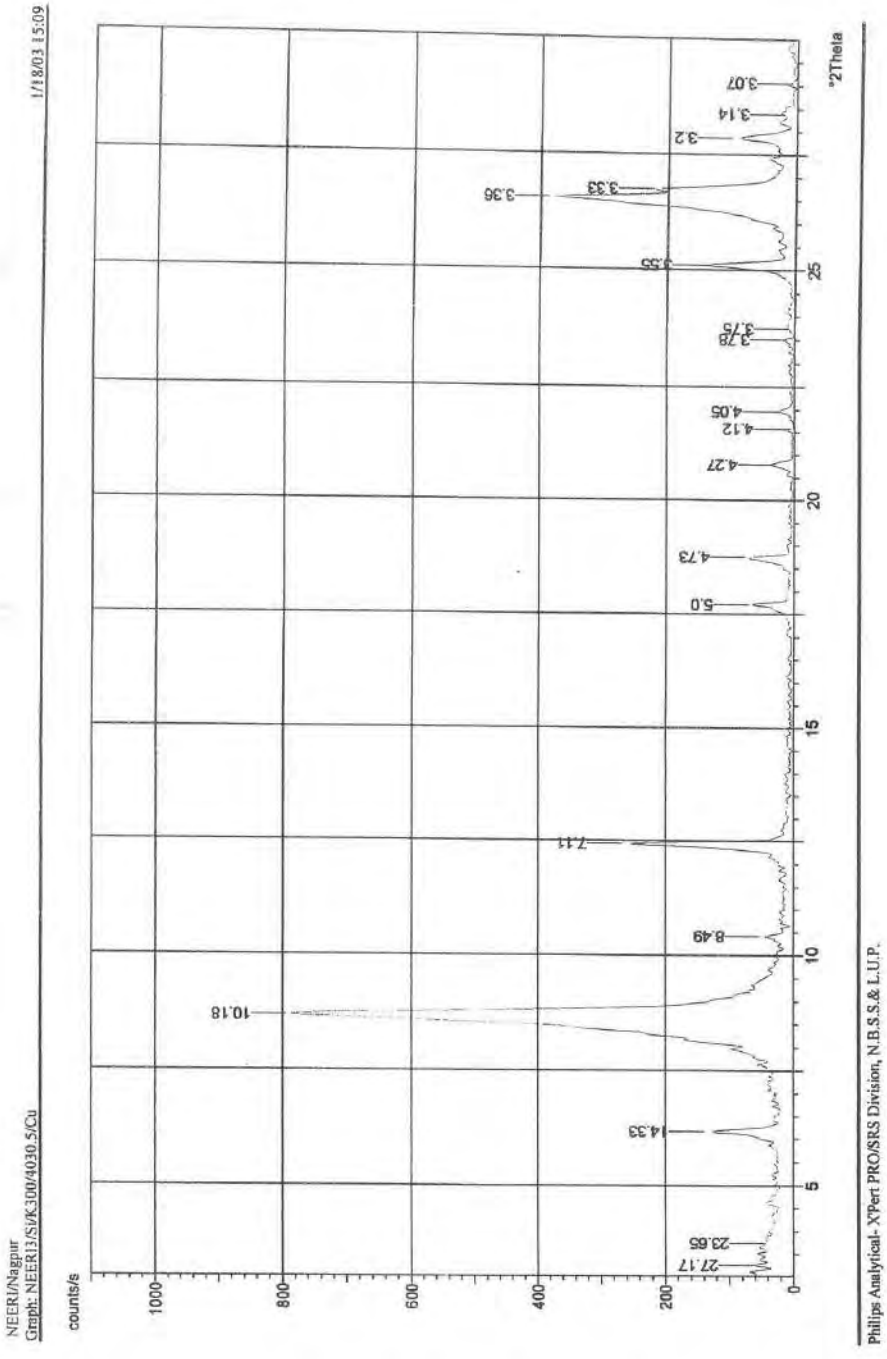
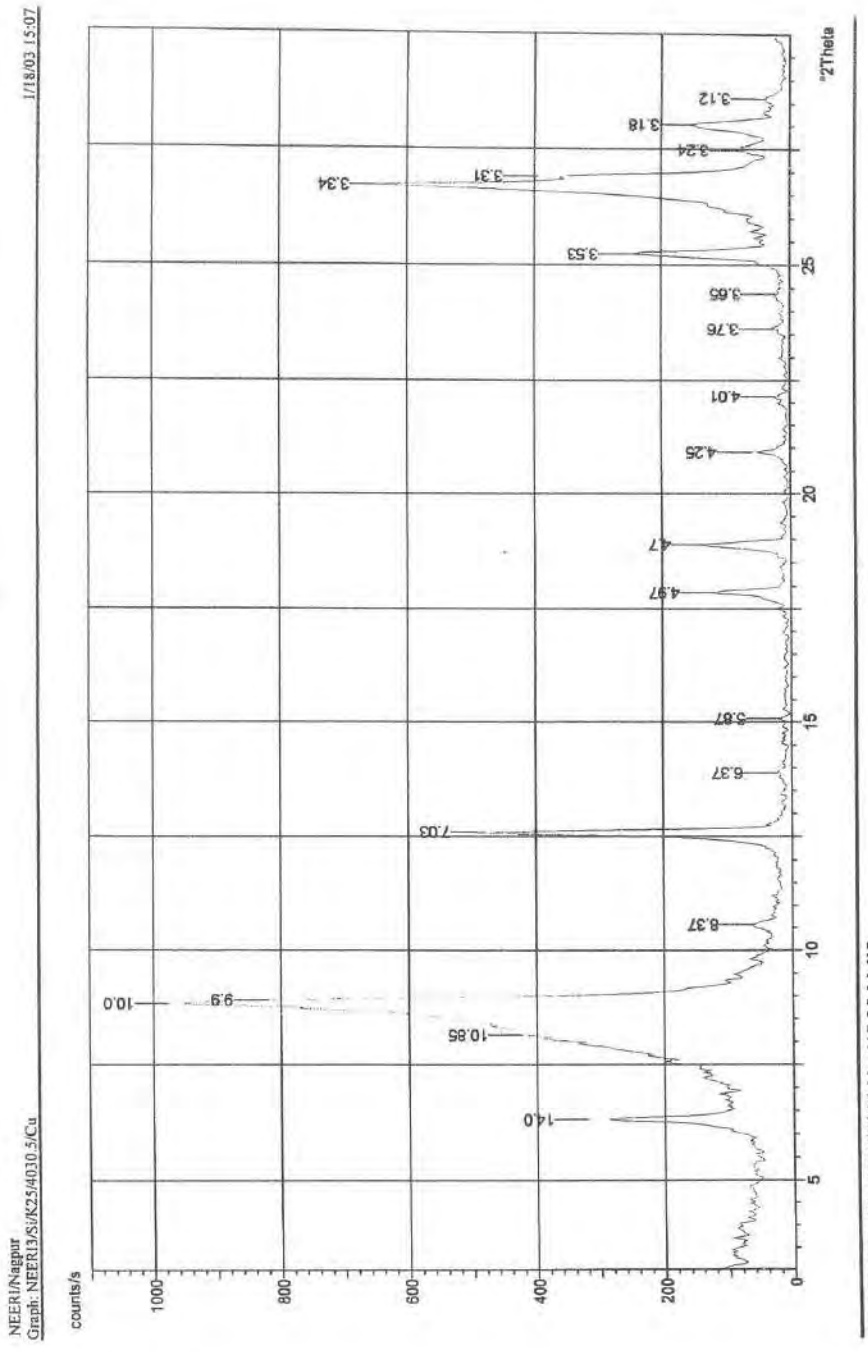
26.35
Philips Analytical - XPert PRO/SRS Division. N.B.S.S.& L.U.P.

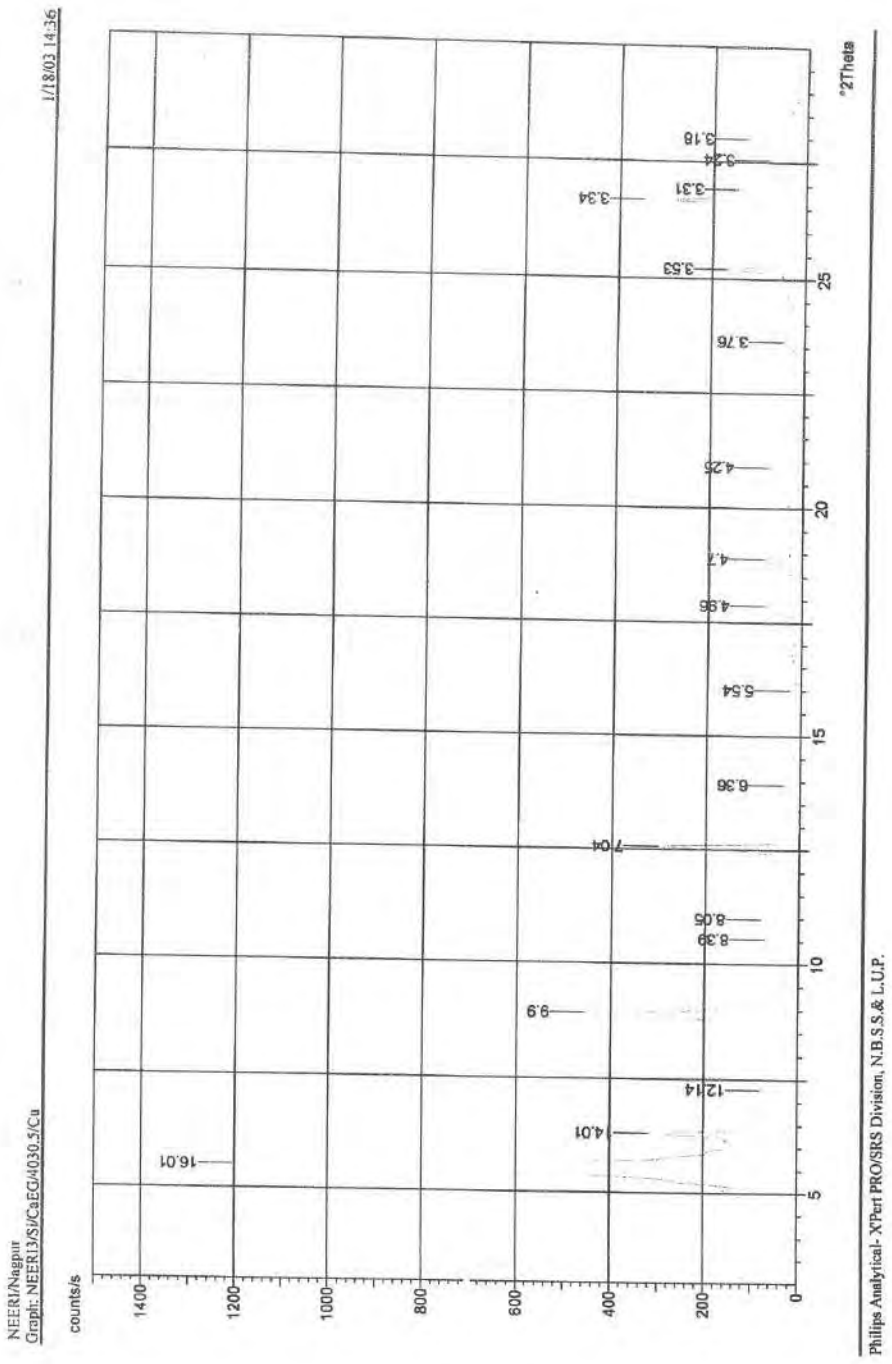

NEERI/Nagpur
Graph: NEERI2/TC/CaEG/4030.5/Cu
1/18/03 13:10
counts/s
5000
4000
3000
2000
1000
0
5
10
15
20
25
°2Theta
3.19
3.24
3.34
3.37
3.53
4.69
4.97
7.03
8.11
9.89
13.31
15.68
15.88
Philips Analytical- X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.


NEERI/Nagpur
Graph: NEERI2/TC/Cu/4030.5/Cu
1/18/03 13:05
counts/s
5000
4000
3000
2000
1000
0
5
10
15
20
25
°2Theta
14.72
12.22
9.56
7.38
7.06
6.37
4.98
4.71
4.04
3.69
3.53
3.34
3.32
3.24
3.19
3.06
Philips Analytical - X'Pert PRO/SRS Division, N.B.S.S. & L.U.P.


NEERI/Nagpur
Graph: NEER13/Si/K550/4030.5/Cu
1/18/03 15:11
counts/s
°2Theta
10.07
14.14
16.48
8.44
5.62
5.0
4.28
4.08
3.57
3.51
3.36
3.33
3.26
3.21
Philips Analytical - X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.


NEERI/Nagpur
Graph: NEERI3/Si/K300/4030.5/Cu
1/18/03 15:09
counts/s
°2Theta
10.18
8.49
7.11
4.33
27.17
23.65
5.0
4.73
4.27
4.12
4.05
3.78
3.55
3.36
3.33
3.2
3.14
3.07
Philips Analytical- X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.


NEER1/Nagpur
Graph: NEER13/Si/K25/4030.5/Cu
1/18/03 15:07
counts/s
°2Theta
Philips Analytical - X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.
14.0
10.85
9.9
10.0
8.37
7.03
6.37
5.87
4.97
4.7
4.25
4.01
3.76
3.65
3.53
3.34
3.31
3.24
3.18
3.12


1/18/03 14:36
NEERI/Nagpur
Graph: NEERI3/S#/CaEG/4030.5/Cu
counts/s
°2Theta
16.01
4.01
12.14
9.9
8.39
8.05
7.04
6.36
5.54
4.96
4.7
4.25
3.76
3.53
3.34
3.31
3.24
3.18
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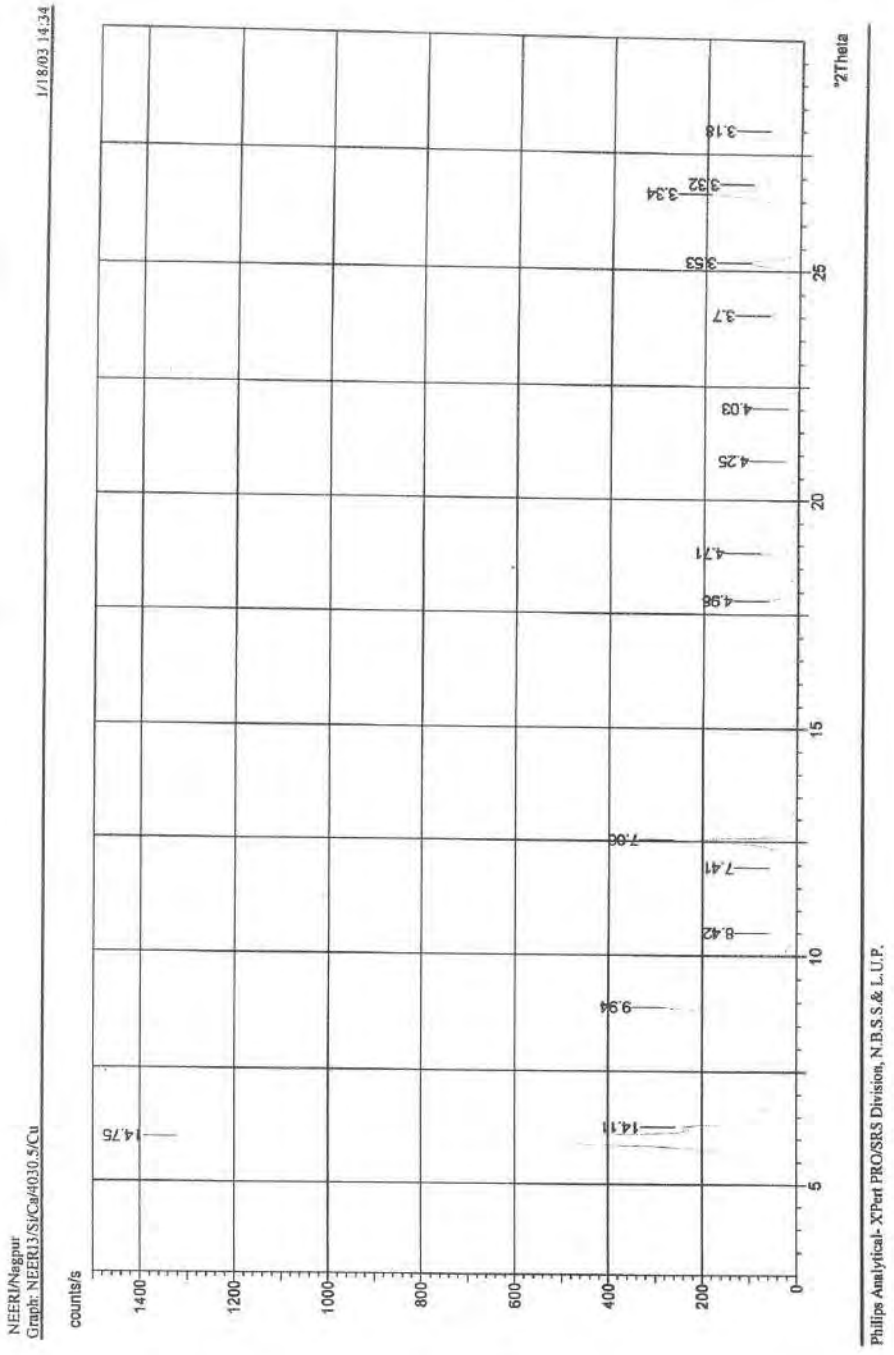
NEERI/Nagpur
Graph: NEERI3/SiCa/4030.5/Cu
1/18/03 14:34
counts/s
0
200
400
600
800
1000
1200
1400
5
10
15
20
25
°2Theta
14.75
14.11
9.94
8.42
7.41
7.06
4.96
4.71
4.25
4.03
3.7
3.53
3.34
3.32
3.18
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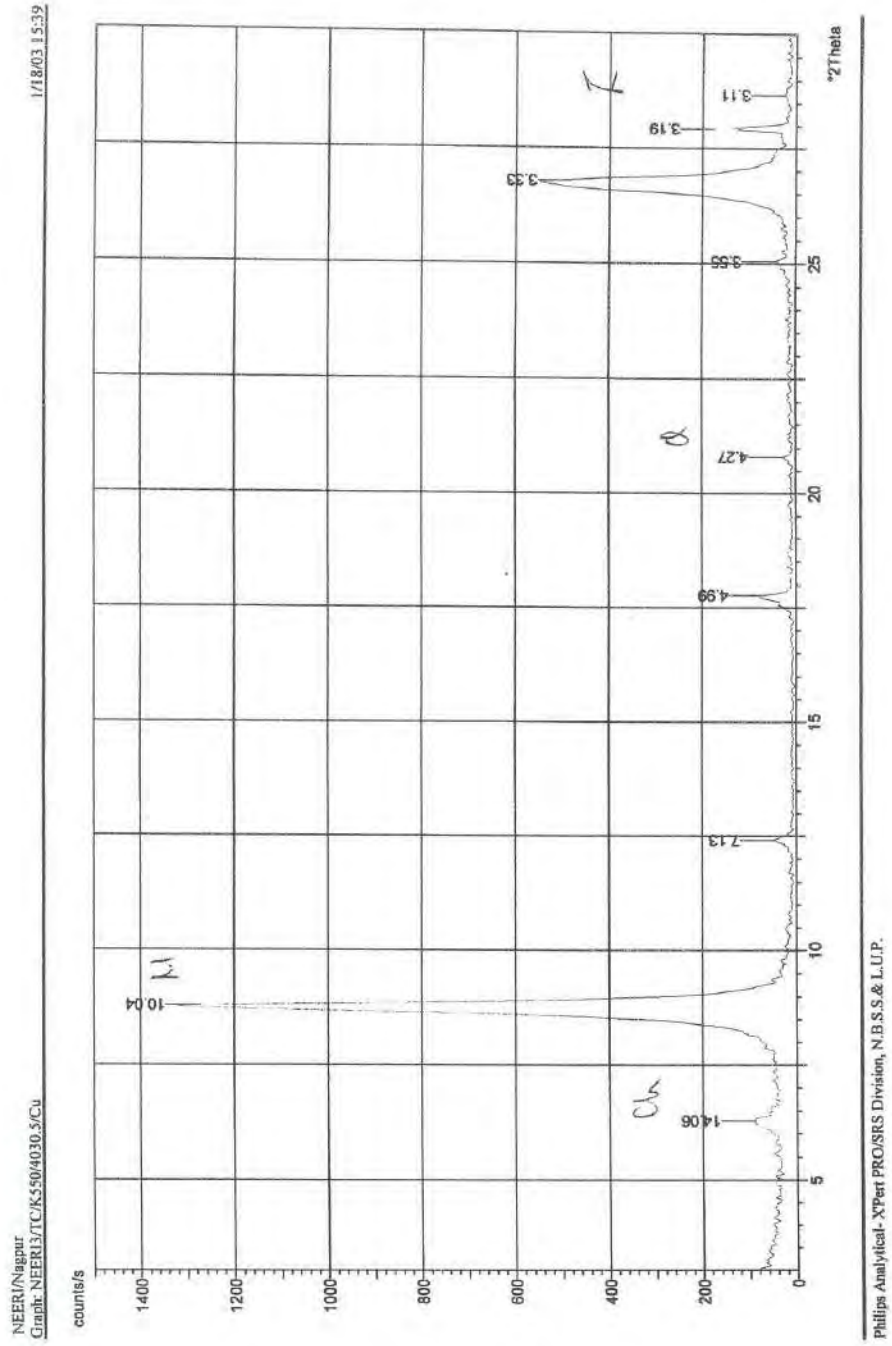
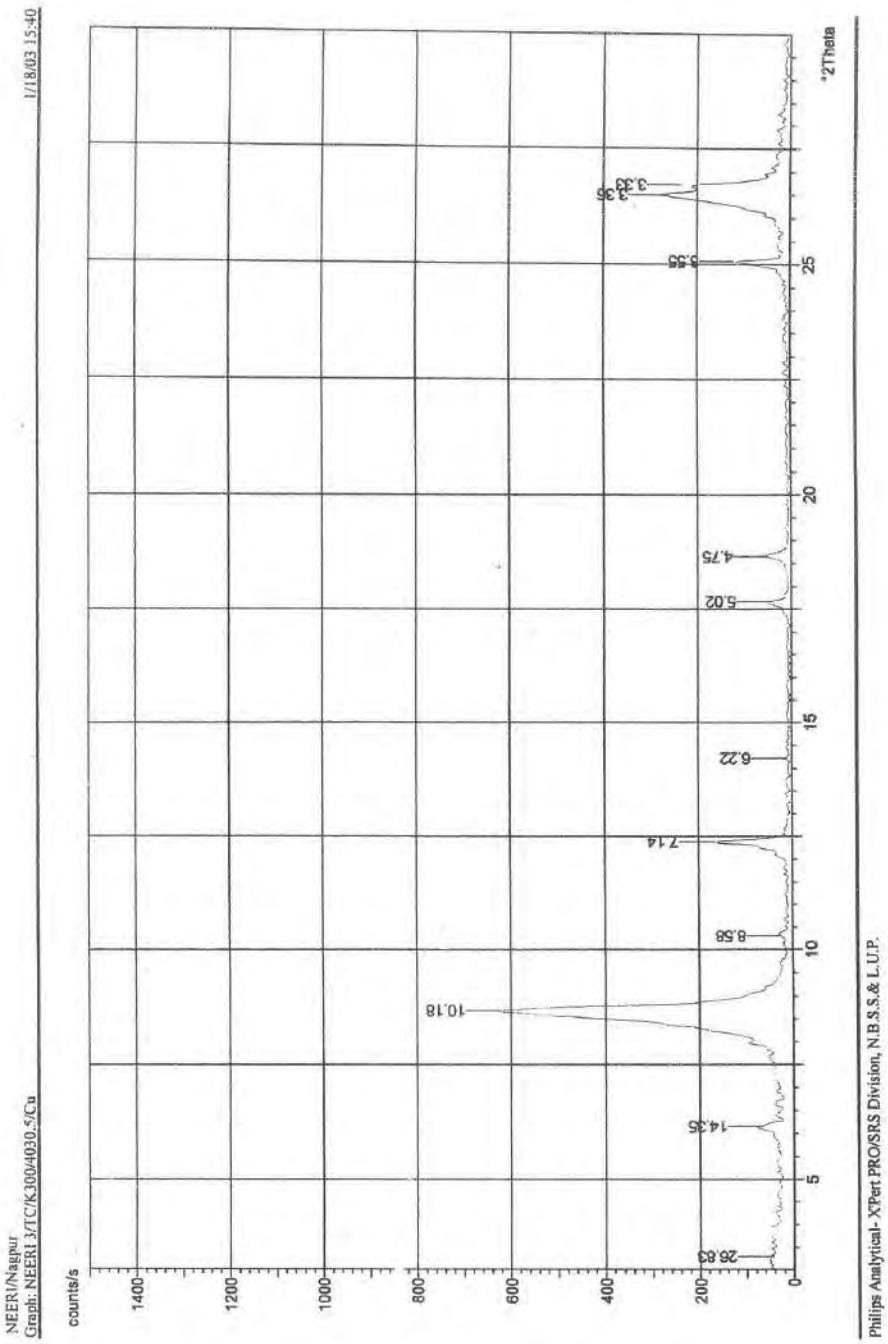
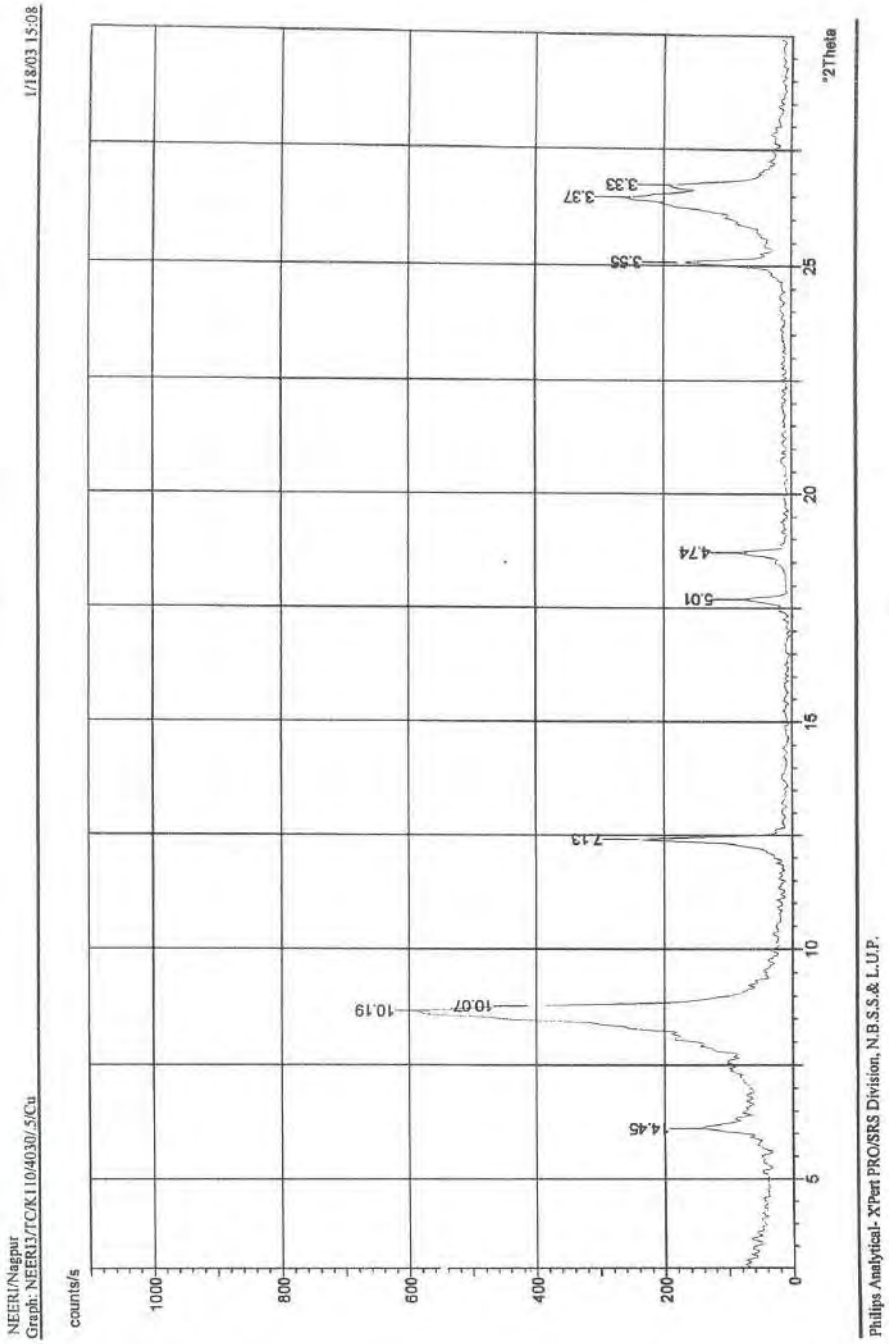
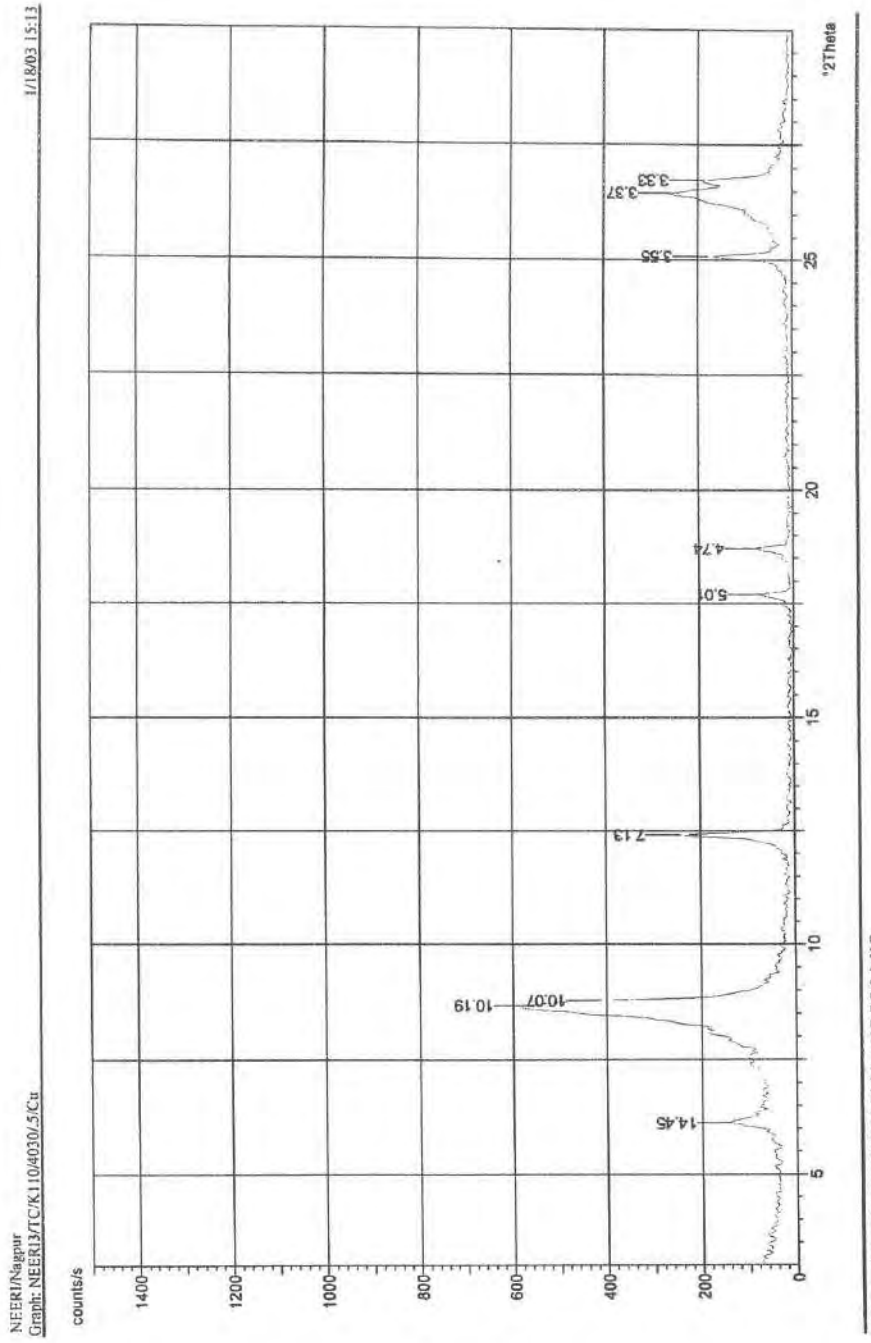
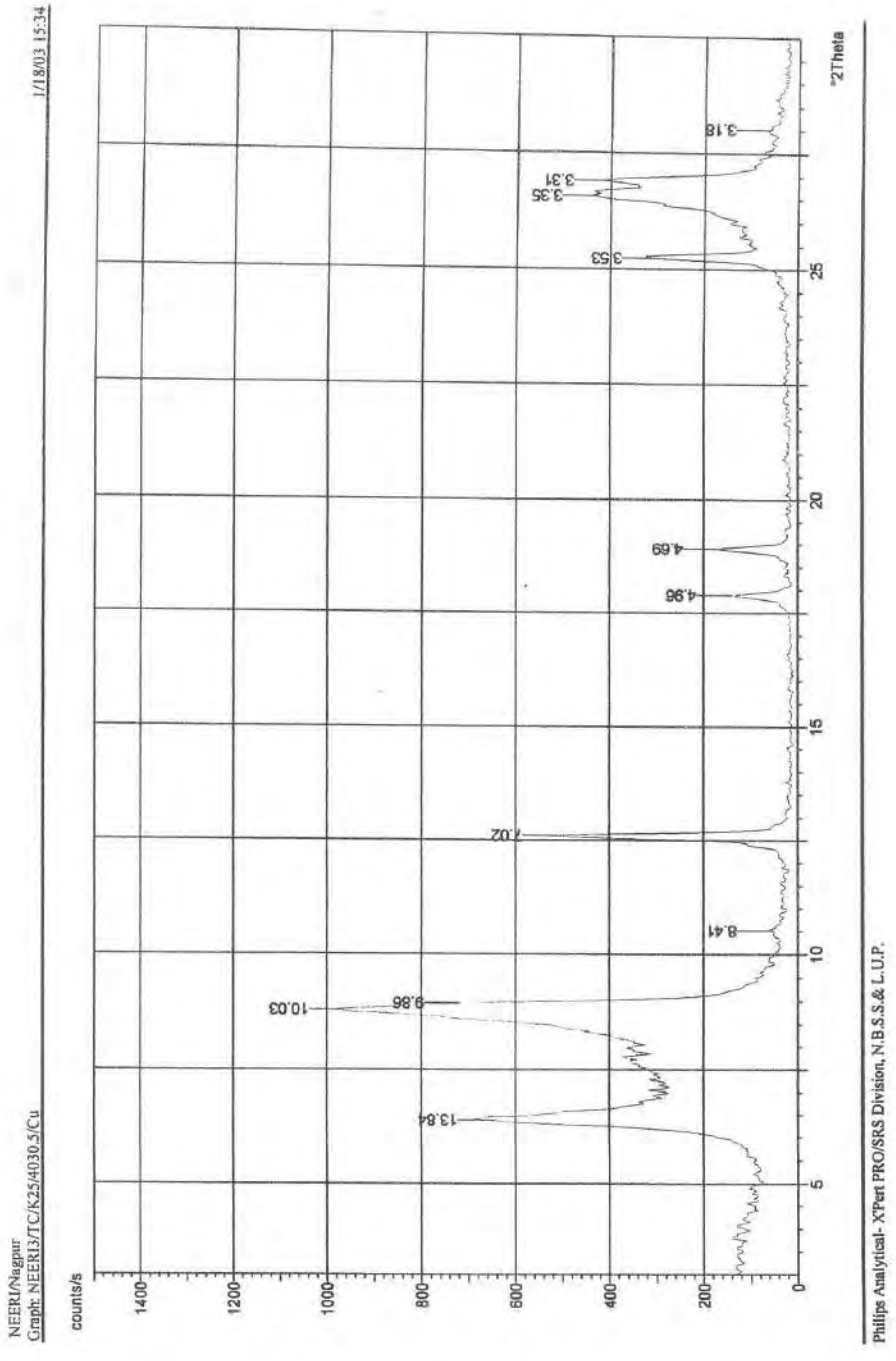


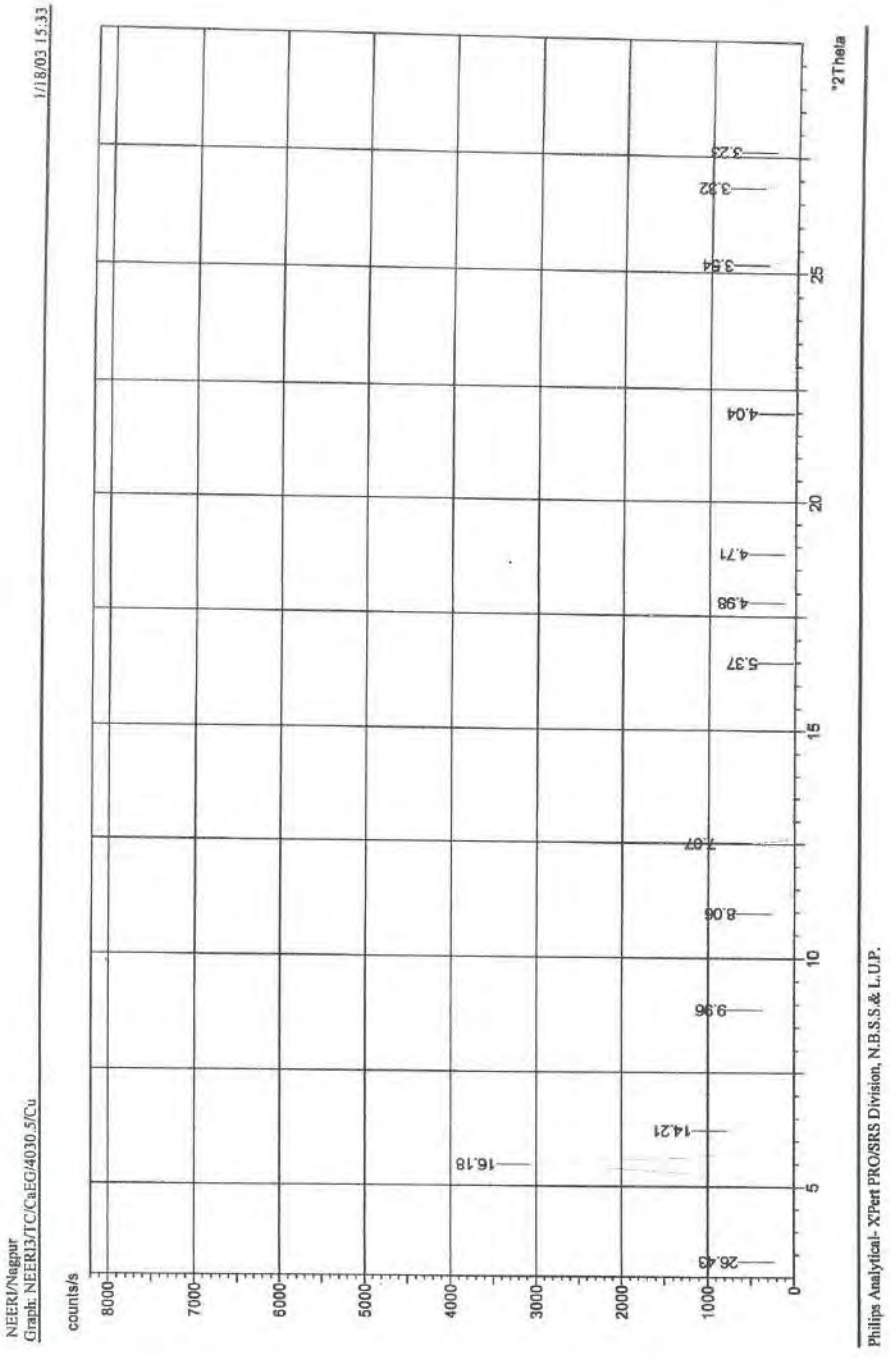
Philips Analytical- XPert PRO/SRS Division, N.B.S.S.& L.U.P.

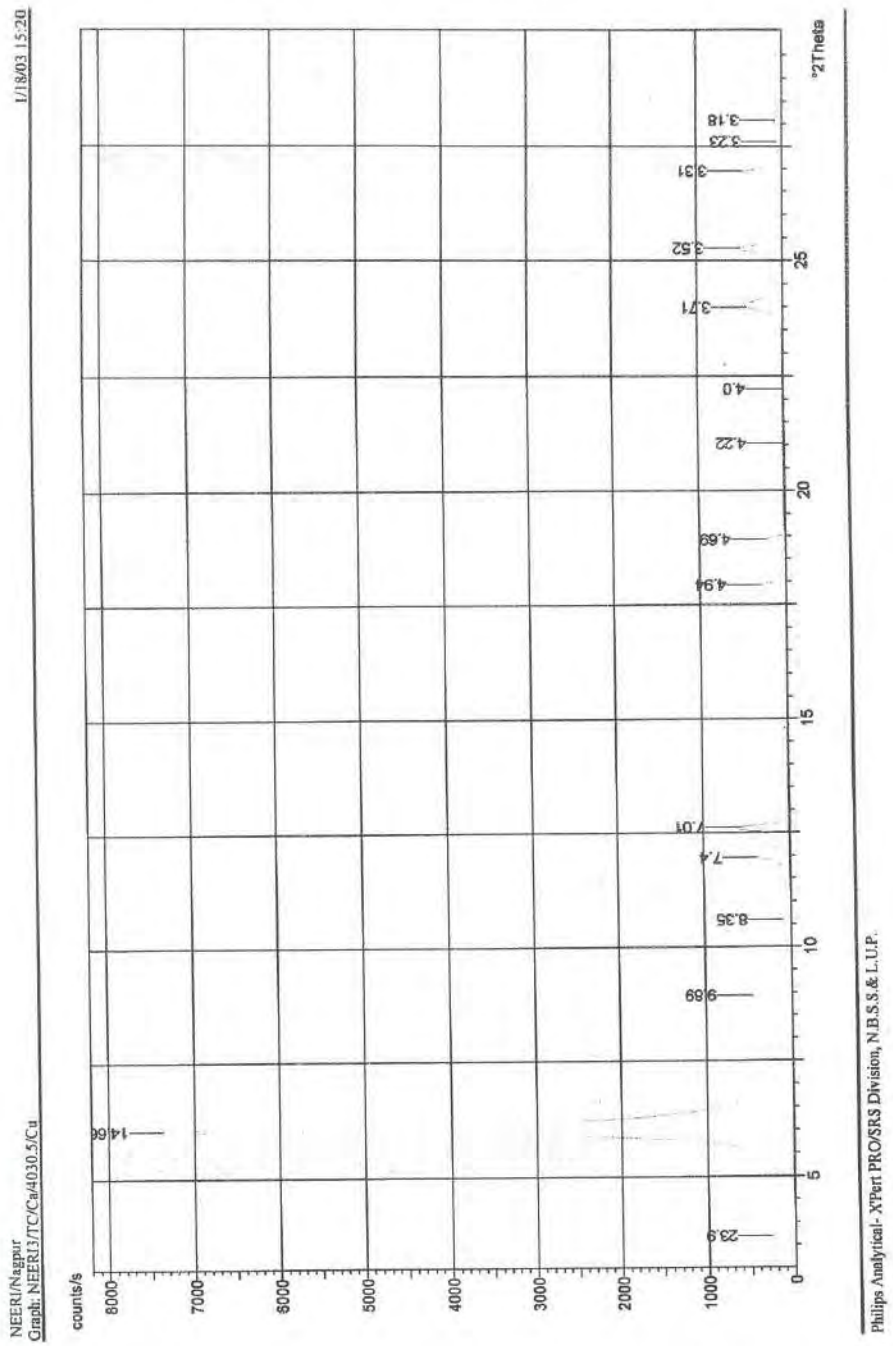

NEERI/Nagpur
Graph: NEERI 3/TC/K300/4030.5/Cu
1/18/03 15:40
counts/s
1400
1200
1000
800
600
400
200
0
5
10
15
20
25
°2Theta
26.83
14.35
10.18
8.58
7.14
6.22
5.02
4.75
3.35
3.33
Philips Analytical- X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.

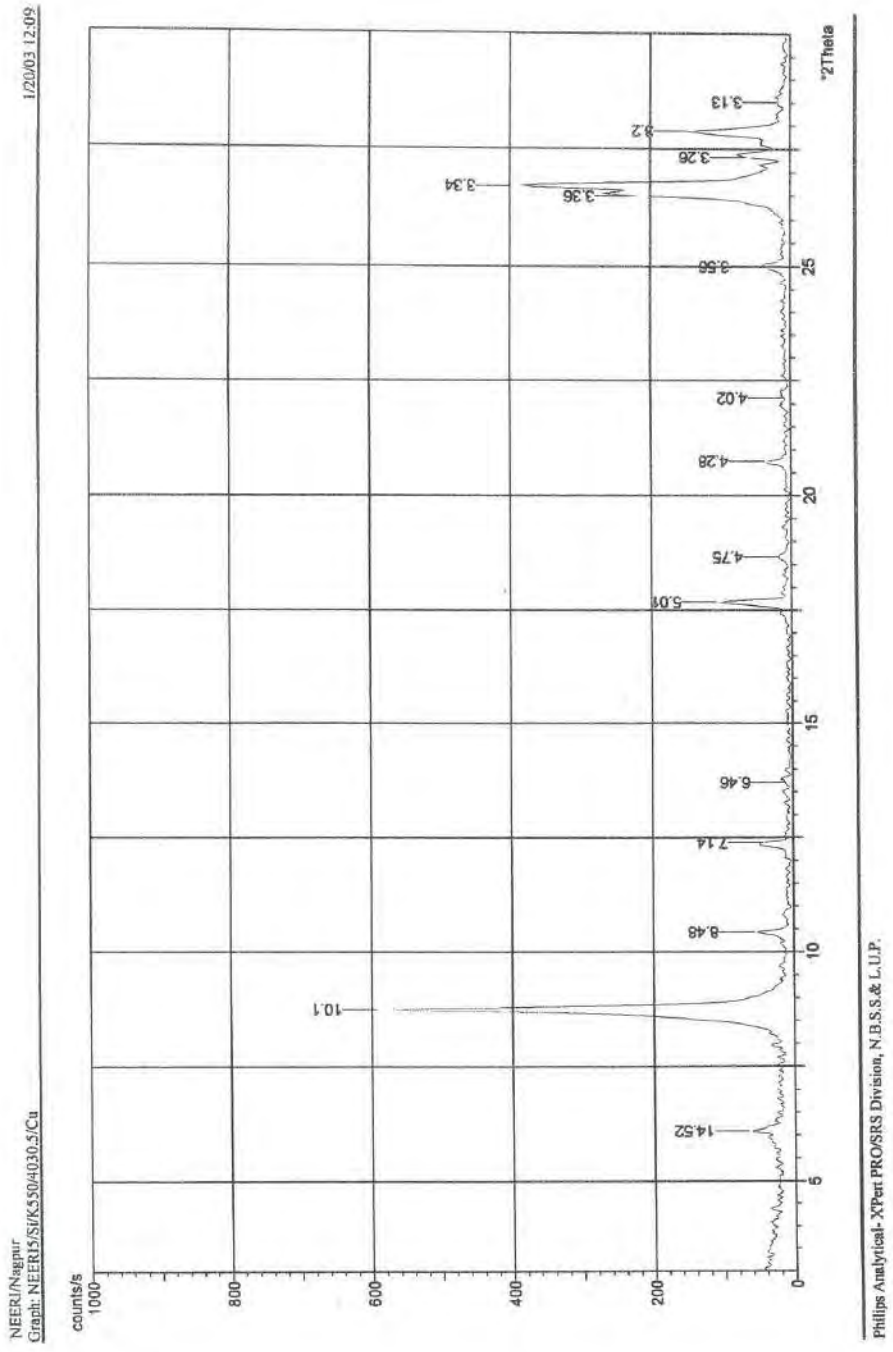

NEERI/Nagpur
Graph: NEER13/TC/K110/4030/.5/Cu
1/18/03 15:08
counts/s
1000
800
600
400
200
0
5
10
15
20
25
°2Theta
4.45
10.19
10.07
7.13
4.74
5.01
3.55
3.33
3.37
Philips Analytical- X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.

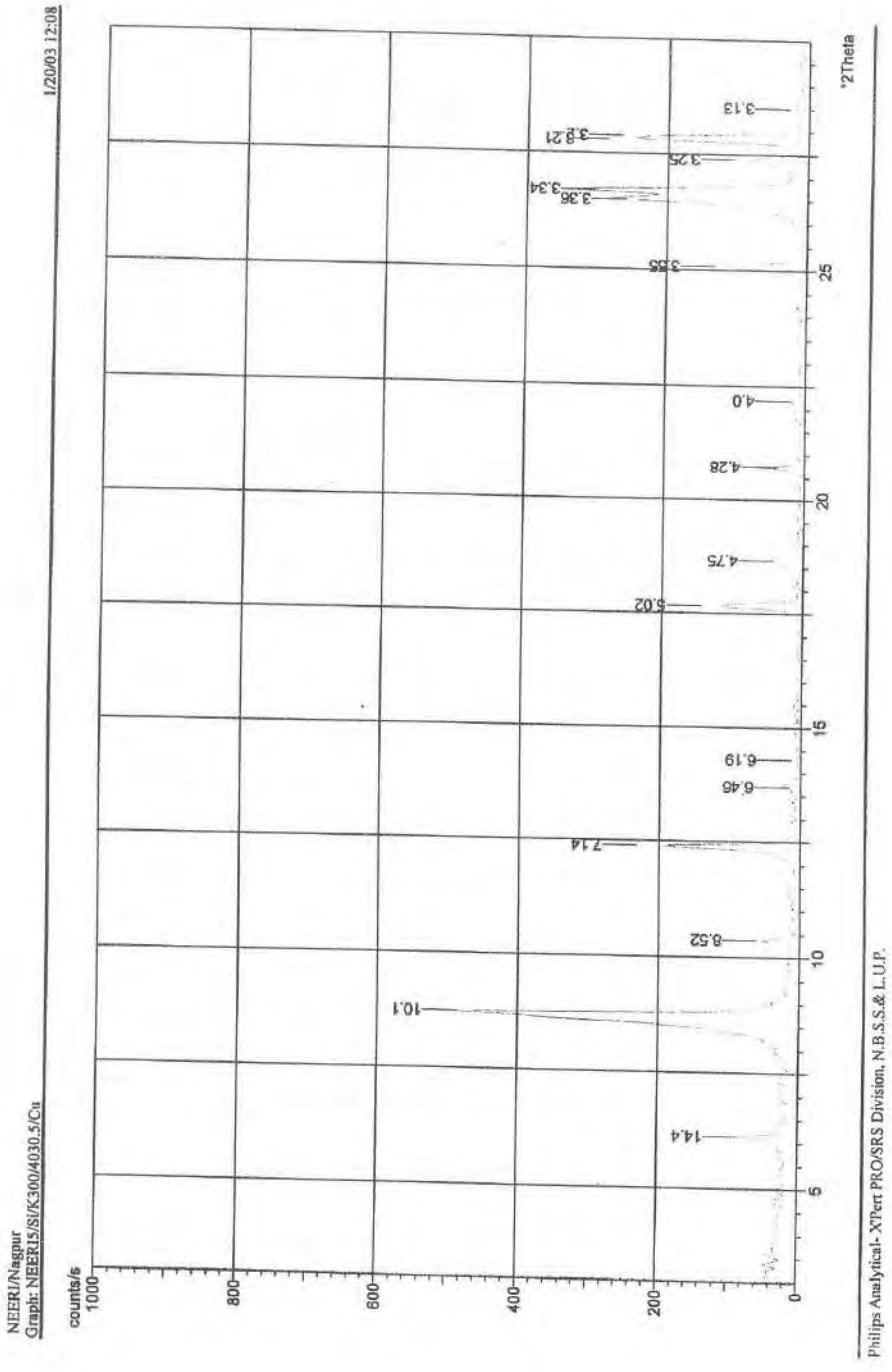

NEERI/Nagpur
Graph: NEERI3/TC/K110/4030/.5/Cu
1/18/03 15:13
counts/s
°2Theta
14.45
10.19
10.07
7.13
5.07
4.74
3.55
3.37
3.33
Philips Analytical- XPert PRO/SRS Division, N.B.S.S.& L.U.P.

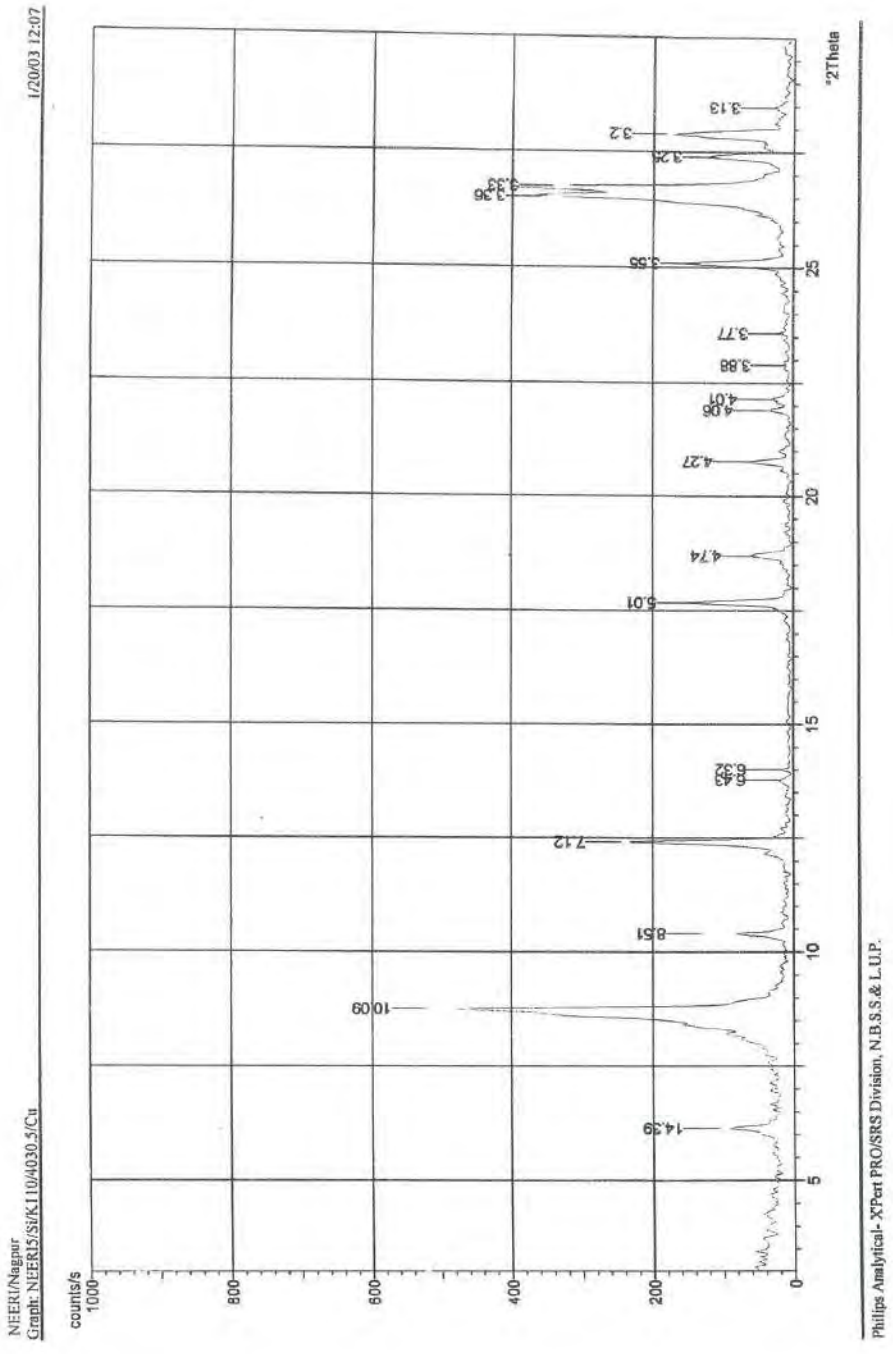

NEERI/Nagpur
Graph: NEERI3/TC/K25/4030.5/Cu
1/18/03 15:34
counts/s
°2Theta
10.03
9.86
13.84
7.02
8.41
4.69
4.96
3.53
3.35
3.31
3.18
Philips Analytical- XPert PRO/SRS Division, N.B.S.S.& L.U.P.

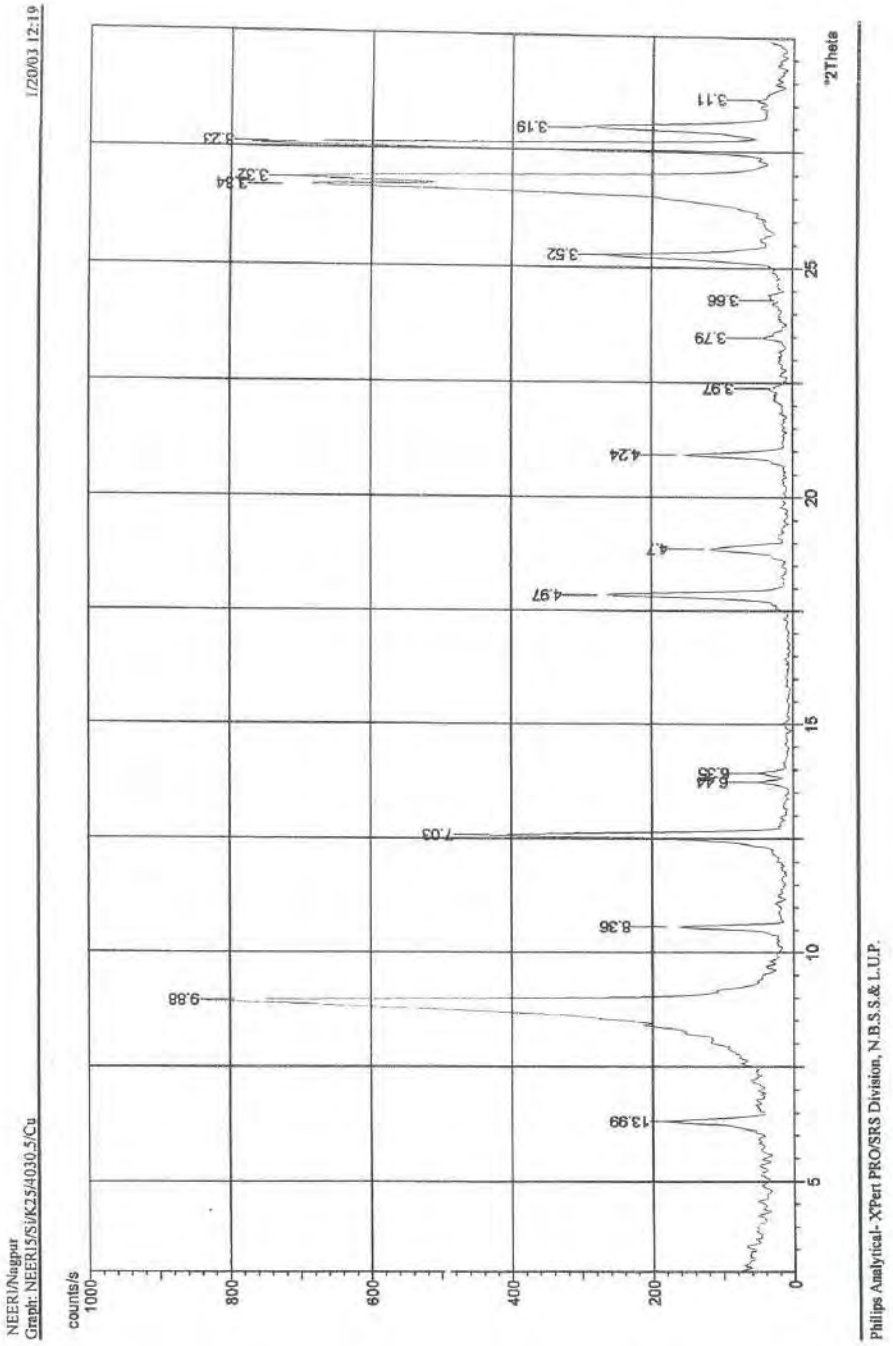

NEERI/Nagpur
Graph: NEERI3/TC/CaEG/4030.5/Cu
1/18/03 15:33
counts/s
8000
7000
6000
5000
4000
3000
2000
1000
0
5
10
15
20
25
°2Theta
26.43
16.18
14.21
9.96
8.06
7.07
5.37
4.98
4.71
4.04
3.84
3.32
3.25
Philips Analytical- XPert PRO/SRS Division, N.B.S.S.& L.U.P.

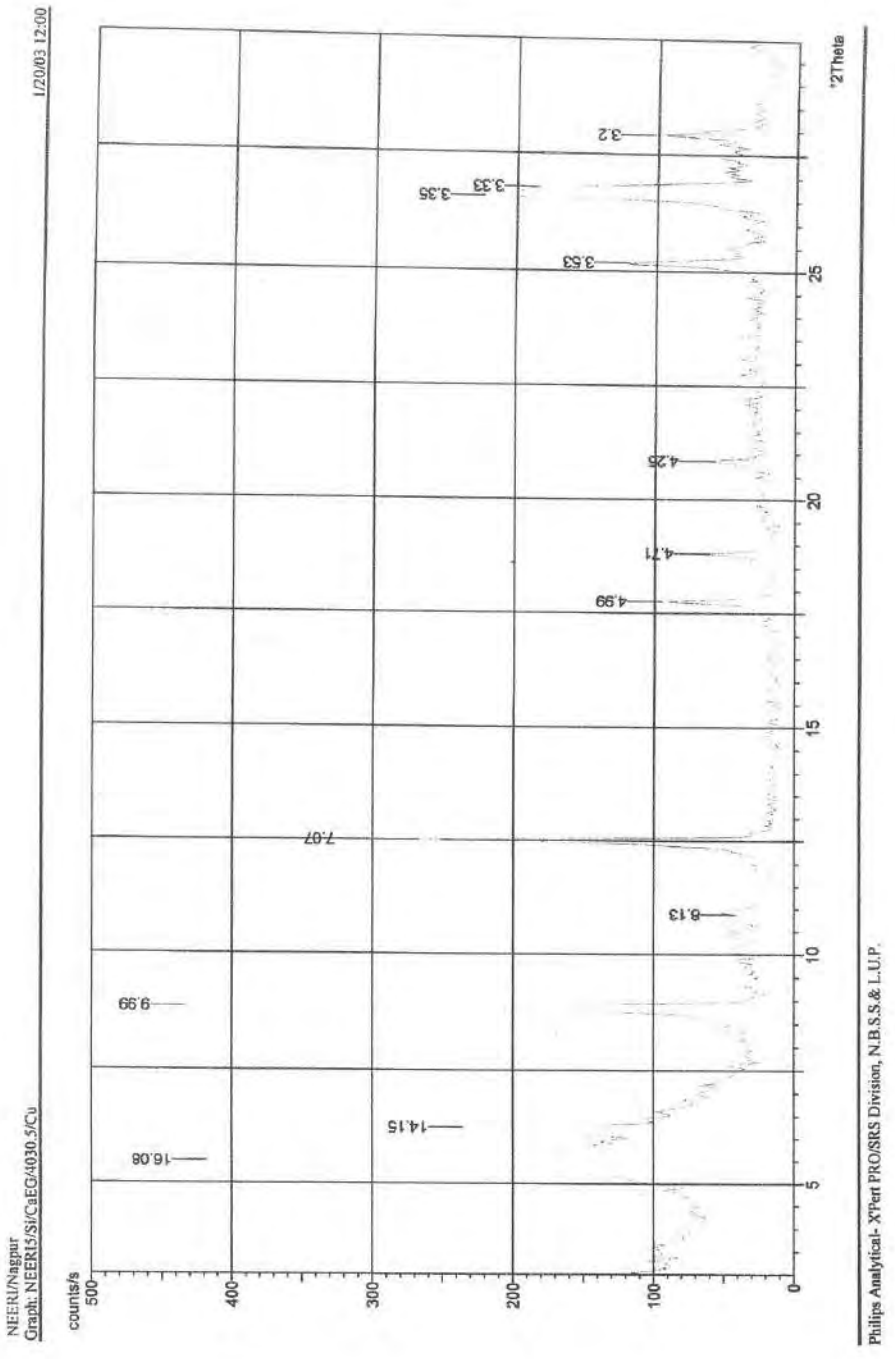

1/18/03 15:20
NEERI/Nagpur
Graph: NEERI3/TC/Ca/4030.5/Cu
counts/s
°2Theta
14.66
9.89
8.35
7.4
7.01
4.94
4.69
4.22
4.0
3.71
3.52
3.31
3.25
3.18
23.9
Philips Analytical - XPert PRO/SRS Division, N.B.S.S. & L.U.P.

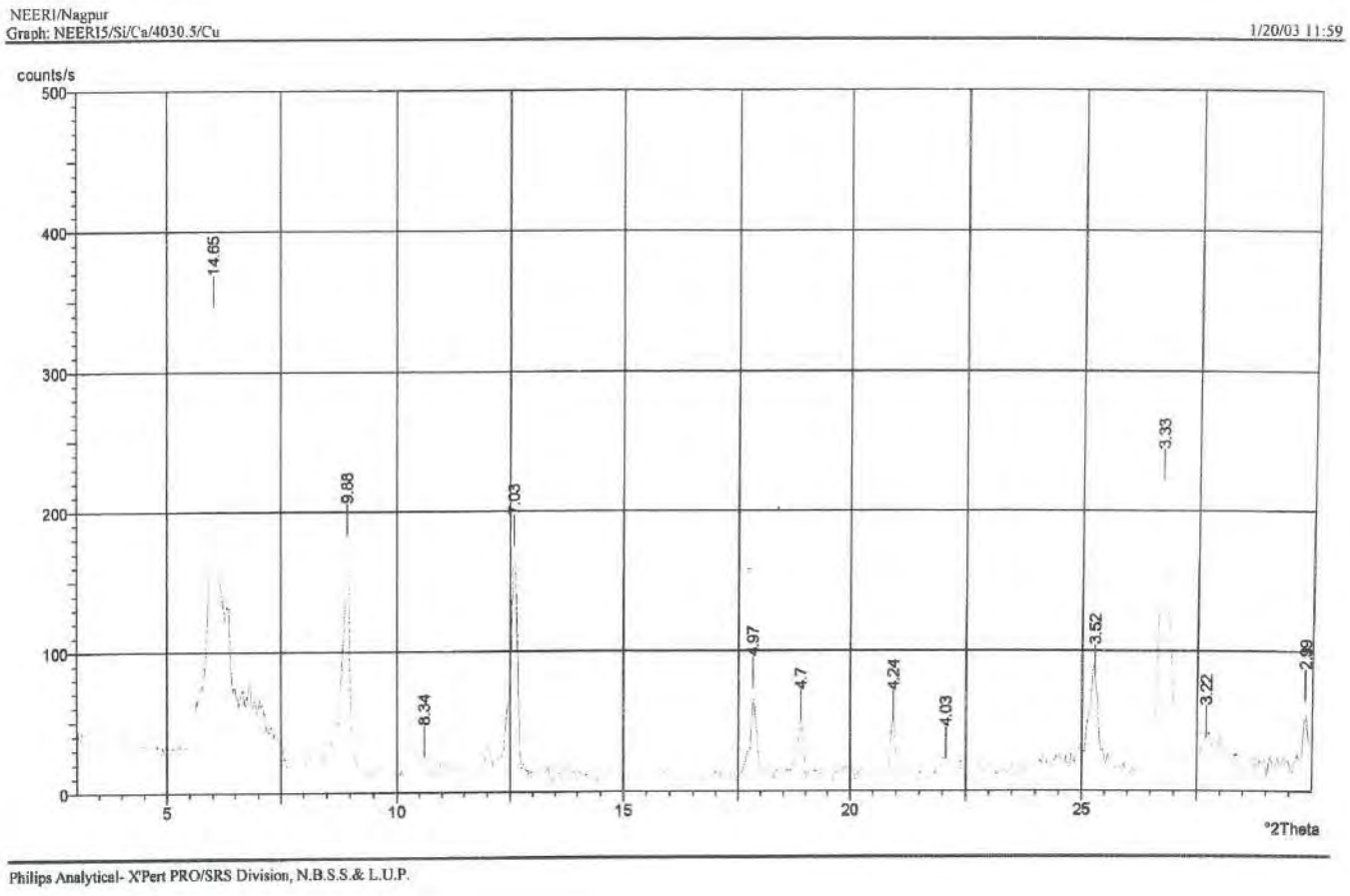

NEERI/Nagpur
Graph: NEER15/Si/K550/4030.5/Cu
1/20/03 12.09
counts/s
1000
800
600
400
200
0
5
10
15
20
25
°2Theta
14.52
10.1
8.48
7.14
6.46
5.01
4.75
4.28
4.02
3.56
3.36
3.34
3.26
3.2
3.13
Philips Analytical- XPert PRO/SRS Division, N.B.S.S.& L.U.P.

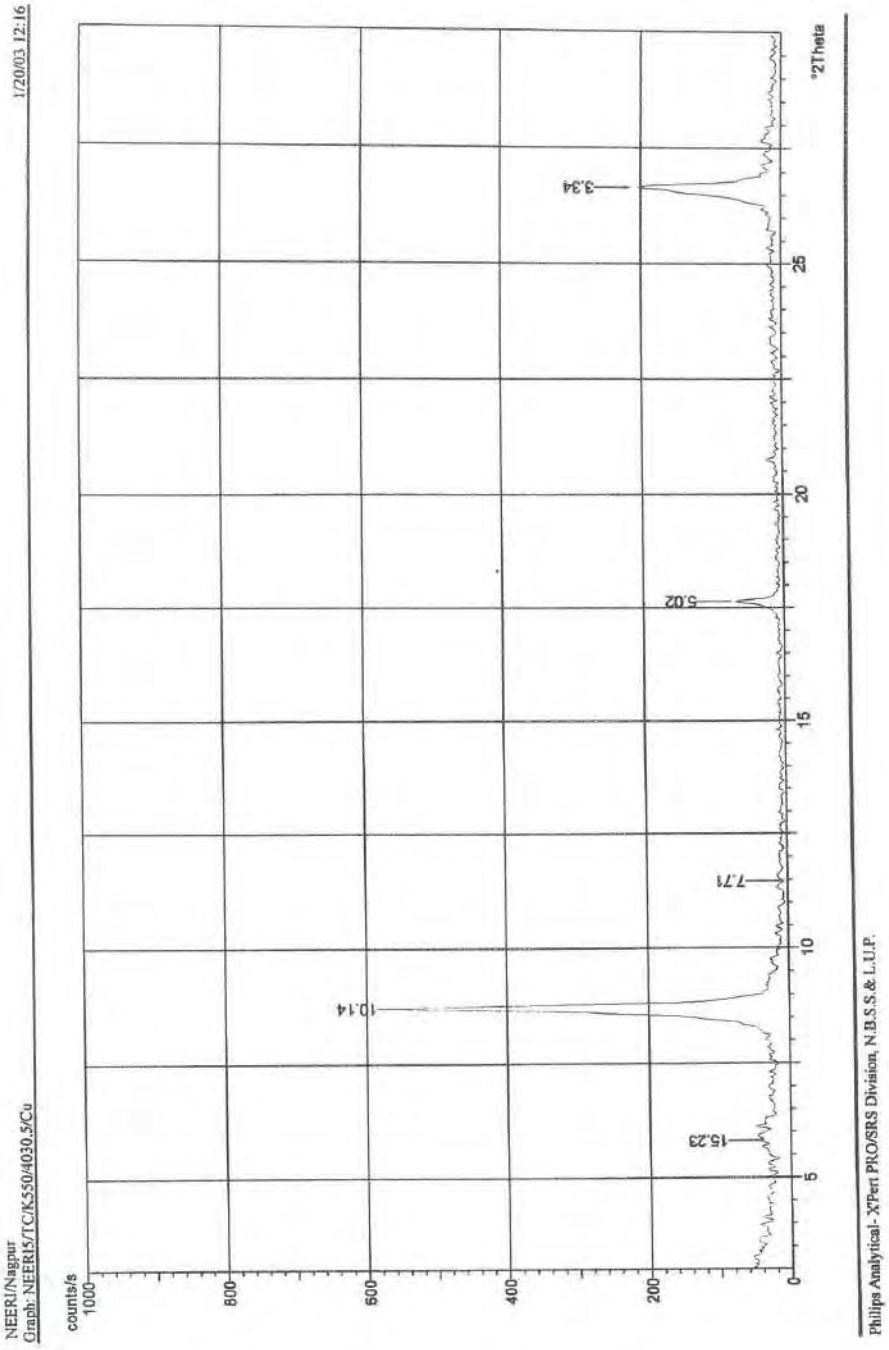

1/20/03 12:08
NEERI/Nagpur
Graph: NEER15/Si/K300/4030.5/Cu
counts/s
1000
800
600
400
200
0
5
10
15
20
25
°2Theta
3.13
3.821
3.25
3.36
3.34
3.35
4.0
4.28
4.75
5.02
6.19
6.46
7.14
8.52
10.1
14.4
Philips Analytical- X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.

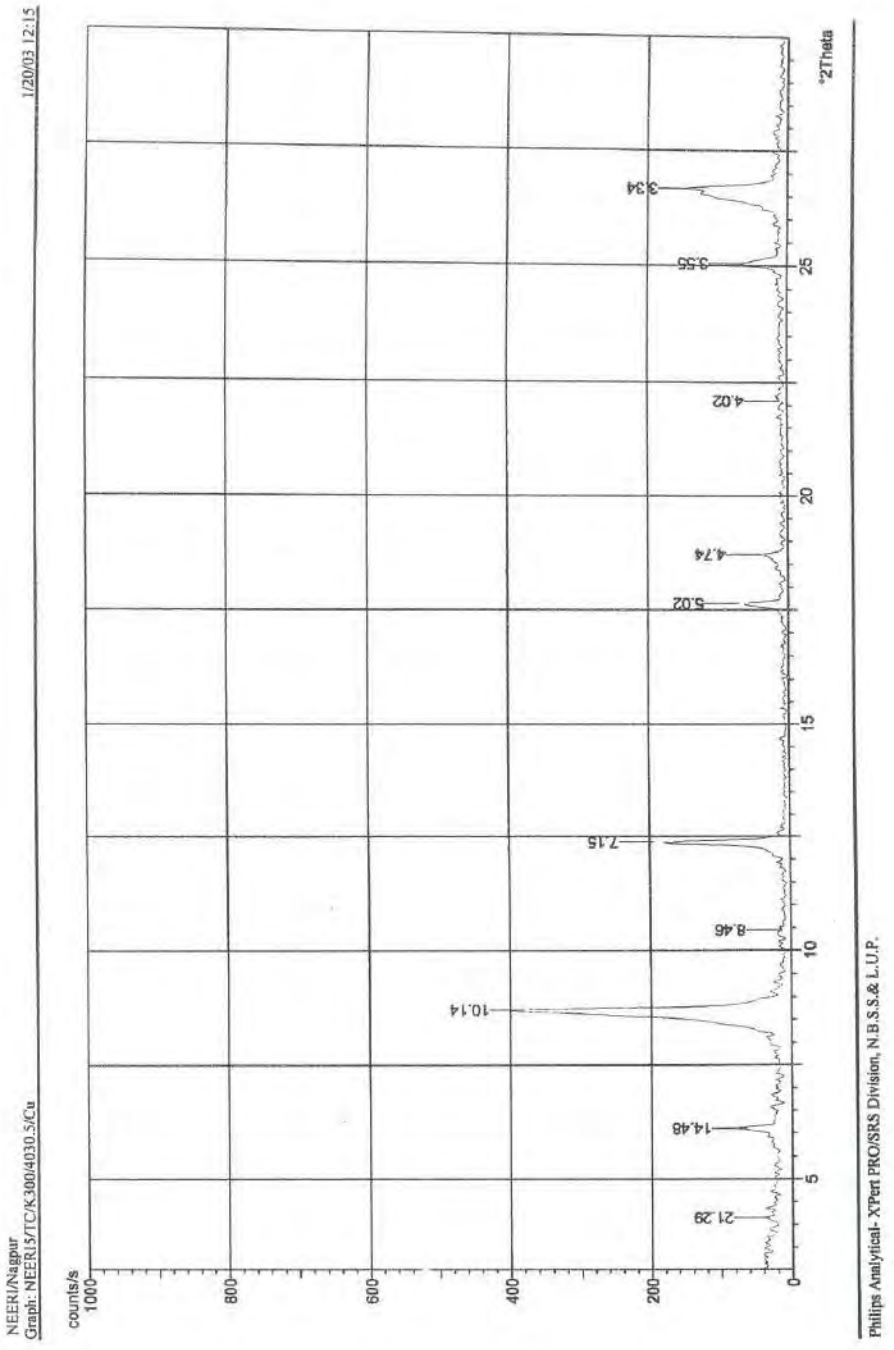

NEERI/Nagpur
Graph: NEER15/SI/K110/4030.3/Cu
1/20/03 12:07
counts/s
1000
800
600
400
200
0
5
10
15
20
25
°2Theta
14.39
10.09
8.51
7.12
6.43
5.01
4.74
4.27
4.06
4.01
3.88
3.77
3.55
3.36
3.24
3.2
3.13
Philips Analytical- XPert PRO/SRS Division, N.B.S.S.& L.U.P.

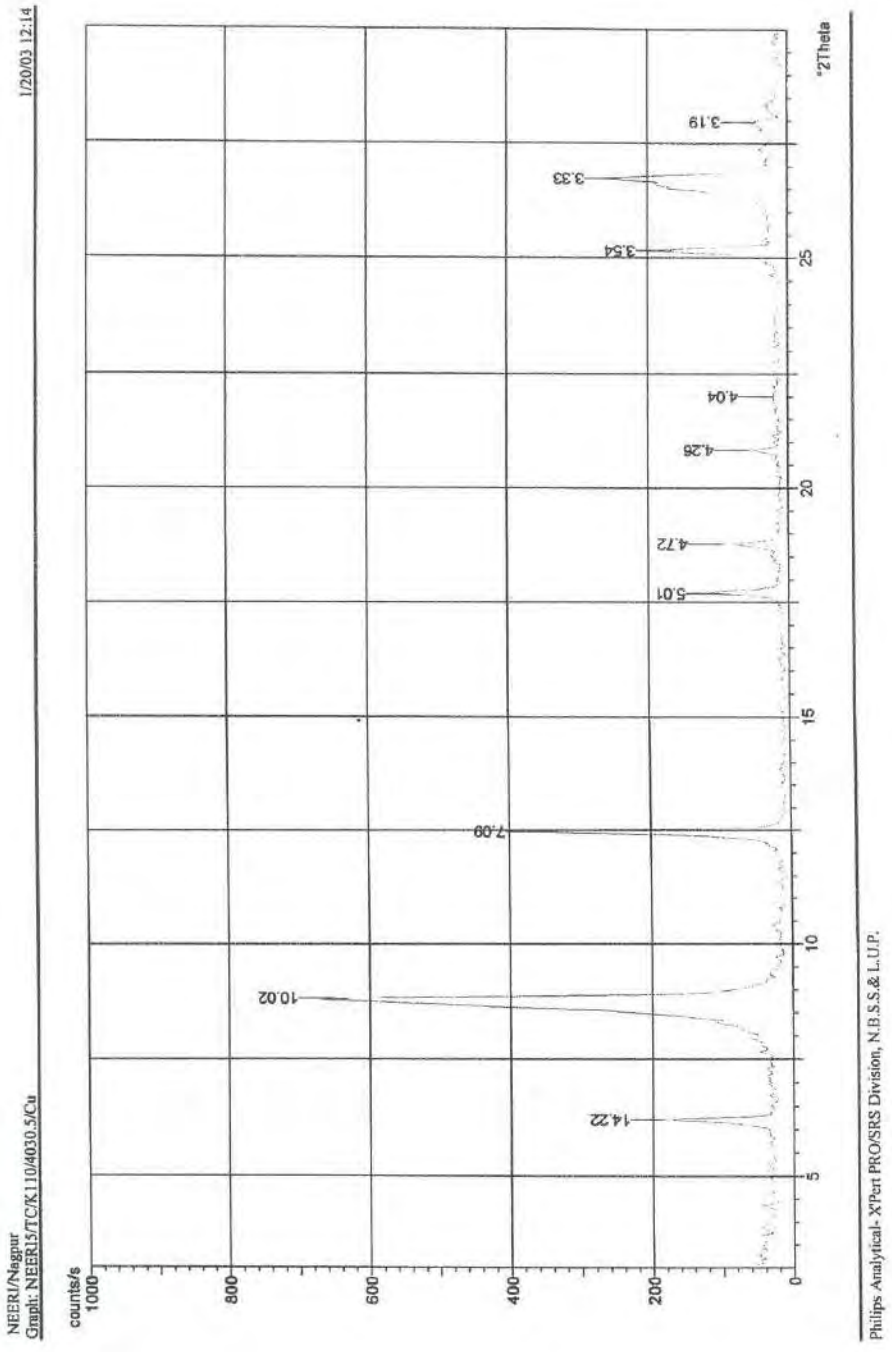

NEERI/Nagpur
Graph: NEERI5/Si/K25/4030.5/Cu
1/20/03 12:19
counts/s
1000
800
600
400
200
0
5
10
15
20
25
°2Theta
9.88
13.99
8.36
7.03
6.44
6.35
4.97
4.7
4.24
3.97
3.79
3.66
3.52
3.34
3.32
3.25
3.19
3.11
Philips Analytical- XPert PRO/SRS Division, N.B.S.S.& L.U.P.

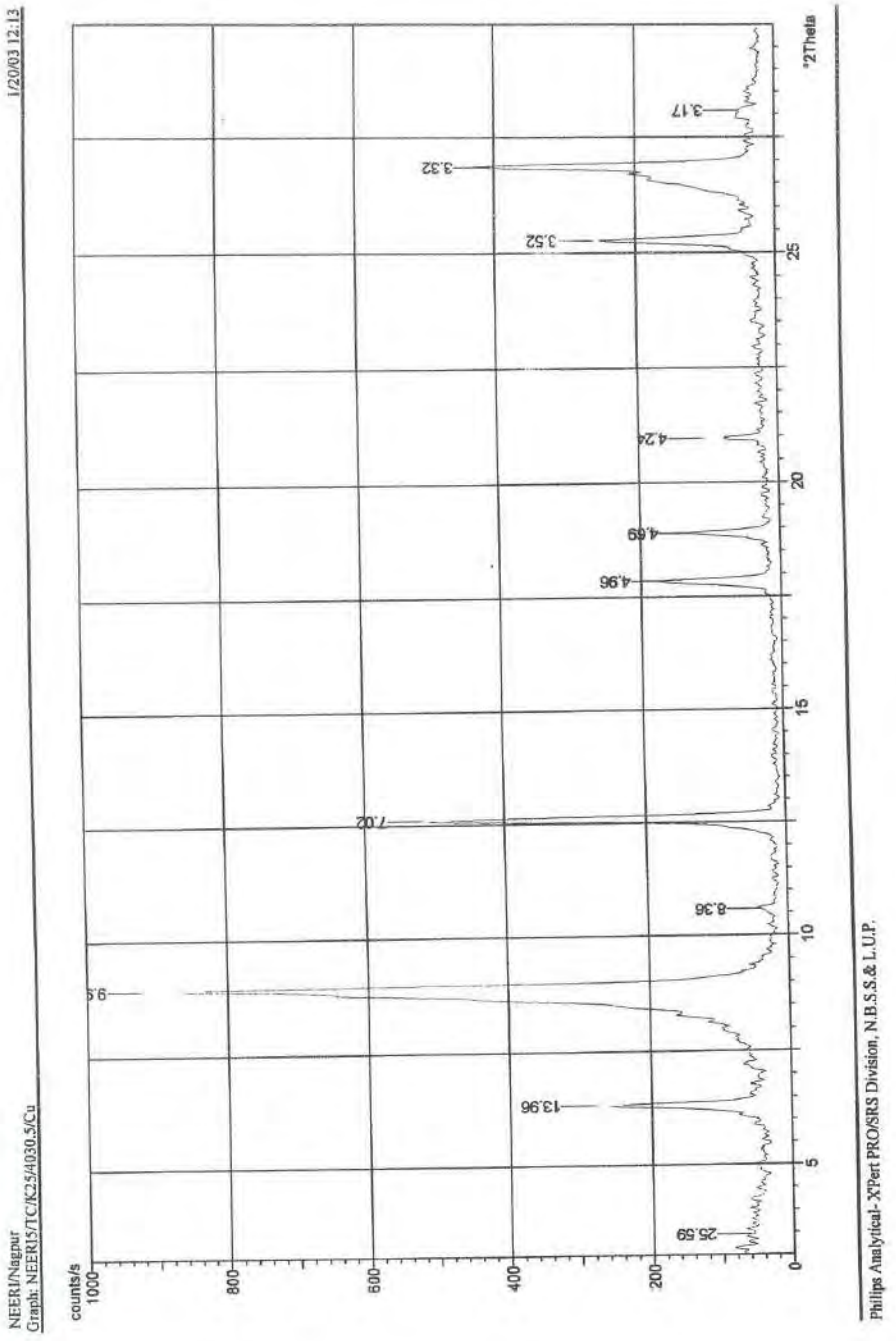

NEERI/Nagpur
Graph: NEERI/Si/CaEG/4030.5/Cu
1/20/03 12:00
counts/s
500
400
300
200
100
0
5
10
15
20
25
°2Theta
16.08
14.15
9.99
8.13
7.07
4.99
4.71
4.25
3.53
3.33
3.35
3.2
Philips Analytical- X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.

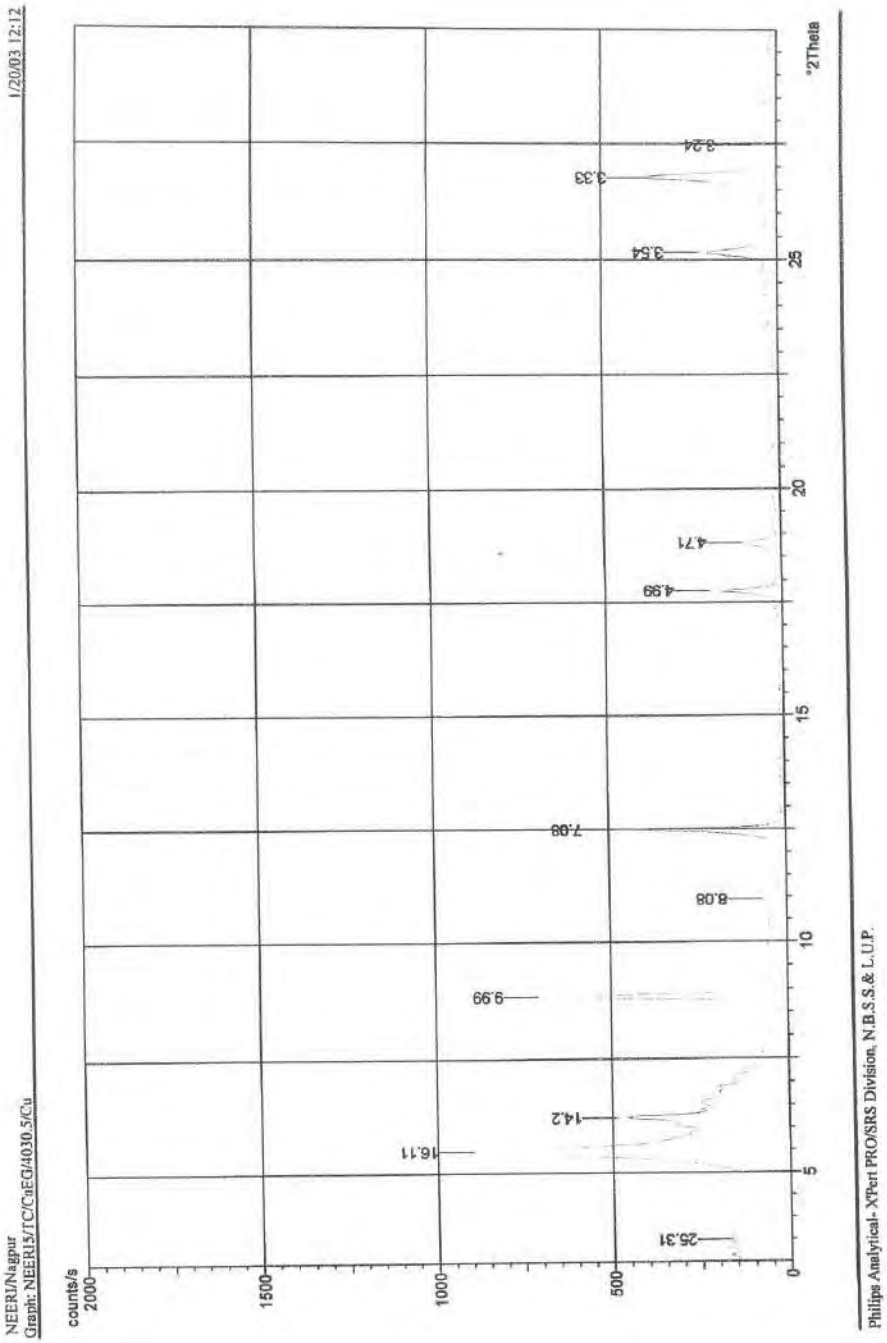

NEERI/Nagpur
Graph: NEER15/Si/Ca/4030.5/Cu
1/20/03 11:59
counts/s
500
400
300
200
100
0
14.65
9.88
8.34
7.03
4.97
4.7
4.24
4.03
3.52
3.33
3.22
2.99
5
10
15
20
25
°2Theta
Philips Analytical- X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.

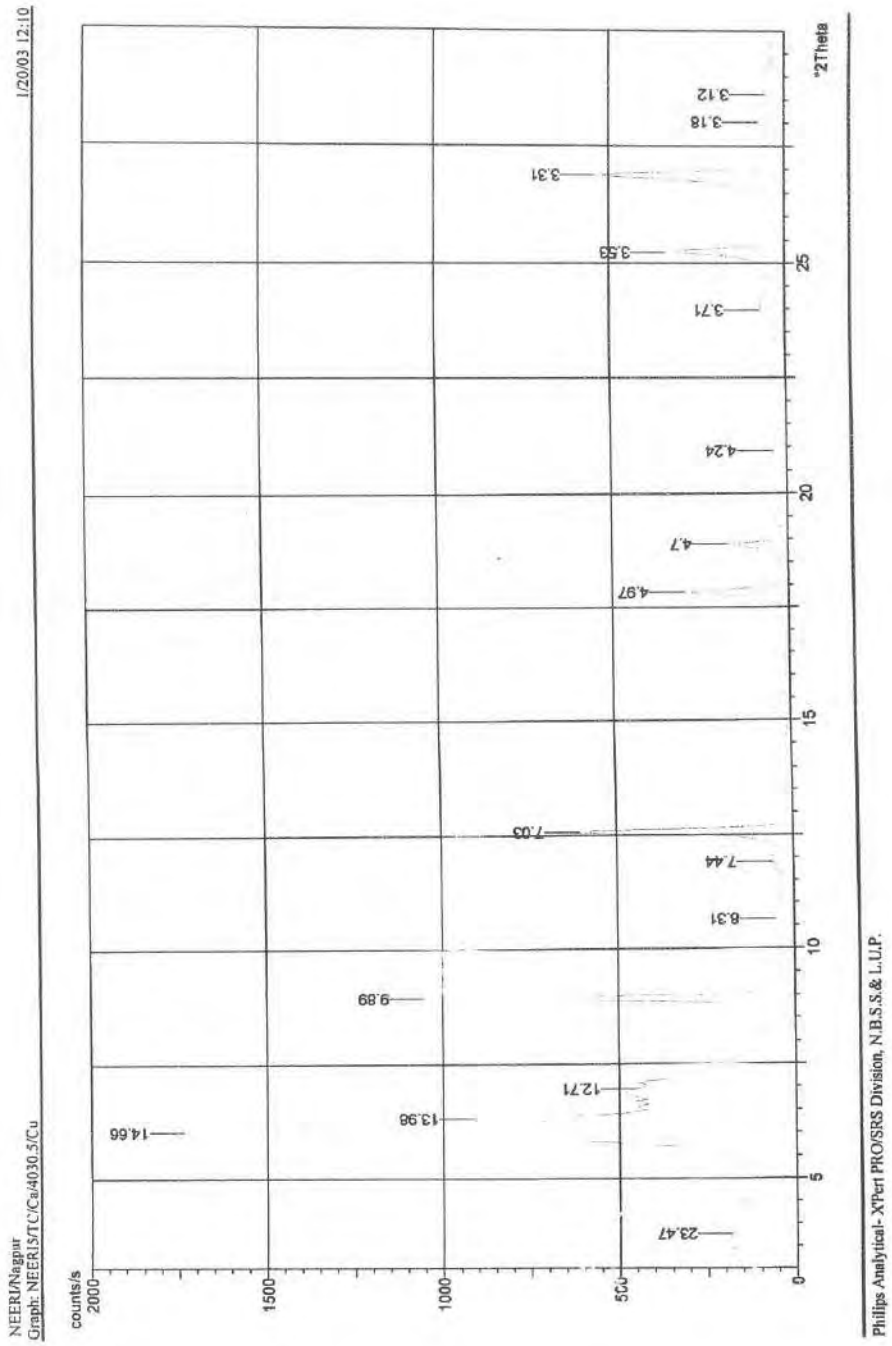

NEERI/Nagpur
Graph: NEER15/TC/K550/4030.5/Cu
1/20/03 12:16
counts/s
1000
800
600
400
200
0
5
10
15
20
25
°2Theta
15.23
10.14
7.71
5.02
3.34
Philips Analytical- X'Pert PRO/SRS Division, N.B.S.S. & L.U.P.

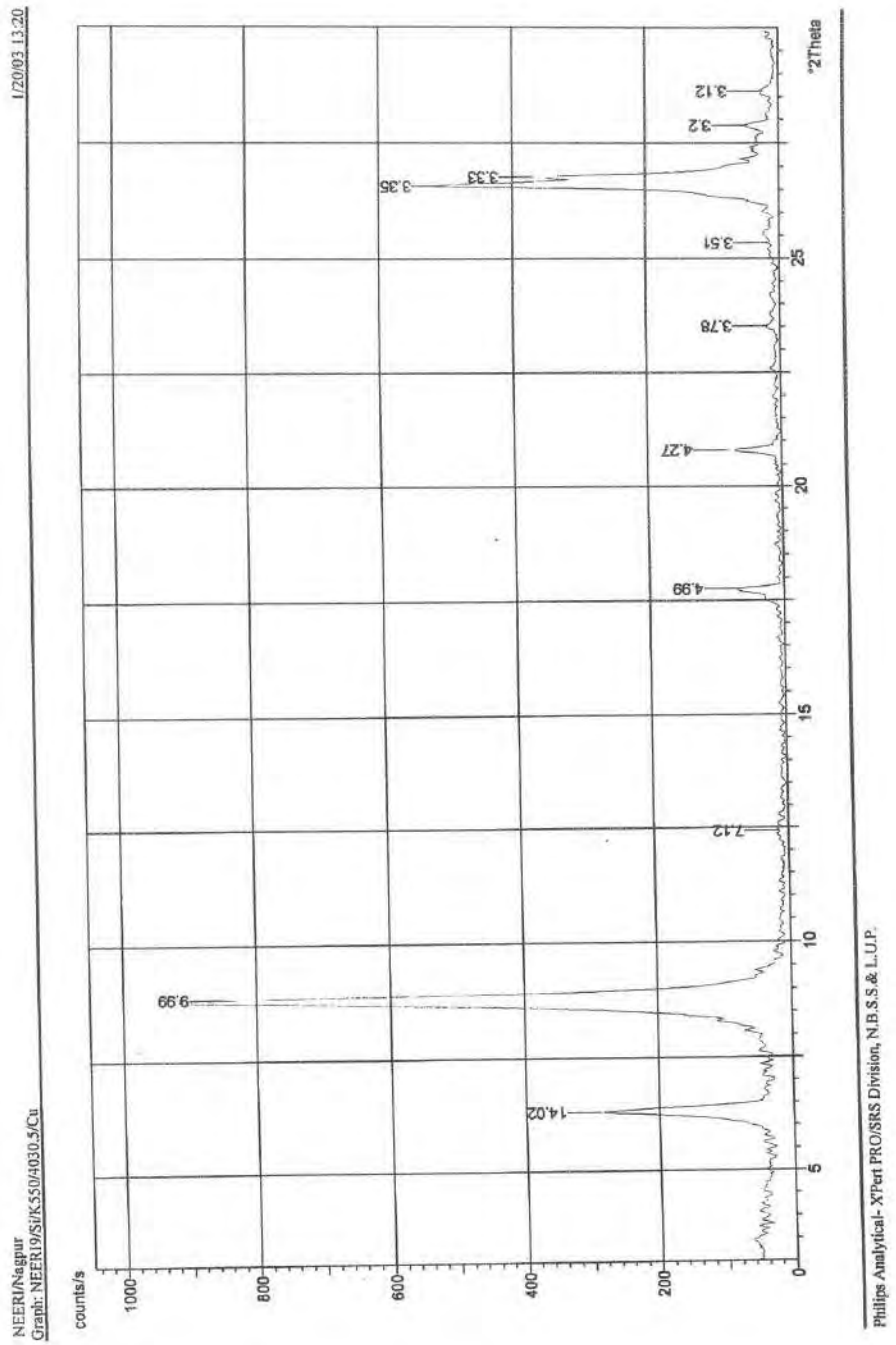

NEERI/Nagpur
Graph: NEERI.5/TC/K300/4030.5/Cu
1/20/03 12:15
counts/s
1000
800
600
400
200
0
5
10
15
20
25
°2Theta
21.29
14.48
10.14
8.46
7.15
5.02
4.74
4.02
3.55
3.34
Philips Analytical- X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.

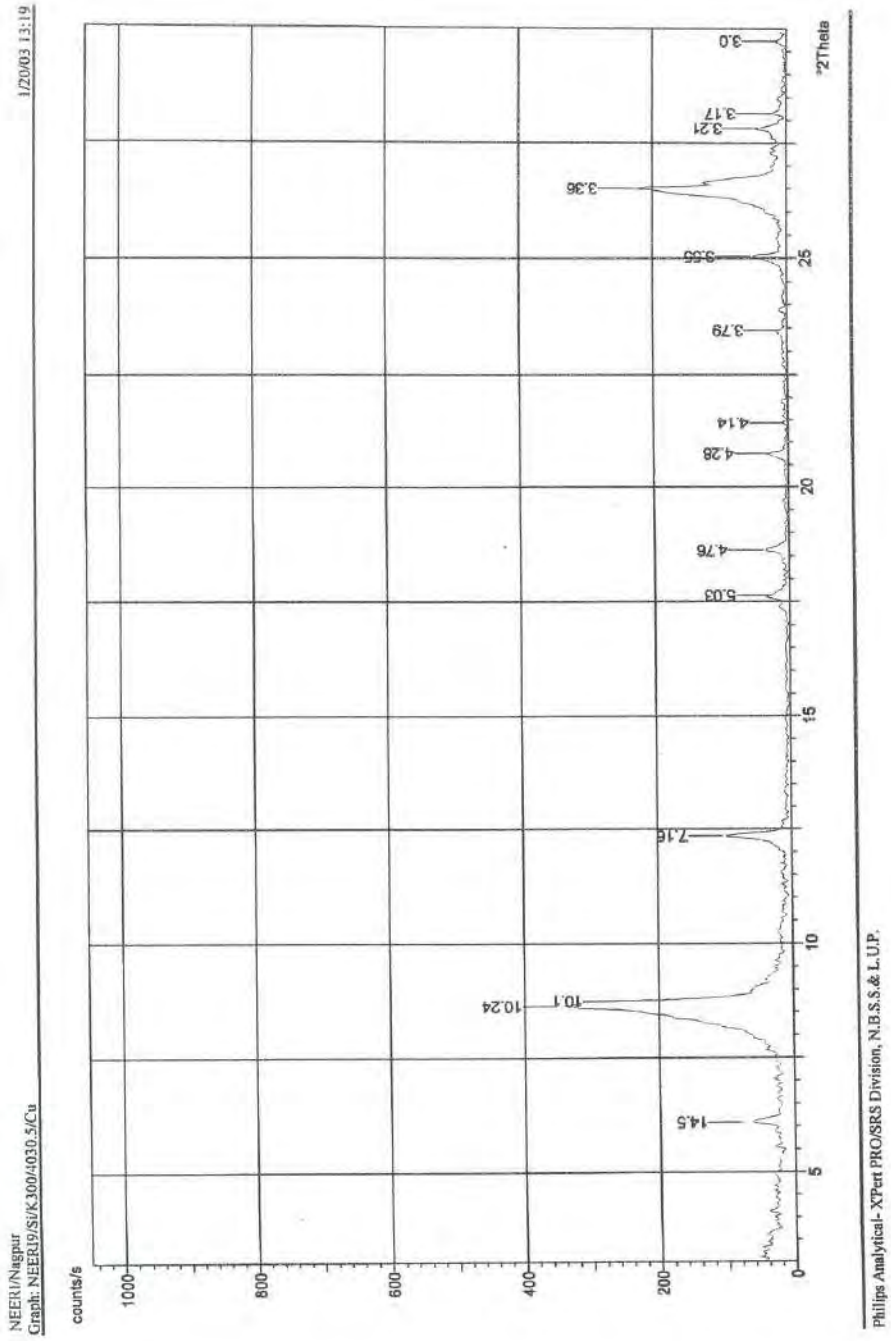

NEERI/Nagpur
Graph: NEERI5/TC/X110/4030.5/Cu
1/20/03 12:14
counts/s
1000
800
600
400
200
0
5
10
15
20
25
°2Theta
14.22
10.02
7.09
5.01
4.72
4.26
4.04
3.54
3.33
3.19
Philips Analytical- X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.

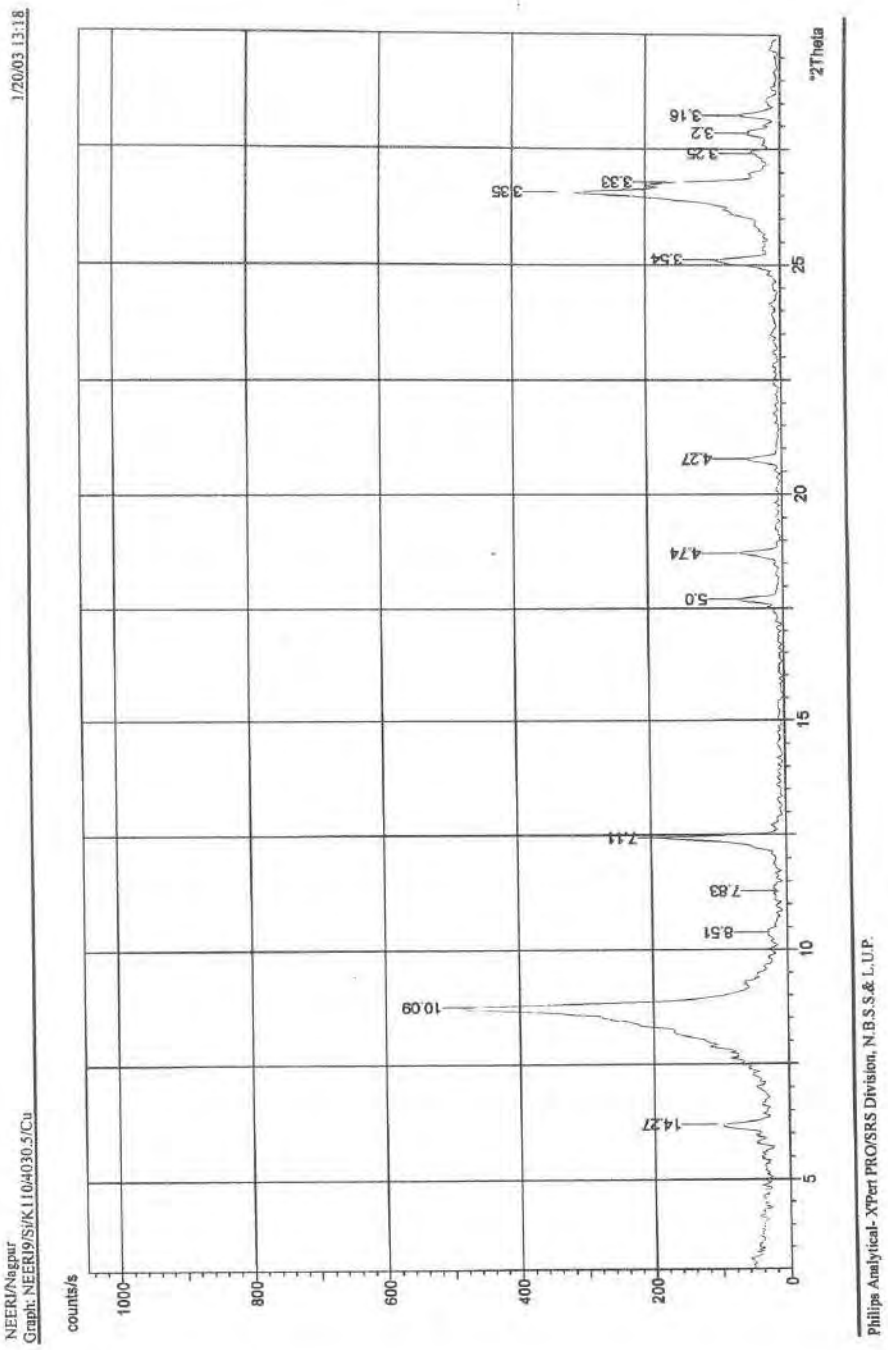

NEERI/Nagpur
Graph: NEER15/TC/K25/4030.5/Cu
1/20/03 12:13
counts/s
1000
800
600
400
200
0
5
10
15
20
25
°2Theta
25.59
13.96
9.5
8.36
7.02
4.96
4.69
4.24
3.52
3.32
3.17
Philips Analytical- X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.

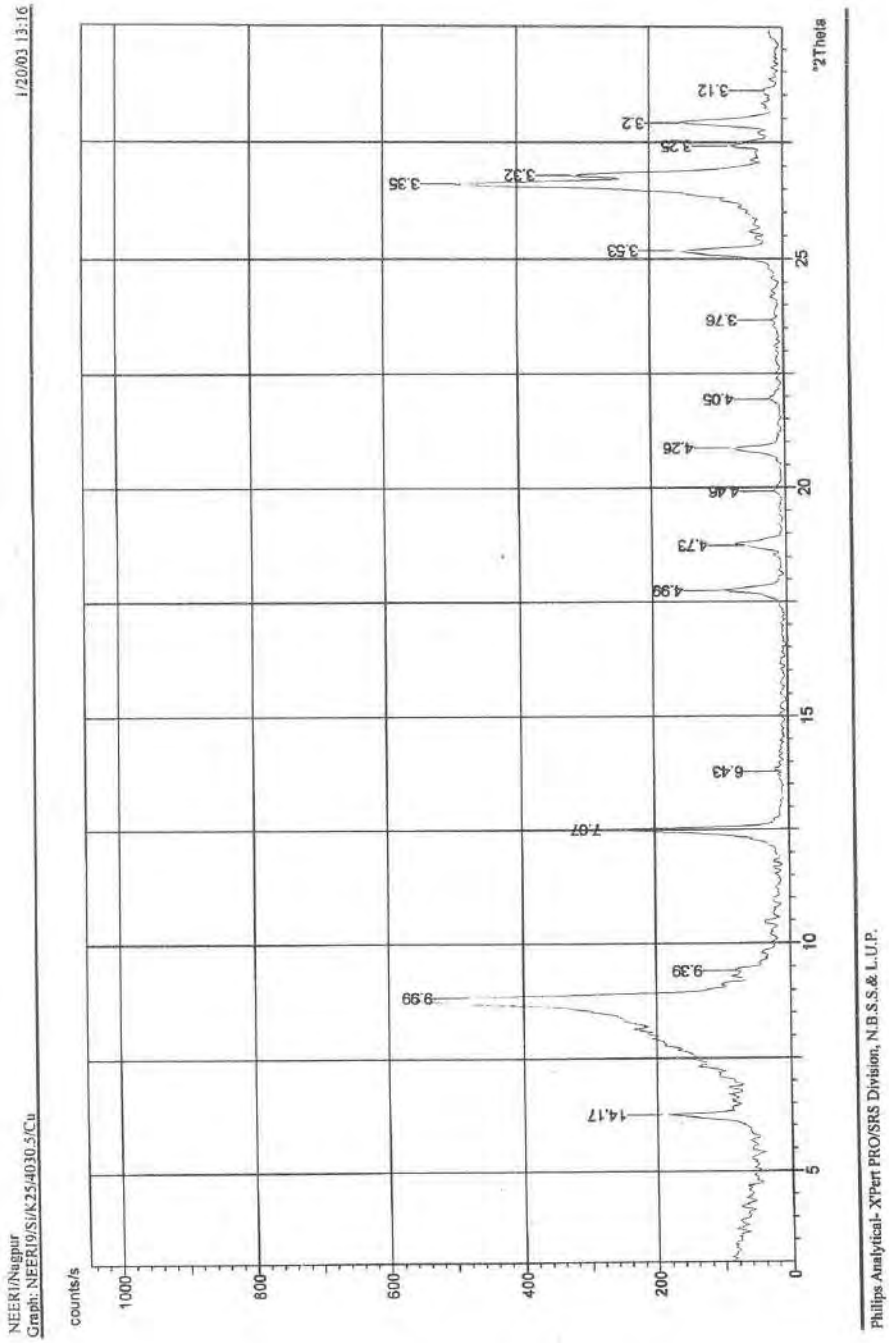

NEERI/Nagpur
Graph: NEERI5/TC/CaEG/4030.5/Cu
1/20/03 12:12
counts/s
2000
1500
1000
500
0
5
10
15
20
25
°2Theta
25.31
16.11
14.2
9.99
8.08
7.08
4.99
4.71
3.54
3.33
3.24
Philips Analytical- XPert PRO/SRS Division, N.B.S.S.& L.U.P.

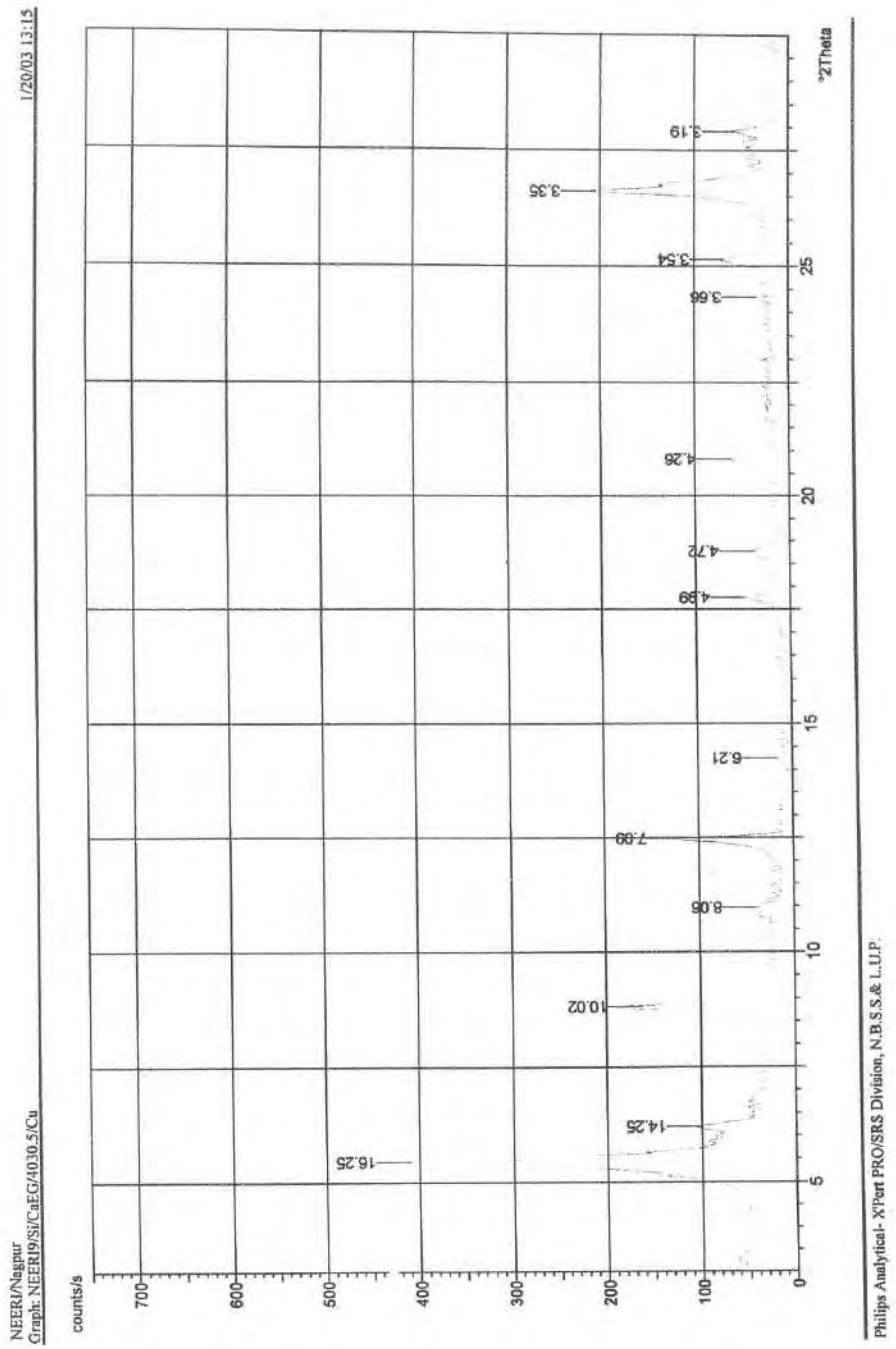

1/20/03 12:10
NEERI/Nagpur
Graph: NEERI/STC/Ca/4030.5/Cu
counts/s
2000
1500
1000
500
0
5
10
15
20
25
°2Theta
23.47
14.66
13.96
12.71
9.89
8.31
7.44
7.03
4.97
4.7
4.24
3.71
3.53
3.31
3.18
3.12
Philips Analytical- XPert PRO/SRS Division, N.B.S.S.& L.U.P.

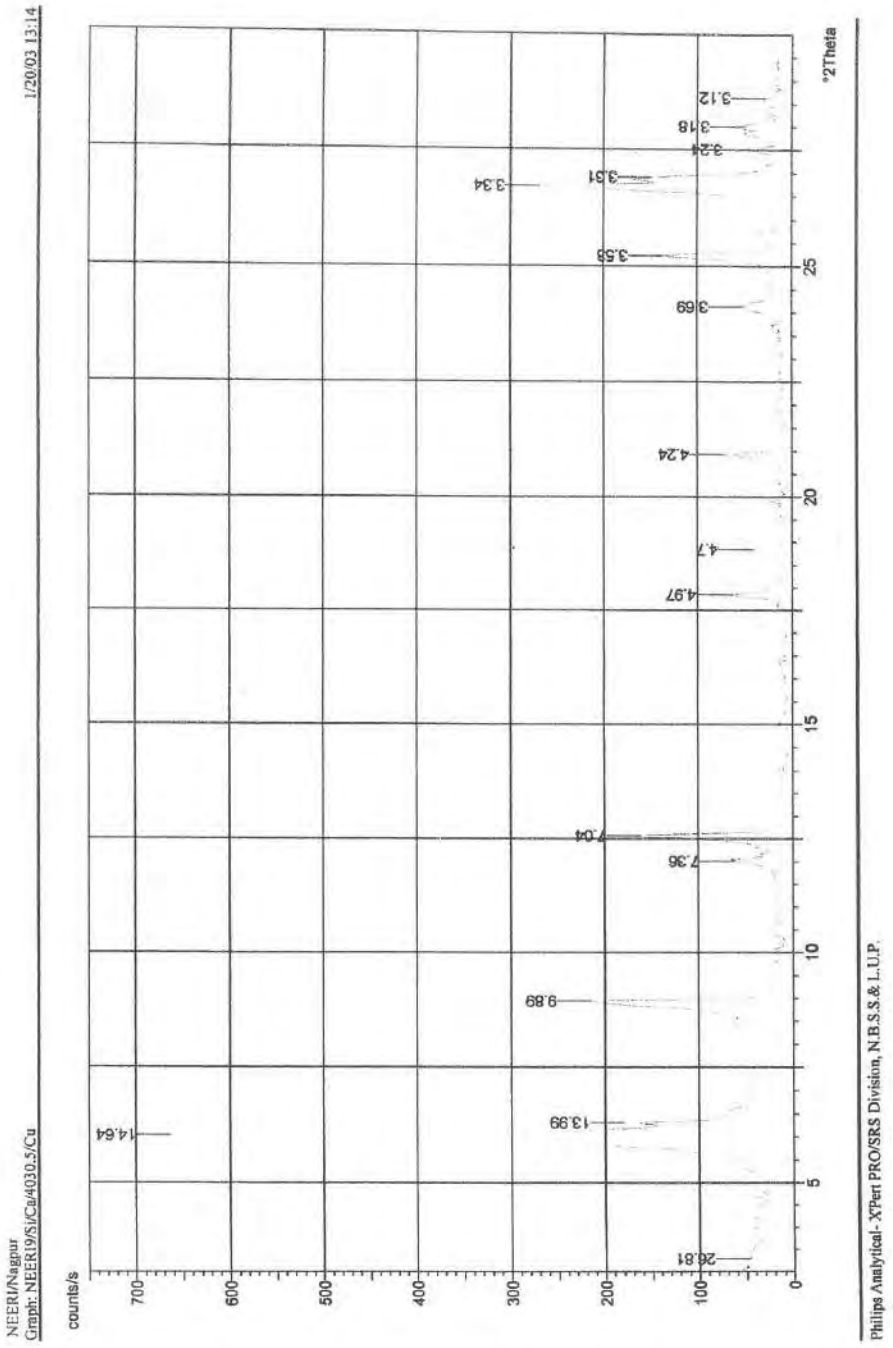

1/20/03 13:20
NEERI/Nagpur
Graph: NEER19/Si/K550/4030.5/Cu
counts/s
1000
800
600
400
200
0
5
10
15
20
25
°2Theta
9.99
14.02
7.12
4.99
4.27
3.78
3.51
3.35
3.33
3.2
3.12
Philips Analytical- XPert PRO/SRS Division, N.B.S.S.& L.U.P.

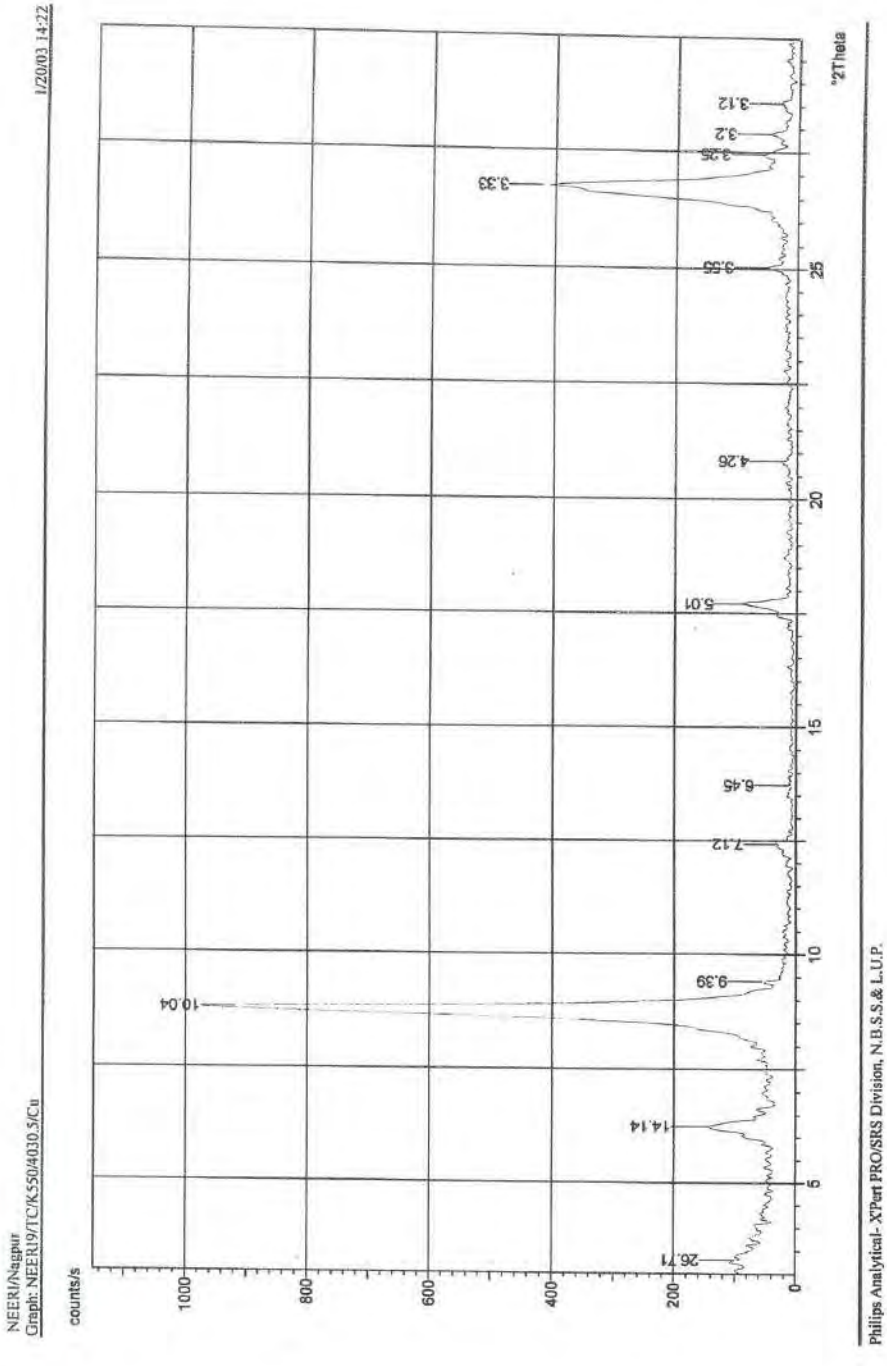

NEERI/Nagpur
Graph: NEERI9/Si/K300/4030.5/Cu
1/20/03 13:19
counts/s
1000
800
600
400
200
0
5
10
15
20
25
°2Theta
14.5
10.1
10.24
7.16
5.03
4.76
4.28
4.14
3.79
3.55
3.36
3.21
3.17
3.0
Philips Analytical- XPert PRO/SRS Division, N.B.S.S.& L.U.P.

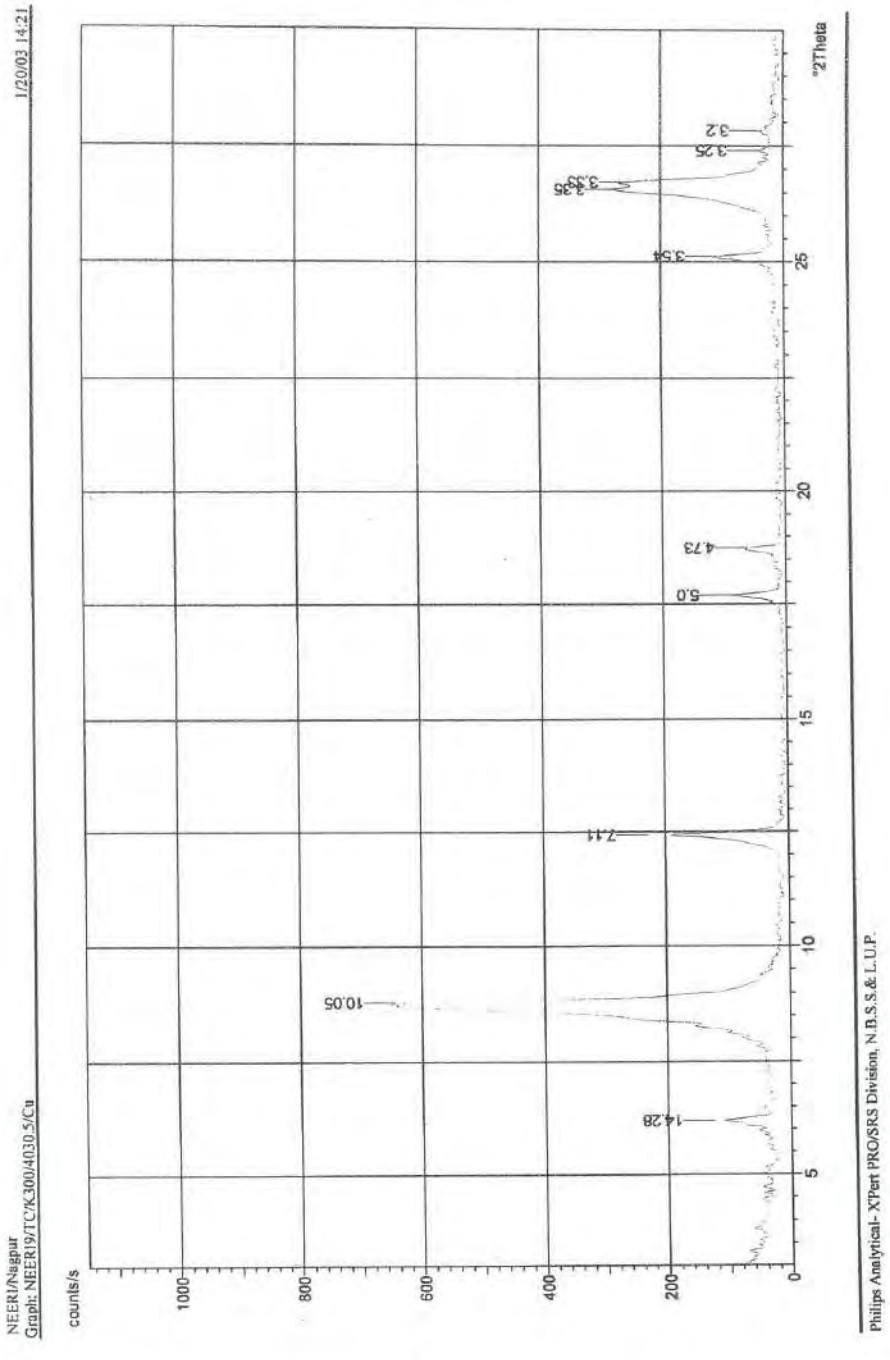

NEERI/Nagpur
Graph: NEERI9/Si/K110/4030.5/Cu
1/20/03 13:18
counts/s
1000
800
600
400
200
0
5
10
15
20
25
°2Theta
14.27
10.09
8.51
7.83
7.11
5.0
4.74
4.27
3.54
3.35
3.33
3.25
3.2
3.16
Philips Analytical- X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.

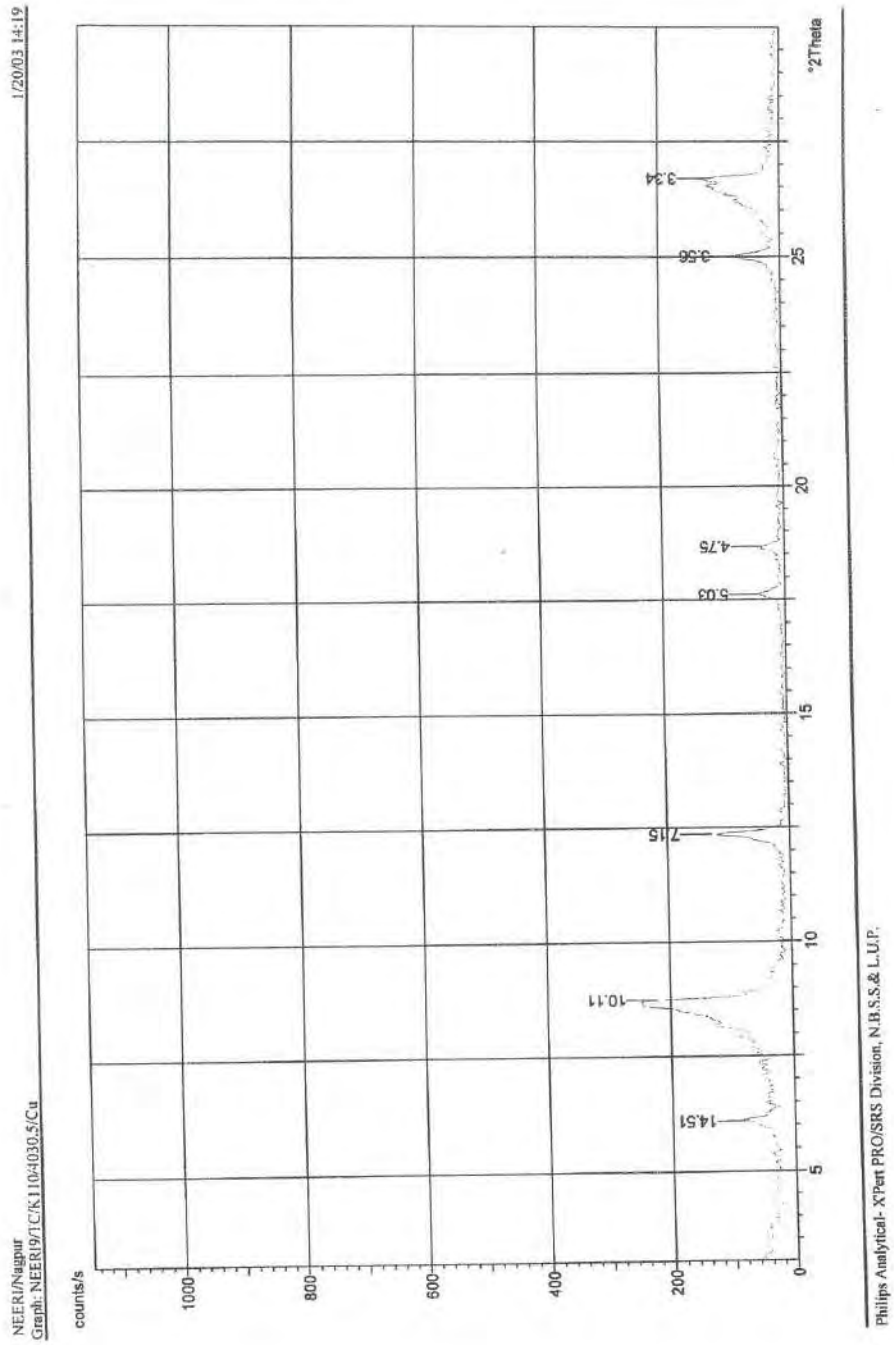

1/20/03 13:16
NEER1/Nagpur
Graph: NEER19/Si/K25/4030.5/Cu
counts/s
°2Theta
14.17
9.99
9.39
7.07
6.43
4.99
4.73
4.46
4.26
4.05
3.76
3.53
3.35
3.32
3.25
3.2
3.12
Philips Analytical- X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.

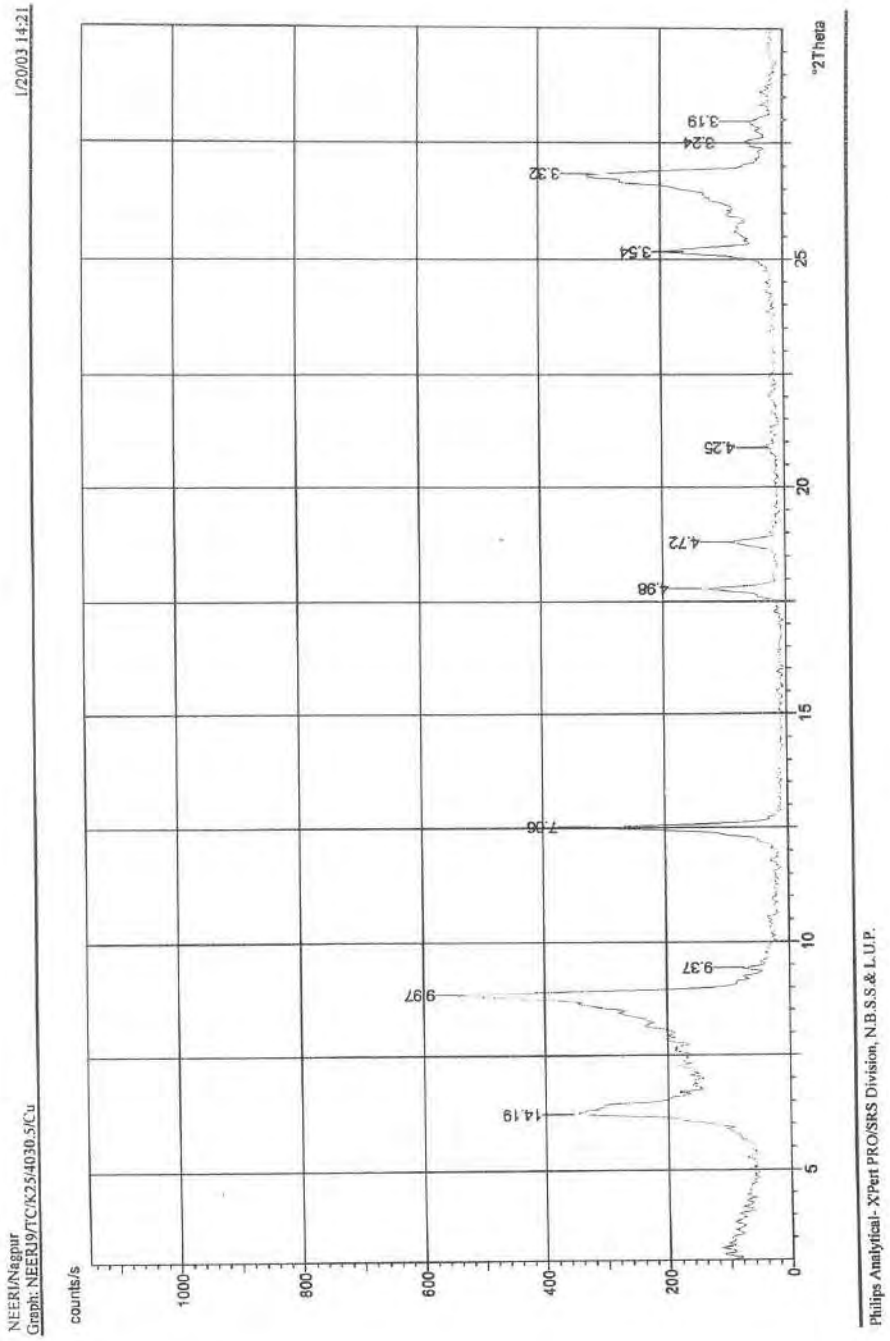

NEERI/Nagpur
Graph: NEERI9/Si/CaEG/40:30.5/Cu
1/20/03 13:15
counts/s
°2Theta
16.25
14.25
10.02
8.05
7.09
6.21
4.89
4.72
4.26
3.66
3.54
3.35
3.19
Philips Analytical- X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.

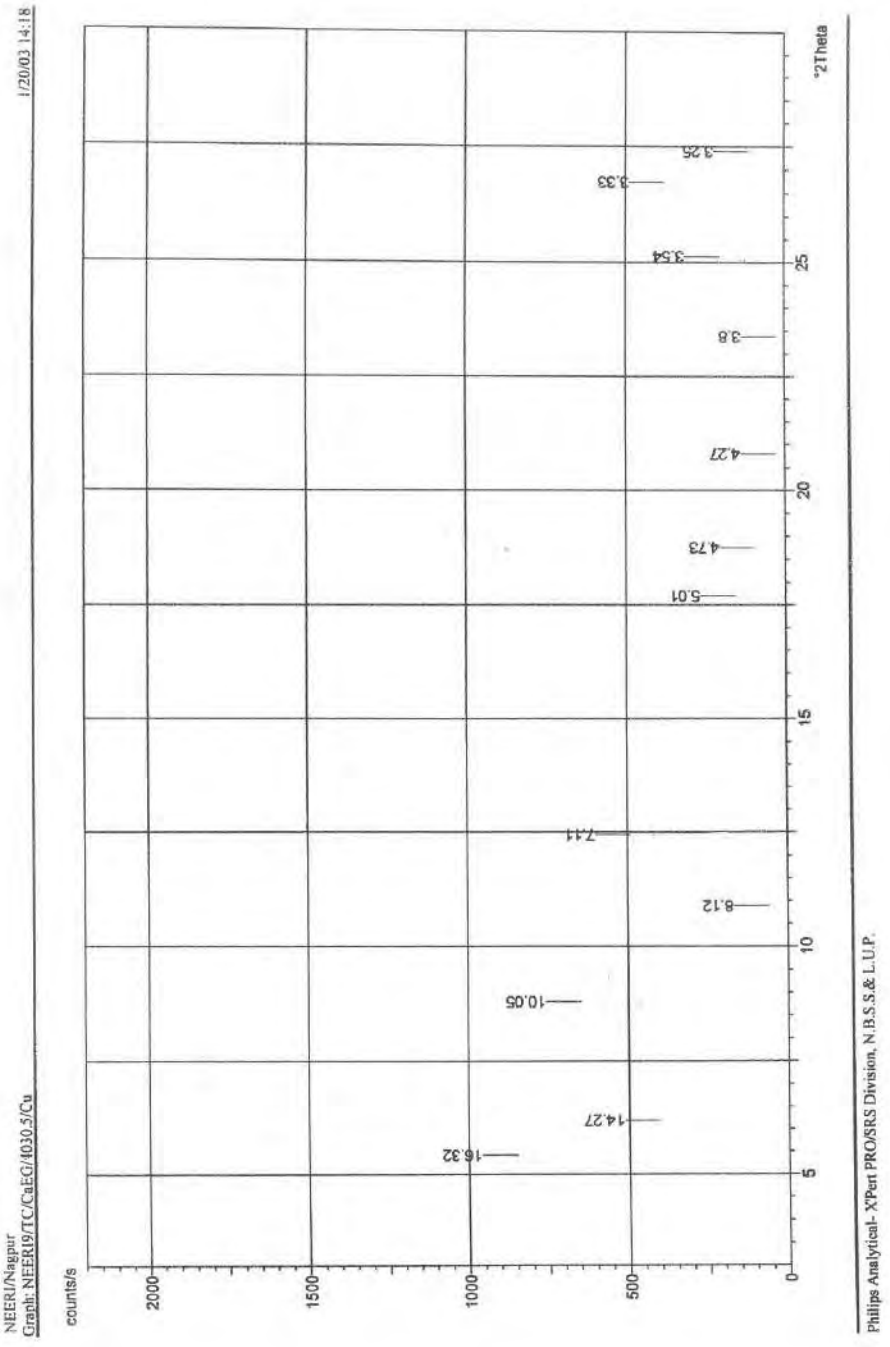

NEERI/Nagpur
Graph: NEER19/SiJCa/4030.5/Cu
1/20/03 13:14
counts/s
°2Theta
26.81
14.64
13.99
9.89
7.36
7.04
4.97
4.7
4.24
3.69
3.58
3.51
3.34
3.18
3.12
Philips Analytical - X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.

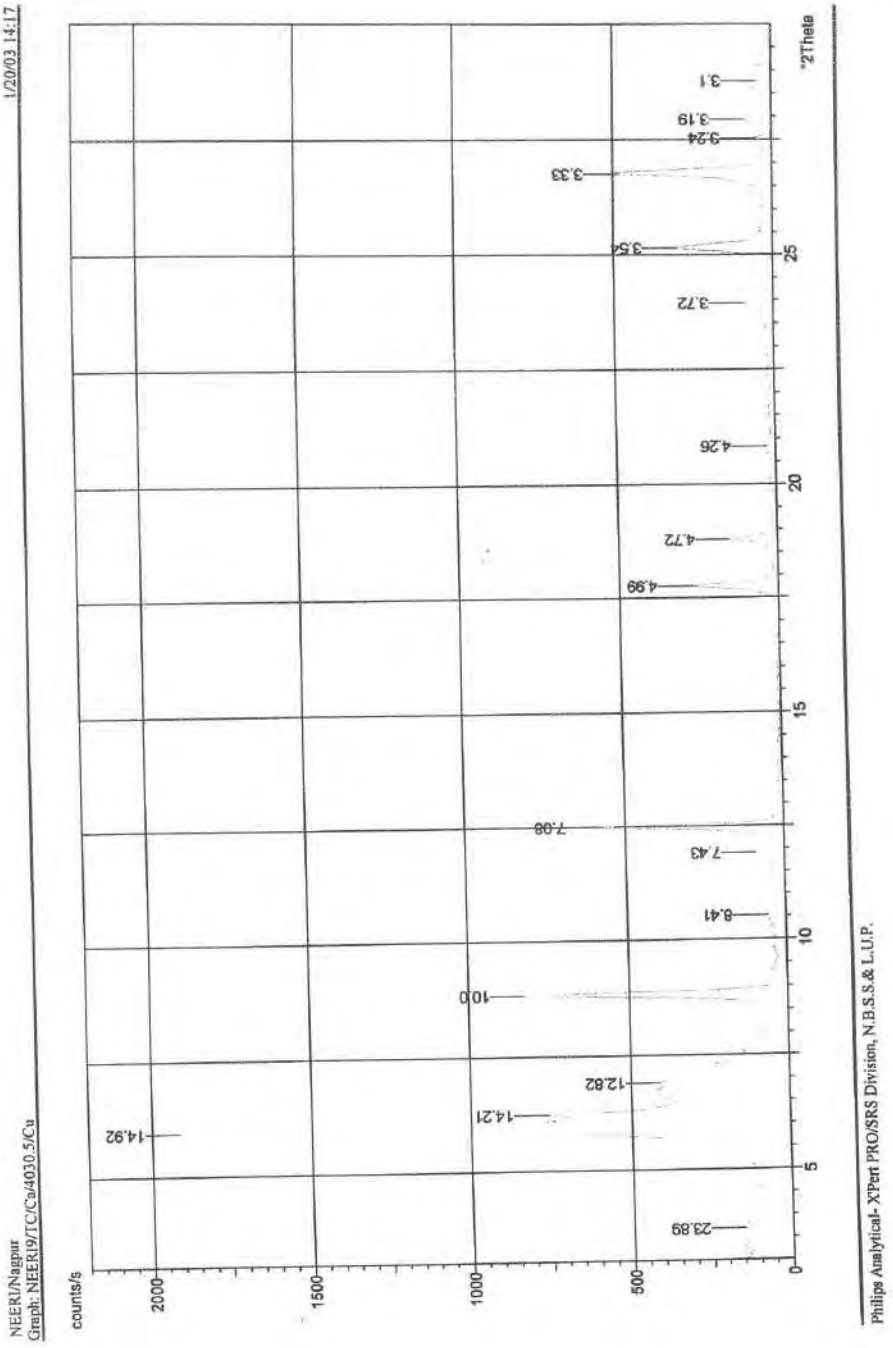

NEERI/Nagpur
Graph: NEERI9/TC/K550/4030.5/Cu
1/20/03 14:22
counts/s
°2Theta
26.71
14.14
10.04
9.39
7.12
6.45
5.01
4.26
3.55
3.33
3.25
3.2
3.12
Philips Analytical- XPert PRO/SRS Division, N.B.S.S.& L.U.P.


NEERI/Nagpur
Graph: NEER19/TC/PK300/4030.5/Cu
1/20/03 14:21
counts/s
°2Theta
14.28
10.05
7.11
5.0
4.73
3.54
3.2
0
200
400
600
800
1000
5
10
15
20
25
Philips Analytical- X'Pert PRO/SRS Division, N.B.S.S.&L.U.P.


NEERI/Nagpur
Graph: NEERI9/TC/K1104030.5/Cu
1/20/03 14:19
counts/s
1000
800
600
400
200
0
5
10
15
20
25
°2Theta
14.51
10.11
7.15
5.03
4.75
3.56
3.34
Philips Analytical- X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.


1/20/03 14:21
NEERI/Nagpur
Graph: NEERI9/TC/K25/4030.5/Cu
counts/s
1000
800
600
400
200
0
5
10
15
20
25
°2Theta
14.19
9.97
9.37
7.36
4.98
4.72
4.25
3.54
3.32
3.24
3.19
Philips Analytical - X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.


NEERI/Nagpur
Graph: NEERI9/TC/CaEG/4030.5/Cu
1/20/03 14:18
counts/s
2000
1500
1000
500
0
5
10
15
20
25
°2Theta
16.32
14.27
10.05
8.12
7.41
5.01
4.73
4.27
3.8
3.54
3.33
3.25
Philips Analytical- X'Pert PRO/SRS Division, N.B.S.S.& L.U.P.


1/20/03 14:17
NEERI/Nagpur
Graph: NEERI9/TC/Ca/4030.5/Cu
counts/s
2000
1500
1000
500
0
5
10
15
20
25
°2Theta
23.89
14.92
14.21
12.82
10.0
8.41
7.43
7.08
4.99
4.72
4.26
3.72
3.54
3.33
3.24
3.19
3.1
Philips Analytical- XPert PRO/SRS Division, N.B.S.S.& L.U.P.

Annexure IV

(6 pages)

भारत सरकार
भारतीय भूवैज्ञानिक सर्वेक्षण
मध्य क्षेत्र

Government of India
Geological Survey of India
Central Region
TECHNICAL CONSULTANCY SERVICES DIVISION

सेमीनरी हिल्स, नागपुर -440006
Seminary Hills, Nagpur -440006
दिनांक /Dated, 19.05.2003.

No. 176 /107/2/TCS/GSI/CR/2002.

To,
Dr.T.Chakraborti,
Director Grade Scientist & Head,
Environmental Biotechnology Division,
NEERI, Nehru Marg,
Nagpur-440 020.

Sub: Mineral analysis by Isodynamic Separation and Identification.
Ref:- Letter No. Nil, dt. 5th November, 2002

With reference to the above referred letter, please find enclosed herewith mineral separation and Identification report of 5 samples submitted by you for further necessary action at your end.

Yours faithfully,

19/5/03

(S.G.Udhoji)
Director TCS,
GSI, CR.

Dr. T.K.G
For n a pl
31/05/03

GOVERNMENT OF INDIA
GEOLOGICAL SURVEY OF INDIA
CENTRAL REGION
PETROLOGY DIVISION

Heavy Mineral Identification

Sender's Name :	Dr. T. Chakrabarty, Director Grade Scientist & Head, Enviromental Biotechnology Division, NEERI, Nagpur.
Investigator :	Smt. Gargi Bhattacharya, Geologist (Jr.)
Sample No. :	1
Mineral assemblage:	Garnet+ Biotite+ Magnetite + Zoisite + Monazite + Epidote + Tourmaline.
Texture:	Heavy mineral grains are mainly sub- rounded to rounded. Average size of the grains vary from .001 mm to .003 mm.

G Bhattacharya

(GARGI BHATTACHARYA)

INVESTIGATOR

GOVERNMENT OF INDIA
GEOLOGICAL SURVEY OF INDIA
CENTRAL REGION
PETROLOGY DIVISION

Heavy Mineral Identification

Sender's Name :	Dr. T. Chakrabarty, Director Grade Scientist & Head, Enviromental Biotechnology Division, NEERI, Nagpur.
Investigator :	Smt. Gargi Bhattacharya, Geologist (Jr.)
Sample No.	2
Mineral assemblage:	Garnet + Biotite + Magnetite + Zoisite + Monazite + Hornblende + Tourmaline.
Texture:	Heavy mineral grains are mainly sub- rounded to rounded. Average size of the grains vary from .002 mm to .0007 mm.

G Bhattacharya

(GARGI BHATTACHARYA)

INVESTIGATOR

GOVERNMENT OF INDIA
GEOLOGICAL SURVEY OF INDIA
CENTRAL REGION
PETROLOGY DIVISION

Heavy Mineral Identification

Sender's Name :	Dr. T. Chakrabarty, Director Grade Scientist & Head, Enviromental Biotechnology Division, NEERI, Nagpur.
Investigator :	Smt. Gargi Bhattacharya, Geologist (Jr.)
Sample No.	3
Mineral assemblage:	Biotite+Apatite+Epidote
Texture:	Heavy mineral grains are mainly sub- rounded to rounded. Average size of the grains vary from .001 mm to .003 mm.

G Bhattacharya

(GARGI BHATTACHARYA)

INVESTIGATOR

GOVERNMENT OF INDIA
GEOLOGICAL SURVEY OF INDIA
CENTRAL REGION
PETROLOGY DIVISION

Heavy Mineral Identification

Sender's Name :	Dr. T. Chakrabarty, Director Grade Scientist & Head, Enviromental Biotechnology Division, NEERI, Nagpur.
Investigator :	Smt. Gargi Bhattacharya, Geologist (Jr.)
Sample No.	5
Mineral assemblage:	Garnet + Biotite + Zoisite + Epidote + Clinopyroxene + Rutile.
Texture:	Heavy mineral grains are mainly sub- rounded to rounded. Some angular grains are also recorded. Average size of the grains vary from .003 mm to .001 mm.

G Bhattacharya

(GARGI BHATTACHARYA)

INVESTIGATOR

GOVERNMENT OF INDIA
GEOLOGICAL SURVEY OF INDIA
CENTRAL REGION
PETROLOGY DIVISION

Heavy Mineral Identification

Sender's Name :	Dr. T. Chakrabarty, Director Grade Scientist & Head, Enviromental Biotechnology Division, NEERI, Nagpur.
Investigator :	Smt. Gargi Bhattacharya, Geologist (Jr.)
Sample No.	9
Mineral assemblage:	Biotite + Epidote + Magnetite + Rutile.
Texture:	Heavy mineral grains are mainly sub- angular to rounded. Average size of the grains vary from .002 mm to .0002 mm.

G Bhattacharya

(GARGI BHATTACHARYA)
INVESTIGATOR

Annexure V

(4 pages)

Fax : 0712-2536438
Ph : 0712-2532469
Grams: ATOMIN

Government of India
Department of Atomic Energy
Atomic Minerals Directorate for Exploration and Research
Central Region

AMD Complex,
Civil Lines,
Nagpur – 01.
Dt. 12.03.2003

No. CR/1/11(A)-94/1610

To,
The Director,
NEERI, Nehru Marg,
Nagpur 440 020.

Sub : Sample assay results - reg.
Ref. : D/6/2002 dt. 04.10.2002.

Sir,

With reference to above, I am sending enclosed herewith the required assay results of the sediment samples received from you.

Thanking you

Yours faithfully

(P.K. Sinha)
Technical Secretary to Regional Director,
Central Region

Government of India
Department of Atomic Energy
Atomic Minerals Directorate for Exploration and Research
Central Region
(Physics Laboratory)

AMD Complex,
Civil Lines, Nagpur-1.
10th March, 2003.

No. AMD/PHY/NGP/2/93/ 58

Sub: Gamma Ray Spectrometric Analytical Report of the sediment samples received from the Director, NEERI, Nagpur.

Sl. No.	Sample Designation	U_3O_8 (ppm)	ThO_2 (ppm)	%K
1.	Gaumukh – 1	7.0	17.8	2.5
2.	Gangotri – 2	7.5	10.3	2.7
3.	Uttarkasi – 3	6.2	20.1	2.2
4.	Rishikesh – 4	5.5	17.6	1.9
5.	Tehri – 5 (Downstream of Bhagirathi)	6.8	22.4	1.8

Bhavesh Kumar Sharma 10/03/2003

(P.K. Sharma)
OIC, Physics Lab., Nagpur.

Fax : 0712-2536438
Ph : 0712-2532469
Grams: ATOMIN

Government of India
Department of Atomic Energy
Atomic Minerals Directorate for
Exploration and Research
Central Region

AMD Complex,
Civil Lines,
Nagpur – 01.

No. CR/1/11(A)-94/3599

213
24/6/03

Dt. 18.06.2003

To,
The Director,
NEERI, Nehru Marg,
Nagpur 440 020.

Sub : Sample assay results - reg.
Ref. : Fax dated. 04.03.2003.

Sir,

With reference to above, I am sending enclosed herewith the required assay results of the sediment samples received from you.

Thanking you

Yours faithfully

(P.K. Sinha)
Technical Secretary to Regional Director,
Central Region

Dr TC
RD2
24/6/03

Dr. K-K Ghosh
25/06/03

Government of India
Department of Atomic Energy
Atomic Minerals Directorate for Exploration and Research
Central Region
(Physics Laboratory)

AMD Complex,
Civil Lines, Nagpur-1.
17th June, 2003.

No. AMD/PHY/NGP/2/93/131

Sub: Gamma Ray Spectrometric Analytical Report of the sediment samples of the rivers/reservoirs in and around Nagpur received from Dr. T. Chakrabarti, Director-grade Scientist and Head, Environmental Biotechnology Division, NEERI, Nagpur.

Sl. No.	Sample Designation	U_3O_8 (ppm)*	ThO_2 (ppm)	%K
1.	Telankhedi reservoir	<1.0	4.8	0.8
2.	Kanhan river	1.7	5.7	2.3
3.	Pili river	1.2	3.9	0.3
4.	Kollar river	1.5	4.6	0.2
5.	Ambazari reservoir	<1.0	4.4	0.7

* Radium equivalent

Bhavin Kumar Sharma
17/06/03
(P.K. Sharma)
OIC, Physics Lab., Nagpur.

To
~~The Regional Director~~
~~AMD, CR, Nagpur-1.~~

Credits

Project Guides

Dr. S. Devotta

Dr. R. N. Singh

Project Leader

Dr. T. Chakrabarti

Dr. T.K. Ghosh

Project Team

Ms. P. Basu
Mr. N. Dafale
Dr. A. M. Deshkar
Dr. S. D. Deshpande
Dr. A. Gupta
Mr. M. W. Joshi
Dr. J. P. Kotangale
Dr. K. Krishnamurthi
Ms. K. Kumar
Dr. S. B. Lakhe
Dr. V. W. Lande
Mr. W. N. Paunikar
Ms. Dipanwita Roy
Dr. Mrs. L.N. Sangolkar
Ms. B. Singh
Mr. T. V. Subbarao
Mr. K. Yadav.
Mr. S. V. Waghmare

Table 49: Detection of Coliphages in water samples of Tehri Reservoir (13-16 January, 2009)

Coliphages (PFU/l) in strains of EC	Sampling Locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
01	-	-	-	-	-	760	-	2520	3640	-
02	-	-	-	-	-	-	-	-	-	-
03	-	-	-	-	-	-	-	40	-	-
04	800	-	-	-	-	-	-	-	-	-
05	-	-	-	-	-	-	-	-	-	1600
06	-	-	-	-	-	-	-	-	-	80
07	-	-	-	-	-	-	-	-	-	720
08	-	-	-	-	-	-	-	-	-	-
09	-	-	-	-	-	-	-	-	1280	-
10	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	1440	-
13	-	-	-	-	-	-	-	-	520	-
14	-	-	-	-	-	-	-	-	1040	-
15	280	-	-	-	-	-	-	-	-	-

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

contd...

Table 49 (contd...)

Coliphages (PFU/l) in strains of EC	Sampling Locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
16	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	200	-	-	560	-
23	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-
28	-	-	-	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-
31	-	-	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-	1000	2280	1320

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

Table 50: Detection of Coliphages in water samples of Tehri Reservoir (17-23 May, 2009)

Coliphages (PFU/l) in strains of EC	Sampling Locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
01	-	-	-	1560	-	-	3900	-	-	5200
02	-	-	-	-	-	-	-	-	-	-
03	-	-	-	-	-	-	-	-	-	-
04	-	-	-	-	-	-	-	-	-	-
05	-	-	-	-	-	-	-	-	-	-
06	-	-	-	-	-	-	-	-	-	-
07	-	-	-	-	-	-	-	-	-	-
08	-	13000	-	-	-	-	1640	-	1040	-
09	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-
12	-	360	-	-	-	2880	4800	-	20	80
13	-	-	-	-	1280	-	-	-	-	-
14	-	8280	-	-	-	-	4400	1800	-	8840
15	-	7560	-	-	6440	-	6000	-	960	-

R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

contd...

Table 50 (contd...)

Coliphages (PFU/l) in strains of EC	Sampling Locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
16	-	10160	4720	-	-	6600	4200	-	280	-
17	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-
20	-	2540	-	-	-	-	-	-	-	-
21	-	-	10440	8360	-	-	-	-	340	-
22	-	15320	-	-	-	170	-	-	640	-
23	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-	-	-
26	-	11040	12420	-	-	-	-	40	220	-
27	-	-	-	-	-	-	-	-	-	-
28	-	-	-	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-	-	-	-
30	-	8820	500	-	-	-	-	2520	-	-
31	-	390	8840	6240	-	-	-	5640	20	-
32	-	10200	-	-	-	-	-	250	-	-

R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

Table 51: Detection of Coliphages in water samples of Tehri Reservoir (22-25 Oct, 2010)

Coliphages (PFU/l) in strains of EC	Sampling Locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
01	-	-	-	-	-	7652	2470	236	-	-
02	5432	-	-	-	-	-	126	-	287	-
03	-	-	-	-	-	-	-	-	-	-
04	673	-	-	-	-	-	-	-	-	-
05	-	-	-	-	-	213	-	-	-	-
06	-	-	-	-	-	-	-	-	-	-
07	-	-	-	-	-	-	-	-	-	-
08	-	-	-	-	-	-	-	-	-	-
09	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	3260	-	-	-
12	-	-	-	-	-	-	-	2360	-	-
13	543	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	4732	-	2478	-	5410
15	4570	-	-	-	-	470	21560	1670	-	3120
16	-	-	-	-	-	620	244	320	-	2728

R-01. Near intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

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Table 51 (contd...)

Coliphages (PFU/l) in strains of EC	Sampling Locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
17	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	3860	-	-	-	-
19	428	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	320	-	-	-
21	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-
25	-	-	-	-	-	248	860	640	2690	280
26	-	-	-	-	-	3980	1468	-	-	-
27	-	-	-	-	-	-	-	-	-	-
28	-	-	-	-	-	-	140	-	-	-
29	-	-	-	-	-	-		-	-	-
30	-	-	-	-	3900	2640	2230	732	-	1460
31	-	-	-	-	790	2800	670	-	130	150
32	-	-	-	-	7440	1400	560	1280	-	-

R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

Lackey's drop method. The data were analyzed for pollution indices, viz. Palmer's Pollution Index, & Shannon Wiener Diversity Index using following formulae.

Shannon Wiener Diversity Index: $SWI = -\sum \frac{ni}{N} \log_2 \frac{ni}{N}$

Where, SWI = Shannon Wiener Diversity Index

N = Total number of individuals of species in a sample

ni = number of individuals of species in a sample

Palmer's Index

Palmer Pollution index employs the taxa of algae. The most tolerant genera and species were given ratings which are used to calculate the index. An alga is recorded as 'present', if there are more than 50 organisms /ml. The sum of the ratings of the recorded algae is then calculated (Hellawell, 1978). If the index value is above 20, the surface water appears to be organically polluted, while a score less than 15 is an evidence of probable oligotrophic state.

In general, phytoplankton was present throughout from locations Devprayag to Rishikesh. Palmer's index values (below 15) indicated highly oligotrophic condition (i.e. presence of organic matter is very negligible) starting from Gomukh to Rishikesh. Algae play a very important role in aquatic ecosystems by supplying oxygen in the purification process. Organic waste entering in the receiving river is broken down by bacterial decomposition to form simple nutrients which are taken up by the algae and used to synthesize new algal cell material in presence of light. CO_2 produced during the oxidation of organic matter enhances the photosynthesis of algae while the oxygen produced by algae during photosynthesis promotes the aerobic degradation process of bacteria and other microorganisms (Fogg, 1953). Renn (1954) refers that algae, viz. *Chlorella, Scenedesmus* etc. are able to take up nitrogen and phosphorus in excess when these are present in medium and high concentration as ammonia, nitrate and phosphate. Algae may also play an indirect part by altering the physico-chemical environment. The utilization of carbon dioxide during active photosynthesis causes a shift in the carbonate-bicarbonate equilibrium with a resultant increase in pH due to hydroxyl ion formation (Pipes, 1961).

High densities of algae may produce toxins that are lethal to animals. The fresh water algal genera, commonly reported as toxic, are *Microcystis, Nodularia, Nostoc, Oscillatoria, Aphanizomenon* etc. (Sangolkar *et al.*, 1999). Large populations of cells are necessary to produce sufficient toxins to kill fish and high toxin activity occurs when phosphorus becomes limiting, because the formation of phospholipids in cell membranes is disrupted, allowing leakage of the toxin. Toxin produced by cyanobacteria may also pose risks to human health, livestock and wild animals. Certain species of the genera *Microcystis, Anabaena* etc. can produce potent poisons, which can induce rapid and fatal liver damage at low concentrations and may also be neurotoxic, causing paralysis and death (Mason, 2002). The algal genera, recorded during the investigation period, are devoid of the abovementioned genera.

Phytoplankton Occurrence

The density and diversity of phytoplankton at different sampling locations of river water samples during different seasons are presented in **Table 52** and for Tehri reservoir water samples, phytoplankton density and diversity results are presented in **Table 53**, while the identified phytoplankton are presented in **Table 54.**

Summer, 2008

Phytoplankton comprised of four groups *viz.* cyanophyceae, chlorophyceae, bacillariophyceae and dinophyceae. Phytoplankton counts varied from nil at Gangotri upstream to 145/ml at Bhilangana river (BR1) and 115/ml at R7 to 182/ml at R3 in Tehri reservoir. Dominant genera, *viz. Spirogyra* sp. (Gangotri downstream), *Oocystis* sp., *Chordetella* sp. (Gangotri Upstream), *Ulothrix* sp., *Spirogyra* sp., *Synedra* sp. (Tehri reservoir upstream), *Microcystis* sp., *Scenedesmus* sp., *Oscillatoria* sp., *Chordetella* sp., *Staurostrum* sp., *Ulothrix* sp., *Spirogyra* sp., *Nitzschia* sp., *Synedra* sp., *Tabellaria* sp.and *Caloneis* sp., were identified at different sampling locations of Bhagirathi river. *Scenedesmus* sp., *Chordetella* sp., *Chlorella* sp., *Oocystis* sp., *Peridinium* sp., and a few diatoms were recorded in the samples collected from Tehri reservoir.

Shannon wiener Index (SWI) of phytoplankton varied from nil to 2.105 at Gomukh and Tehri (Upstream) whereas SWI ranged from 0.775 to 2.061 at Tehri reservoir.

Table 52: Composition of Phytoplankton at different Sampling locations of the Rivers/ Tributaries in the Study Area (different seasons)

Phytoplankton	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
29-31 May, 2008														
Total Counts/ml	-	116	144	115	131	128	145	121	101	111	123	115	120	140
Cyanophyceae	-	-	-	-	-	-	-	-	-	-	-	-	6.15	50.02
Chlorophyceae	-	88.89	100.0	40.0	100.0	100.0	100.0	-	-	-	-	98.98	81.55	17.66
Bacillario-phyceae	-	11.11	-	60.0	-	100.0	-	100.0	100.0	100.0	100.0	1.02	12.30	32.32
Dinophyceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SWI	-	1.458	-	1.571	0.811	2.105	1.628	1.0	1.0	0.302	0.811	1.071	1.788	2.006
25-30 September, 2008														
Total Counts/ml	-	-	118	144	131	140	118	122	146	115	138	125	124	181
Cyanophyceae	-	-	-	0.041	-	0.0231	0.0325	-	-	-	-	-	0.0033	0.0075
Chlorophyceae	-	-	66.0	27.6	90.1	3.8	7.8	40.0	41.4	-	25.8	25.1	-	-
Bacillario-phyceae	-	-	44.0	31.0	9.9	30.7	6.5	60.0	17.1	66.7	74.2	37.6	96.7	52.8
Dinophyceae	-	-	-	-	-	42.4	48.1	-	34.7	-	-	37.3	-	39.7
SWI	-	-	1.37	2.407	0.589	2.46	2.368	1.921	2.472	1.584	3.045	2.487	3.412	2.216
13-16 January, 2009														
Total Counts/ml	-	-	-	-	127	121	-	-	-	111	115	-	-	135
Cyanophyceae	-	-	-	-	-	4.8	-	-	-	-	-	-	-	-
Chlorophyceae	-	-	-	-	1.9	42.8	-	-	-	24.2	2.9	-	-	-
Bacillario-phyceae	-	-	-	-	98.1	52.4	-	-	-	75.8	97.1	-	-	100
Dinophyceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SWI	-	-	-	-	1.6	1.803	-	-	-	0.947	2.0	-	-	1.047
17-23 May, 2009														
Total Counts/ml	-	-	-	122	154	182	113	133	-	172	192	213	201	242
Cyanophyceae	-	-	-	7.7	-	15.1	-	-	-	-	8.7	-	25.0	15.6
Chlorophyceae	-	-	-	46.3	21.3	15.1	13.5	5.2	-	92.2	-	5.2	-	26.9
Bacillario-phyceae	-	-	-	46.0	87.7	60.6	66.5	94.8	-	7.8	91.3	94.8	75	49.8
Dinophyceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SWI	-	-	-	2.897	3.511	2.91	2.318	2.943	-	1.488	2.564	2.943	2.958	3.479

Except total counts and SWI, all others are presented in percent composition in groups

contd..

Table 52 (contd...)

Phytoplankton	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
	22-30 October, 2010													
Total Counts/ml	-	59	20	89	63	149	126	-	13	7	40	17	36	-
Cyanophyceae	-	-	-	3.7	-	8.8	-	-	50	-	-	-	-	-
Euglenophyceae	-	-	-	-	-	24.9	-	-	-	-	-	-	-	-
Chlorophyceae	-	100	-	88.8	21	24.4	92.1	-	50	-	16.6	100	-	-
Bacillario-phyceae	-	-	100	7.5	79	41.9	7.9	-	-	100	83.4	-	100	-
Dinophyceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SWI	-	-	1.916	0.68	2.504	3.401	1.275	-	1.00	0.919	2.518	0.971	0.44	-

Except total counts and SWI, all others are presented in percent composition in groups

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Table 53: Composition of Phytoplankton at different Sampling locations of the Tehri reservoir (different seasons)

Phytoplankton	Sampling locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
29-31 May, 2008										
Total Counts/ml	130	122	182	166	120	128	115	127	121	137
Cyanophyceae	1.17	1.0	-	-	-	-	-	1.0	-	-
Chlorophyceae	91.77	97.10	98.32	100	99.0	100	81.64	94.96	100	94.0
Bacillariophyceae	3.53	1.90	1.68	-	1.0	-	-	2.02	-	6.0
Dinophyceae	3.53	-	-	-	-	-	18.36	2.02	-	-
SWI	2.061	1.574	2.059	0.775	1.452	1.192	2.033	0.867	1.628	1.396
25-30 September, 2008										
Total Counts/ml	145	157	149	163	128	115	112	109	139	145
Cyanophyceae	25.6	89.1	9.4	17.1	3.0	2.7	2.8	5.0	11.2	21.6
Chlorophyceae	73.4	10.9	6.3	43.9	38.4	80.0	17.8	20.8	5.3	16.2
Bacillariophyceae	1.0	-	53.2	26.9	4.6	9.3	23.3	3.0	5.0	-
Dinophyceae	-	-	31.1	12.1	54.0	8.0	56.1	71.2	78.5	62.2
SWI	1.048	0.706	2.37	2.696	2.047	1.01	1.68	1.74	1.329	1.566
13-16 January, 2009										
Total Counts/ml	156	-	121	131	123	-	-	142	137	155
Cyanophyceae	5.3	-	-	-	75.0	-	-	-	-	55.5
Chlorophyceae	42.2	-	49.4	75.5	12.5	-	-	38.9	49.8	11.1
Bacillariophyceae	52.5	-	50.6	24.5	12.5	-	-	61.1	50.2	33.4
Dinophyceae	-	-	-	-	-	-	-	-	-	-
SWI	1.58	-	0.947	0.509	1.105	-	-	1.371	1.419	1.438

R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

contd...

Table 53 (contd...)

Phytoplankton	Sampling locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
	17-23 May, 2009									
Total Counts/ml	116	182	200	171	142	125	165	216	146	131
Cyanophyceae	10.4	1.2	1.2	1.6	-	-	2.4	1.0	1.0	-
Chlorophyceae	83.1	94.6	98.8	97.4	95.5	100	96.4	98.0	97.0	38.0
Bacillario-phyceae	6.5	3.0	-	1.0	4.5	-	1.2	1.0	2.0	-
Dinophyceae	-	-	-	-	-	-	-	-	-	62.0
SWI	1.795	0.931	0.669	0.819	1.769	0.397	1.356	0.322	1.003	1.297
	22-30 October, 2010									
Total Counts/ml	184	146	135	149	198	175	160	145	130	104
Cyanophyceae	1.4	3.12	1.8	1.9	4.9	5.6	-	43.1	11.0	-
Euglenophyceae	1.0	2.73	-	1.0	3.0	7.5	2.7	11.4	-	12.6
Chlorophyceae	92.4	93.15	96.40	97.1	92.10	86.9	95.5	36.5	89	79.8
Bacillario-phyceae	1.0	1.0	1.8	-	-	-	1.8	9.0	-	3.8
Dinophyceae/ Chrysophyceae	-	-	-	-	-	-	-	-	-	3.8
SWI	2.446	1.394	1.376	0.784	2.158	2.397	1.259	3.289	2.191	2.33

R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

Table 54: List of identified Phytoplankton (Five seasons)

Group	Genera
Cyanophyceae	*Chroococcus* sp., *Aphanothecae* sp., *Microcystis* sp., *Gloeocapsa* sp., *Glaucocystis* sp., *Aphanocapsa* sp., *Oscillatoria* sp., *Anabaena* sp., *Spirulina* sp., *Merismopedia* sp.,
Euglenophyceae	*Phacus* sp., *Phacotus* sp.,
Chlorophyceae	*Ankistrodesmus* sp., *Chlorella* sp., *Chodatella* sp., *Desmidium* sp., *Scenedesmus* sp., *Chlamydomonas* sp., *Ulothrix* sp., *Closterium* sp., *Cosmarium* sp., *Netrium* sp.,*Elakatothrix* sp., *Spirogyra* sp., *Oocystis* sp., *Staurastrum* sp., *Stigeoclonium* sp.,*Mougeotia* sp., *Pediastrum* sp., *Zygnema* sp.
Bacillariophyceae	*Nitzschia* sp., *Navicula* sp., *Mastogloia* sp., *Synedra* sp.,*Ceratonesis* sp., *Coscinodiscus* sp., *Denticula* sp., *Stephanodiscus* sp., *Tabellaria* sp., *Rhoicosphenia sp., Cocconeis sp., Cymbella* sp.,*Amphipleura* sp., *Gyrasigma* sp., *Fragillaria* sp.,*Gomphoneis* sp., *Caloneis* sp., *Amphora* sp., *Rhizosolenia* sp., *Diatoma* sp., *Meridion* sp., *Anomononeis* sp.
Dinophyceae	*Hemidinium* sp., *Ceratium* sp., *Goniochloris* sp., *Batrachospermum* sp., *Peridunium* sp.

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Post Monsoon, 2008

Five groups, *viz.* Cyanophyceae, euglenophyceae, chlorophyceae, bacillariophyceae and dinophyceae were observed in the Bhagirathi river water and Tehri reservoir. *Anabaena* sp., and *Peridinium* sp. were predominant in Bhilangana river, while *Scenedesmus* sp., *Nitschia* sp. *Navicula* sp., *Peridinium* sp. were mostly observed in Bhagirathi river. Increasing counts were observed in downstream of Bhagirathi river. Phytoplankton counts ranged from Nil at Gomukh to 181/ml at Rishikesh downstream, while the counts varied from 109 to 163 /ml in Tehri reservoir. *Oocystis* sp., *Scenedesmus* sp., *Navicula* sp., *Glaucocystis* sp., *peridinium* sp. were distinctly present in the reservoir. SWI ranged from nil to 3.412 and 0.706 to 2.696 in Bhagirathi river and Tehri reservoir respectively.

Winter, 2009

Water quality observed during post monsoon was better than pre monsoon and monsoon seasons. Phytoplankton and zooplankton were observed in fewer quantities during post monsoon. Samples from upper stream of river Bhagirathi were not collected due to bad weather in the winter season. Phytoplankton samples showed Nil to 135/ml from Gangotri upstream to Rishikesh downstream. Phytoplankton counts were intermittent at other sampling stations. Chlorophyceae and bacillariophyceae were represented in maximum numbers in the samples collected from Bhagirathi river. Cyanophyceae group was only observed at Tehri upstream during post monsoon. Tehri reservoir samples indicated oligotrophic waters during January 2009. Less number of phytoplankton ranging from Nil at R7 to 156/ml at R1 were observed in the reservoir water. Maximum numbers of phytoplankton genera belonged to chlorophyceae and bacillariophyceae. Cyanophyceae were present at R1, R5 and R10 sampling locations in the reservoir. Euglenophyceae was found at sampling locations R1 and R7 in Tehri reservoir, while dinophyceae was almost nil in the samples. Shannon wiener index ranged from 0.509 at R4 to 1.58 at R1 sampling locations.

Maximum SWI of 1.80 was observed at Alaknanda upstream at Devprayag. Twenty five genera of phytoplankton belonging to cyanophyceae (4 genera), euglenophyceae (1 genera), chlorophyceae (5 genera) and bacillariophyceae (15

genera) were observed in the river Bhagirathi/Tehri reservoir. Major genera were *Gloeocapsa* sp., *Chroococcus* sp., *Aphanothecae* sp and *Microcystis* sp. of cyanophyceae, *Chordetella* sp., *Chlorella* sp., *Scenedesmus* sp of chlorophyceae, and *Navicula* sp. *Nitzschia* sp., *Cymbella* sp. and *Synedra* sp. of bacillariophyceae in river Bhagirathi.

Summer, 2009

Mandakini and Alaknanda confluence point with river Bhagirathi showed wide variation in phytoplankton. Phytoplankton counts varied from Nil at Gomukh to 242/ml at Rishikesh downstream. Diatoms were maximum observed among identified phytoplankton groups. *Chordetella* sp., *Chlorella* sp., *Scenedesmus* sp, *Cymbella* sp, *Synedra* sp, *Rohicosphenia* sp, *Caloneis* sp and *Navicula* sp were dominant among different groups of cyanophyceae, euglenophyceae, bacillariophyceae. Phytoplankton counts varied from 116/ml at R1 to 216/ml at R8 in Tehri reservoir. *Chlamydomonas* sp, *Chordetella* sp., *Chlorella* sp, *Nitzschia* sp. and *Synedra* sp. were mostly common in Tehri reservoir. SWI ranged from 0.322 at R8 to 1.795 at R1 of Tehri reservoir.

Post Monsoon, 2010

Water is pristine to semi productive with plankton in river stretch and reservoir from Gangotri and Badrinath to Rishikesh. Along the Bhagirathi River, Alaknanda river and Mandakini river stretches from Gangotri and Badrinath to Rishikesh, sporadic presence of phytoplankton species were observed in the surface water ranging from nil at Gomukh to 149/ml at Tehri upstream. Dominance of bacillariophyceae was observed followed by chlorophyceae in the river water. *Fragillaria* sp., *Nitzschia* sp., *Navicula* sp., *Rhoicosphenia* sp., of bacillariophyceae and *Scenedesmus* sp., *Pediastrum* sp., *Phacotus* sp., *Goniochloris* sp., showed sporadic presence in the Bhagirathi river. SWI of phytoplankton of river varied from nil to 3.4 in the surface water.

Tehri reservoir exhibited high phytoplankton counts ranging from 104 at R10 to 198/ml at R5. Different dominant phytoplankton genera were *Oocystis* sp., *Staurostrum* sp., *Scenedesmus* sp. of chlorophyceae, while comparatively less numbers of cyanophyceae, euglenophyceae and bacillariophyceae were recorded in

Tehri reservoir. Shannon wiener index varied from 0.784 to 3.289 in the surface waters of the reservoir.

4.1.6.2 Zooplankton

A measured quantity of surface water from each sampling point was passed through a plankton net made of Nylon bolt cloth no. 20 (mesh size 75μ). The filtered water comprising of plankters was transferred into a sampling bottle and preserved immediately with 5% formalin. The analysis of zooplankton was done microscopically using Sedgwick Rafter Cell Method and enumerated as counts per meter cube of water.

Microscopic analysis of the zooplankton revealed the following salient features (Tables 55 to 57):

- During the study period, the locations Gomukh were totally devoid of zooplankton as the climate was extremely cold throughout the year and there was no prey (phytoplankton) in this region.
- Shannon Wiener Index or biotic index takes account of the sensitivity or tolerance of individual species / groups to pollution and assign them a value, the sum of which gives an index of pollution for site. The index value ranging from 0.00 to 2.767 exhibited nil to mild organic pollution along the river stretch.

The biota of the rhithrons Bhagirathi is of mixed assemblage of a wide variety of micro fauna and flora. The composite picture in rhithronic ecosystem is interesting and exhibits a series of trophic levels. Amongst the zooplankton, the most commonly occurring groups like small crustacea, larval forms of insects, in addition to some protozoans and rotifers constitute the secondary trophic level. It has been recorded that the cold water streams are inherently poor in biological productivity, resulting in limitation of available quantity of food, and hence a keen competition. The indicator value of plankton is well established (Kolkwitz, 1908; Marsson, 1909; Nygaard, 1949; Palmer, 1969). Except for disturbed sites, the plankton density (quanta) and diversity (spectra) profile showed a general tendency to increase as the current velocity decreased. Current velocity is known to be a factor detrimental to plankton density in

Table 55: Composition of Zooplankton at different Sampling locations of the Rivers/ Tributaries in the Study Area (different seasons)

Zooplankton	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
29-31 May, 2008														
Total Counts/M³	-	-	40	40	53	67	147	153	113	136	93	127	148	157
Ciliata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rotifera	-	-	-	66.76	-	-	-	-	-	-	-	-	-	9.52
Copepoda	-	-	100	33.24	100	60.0	82.94	79.60	81.25	85.0	57.16	86.95	75.0	42.87
Cladocera	-	-	-	-	-	40.0	17.06	20.40	18.75	15.0	42.84	13.05	25.0	47.61
SWI	-	-	0.811	0.928	-	2.32	1.526	1.929	1.516	1.633	1.693	0.696	1.50	2.767
25-30 September, 2008														
Total Counts/M³	-	13	27	87	80	115	122	130	136	107	-	132	127	153
Ciliata	-	-	-	12.0	33.3	-	-	50	-	-	-	-	-	-
Rotifera	-	-	-	-	-	3.8	-	-	-	-	-	-	-	
Copepoda	-	49.8	100	50.4	34.2	50.1	100	-	-	-	-	-	50	50
Cladocera	-	50.2	-	37.6	32.5	46.1	-	50	100	100	-	100	50	50
SWI	-	0.5	-	1.688	2.252	1.377	0.632	1.0	-	-	-	-	1.0	1.0
13-16 January, 2009														
Total Counts/M³	-	-	-	133	126	140	136	-	-	-	-	120	154	123
Ciliata	-	-	-	-	-	6.1	-	-	-	-	-	-	16.7	28.7
Rotifera	-	-	-	-	-	-	-	-	-	-	-	16.1	-	-
Copepoda	-	-	-	30.0	100	76.7	100	-	-	-	-	19.4	83.3	71.3
Cladocera	-	-	-	70.0	-	17.2	-	-	-	-	-	64.5	-	-
SWI	-	-	-	0.856	0.5	0.56	0.0	-	-	-	-	1.298	0.79	1.411

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

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Table 55 (contd...)

Zooplankton	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
17-23 May, 2009														
Total Counts/M^3	-	60	-	103	122	136	124	100	94	116	80	60	128	116
Ciliata	-	-	-	-	-	-	16.7	-	-	-	-	-	-	-
Rotifera	-	-	-	11.2	36.4	5.4	50.0	-	2.2	-	-	-	14.2	-
Copepoda	-	66.7	-	38.5	45.4	77.8	8.3	48.0	80.8	74.1	100	100	64.2	100
Cladocera	-	33.3	-	50.3	18.2	16.8	25.0	52.0	17.0	25.9	-	-	21.6	-
SWI	-	0.918	-	2.117	1.678	0.946	1.729	1.404	1.032	1.664	-	-	1.948	-
22-30 October, 2010														
Total Counts/M^3	-	56	-	-	70	96	82	118	115	125	135	130	120	160
Ciliata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rotifera	-	-	-	-	-	-	-	-	-	-	-	33	-	-
Copepoda	-	100	-	-	100	98	100	87.5	100	80	75	67	33.4	75
Cladocera	-	-	-	-	-	2.0	-	21.5	-	20	-	-	-	25
Ostracoda	-	-	-	-	-	-	-	-	-	-	25	-	66.6	-
SWI	-	0.847	-	-	-	0.509	-	0.544	1.346	1.921	1.5	1.584	0.811	0.919

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

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Table 56: Composition of Zooplankton at different Sampling locations of the Tehri reservoir (different seasons)

Zooplankton	Sampling locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
29-31 May, 2008										
Total Counts/M³	163	80	93	127	153	136	143	177	140	148
Ciliata	-	-	-	-	-	-	-	-	-	-
Rotifera	100	100	-	-	-	-	-	2.94	2.94	-
Copepoda	-	-	85.32	50.0	100	88.24	90.0	73.76	81.58	100
Cladocera	-	-	14.68	50.0	-	11.76	10.0	23.3	15.48	-
SWI	1.00	0.91	1.398	1.00	0.544	1.657	1.555	1.702	1.666	-
25-30 September, 2008										
Total Counts/M³	53	113	107	93	133	158	167	97	83	103
Ciliata	-	8.7	50.0	-	-	-	-	-	-	-
Rotifera	-	2.2	-	-	-	-	-	-	-	-
Copepoda	50.0	32.6	37.5	57.2	91.8	85.5	100	80.0	100	100
Cladocera	50.0	56.5	12.5	42.8	8.2	14.5	-	20.0	-	-
SWI	1.5	1.783	1.406	1.449	1.18	0.903	0.971	1.522	0.811	0.0
13-16 January, 2009										
Total Counts/M³	-	-	123	-	110	95	86	-	106	114
Ciliata	-	-	-	-	-	-	-	-	-	-
Rotifera	-	-	-	-	-	-	-	-	-	-
Copepoda	-	-	100	-	100	100	100	-	100	100
Cladocera	-	-	-	-	-	-	-	-	-	-
SWI	-	-	0.0	-	0.0	0.0	0.0	-	0.0	0.0
17-23 May, 2009										
Total Counts/M³	160	180	188	120	128	153	140	150	172	156

01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; 08.Uppu; R-09. Motna; R-10. Bhaldiana

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Table 56 (contd...)

Zooplankton	Sampling locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
Ciliata	-	-	-	-	-	-	-	-	-	-
Rotifera	4.5	1.0	1.0	1.0	-	-	-	-	-	-
Copepoda	75.2	79.2	95.4	97.0	18.4	81.3	66.7	70.0	94.4	88.0
Cladocera	20.3	19.8	3.6	2.0	81.6	18.7	33.3	30.0	5.6	12.0
SWI	1.532	0.868	0.504	0.436	1.316	1.199	1.459	1.571	1.054	1.523
22-30 October, 2010										
Total Counts/M^3	183	164	98	105	163	166	122	148	182	165
Ciliata	-	-	-	-	-	-	9.6	-	-	-
Rotifera	-	-	3.5	-	6.6	7.8	90.4	2.1	-	-
Copepoda	89.8	80.3	92.8	91.6	86.8	92.2	-	83.3	90.2	93.1
Cladocera	10.2	19.7	3.7	8.4	6.6	-	-	14.6	9.8	6.9
SWI	0.847	1.06	0.922	1.039	1.237	0.860	1.068	1.849	1.404	0.933

R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

Table 57: List of identified Zooplankton in four seasons

S.No.	Group	Genera
1.	Ciliata	*Tintinnopsis* sp., *Epistylis* sp.
2.	Rotifera	*Brachionus* sp., *Filinia* sp., *Philodina* sp., *Lecane* sp., *Notholca* sp.
3.	Copepoda	*Diaptomus* sp., *Cyclops* sp., Zoea larva, Nauplius Larva, *Harpacticoida* sp., *Bryocamptus* sp.
4.	Cladocera	*Daphnia* sp., *Moina* sp., *Alonella* sp., *Bosmina* sp.
5.	Ostracoda	*Cypricercus sp.*

the hilly streams (Nautiyal, 1984, 1986). The discharge of organic load imposes a natural restriction on diversity, but the current velocity rapidly minimizes the discharge load by carrying it downstream and with subsequent dilution. The water quality of river Ganga was monitored using certain physical, chemical and biological characteristics and the study indicated an oligotrophic state of the river during the year 1994 (Gautam, 1994).

The animal communities are fairly common in the meta-rhithronic zone (i.e. Uttarkashi to Devprayag) and hypo (Devprayag to Rishikesh) rhithronic subzones of the Bhagirathi river, whereas, the epi-rithronic subzone (Gomukh to Gangotri) is not able to support a wide variety of animal life.

The effect of zooplankton on river ecology is primarily dependent on their population densities and the specific rates of feeding, respiration and growth. However, the major influence of nematodes is probably on decomposition processes by their metabolism and on bacteria by their grazing activities. Meiofauna, in general, and nematodes, in particular, may have important effects on bacterial activity, but that the direct role of nematodes in used-water decomposition is likely to be negligible (Curds and Hawkes, 1975). The dominant rotifers feed mainly on primary producers and play only a secondary role in the removal of organic wastes. Their contribution to the overall balance of the ecosystem cannot be overlooked.

It is evident from literature that the dominant types of protozoa, found in organically riched water, feed mainly on bacteria and so it has often been suggested that the predatory activities of the protozoa might be responsible for bacterial removal (Sandon, 1932). Zooplankters of higher groups maintain ecological balance of the water bodies.

Zooplankton Occurrence

Summer, 2008

Zooplankton comprised of six groups rotifera, copepoda, cladocera, mollusca, and chrionomidae in the samples collected from Bhagirathi river and Tehri reservoir. Zooplankton counts ranges from Nil at Gomukh to 157/ M^3 at Rishikesh downstream and 80/M^3 at R2 to 177/M^3 at R8 of Tehri reservoir. Zoea larvae, Nauplius larvae, *Diaptomus* sp., *Cyclops* sp. *Brachinous* sp., *Daphnia* sp., *Alonella* sp., and *Moina* sp., were identified from Bhagirathi river. *Philodina* sp., *Brachionus* sp., *Zoea* larvae, *Diaptomus* sp., *Cyclops* sp., *Daphnia* sp., *Moina* sp., *Alonella* sp. were also seen in the reservoir stations R1 to R10. Shannon Wiener Index ranged from Nil at Uttarkashi downstream to 2.767 at Rishikesh (Downstream) in Bhagirathi river and Nil at R10 to 1.702 at R8 in the samples of Tehri reservoir.

Post Monsoon, 2008

Zooplankton counts varied from Nil at Gomukh to 153/ M^3 at Rishikesh downstream and from 53 at R1 to 167 at R7 in Tehri reservoir. Similarly SWI varied from Nil to 2.252, and Nil to 1.783 in Bhagirathi river and Tehri reservoir respectively. Protozoa, rotifera, copepoda and cladocera groups were recorded.

Winter, 2009

Samples of zooplankton from upper stream were not collected due bad weather in this season. Zooplankton samples were collected from Uttarkashi upstream to Rishikesh downstream. Zooplankton numbers varied from Nil at Alaknanda upstream at Devprayag to 154/ M^3 at Rishikesh upstream in Bhagirathi river. Ciliata, rotifera, and cladocera were observed in few numbers at 7 sampling stations. Copepoda and cladoceran were dominatant among other groups of zooplankton in Bhagirathi river. Ciliates were observed only at Tehri upstream and Rishikesh upstream. SWI varied from Nil to maximum of 1.411 at different sampling stations of river Bhagirathi. Minimum number of zooplankton being nil to maximum of 123/ M^3 were observed in the Tehri reservoir. Only copepoda group was represented in the samples.

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Summer, 2009

Zooplankton population was comprised of dominant species of *Diaptomus* sp. *Daphnia* sp., *Moina* sp., and *Alonella* sp. Zooplankton count was comparatively less in the upstream of river Bhagirathi and the number was more at downstream. The counts varied from nil at Gomukh to 136/ M^3 at Devprayag. Zooplankton counts varied from 120/ M^3 at R4 to188/ M^3 at R3 in the reservoir.

Post Monsoon, 2010

Copepods dominated other groups, particularly rotifers and cladocerans in Bhagirathi, Alaknanda and Mandakini rivers within the study area. While zooplankton count ranged from nil to 160/ M^3, SWI varied from nil to 1.921. Tehri reservoir water also showed low count varying from 98 to 183 per M^3 and diversity indices from 0.847 to 1 .849 indicating poor productivity. Copepods were primarily dominant in reservoir too.

4.2 Sediment Quality

The transport of sediment within a river system is a complex phenomenon. Weathering of pre-existing rocks results in disintegrated and decomposed material (sediment), transported by the river, with its deposited material downstream away from their place of formation. Sediment, in general, is a term used to describe both suspended and deposited materials. Different fractions of sediment are of great importance, according to their nature.

The sediments have a great influence on the water quality of the river Bhagirathi. The metal ions, originally derived from the breaking of rocks, are controlled by several river valley conditions – physical as well as chemical. Many metals which are not derived from these rock-fragments are also affected by sediment concentration and composition. Earlier studies carried out by Golterman et al. (1983) on the qualitative observations of minerals in sediments (by Bromoform treatment) of the river Bhagirathi at different locations, viz. Uttarkashi, Tehri and Devprayag have been presented in Table 58.

Table 58: Qualitative observations of minerals in sediments of the river Bhagirathi at different locations

Station	Silli-manite	Musco-vite	Chlo-rite	Biotite	Quarrtz	Phy-llite	Felds-par
Uttarkashi	-	-	X	*	*	X	*
Tehri	-	-	-	-	*	*	*
Devprayag	X	-	*	-	*	-	*

(Source: Gautam, 1990)
* Abundance; - Medium; X not present

4.2.1 Physico-chemical Characteristics

The physico-chemical characteristics of the sediments of the rivers in the study area are shown in **Table 59,** while the average values are presented in **Table 60.**

4.2.2 Metals in Sediments

The levels of metal concentrations in river sediments are presented in **Tables 61 through 65** and comparison with seasons are presented in **Table 66,** while the average values are shown in **Table 67.** The reservoir sediment metal concentrations are presented in **Tables 68 through 72** and comparative results of different seasons are presented in **Table 73.** The average metals concentrations are presented in **Table 74.** The heavy metal concentrations in sediment samples collected from Badrinath to Rudraprayag are presented in **Table 75.**

The highest concentration was observed for Iron followed by Manganese, which implies that the major geochemical phases (in addition to silica) in the rocks of the region are iron oxide and manganese oxide. This interpretation is found to be in close agreement with the mineral analysis of sediments followed by XRD technique (Table 76) which identified smectite and vermiculite as major minerals in clay and silt fractions. The metal ions present in the bed sediments are not expected to present any deleterious effect as long as they are not released completely from the sediments. The levels of heavy metals, viz. cadmium, copper, zinc, nickel, chromium and arsenic in river water were very low and within the limits stipulated in drinking water standards (IS10500 : 1994). However, the concentrations of these metals in sediments were fairly high. Literature reveals that heavy metal levels in Ganga sediments are comparatively higher than crustal average. For example, the

Table 59: Physico-chemical characteristics of Sediments at different Sampling Points in the Study Area

parameters (mg/kg)	Sampling date	Sampling Locations													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Volatile matter	Summer1	6.8	2.43	6.92	3.98	7.68	7.84	5.24	5.84	5.24	6.97	8.14	6.82	7.69	10.62
	Monsoon1	4.6	1.69	4.98	3.16	6.24	5.24	5.03	5.76	5.36	7.41	7.15	5.83	7.82	10.05
	Winter	5.4	3.81	5.86	4.96	7.82	7.98	6.41	6.02	5.08	7.26	7.08	7.16	8.06	12.21
	Summer2	4.2	3.01	8.64	7.82	7.82	8.89	7.24	7.64	6.94	7.58	9.64	8.26	9.68	16.41
	Monsoon2	4.8	2.65	4.63	3.42	6.37	5.83	5.36	5.4	5.64	7.21	7.47	6.82	7.35	10.27
COD	Summer1	10.3	7.12	10.24	13.62	14.61	14.02	13.91	9.84	8.12	8.20	11.35	8.64	12.84	10.83
	Monsoon1	9.4	5.89	4.23	8.96	10.14	12.67	11.87	8.23	8.04	8.20	9.97	8.21	10.16	8.96
	Winter	9.8	6.49	5.64	7.98	13.86	14.12	14.69	7.96	7.94	10.84	10.65	10.52	10.84	10.64
	Summer2	10.0	6.08	9.76	12.6	14.54	14.86	14.97	10.06	9.28	10.87	12.38	12.34	12.87	13.84
	Monsoon2	9.11	5.34	5.27	8.42	9.88	12.51	12.02	8.54	8.13	8.38	9.46	9.1	10.25	10.89
Sulphate	Summer1	0.986	2.410	2.321	2.461	3.042	2.841	2.140	1.982	1.240	1.381	2.870	2.641	2.938	2.892
	Monsoon1	0.972	1.842	0.864	1.762	2.681	1.124	1.531	0.986	0.864	1.238	1.952	1.187	2.846	2.698
	Winter	0.916	1.806	1.642	2.064	2.653	2.461	2.010	1.402	0.986	1.309	2.684	2.165	2.961	2.901
	Summer2	0.984	1.989	1.975	3.184	3.476	2.988	2.040	1.657	1.920	2.165	2.426	3.085	3.164	3.542
	Monsoon2	0.965	1.758	1.261	1.53	2.735	1.813	1.744	0.994	1.012	1.35	1.857	1.764	2.466	2.924

. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01;
. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream;14. Rishikesh downstream.

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Table 59 (contd...)

parameters (mg/kg)	Sampling date	Sampling Locations													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Phosphate as P	Summer1	4.82	6.216	6.941	7.314	4.213	5.862	3.682	2.641	2.164	3.142	4.846	3.621	3.421	4.651
	Monsoon1	3.24	3.964	3.262	4.026	3.110	2.943	2.064	1.241	1.064	1.980	1.652	1.564	1.985	2.164
	Winter	4.68	3.098	5.142	6.271	5.160	4.687	2.851	2.018	1.976	1.975	1.847	1.762	1.854	2.864
	Summer2	5.02	6.612	7.024	7.682	5.234	6.542	2.973	2.621	2.106	2.165	2.361	2.287	2.681	4.968
	Monsoon2	3.68	3.925	3.247	4.011	3.37	3.02	2.823	1.83	1.941	2.11	1.852	1.926	2.1	2.351
Calcium	Summer1	0.398	0.496	0.396	0.316	0.894	2.104	0.926	0.982	0.978	0.865	2.651	0.986	1.264	2.543
	Monsoon1	0.346	0.294	0.241	0.186	0.316	0.514	0.486	0.096	0.264	0.643	0.985	0.874	0.988	2.087
	Winter	0.483	0.321	0.240	0.284	0.624	0.782	0.894	0.524	0.386	0.796	1.416	1.865	1.825	2.036
	Summer2	0.496	0.684	0.561	0.473	0.864	1.621	1.346	1.089	1.010	1.284	1.602	2.025	2.569	2.961
	Monsoon2	0.392	0.301	0.253	0.269	0.302	0.528	0.564	0.133	0.283	0.72	1.12	0.993	1.563	2.13
Magnesium	Summer1	3.518	2.103	2.224	2.682	3.364	4.010	5.612	3.122	3.046	2.951	3.925	2.286	1.989	5.283
	Monsoon1	3.214	1.106	1.873	2.082	3.104	3.421	2.841	2.968	1.984	2.534	2.851	2.164	3.168	4.362
	Winter	2.86	1.948	2.041	2.416	3.463	3.846	3.642	3.186	3.064	2.986	2.658	2.964	3.682	3.978
	Summer2	4.04	1.984	2.586	2.485	3.482	4.214	5.861	3.196	3.103	3.084	4.975	4.851	4.768	4.957
	Monsoon2	3.425	1.649	1.723	1.992	3.114	3.253	2.641	2.783	2.925	2.604	2.821	2.548	3.265	3.962

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream;14. Rishikesh downstream.

Table 60: Average Physico-chemical characteristics of Sediments at different Sampling Points in the Study Area

parameters (mg/kg)	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
Volatile matter	5.16 (±1.01)	2.71 (±0.77)	6.20 (±1.62)	4.66 (±1.89)	7.18 (±0.80)	7.15 (±1.54)	5.85 (±0.93)	6.13 (±0.87)	5.65 (±0.74)	7.28 (±0.22)	7.89 (±1.60)	6.97 (±0.87)	8.12 (±0.90)	11.91 (±2.65)
COD	9.72 (±0.47)	6.18 (±0.66)	6.18 (±2.76)	10.31 (±2.59)	12.60 (±2.38)	13.63 (±1.01)	13.49 (±1.46)	8.92 (±1.96)	8.30 (±0.55)	9.29 (±1.42)	10.76 (±1.15)	9.76 (±1.68)	11.39 (±1.36)	11.03 (±1.76)
Sulphate	0.96 (±0.02)	1.96 (±0.26)	1.61 (±0.57)	2.20 (±0.65)	2.91 (±0.34)	2.24 (±0.77)	1.89 (±0.24)	1.40 (±0.43)	1.20 (±0.42)	1.48 (±0.38)	2.35 (±0.44)	2.16 (±0.73)	2.87 (±0.25)	2.99 (±0.32)
Phosphate as P	4.28 (±0.78)	4.76 (±1.55)	5.12 (±1.86)	5.86 (±1.75)	4.21 (±0.98)	4.61 (±1.62)	2.87 (±0.57)	2.07 (±0.58)	1.85 (±0.44)	2.27 (±0.49)	2.51 (±1.33)	2.23 (±0.82)	2.40 (±0.64)	3.39 (±1.31)
Calcium	0.42 (±0.06)	0.41 (±0.16)	0.33 (±0.14)	0.30 (±0.10)	0.6 (±0.28)	1.10 (±0.71)	0.84 (±0.34)	0.56 (±0.46)	0.58 (±0.37)	0.86 (±0.25)	1.55 (±0.65)	1.34 (±0.54)	1.64 (±0.60)	2.35 (±0.39)
Magnesium	3.41 (±0.43)	1.75 (±0.40)	2.08 (±0.33)	2.33 (±0.28)	3.30 (±0.18)	3.74 (±0.40)	4.11 (±1.52)	3.50 (±0.17)	2.82 (±0.47)	2.83 (±0.24)	3.44 (±0.99)	2.96 (±1.09)	3.37 (±1.001)	4.60 (±0.59)

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

Table 61: Metal concentrations in sediments at different sampling points of the River/Tributaries in the study area (29-31 May, 2008)

Metals (mg/kg)	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
Arsenic	8.02	4.20	6.8	4.8	6.8	11.0	12.2	13.2	15.0	12.4	15.0	NS	12.2	10.6
Zinc	2.26	2.14	8.8	7.0	14.0	10.0	3.40	2.6	8.24	13.4	17.4	NS	5.20	5.80
Lead	35.4	15.4	45.4	41.4	31.4	41.4	40.6	54.6	44.6	49.4	42.6	NS	50.6	50.4
Cadmium	6.0	6.4	5.4	7.2	10.8	7.2	7.4	4.0	6.2	7.4	12.2	NS	6.2	7.8
Nickel	8.4	12.0	10.6	11.4	12.8	10.6	16.2	15.0	21.2	15.8	16.6	NS	12.6	19.2
Cobalt	12.6	13.0	20.4	22.0	17.0	14.8	15.8	20.4	15.4	13.2	13.4	NS	16.0	15.6
Manganese	27.6	14.2	23.2	28.2	25.2	15.4	20.2	16.8	25.2	13.2	17.2	NS	17.8	18.2
Iron	980	800	482	930	1400	1030	1220	4480	8920	8920	1780	NS	1580	1080
Chromium	18.0	21.4	8.8	18.2	15.4	13.6	21.8	0.4	8.2	19.8	14.8	NS	9.6	21.8
Copper	29.8	12.0	8.8	17.0	27.8	13.0	10.2	14.4	26.4	9.8	27.6	NS	10.2	10.4
Mercury	1.2	1.02	0.98	1.06	1.04	1.0	1.40	1.05	0.64	0.92	1.01	NS	1.28	1.13

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

Table 62: Metal concentrations in sediments at different sampling points of the River/Tributaries in the study area (25-30 September, 2008)

Metals (mg/kg)	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
Arsenic	6.0	4.8	2.2	3.4	7.6	10.6	12.6	9.8	6.2	3.8	10.6	12.2	13.2	13.0
Zinc	1.4	2.6	3.6	13.6	4.2	2.4	2.0	14.8	13.9	12.8	11.4	10.2	10.8	11.6
Lead	25.6	13.6	57.8	53.0	25.6	23.0	16.6	8.6	18.6	20.8	23.6	20.2	23.6	23.6
Cadmium	BDL	1.6	BDL	BDL	BDL	0.6	9.2	BDL	4.0	BDL	0.4	1.0	0.2	1.2
Nickel	8.2	10.2	6.6	12.0	8.6	11.6	10.4	8.6	11.6	14.2	9.0	11.2	7.6	10.0
Cobalt	5.4	5.8	7.2	5.4	2.8	5.4	6.2	4.4	10.2	4.9	5.6	6.2	4.02	4.4
Manganese	63.2	126.8	47.6	113.2	78.6	242.2	114.2	181.8	338.2	146.2	156.4	184.6	126.4	143.4
Iron	571.8	491.8	931.8	1057	607.8	1451.8	2891.8	6151.8	2431.8	4057	991.8	1011.8	2191.8	1831.8
Chromium	3.4	11.4	BDL	BDL	BDL	4.4	20	0.4	5.4	1.6	7.2	5.0	2.8	3.2
Copper	3.8	7.8	5.8	7.4	6.4	48.4	28.8	13.4	21.2	13	9.6	6.4	9.0	7.0
Mercury	2.12	1.48	1.2	2.06	2.18	2.08	2.94	1.42	0.86	1.10	1.18	1.66	2.14	1.58

BDL: below detectable limits

1_ Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9_ Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

Table 64: Metal concentrations in sediments at different sampling points of the River/Tributaries in the study area (17-23 May, 2009)

Metals (mg/kg)	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
Arsenic	NS	5.90	6.40	4.6	6.8	6.2	2.6	3.8	4.4	2.4	10.8	10.4	12.7	13.1
Zinc	NS	1.90	8.0	5.6	8.8	2.4	2.4	4.2	9.1	9.8	8.4	8.2	4.8	8.8
ead	NS	28.0	20.40	29.0	22.4	34.0	30.0	29.4	36.4	38.4	36.2	29.2	34.0	40.8
admium	NS	4.8	3.6	2.6	5.8	3.4	4.0	4.20	4.6	4.6	4.2	9.1	5.2	7.3
ickel	NS	6.2	2.9	4.4	3.6	6.6	5.2	4.4	7.4	3.8	4.4	8.6	7.0	9.8
obalt	NS	6.2	5.2	2.4	5.8	3.0	3.6	4.1	4.2	4.2	3.6	3.4	3.8	4.4
anganese	NS	120.0	76.0	127.4	217.3	224.6	320.4	421.0	424.8	317.2	215.2	213.8	616.8	760.2
n	NS	940.0	869.0	761.2	952.2	682.4	672.4	876.2	1482.4	2601.2	3781.2	1962.4	3582.4	4682.4
romium	NS	10.0	9.6	10.8	32.8	21.4	12.8	10.0	10.0	12.0	32.2	26.8	10.2	26.4
pper	NS	6.8	8.0	8.8	16.8	16.6	20.4	10.0	29.4	12.8	9.2	27.4	15.8	8.6
rcury	NS	0.90	0.80	0.70	0.65	0.46	0.48	0.24	0.32	0.40	0.46	0.53	0.64	0.50

L: below detectable limit, NS: not sampled

omukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; ehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

Table 65: Metal concentrations in sediments at different sampling points of the River/Tributaries in the study area (22-30 October, 2010)

Metals (mg/kg)	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
Arsenic	NS	3.3	5.2	5.7	5.3	5.8	2.0	3.5	4.1	3.6	10.0	11.4	13.0	13.8
Zinc	NS	3.6	8.5	4.2	6.5	5.1	3.6	7.3	10.2	9.2	13.2	12.7	15.2	14.8
Lead	NS	22.6	18.6	18.0	18.3	29.4	19.6	31.2	37.4	36.6	26.2	25.6	31.8	33.6
Cadmium	NS	2.8	1.8	2.6	3.0	5.3	2.8	3.0	6.0	5.8	3.6	4.5	3.2	3.8
Nickel	NS	4.8	3.6	5.8	4.0	4.7	3.5	5.7	8.6	3.0	5.3	6.2	6.6	7.2
Cobalt	NS	5.3	4.5	3.0	3.5	4.7	3.5	4.6	5.3	4.8	5.5	5.1	4.4	4.7
Manganese	NS	63.0	47.8	83.0	89.2	330.6	48.4	182.4	292.4	260.4	109.4	146.6	150.0	113.8
Iron	NS	618.4	348.4	538.4	798.4	740.8	658.4	1518.4	1698.4	1498.4	1798.4	1898.4	2296.8	2536.8
Chromium	NS	7.0	4.4	5.4	7.3	12.1	5.2	4.2	6.8	6.2	15.6	13.8	6.2	9.5
Copper	NS	4.4	6.2	7.6	12.4	28.6	28.5	12.2	22.6	14.5	11.3	13.5	12.2	12.4
Mercury	NS	1.24	1.10	1.63	1.60	1.54	1.74	1.12	0.95	0.84	0.92	0.96	1.30	1.13

NS: not sampled, BDL: below detectable

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

Table 66: Seasonal Metal concentration in Sediments at different sampling points of Rivers/Tributaries in the study area

Metals (mg/kg)	Sampling date	Sampling Locations													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Arsenic	Summer1	8.02	4.20	6.8	4.8	6.8	11.0	12.2	13.2	15.0	12.4	15.0	NS	12.2	10.6
	Monsoon1	6.0	4.8	2.2	3.4	7.8	10.8	12.6	9.8	6.2	3.8	10.6	12.2	13.2	13.0
	Winter	NS	NS	NS	2.4	5.8	5.4	6.21	5.20	10.21	NS	NS	12.6	12.0	13.2
	Summer2	NS	5.90	6.40	4.6	6.8	6.2	2.6	3.8	4.4	2.4	10.8	10.4	12.7	13.1
	Monsoon2	NS	3.3	5.2	5.7	5.3	5.8	2.0	3.5	4.1	3.6	10.0	11.4	13.0	13.8
Zinc	Summer1	2.26	2.14	8.8	7.0	14.0	10.0	3.40	2.6	8.24	13.4	17.4	NS	5.20	5.80
	Monsoon1	1.4	2.6	3.6	13.8	4.2	2.4	2.0	14.8	13.9	12.8	11.4	10.2	10.8	11.6
	Winter	NS	NS	NS	7.6	17.8	17.6	24.8	21.6	7.6	NS	NS	27.6	17.6	11.8
	Summer2	NS	1.90	8.0	5.6	6.8	2.4	2.4	4.2	9.1	9.8	8.4	8.2	4.8	8.8
	Monsoon2	NS	3.6	8.5	4.2	6.5	5.1	3.8	7.3	10.2	9.2	13.2	12.7	15.2	14.8
Lead	Summer1	35.4	15.4	45.4	41.4	31.4	41.4	40.8	54.6	44.6	49.4	42.6	NS	50.6	50.4
	Monsoon1	25.6	13.6	57.8	53.0	25.6	23.0	16.6	8.6	18.6	20.8	23.6	20.2	23.6	23.6
	Winter	NS	NS	NS	38.0	24.6	16.2	19.8	13.4	13.0	NS	NS	13.6	13.0	13.8
	Summer2	NS	28.0	20.40	29.0	22.4	34.0	30.0	29.4	36.4	38.4	36.2	29.2	34.0	40.8
	Monsoon2	NS	22.6	18.6	18.0	18.3	29.4	19.6	31.2	37.4	36.6	26.2	25.6	31.8	33.6
Cadmium	Summer1	6.0	6.4	5.4	7.2	10.8	7.2	7.4	4.0	6.2	7.4	12.2	NS	6.2	7.8
	Monsoon1	BDL	1.6	BDL	BDL	BDL	0.6	9.2	BDL	4.0	BDL	0.4	1.0	0.2	1.2
	Winter	NS	NS	NS	2	3.2	2	2.6	5.2	3	NS	NS	5.8	3.2	3
	Summer2	NS	4.8	3.6	2.6	5.8	3.4	4.0	4.20	4.6	4.6	4.2	9.1	5.2	7.3
	Monsoon2	NS	2.8	1.8	2.6	3.0	5.3	2.8	3.0	6.0	5.8	3.6	4.5	3.2	3.8
Nickel	Summer1	8.4	12.0	10.6	11.4	12.8	10.6	16.2	15.0	21.2	15.8	16.6	NS	12.6	19.2
	Monsoon1	8.2	10.2	6.6	12.0	8.6	11.6	10.4	8.6	11.6	14.2	9.0	11.2	7.6	10.0
	Winter	NS	NS	NS	0.4	3.8	0	0.8	6.4	1.8	NS	NS	6.6	2.8	2
	Summer2	NS	6.2	2.9	4.4	3.6	6.6	5.2	4.4	7.4	3.8	4.4	8.6	7.0	9.8
	Monsoon2	NS	4.8	3.6	5.8	4.0	4.7	3.5	5.7	8.6	3.0	5.3	6.2	6.6	7.2

NS: not sampled; BDL: below detectable limit

. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01;

. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

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Table 66 (contd...)

Metals (mg/kg)	Sampling date	Sampling Locations													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cobalt	Summer1	12.6	13.0	20.4	22.0	17.0	14.8	15.8	20.4	15.4	13.2	13.4	NS	16.0	15.8
	Monsoon1	5.4	5.8	7.2	5.4	2.8	5.4	6.2	4.4	10.2	4.9	5.6	6.2	4.02	4.4
	Winter	NS	NS	NS	19	29.4	15.6	30.6	54.6	26.6	NS	NS	61	25.2	26
	Summer2	NS	6.2	5.2	2.4	5.8	3.0	3.6	4.1	4.2	4.2	3.6	3.4	3.8	4.4
	Monsoon2	NS	5.3	4.5	3.0	3.5	4.7	3.5	4.6	5.3	4.8	5.5	5.1	4.4	4.7
Manganese	Summer1	27.6	14.2	23.2	28.2	25.2	15.4	20.2	16.8	25.2	13.2	17.2	NS	17.8	18.2
	Monsoon1	63.2	126.8	47.6	113.2	78.6	242.2	114.2	181.8	338.2	146.2	156.4	184.6	126.4	143.4
	Winter	NS	NS	NS	22.8	26.9	25.8	17.8	26.8	17.2	NS	NS	28.8	13.8	18.6
	Summer2	NS	120.0	76.0	127.4	217.3	224.6	320.4	421.0	424.8	317.2	215.2	213.8	616.8	760.2
	Monsoon2	NS	63.0	47.8	83.0	89.2	330.6	48.4	182.4	292.4	260.4	109.4	146.6	150.0	113.8
Iron	Summer1	980	800	482	930	1400	1030	1220	4480	8920	8920	1780	NS	1580	1080
	Monsoon1	980	800	482	930	1400	1030	1220	4480	8920	8920	1780	NS	1580	1080
	Winter	NS	NS	NS	3309	4529	3261.2	5521.2	941.2	1341.2	NS	NS	1101.2	4189	4149
	Summer2	NS	940.0	869.0	761.2	952.2	682.4	672.4	876.2	1482.4	2601.2	3781.2	1962.4	3582.4	4682.4
	Monsoon2	NS	618.4	348.4	538.4	798.4	740.8	658.4	1518.4	1698.4	1498.4	1798.4	1898.4	2296.8	2536.8
Chromium	Summer1	18.0	21.4	8.8	18.2	15.4	13.6	21.8	0.4	8.2	19.8	14.8	NS	9.6	21.8
	Monsoon1	3.4	11.4	BDL	BDL	BDL	4.4	20	0.4	5.4	1.6	7.2	5.0	2.8	3.2
	Winter	NS	NS	NS	8.6	10.0	8.8	14.0	6.8	8.2	NS	NS	0.8	10.0	18.0
	Summer2	NS	10.0	9.6	10.8	32.8	21.4	12.8	10.0	10.0	12.0	32.2	26.8	10.2	26.4
	Monsoon2	NS	7.0	4.4	5.4	7.3	12.1	5.2	4.2	6.8	6.2	15.6	13.8	6.2	9.5
Copper	Summer1	29.8	12.0	8.8	17.0	27.8	13.0	10.2	14.4	26.4	9.8	27.6	NS	10.2	10.4
	Monsoon1	3.8	7.8	5.8	7.4	6.4	48.4	28.8	13.4	21.2	13	9.6	6.4	9.0	7.0
	Winter	NS	NS	NS	11	17	17	28	13.4	11.8	NS	NS	28.8	36.6	10.6
	Summer2	NS	6.8	8.0	8.8	16.8	16.6	20.4	10.0	29.4	12.8	9.2	27.4	15.8	8.6
	Monsoon2	NS	4.4	6.2	7.6	12.4	28.6	28.5	12.2	22.6	14.5	11.3	13.5	12.2	12.4
Mercury	Summer1	1.2	1.02	0.98	1.06	1.04	1.0	1.40	1.05	0.64	0.92	1.01	NS	1.28	1.13
	Monsoon1	2.12	1.48	1.2	2.06	2.18	2.08	2.94	1.42	0.86	1.10	1.18	1.66	2.14	1.58
	Winter	NS	NS	NS	1.32	0.36	0.34	0.34	0.2	1.34	NS	NS	0.74	0.32	0.34
	Summer2	NS	0.90	0.80	0.70	0.65	0.46	0.48	0.24	0.32	0.40	0.46	0.53	0.64	0.50
	Monsoon2	NS	1.24	1.10	1.63	1.60	1.54	1.74	1.12	0.95	0.84	0.92	0.96	1.30	1.13

NS: not sampled; BDL: below detectable limit

Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

Table 67: Average Metal concentrations in sediments at different sampling points of the River/Tributaries in the study area

Metals (mg/kg)	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
Arsenic	7.01 (±1.4)	4.55 (±1.09)	5.15 (±2.08)	5.22 (±1.56)	8.86 (±5.06)	10.24 (±4.76)	10.84 (±9.29)	10.38 (±7.49)	7.46 (±4.44)	5.55 (±4.60)	11.6 (±2.29)	15.4 (±8.16)	13.74 (±2.19)	12.46 (±1.26)
Zinc	1.83 (±0.60)	2.56 (±0.75)	7.22 (±2.43)	7.60 (±3.6)	10.26 (±5.56)	7.50 (±6.44)	7.24 (±9.83)	10.1 (±7.95)	9.81 (±2.48)	11.3 (±2.1)	12.6 (±3.76)	14.67 (±8.81)	10.72 (±5.76)	10.56 (±3.4)
Lead	30.5 (±6.9)	19.9 (±6.65)	35.55 (±19.22)	35.88 (±13.18)	24.46 (±4.78)	28.8 (±9.72)	25.32 (±9.93)	27.44 (±18.08)	30.0 (±13.48)	36.3 (±11.78)	32.15 (±8.83)	22.15 (±6.79)	30.6 (±13.89)	32.44 (±14.31)
Cadmium	6.0 (±0.0)	3.9 (±2.12)	3.6 (±1.8)	3.6 (±2.41)	5.7 (±3.63)	3.7 (±2.61)	5.2 (±2.94)	4.1 (±0.90)	4.7 (±1.35)	5.9 (±1.40)	5.1 (±5.01)	5.1 (±3.34)	3.6 (±2.30)	4.62 (±2.84)
Nickel	8.3 (±0.14)	8.3 (±3.36)	5.92 (±3.50)	6.8 (±4.89)	6.56 (±4.06)	6.7 (±4.69)	7.22 (±6.12)	8.02 (±4.18)	10.12 (±7.13)	9.2 (±6.73)	8.82 (±5.55)	8.15 (±2.3)	7.32 (±3.5)	9.64 (±6.24)
Cobalt	9.0 (±5.0)	7.57 (±3.63)	9.32 (±7.47)	10.36 (±9.38)	11.70 (±11.43)	8.7 (±6.0)	11.94 (±11.58)	17.62 (±21.80)	12.34 (±9.12)	6.77 (±4.29)	7.02 (±4.34)	18.92 (±28.07)	10.68 (±9.62)	11.02 (±9.65)
Manganese	45.4 (±25.2)	81.0 (±52.9)	48.65 (±21.58)	74.92 (±47.91)	87.44 (±78.23)	167.22 (±140.2)	104.2 (±126.9)	165.76 (±163.6)	219.56 (±187.2)	184.25 (±134.3)	124.55 (±83.6)	143.45 (±81.2)	184.92 (±249.2)	210.84 (±312.2)
Iron	775.9 (±0.0)	712.5 (±80.8)	657.8 (±286)	1319.1 (±1129)	1657.5 (±1631)	1433.2 (±1066)	2192.7 (±2072)	2793.5 (±2062)	3174.7 (±4335)	4269.1 (±3648)	2087.8 (±1155)	1493.4 (±608)	2768.0 (±1354)	2856.0 (±1938)
Chromium	10.7 (±10.3)	12.45 (±6.2)	7.6 (±2.8)	10.75 (±5.43)	16.37 (±11.45)	12.06 (±6.3)	14.76 (±6.57)	4.36 (±4.15)	7.72 (±1.72)	9.9 (±7.85)	17.4 (±10.5)	11.6 (±11.49)	7.76 (±3.21)	15.8 (±9.37)
Copper	16.8 (±18.3)	7.7 (±2.7)	7.2 (±1.5)	10.3 (±3.97)	16.1 (±7.84)	24.7 (±14.4)	23.2 (±8.06)	12.6 (±1.68)	22.2 (±6.68)	12.5 (±1.96)	14.4 (±8.83)	19.0 (±10.8)	16.7 (±11.38)	9.8 (±2.06)
Mercury	1.66 (±0.65)	1.16 (±0.25)	1.02 (±0.17)	1.35 (±0.52)	1.16 (±0.73)	1.08 (±0.73)	1.38 (±1.05)	0.80 (±0.55)	0.82 (±0.37)	0.81 (±0.29)	0.89 (±0.30)	0.97 (±0.49)	1.13 (±0.70)	0.93 (±0.50)

NS: not sampled: BDL: below detectable limit

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

Table 68: Metal concentrations in sediments at different sampling points of Tehri Reservoir (29-31 May, 2008)

Metals (mg/kg)	Sampling locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
Arsenic	50.2	43.2	55.2	43.2	50.6	43.2	50.6	35.6	50.6	34.6
Zinc	18.0	15.2	23.6	32.0	90.8	54.6	88.0	30.2	96.4	23.8
Lead	48.0	82.0	80.0	88.0	107.2	112.0	209.2	147.2	201.2	149.2
Cadmium	36.0	29.6	37.6	28.0	35.2	29.2	33.6	23.6	33.8	24.0
Nickel	91.4	96.8	98.6	77.2	81.8	80.6	90.8	63.2	90.2	61.2
Cobalt	63.0	103.0	135.0	175.0	207.4	227.0	203.6	205.4	231.4	205.4
Manganese	627.2	985.2	525.2	887.2	831.2	997.2	701.2	915.2	891.2	855.2
Iron	73179	61978	76778	55578	66180	56179	66980	45980	65580	42180
Chromium	141.8	142.0	137.0	128.4	183.8	137.8	105.6	135.0	166.6	139.4
Copper	82.8	86.4	80.4	77.2	83.2	56.4	77.0	48.8	86.0	38.8
Mercury	2.3	3.5	2.85	0.98	1.03	1.16	4.24	3.85	4.08	3.61

NS: not sampled; BDL: below detectable limit
R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

Table 69: Metal concentrations in sediments at different sampling points of Tehri Reservoir (25-30 September, 2008)

Metals (mg/kg)	Sampling locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
Arsenic	228	690	560	316	222	440	644	632	848	872
Zinc	98.4	157.2	113	73	41.2	54.6	99.8	150.6	163.6	168.4
Lead	105.2	161	115.6	77	56.6	82.6	130.4	145	164.8	170
Cadmium	13.8	24.6	16.0	10.8	4.0	7.2	17.4	19.6	21.8	23
Nickel	48	74.4	63.6	43.4	24.2	28.6	56.2	67.4	74.2	78.4
Cobalt	248	336	304	238	121.8	153.4	292	310	332	348
Manganese	688.6	1034.6	738.6	392.6	340.6	550.6	1148.6	814.6	924.6	1064.6
Iron	37388.6	53588.6	43988.6	35388.6	18808.6	22788.6	43988.6	46788.6	49188.6	52188.6
Chromium	30.2	60	33.6	11.0	34.2	18.8	43.6	75.6	61.6	63.4
Copper	52.2	65.4	68.8	42.8	20.6	104.2	63.6	55.6	65.2	65.6
Mercury	4.82	6.32	5.06	1,1	1.66	1.58	7.34	6.84	7.38	6.04

NS: not sampled; BDL: below detectable limits
R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

Table 70: Metal concentrations in sediments at different sampling points of Tehri Reservoir (13-16 January, 2009)

Metals (mg/kg)	Sampling locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
Arsenic	422	NS	NS	NS	152.2	162.2	248	284	396	298
Zinc	72.4	NS	NS	NS	27.8	33.6	40.6	81.6	86.8	65
Lead	51.8	NS	NS	NS	6.8	0	13.8	25	44.8	26.2
Cadmium	14.2	NS	NS	NS	7	6.4	9.6	10.8	14.2	10.6
Nickel	39.2	NS	NS	NS	16.2	12	18.8	27.4	39.8	25.2
Cobalt	162.6	NS	NS	NS	90	67.6	117.8	128.6	160.6	116.8
Manganese	670.8	NS	NS	NS	426.8	480.8	488.8	358.8	668.8	368.8
Iron	27389	NS	NS	NS	13449	11589	17209	21189	25589	20581.2
Chromium	24	NS	NS	NS	4	5.6	12.4	13.4	23.6	19.8
Copper	44.6	NS	NS	NS	13	21	27.4	47.4	51.4	40.6
Mercury	2.6	NS	NS	NS	1.56	1.36	4.08	3.3	2.06	2.36

NS: not sampled; BDL: below detectable limit

R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

Table 71: Metal concentrations in sediments at different sampling points of Tehri Reservoir (17-23 May, 2009)

Metals (mg/kg)	Sampling locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
Arsenic	146	140.6	189	138	216	222	168	186	284	296
Zinc	60.6	33.6	28.6	60.2	54.6	23.2	65.6	27.6	78.4	77.8
Lead	40.2	38.2	21.0	55.2	42.6	17.8	61.0	72.2	49.4	62.2
Cadmium	12.0	6.4	8.8	12.6	11.6	8.8	12.8	7.8	13.2	13.6
Nickel	34.4	15.2	26.2	40.2	32.6	20.0	38.4	19.4	39.4	39.4
Cobalt	123.8	65.6	103.4	141.6	122	105	153.4	91.8	149.8	145
Manganese	396.8	286.8	378.8	746.8	538.8	460.8	1164.8	468.8	584.8	1054.8
Iron	22182.4	11442.4	17582.4	24182.4	21382.4	16902.4	25182.4	15522.4	25982.4	25782.4
Chromium	20.4	8	8.6	18.4	18.2	13	19.2	9.8	25.4	23.2
Copper	50.4	35.4	56	52	44.2	28.4	58.2	29.2	50.6	57.2
Mercury	NS	3.2	3.1	1.02	1.08	1.14	4.15	3.7	3.82	3.4

NS: not sampled; BDL: below detectable limit
R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

Table 72: Metal concentrations in sediments at different sampling points of Tehri Reservoir (22-30 October, 2009)

Metals (mg/kg)	Sampling locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
Arsenic	NS	200.4	254.7	175.2	286.1	310.4	237.7	224	315.5	406.4
Zinc	NS	153	123.6	90.6	89.2	51.8	110.2	90.8	89.2	84.6
Lead	NS	146	87.4	107.8	100.2	66.4	122.6	107.6	108.2	82.2
Cadmium	NS	11.4	11	13	11.4	7.8	14	9.6	12.6	9.4
Nickel	NS	17.6	32.2	37.6	35.6	22.4	41.2	21.5	40.1	30.8
Cobalt	NS	290.6	306.6	230.6	216.6	275.6	268.6	225.6	236.6	284.6
Manganese	NS	696.6	718.6	774.6	564.6	454.6	582.6	364.6	694.6	590.6
Iron	NS	44980.8	33780.8	35780.8	28780.8	20180.8	34980.8	26580.8	34380.8	24980.8
Chromium	NS	45.2	13	22.2	26.6	14.6	30.6	20	24.8	16.8
Copper	NS	63.6	59.2	71.4	44.2	27.8	52.8	46.4	55	37.2
Mercury	NS	5.6	5.1	1.38	1.49	1.3	4.53	4.2	6.42	5.23

NS: not sampled; BDL: below detectable limit
R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra;R-08.Uppu; R-09. Motna; R-10. Bhaldiana

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Table 73: Seasonal Metal concentrations in Sediments at different sampling points of Tehri Reservoir

Metals (mg/kg)	Sampling date	Sampling Locations									
		R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
Arsenic	Summer1	50.2	43.2	55.2	43.2	50.6	43.2	50.6	35.6	50.6	34.6
	Monsoon1	228	690	560	316	222	440	644	632	848	872
	Winter	422	NS	NS	NS	152.2	162.2	248	284	396	298
	Summer2	146	140.6	189	138	216	222	168	186	284	296
	Monsoon2	NS	200.4	254.7	175.2	286.1	310.4	237.7	224	315.5	406.4
Zinc	Summer1	18.0	15.2	23.6	32.0	90.8	54.6	88.0	30.2	96.4	23.8
	Monsoon1	98.4	157.2	113	73	41.2	54.6	99.8	150.6	163.6	168.4
	Winter	72.4	NS	NS	NS	27.8	33.6	40.6	81.6	86.8	65
	Summer2	60.6	33.6	28.6	60.2	54.6	23.2	65.6	27.6	78.4	77.8
	Monsoon2	NS	153	123.6	90.6	89.2	51.8	110.2	90.8	89.2	84.6
Lead	Summer1	48.0	82.0	80.0	88.0	107.2	112.0	209.2	147.2	201.2	149.2
	Monsoon1	105.2	161	115.6	77	56.6	82.6	130.4	145	164.8	170
	Winter	51.8	NS	NS	NS	6.8	0	13.8	25	44.8	26.2
	Summer2	40.2	38.2	21.0	55.2	42.6	17.8	61.0	72.2	49.4	62.2
	Monsoon2	NS	146	87.4	107.8	100.2	66.4	122.6	107.6	108.2	82.2
Cadmium	Summer1	36.0	29.6	37.6	28.0	35.2	29.2	33.6	23.6	33.8	24.0
	Monsoon1	13.8	24.6	16.0	10.8	4.0	7.2	17.4	19.6	21.8	23
	Winter	14.2	NS	NS	NS	7	6.4	9.6	10.8	14.2	10.6
	Summer2	12.0	6.4	8.8	12.6	11.6	8.8	12.8	7.8	13.2	13.6
	Monsoon2	NS	11.4	11	13	11.4	7.8	14	9.6	12.6	9.4
Nickel	Summer1	91.4	96.8	98.6	77.2	81.8	80.6	90.8	63.2	90.2	81.2
	Monsoon1	48	74.4	63.6	43.4	24.2	28.6	56.2	67.4	74.2	78.4
	Winter	39.2	NS	NS	NS	16.2	12	18.8	27.4	39.8	25.2
	Summer2	34.4	15.2	26.2	40.2	32.6	20.0	38.4	19.4	39.4	39.4
	Monsoon2	NS	17.6	32.2	37.6	35.6	22.4	41.2	21.5	40.1	30.8
Cobalt	Summer1	63.0	103.0	135.0	175.0	207.4	227.0	203.6	205.4	231.4	205.4
	Monsoon1	248	336	304	238	121.8	153.4	292	310	332	348
	Winter	162.6	NS	NS	NS	90	67.6	117.8	128.6	160.6	116.8
	Summer2	123.8	65.6	103.4	141.6	122	105	153.4	91.8	149.8	145
	Monsoon2	NS	290.6	306.6	230.6	216.6	275.6	268.6	225.6	236.6	284.6

NS: not sampled; BDL: below detectable limit

R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motne; R-10. Bhaldiana

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Table 73 (contd...)

Metals	Sampling date	Sampling Locations									
		R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
Manganese	Summer1	627.2	985.2	525.2	887.2	831.2	997.2	701.2	915.2	891.2	855.2
	Monsoon1	688.6	1034.6	738.6	392.6	340.6	550.6	1148.6	814.6	924.6	1064.6
	Winter	670.8	NS	NS	NS	426.8	480.8	488.8	358.8	668.8	368.8
	Summer2	396.8	286.8	378.8	746.8	538.8	460.8	1164.8	468.8	584.8	1054.8
	Monsoon2	NS	696.6	718.6	774.6	564.6	454.6	582.6	364.6	694.6	590.6
Iron	Summer1	73179	61978	76778	55578	66180	56179	66980	45980	65580	42180
	Monsoon1	37388.6	53588.6	43988.6	35388.6	18808.6	22788.6	43988.6	46788.6	49188.6	52188.6
	Winter	27389	NS	NS	NS	13449	11589	17209	21189	25589	20581.2
	Summer2	22182.4	11442.4	17582.4	24182.4	21382.4	16902.4	25182.4	15522.4	25982.4	25782.4
	Monsoon2	NS	44980.8	33780.8	35780.8	28780.8	20180.8	34980.8	26580.8	34380.8	24980.8
Chromium	Summer1	141.8	142.0	137.0	128.4	183.8	137.8	105.6	135.0	166.6	139.4
	Monsoon1	30.2	60	33.6	11.0	34.2	18.8	43.6	75.6	61.6	63.4
	Winter	24	NS	NS	NS	4	5.6	12.4	13.4	23.6	19.8
	Summer2	20.4	8	8.6	18.4	18.2	13	19.2	9.8	25.4	23.2
	Monsoon2	NS	45.2	13	22.2	26.6	14.6	30.6	20	24.8	16.8
Copper	Summer1	82.8	86.4	80.4	77.2	83.2	56.4	77.0	48.8	86.0	38.8
	Monsoon1	52.2	65.4	68.8	42.8	20.6	104.2	63.6	55.6	65.2	65.6
	Winter	44.6	NS	NS	NS	13	21	27.4	47.4	51.4	40.6
	Summer2	50.4	35.4	56	52	44.2	28.4	58.2	29.2	50.6	57.2
	Monsoon2	NS	63.6	59.2	71.4	44.2	27.8	52.8	46.4	55	37.2
Mercury	Summer1	2.3	3.5	2.85	0.98	1.03	1.16	4.24	3.85	4.09	3.16
	Monsoon1	4.82	6.32	5.06	1.1	1.66	1.58	7.34	6.84	7.38	6.04
	Winter	2.6	NS	NS	NS	1.56	1.36	4.08	3.3	2.06	2.36
	Summer2	NS	3.2	3.1	1.02	1.08	1.14	4.15	3.7	3.82	3.4
	Monsoon2	NS	5.6	5.1	1.38	1.49	1.3	4.53	4.2	6.42	5.23

NS: not sampled; BDL: below detectable limit
R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaidiana

Table 74: Average Metal concentrations in sediments at different sampling points of Tehri Reservoir

Metals (mg/kg)	Sampling locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
Arsenic	211.5 (+157)	291 (+348)	268 (+261)	165 (+138)	160 (+79)	216 (+166)	277 (+257)	284 (+253)	394 (+334)	375 (+353)
Zinc	62.3 (+33.5)	68.6 (+77.2)	55.0 (+50.2)	55.0 (+20.9)	53.6 (+27.1)	41.5 (+15.7)	73.5 (+26.1)	72.5 (+57.6)	106 (+38.9)	83.7 (+60.9)
Lead	61.3 (+29.6)	93.7 (+62.2)	72.2 (+47.7)	73.4 (+16.6)	53.3 (+41.6)	53.1 (+52.9)	106 (+85.1)	97.3 (+59.5)	115 (+79.8)	101 (+68.7)
Cadmium	19 (+11.3)	20.2 (+12.2)	20.8 (+14.9)	17.1 (+9.4)	14.4 (+14.1)	12.9 (+10.9)	18.3 (+10.6)	15.4 (+7.3)	20.7 (+9.5)	17.8 (+6.7)
Nickel	53.2 (+26.0)	62.1 (+42.1)	62.8 (+36.2)	53.6 (+20.5)	38.7 (+29.5)	35.3 (+30.9)	51.0 (+30.5)	44.3 (+24.4)	60.9 (+25.4)	51.0 (+23.4)
Cobalt	149 (+77.4)	168 (+146.5)	180 (+107)	184 (+48.9)	135 (+50.3)	138 (+68.8)	191 (+75.5)	183 (+96.4)	218 (+83.9)	203 (+102)
Manganese	595 (+135)	768 (+418)	547 (+180)	675 (+254)	534 (+213)	622 (+252)	875 (+335)	639 (+267)	767 (+166)	835 (+325)
Iron	40034 (+22979)	42336 (+27081)	46116 (+29655)	38383 (+15910)	29955 (+24375)	26864 (+20071)	38340 (+22149)	32370 (+16350)	41585 (+19432)	35183 (+14602)
Chromium	54.1 (+58.6)	70 (+67.5)	59.7 (+68.0)	52.6 (+65.7)	60.0 (+83.4)	43.8 (+62.8)	45.2 (+42.4)	58.4 (+59.3)	69.3 (+67.1)	61.4 (+55.6)
Copper	57.5 (+17.1)	62.4 (+25.6)	68.4 (+12.2)	57.3 (+17.8)	40.2 (+31.5)	52.5 (+37.6)	56.5 (+20.9)	45.2 (+11.2)	63.3 (+16.5)	50.5 (+13.0)
Mercury	3.09 (+1.16)	4.65 (+1.54)	4.02 (+1.21)	1.12 (+ 0.18)	1.36 (+ 0.28)	1.30 (+ 0.17)	4.86 (+ 1.39)	4.37 (+ 1.41)	4.75 (+ 2.13)	4.12 (+ 1.48)

NS: not sampled; BDL: below detectable limit
R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

Table 75: Metal characteristics of sediments at different sampling points of the River/Tributaries in the study area (17-23 May, 2009 and 22-30 October, 2010)

Heavy Metals (mg/kg)	Sampling date	Sampling Locations		
		Badrinath	Mandakini (BC) (Rudraprayag)	Alaknanda(AC) (Rudraprayag)
Arsenic	Summer2	3.4	3.8	4.2
	Monsoon2	3.2	3.5	3.8
Zinc	Summer2	3.7	4.1	3.4
	Monsoon2	3.3	3.7	2.8
Lead	Summer2	18.04	20.33	28.21
	Monsoon2	16.05	18.5	26.9
Cadmium	Summer2	BDL	1.8	1.6
	Monsoon2	1.5	2.3	2.5
Nickel	Summer2	8.6	10.5	11.2
	Monsoon2	6.2	8.3	9.8
Cobalt	Summer2	12.1	10.8	10.6
	Monsoon2	10.5	9.7	9.5
Manganese	Summer2	83.5	103.8	94.7
	Monsoon2	75.0	93.4	89.8
Iron	Summer2	955.0	863.5	984.1
	Monsoon2	884.0	724.8	812.6
Chromium	Summer2	2.8	3.5	4.7
	Monsoon2	3.2	3.0	3.5
Copper	Summer2	3.1	5.3	5.8
	Monsoon2	2.7	4.2	3.9
Mercury	Summer2	1.56	1.12	1.65
	Monsoon2	1.43	1.50	1.52

BDL: below detectable limit

Table 76: Mineral Analysis of Sediments of River Bhagirathi followed by XRD Techniques
(Analysed by National Bureau of Soil Survey and Land Use Planning)

Sample Station	Year	Silt (50-2 μm)	Clay (<2 μm)
Gomukh	2003	Sm(D), Vm, Ch, M, K, Q, F	Vm(D),Sm, Ch, M, K (Tr), Q
	2009	M, M-L, Vm, Ch, Sm, Q, F	NY
Gangotri	2003	M (D) Sm,Vm, M, K, Q, F	Vm(D),Sm,M, K (Tr), Q(Tr) ,F(Tr)
	2009	M, M-L, Vm, Ch, Sm, Q, F	NY
Uttarkashi	2003	Sm(D), Vm, Ch, M, K (Tr), Q, F	Sm(D), Vm, Ch, M,Q(Tr), F(Tr)
	2009	M, M-L, Vm, Ch, Sm (D), Q, F	NY
Devprayag Downstream	2003	NA	NA
	2009	M, M-L, Vm, Ch, Sm (D), Q, F	NY
Alknanda upstream (Devprayag)	2003	NA	NA
	2009	M, M-L, Vm, Ch, Sm (D), Q, F	NY
Bhagirathi upstream (Devprayag)	2003	NA	NA
	2009	M, M-L, Vm, Ch, Sm (D), Q, F	NY
Tehri (upstream of Bhagirathi)	2003	Sm(D); Vm, Ch, M, K (Tr), Q, F	Sm(D), Vm, Ch, M,Q(Tr), F(Tr), K(Tr)
	2009	M, M-L, Vm, Ch, Sm (D), Q, F	NY
Tehri (dowstream of Bhagirathi)	2003	Sm(D), Vm, Ch, M, K (Tr), Q, F	Sm(D), Vm, Ch, M,Q(Tr), F(Tr), K(Tr)
	2009	M, M-L, Vm, Ch, Sm (D), Q, F	NY
R 07 (N30°26'29.6" E 078°26'12.0") (Reservoir)	2003	NA	NA
	2009	M, M-L, Vm, Ch, Sm (D), Q, F	Sm, Vm, M, M-L, Ch, Q, F
Rishikesh	2003	Sm(D), Vm, Ch, M, K (Tr), Q, F	Sm(D), Vm, Ch, M,Q(Tr), F(Tr)
	2009	M, M-L, Vm, Ch, Sm (D), Q, F	NY

Sm =Smectite; Vm = vermiculite; Ch= chlorite; M= mica; K= kaolinite; Q= quartz; F= eldspar; D= dominant; Tr= trace, NY= could not yield clay fraction, NA= Not analysed

concentration of Cd in Ganga sediment (15 mg/kg) is alarmingly high as compared to crustal average of 0.22 mg/kg (Ghose and Sharma, 1989). Suspended sediments of Ganga and Brahmaputra rivers were found (Subramanian et.al., 1987) to be 5 to 10 times richer in heavy metals than the bed sediments.

The metal ions available in the bed sediments were not expected to exhibit any deleterious effect as long as these are not released completely from the sediments. If the levels of various parameters like pH, ionic strength, Eh etc. in river water vary in course of time, then it may result in remobilization of metal ions, the extent of which depends upon the speciation of metals. Also in case of Bhagirathi river, the rate of siltation is extremely high.

4.2.3 Mineral Composition

4.2.3.1 Mineralogical Properties of the Soils

The inorganic fraction of soils is composed of rock fragments and minerals of varying size and composition. These are sometimes distinguished as primary and secondary minerals. Primary minerals are rock - forming minerals that are present in soils and are chemically unchanged, whereas secondary minerals are formed by weathering of primary minerals. Sometimes, secondary minerals may well be regarded as primary on a pedological basis. Both the physical and chemical properties of any soil are controlled to a large extent by the minerals of the soil and especially by those constituting the clay fraction. Identification, characterization and understanding of properties of the different minerals materially aid in evaluation of soils in relation to classification, agronomic practices and engineering properties.

X-ray diffraction technique is used for mineral identification and mineralogical composition in clay and silt components in soils of the study area. Total clay and silt samples prepared for analysis were examined in the following order for most efficient identification and differentiation of mineral species: (1) K-saturated heated sample (550^0 C), (2) K-saturated heated sample (300^0 C), (3) K-saturated heated sample

(110^0 C) (4) K-saturated air dried sample(25^0 C), (5) Ca-saturated, ethylene glycol – solvated sample, (6) Ca- saturated, air dried sample.

4.2.3.2 Identification of Minerals

Primary minerals:

Quartz: The framework of quartz is very densely packed and occurs in a high degree of purity. It is strongly resistant to physical and chemical weathering as the structure is densely packed, electrically neutral and prevents any form of substitution. With time it gets accumulated in soil as the other susceptible minerals decompose to form clay and decrease in their respective amounts. As such, the abundance of quartz more in soils is next only to feldspar. With X-ray analysis quartz yields a d (100) spacing of 4.28 A° and d (101) spacing of 3.34 A°. Frequently the d (100) diffraction peak at 4.28 A° is very weak in intensity, leaving the usually strong 3.34 A° X-ray diffraction peak for use in diagnosis of quartz.

Feldspar: Feldspars are most abundant among rock forming minerals and constitute nearly 61% of the minerals that are found in the earth's crust. These are non-ferromagnesian minerals and act as storehouse for sodium, calcium, potassium and many trace elements in soil. With X-ray analysis, feldspar can be identified by a (001) d spacing of 3.2 A°. This peak does not shift or collapse after heating salvation to 500° C or solvation with ethylene glycol.

Secondary minerals

Smectite: The minerals are generally very fine grained, whereas the component layers are not bonded strongly. In contact with water, the mineral exhibits interlayer swelling, causing the volume of the clay to double. Indications are available that the basal spacing of smectite increases uniformly with absorption of water. Several authors noted that the increase in basal spacing could occur stepwise, suggesting formation of hydration shells around interlayer cations. The high swell-shrink potential is why the mineral can admit and fix metal ions and organic compounds. The absorption of organic compounds leads to the formation organo-mineral compounds. Organic ions are believed to be able to replace inorganic cations in the interlayer position. Monolayers, sometimes double layers, of organic molecules are

adsorbed, depending on the size of the cations and the charge deficit of the layers. Among the several species of clays in soils, the mineral smectite is perhaps the most widely distributed member. Most soil smectite (montmorillonites) are dioctahedral.

Adsorption of organic compounds such as glycerol and ethylene glycol, is diagnostic in identification of smectite by x-ray diffraction analysis. Oven dry (105^0 C) smectite is usually characterized by a basal (001) d spacing diffraction peak at 10 A°. In air dry condition, the mineral has some interlayer water and the characteristic spacing is approximately 12.4 – 14 A°. After solvation or intercalation with ethylene glycol, the basal (001) spacing expands to 17.0 A°.

Vermiculite: The common occurrence of vermiculite is mixed layers with smectite, chlorite, illite and biotite yields many difficulties in the positive identification of vermiculite. Many clay vermiculite may have been identified in the past as smectite. The vermiculite group of minerals also forms mica like flakes as illites. It is also a mica alteration product. Vermiculite can be divided into two categories: *true vermiculite* and *clay vermiculite*. True vermiculite is not considered a clay mineral, but a rock forming mineral. The clay-sized vermiculite found in soils is considered clay vermiculite or soil vermiculite. The detection of vermiculite in soils is based on its x-ray diffraction peak at 14 A° at the basal spacing of (001) d. This is why it is often called 14 A° mineral. Clay vermicullite is a magnesium aluminium silicate with Mg occupying the octahedral position between two silica tetrahedral sheets. Some iron may also be present.

Chlorites: Chlorites are hydrated magnesium and aluminum silicates, which are related to mica minerals in appearance. Depending on the species, the characteristic of the basal spacing (001) d of chlorite is 14.0 A°, as determined by X-ray diffraction analysis using oriented specimens. This peak does not shift or collapse by treatments of the sample with ethylene glycol or by heating to 500 –550°C. Swelling chlorite may have a basal spacing of 28A°, which increases to 32 A ° by solvation.

Abundance and frequency of occurrence of chlorite are considered low. Isomorphous substitution of magnesium by aluminium (in brucite) creates positive charge practically neutralizes the negative charge of mica layer. Therefore, chlorite has only a very small negative charge, and consequently small CEC. The hydroxy

interlayers are sites for anion retention. Phosphorous is reported to be fixed by interlayer hydroxides of chlorites. On the other hand, the presence of these interlayers reduces fixation of K^+ or NH_4 ions.

Mica: Mica (biotite, muscovite) mineral belongs to phyllosilicates, which have sheet structure of honeycomb like tetrahedral structure. In biotite, the positive charged ions holding inner surface are iron and magnesium. In muscovite, each pair of tetrahedral sheets is tightly connected together by ions of aluminium rather than iron and magnesium. In view of perfect cleavage along surfaces of these weak K+ bonds, micas can be peeled off easily. For oriented samples, the basal (001) d X-ray diffraction peak is at 10A°. This peak will not shift or collapse upon solvation with ethylene glycol or heating the mineral at 500° C.

Kaolinite: Kaolinite is known for low plasticity and shrinkage and swelling properties. Its restricted surface area limits the adsorption capacity for cations. The specific surface area is approximately 7-30 m^2/g. The presence of kaolinite can be identified by a basal (001) d spacing of 7.14 A° X-ray diffraction, and by a second order 3.57 A° diffraction in oriented samples. These diffraction peaks will disappear after heating the kaolinite mineral to 500-550° C.

4.2.3.3 Mineral Composition of the Sediments of Study Area

Analysis of sediment sample from Gomukh revealed that the silt component is dominated by smectite (dioctahedral) followed by vermiculite, chlorite, mica, kaolinite, quartz and feldspar, whereas the total clay component is dominated by vermiculite (dioctahedral) followed by smectite, mica, kaolinite (trioctahedral), chlorite, quartz (trioctahedral) and feldspar (trioctahedral).

Samples collected from Gangotri showed mica (dioctahedral) as the dominant mineral in silt followed by smectite, vermiculite, kaolinite, quartz and feldspar, whereas clay components are dominated by vermiculite (dioctahedral) followed by smectite, mica, kaolinite, quartz (trioctahedral) and feldspar (trioctahedral). Silt component from Uttarkashi is dominated by smectite (dioctahedral) followed by chlorite, vermiculite, kaolinite (trioctahedral), mica, quartz and feldspar, whereas the

clay component is dominated by smectite (dioctahedral), followed by vermiculite, chlorite, mica, quartz (trioctahedral) and feldspar (trioctahedral).

Tehri (d/s of Bhagirathi) sample showed smectite (dioctahedral) as the dominant mineral followed by vermiculite, chlorite, mica, kaolinite (trioctahedral), quartz and feldspar in silt components, whereas the clay portion is dominated by smectite (dioctahedral), followed by vermiculite, mica, kaolinite (trioctahedral), quartz (trioctahedral) and feldspar (trioctahedral).

Sample collected from Rishikesh is dominated by smectite (dioctahedral) followed by vermiculite, chlorite, mica, kaolinite (trioctahedral), quartz and feldspar silt components where as the total clay components is dominated by smectite (dioctahedral), followed by vermiculite, mica, chlorite, quartz (trioctahedral) and feldspar (trioctahedral). Subramanian (1979) studied the chemical and suspended characteristics of most of the major Indian rivers including that of Ganga. He observed that the kaolinite, illite and chlorite are the main constituents carried in suspension particulate of the Ganga and Brahmaputra, while the Peninsular rivers eg. Krishna and Godavari carry high amount of montmorillonite alongwith very insignificant amount of mixed clays. Literature reveals that cation exchange capacity (CEC) for Sm and Vm is very high and lies in the range of 60-100 meq/100gm and 80-150 meq/100gm respectively. For kaolinite and chlorite, the values are 2-8meq/100gm and 10-40meq/100gm respectively. The cation exchange property is due to displacement of Si^{4+} by Al^{3+} and Al^{3+} by Mg^{2+} in their lattice, which causes charge deficiency in the lattice that finally results in migration of cations from water to sediments.

4.2.4 Particle Size Analysis

The particle size analysis of sediments (Table 77) showed that the clay and silt fractions constituted around 15% of the total sediments. It was thus, necessary to evaluate whether sand also got adsorption or ion exchange property.

Table 77: Particle Size Distribution of Sediments of River Bhagirathi/ Ganga

Sampling Station	Sand (2000-50 μm)	Silt (50-2 μm)	Clay (<2 μm)
Gomukh	84.5	12.6	2.8
Gangotri (downstream)	94.8	3.8	1.4
Uttarkashi (downstream)	88.5	9.1	2.4
Tehri (downstream) Bhagirathi	90.9	1.8	7.3
Rishikesh (downstream)	88.4	9.6	2.0

4.2.5 Bacteriological Quality

Sediment samples from Bhagirathi river were collected from Gomukh, Gangotri, Uttarkashi, Upstream of Tehri dam, downstream of Tehri dam, Devprayag before confluence with Alaknanda river. Ganga river sediments were collected at Devprayag after confluence with Alaknanda river and also at Rishikesh. All collected samples were analyzed for indicator bacteria, i.e. total coliforms, faecal coliforms, *E. coli* and faecal streptococci.

Sediment samples collected from Gomukh to Rishikesh were found to contain total coliforms. The density of coliforms was found to increase as the river flows downwards to Devprayag. Alaknanda river sediment was found to contain the total coliform count in the range of 84 to 4782 CFU/g. TC count in sediments collected from Ganga river after confluence at Devprayag was observed to be in the range of 27 to 651 CFU/g (Table 66). Further downstream at Rishikesh, TC count of sediment was found to be in the range of 812 to 11500 CFU/g. The bacteriological characteristics of river and Tehri reservoir sediments are presented in **Tables 78** and **79.**

Table 78: Bacteriological quality of Sediments at different sampling points of River/Tributaries in the study area

Type of Bacteria (CFU/g)	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
29-31 May, 2008														
Total Coliforms	-	-	238	1000	2272	250	40	370	250	760	4782	NS	1750	11500
Fecal Coliforms	-	-	119	606	400	76	26	250	125	370	2170	NS	750	9000
E. coli	-	-	33	18	283	23	6	85	160	124	504	NS	165	4000
Fecal Streptococci	-	-	100	480	-	-	-	-	-	-	-	NS	10	100
25-30 September, 2008														
Total Coliforms	-	-	1	182	426	5324	18	25	32	114	84	27	262	1619
Fecal Coliforms	-	-	-	94	213	3376	18	19	25	51	78	13	212	1175
E. coli	-	-	-	24	80	2727	9	25	13	38	52	7	144	900
Fecal Streptococci	-	-	-	-	-	603	-	-	5	13	26	20	55	769
13-16 January, 2009														
Total Coliforms	NS	NS	NS	35	180	26	27	62	72	NS	NS	651	238	812
Fecal Coliforms	NS	NS	NS	18	120	22	9	44	50	NS	NS	538	200	650
E. coli	NS	NS	NS	13	100	19	9	25	13	NS	NS	135	120	300
Fecal Streptococci	NS	NS	NS	33	35	-	-	-	9	NS	NS	81	50	787
17-23 May, 2009														
Total Coliforms	NS	51	291	133	329	325	73	50	13	43	NS	173	475	962
Fecal Coliforms	NS	38	44	60	206	84	64	38	13	24	NS	120	225	284
E. coli	NS	13	6	80	129	78	64	13	6	20	NS	107	219	194
Fecal Streptococci	NS	338	342	243	454	75	58	128	15	-	NS	139	200	338
22-30 Oct, 2010														
Total Coliforms	NS	-	112	1152	1228	6624	116	920	642	260	134	128	1468	2148
Fecal Coliforms	NS	-	34	94	223	4370	30	510	324	116	80	96	914	1280
E. coli	NS	-	12	78	94	2620	26	128	118	112	64	26	164	1200
Fecal Streptococci	NS	-	-	48	86	700	-	-	12	18	34	20	160	580

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

Table 79: Bacteriological quality of Sediments at different sampling points of Tehri reservoir

Type of Bacteria (CFU/g)	Sampling locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
29-31 May, 2008										
Total Coliforms	3892	21	18	5	5	1395	13877	368	14700	32
Fecal Coliforms	2122	10	12	2	4	193	3346	195	3908	20
E. coli	1976	10	-	2	-	39	2284	176	2610	15
Fecal Streptococci	-	-	-	-	-	-	170	66	108	-
25-30 September, 2008										
Total Coliforms	588	-	32	15	33	430	29	261	250	167
Fecal Coliforms	294	-	11	8	22	281	10	203	176	83
E. coli	98	-	11	8	10	263	10	109	92	58
Fecal Streptococci	-	-	-	-	-	-	8	-	-	-
13-16 January, 2009										
Total Coliforms	59	NS	NS	NS	89	35	117	43	130	83
Fecal Coliforms	39	NS	NS	NS	78	26	88	28	83	60
E. coli	10	NS	NS	NS	22	26	69	15	37	58
Fecal Streptococci	16	NS	NS	NS	80	-	22	-	7	27
17-23 May, 2009										
Total Coliforms	60	57	43	606	378	35	60	29	130	250
Fecal Coliforms	59	47	32	291	356	9	29	16	56	142
E. coli	49	42	21	76	333	9	10	14	55	63
Fecal Streptococci	12	128	9	379	1529	-	8	3	148	760
22-25 Oct, 2010										
Total Coliforms	NS	64	38	16	32	580	628	180	242	166
Fecal Coliforms	NS	18	34	12	12	330	160	124	160	68
E. coli	NS	10	26	6	10	240	116	110	86	48
Fecal Streptococci	NS	-	-	-	-	-	10	-	-	-

R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

The river sediment samples from Badrinath, Mandakini (before confluence at Rudraprayag) and Alaknanda (after confluence at Rudraprayag) were also collected for analysis during two seasons *viz.*, May, 2009 and Oct, 2010. The range of total coliform, fecal coliform, E.coli and fecal streptococci in Badrinath were 8-80, 20-40, 8-30 and 109 CFU/g respectively. Similarly, in Mandakini (before confluence at Rudraprayag) and Alaknanda (after confluence at Rudraprayag), range of total coliform, fecal coliform, E.coli and fecal streptococci were 312-1120, 183-480, 175-460 and 88 CFU//g and 80-1034, 53-368, 40-280 and 21 CFU//g respectively **(Tables 80 & 81)**

4.2.6 Detection of Coliphages

Sediment samples were collected from Ganga river at different locations i.e. Gomukh, Gangotri, Uttarkashi, upstream and downstream of Tehri dam, Devprayag before & after confluence with Alaknanda river and also at Rishikesh. Twenty percent suspension of the sediment was prepared in 3% BEMB solution of pH 7.1 and stirred for 30 minutes. Supernatant was collected after centrifugation at 3000 rpm and made free from bacterial contamination by filtering through 0.45µm membrane filter and was assayed for coliphages by plaque assay method using different types of *E. coli* host cells. The counts of coliphages detected in Ganga river sediment samples at different locations are presented in **Tables 82 through 86**. The sediments analyzed for the coliphages in different periods indicate that most of the phages were lytic for bacterial hosts under consideration. It has been observed that different types of coliphages were present in Ganga river sediments and could be detected by using different types of susceptible host cells. Thirty two different host of *E. coli*, isolated from water and sediment samples of rivers in the study area, were used to detect coliphages.

The coliphages recorded in Tehri reservoir sediments are presented in **Tables 87 through 91.** The results observed for coliphages in reservoir indicate that most of the phages could not be detected in summer 2008, as these were possibly in lysogenic condition. However, during other seasons, including in summer 2009, phages were recorded in innumerous number indicating lytic activity.

The river water and sediment samples from Badrinath, Mandakini (before confluence at Rudraprayag) and Alaknanda (after confluence at Rudraprayag) were

Table 80: Bacteriological quality of River sediments (17-23 May 2009)

Sr. No.	Sampling Location	TC	FC	EC	FS
		CFU/g			
1	Badrinath	80	40	30	109
2	Mandakini (BC) at Rudraprayag	312	183	175	88
3	Alaknanda (AC) at Rudraprayag	80	53	40	21

TC: Total coliforms; FC: Fecal coliforms; EC: E. *coli*; FS: Fecal *Streptococci;*

Table 81: Bacteriological quality of River Sediments (22-30 October 2010)

Sr. No.	Sampling Location	TC	FC	EC	FS
		CFU/g			
1	Badrinath	38	20	8	-
2	Mandakini (BC) at Rudraprayag	1120	480	460	-
3	Alaknanda (AC) at Rudraprayag	1034	368	280	-

TC: Total coliforms; FC: Fecal coliforms; EC: *E. coli*; FS: Fecal *Streptococci*

Table 82: Detection of Coliphages in river Sediments of Bhagirathi/Ganga (29-31 May, 2008)

Coliphages (PFU/g) in strains of EC	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
01	-	-	-	-	-	-	-	274	-	-	-	NS	-	-
02	-	-	-	-	8	-	-	4	20	-	-	NS	-	20
03	-	-	267	-	-	-	-	1947	-	-	-	NS	-	-
04	-	-	-	-	-	-	-	3	-	-	-	NS	-	-
05	-	-	520	1600	2240	-	-	1467	-	-	-	NS	-	-
06	-	-	-	-	-	-	-	-	-	-	-	NS	-	-
07	-	-	-	-	-	-	-	-	-	-	-	NS	-	-
08	-	-	210	-	-	-	-	-	-	-	-	NS	-	-
09	-	-	-	-	-	-	-	-	-	-	-	NS	-	-
10	-	-	786	-	5632	-	-	486	-	-	-	NS	-	-
11	-	-	717	-	5028	-	-	1000	-	-	-	NS	-	8
12	-	-	-	-	-	-	-	-	-	-	-	NS	-	-
13	-	-	495	-	840	-	-	560	-	-	-	NS	-	-
14	-	-	-	-	32	-	-	-	-	-	-	NS	-	-
15	-	-	888	-	-	-	-	1600	-	-	-	NS	10	40

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

contd...

Table 82 (contd...)

Coliphages (PFU/g) in strains of EC	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
16	-	-	-	-	-	-	-	1173	-	-	-	NS	-	-
17	-	-	-	-	-	-	-	-	-	-	-	NS	-	36
18	-	-	368	-	-	-	-	2306	3500	-	-	NS	46	2350
19	-	-	-	-	-	-	-	3	-	-	-	NS	-	60
20	-	-	5079	650	6400	-	-	1014	980	-	-	NS	-	-
21	-	-	-	-	-	-	-	-	-	-	-	NS	-	-
22	-	-	178	-	-	-	-	532	-	-	-	NS	-	-
23	-	-	-	-	-	-	-	-	-	-	-	NS	-	-
24	-	-	-	-	-	-	-	3520	-	-	-	NS	-	-
25	-	-	-	-	-	-	-	-	-	-	-	NS	-	-
26	-	-	-	-	-	-	-	-	-	-	-	NS	-	-
27	-	-	-	-	-	-	-	-	-	-	-	NS	-	-
28	-	-	-	-	-	-	-	10	-	-	-	NS	-	-
29	-	-	-	-	-	-	-	-	-	-	-	NS	-	-
30	-	-	-	-	-	-	-	-	-	-	-	NS	-	-
31	-	-	-	-	-	-	-	-	-	-	-	NS	-	-
32	-	-	-	-	1540	-	-	-	-	-	-	NS	-	-

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

Table 83: Detection of Coliphages in river Sediments of Bhagirathi/Ganga (25-30 September, 2008)

Coliphages (PFU/g) in strains of EC	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
01	-	-	8	-	720	-	-	440	470	-	-	577	800	1090
02	-	-	-	-	-	-	-	105	425	3	405	-	-	-
03	-	-	-	-	-	-	-	-	-	5	530	-	-	-
04	-	-	-	-	-	-	-	-	-	-	-	-	-	-
05	-	-	-	-	-	-	-	-	-	-	-	-	-	-
06	-	-	-	-	-	-	-	-	-	-	-	-	-	-
07	-	-	-	-	-	-	-	-	-	-	-	-	-	-
08	-	-	-	-	-	-	-	-	-	-	-	-	-	-
09	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	91	-	2493	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	88	3	73	-	-	-
14	-	-	142	-	2330	-	-	-	-	-	873	-	-	86
15	-	-	192	-	-	-	-	1888	250	-	-	-	-	-

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

contd...

Table 83 (contd...)

Coliphages (PFU/g) in strains of EC	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
16	-	-	532	-	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	363	-	-	239	-	-	-
19	-	-	-	-	-	-	-	-	150	3	-	-	-	-
20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-	-	374	-	-	-	-
26	-	-	-	-	-	-	7	-	-	-	-	-	90	370
27	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	1002	-	182	-	-	3	-	-	287	1368
31	-	-	-	-	2373	-	-	-	-	314	-	-	252	276
32	-	-	-	-	1899	-	-	-	-	-	-	-	-	-

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

Table 84: Detection of Coliphages in river Sediments of Bhagirathi/Ganga (13-16 January, 2009)

Coliphages (PFU/ g) in strains of EC	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
01	NS	NS	NS	555	768	-	807	-	700	NS	NS	-	400	919
02	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	-
03	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	618	-
04	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	-
05	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	-
06	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	-
07	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	-
08	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	-
09	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	185	-
10	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	-
11	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	-
12	NS	NS	NS	-	-	-	-	-	750	NS	NS	-	-	1362
13	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	-
14	NS	NS	NS	-	213	-	-	-	712	NS	NS	-	1018	970
15	NS	NS	NS	732	181	-	14	-	1150	NS	NS	-	-	715

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

contd...

Table 84 (contd...)

Coliphages (PFU/ g) in strains of EC	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
16	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	749
17	NS	NS	NS	-	-	-	-	-	-	NS	NS	143	-	-
18	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	-
19	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	-
20	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	-
21	NS	NS	NS	-	-	-	-	-	400	NS	NS	-	-	-
22	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	-
23	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	-
24	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	-
25	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	-
26	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	-
27	NS	NS	NS	-	-	587	-	-	-	NS	NS	-	-	-
28	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	-
29	NS	NS	NS	-	-	-	-	-	-	NS	NS	-	-	-
30	NS	NS	NS	-	-	-	-	-	980	NS	NS	-	-	442
31	NS	NS	NS	-	-	-	-	-	950	NS	NS	-	-	919
32	NS	NS	NS	-	-	797	-	-	820	NS	NS	557	-	-

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

Table 85: Detection of Coliphages in river Sediments of Bhagirathi/Ganga (17-23 May, 2009)

Coliphages (PFU/ g) in strains of EC	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
01	NS	-	4256	-	5215	1089	-	-	2850	152	NS	533	1028	1187
02	NS	-	-	-	-	-	-	-	-	-	NS	-	-	-
03	NS	-	-	1333	-	-	-	-	-	96	NS	-	-	-
04	NS	-	-	-	-	-	-	-	-	-	NS	-	-	-
05	NS	-	-	-	-	-	-	-	-	-	NS	-	-	-
06	NS	-	-	-	-	-	-	-	-	-	NS	-	-	-
07	NS	-	-	-	-	-	-	-	-	-	NS	-	-	-
08	NS	-	-	2029	-	-	945	4500	-	-	NS	-	-	-
09	NS	-	-	-	-	-	-	-	-	-	NS	-	-	-
10	NS	-	-	-	-	-	-	-	-	-	NS	-	-	-
11	NS	-	-	-	-	-	-	-	-	-	NS	-	-	-
12	NS	-	-	-	7088	-	-	-	-	-	NS	-	-	-
13	NS	-	-	-	-	-	-	-	-	-	NS	-	-	1762
14	NS	1020	-	1519	2960	-	-	475	-	-	NS	-	-	1637
15	NS	2730	7746	-	200	2202	-	8000	336	6250	NS	-	2028	2100

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

contd...

Table 85 (contd...)

Coliphages (PFU/ g) in strains of EC	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
16	NS	-	886	5329	-	-	-	-	-	-	NS	5840	-	-
17	NS	-	-	-	-	-	-	-	-	-	NS	-	-	-
18	NS	564	-	-	-	-	248	-	-	-	NS	-	-	-
19	NS	-	1670	-	-	-	-	-	-	-	NS	-	-	-
20	NS	-	-	-	-	-	-	-	-	-	NS	-	-	-
21	NS	-	-	-	-	-	-	-	-	-	NS	-	-	-
22	NS	-	-	-	-	-	-	1937	-	4303	NS	-	5763	-
23	NS	-	-	-	-	-	-	-	-	-	NS	-	-	-
24	NS	-	-	-	-	-	-	-	-	-	NS	-	-	-
25	NS	-	-	-	-	-	-	-	-	-	NS	-	-	-
26	NS	2436	-	-	93	-	-	7825	-	5189	NS	9333	-	19250
27	NS	-	-	-	-	-	-	-	-	-	NS	-	-	-
28	NS	-	-	-	15200	-	-	-	-	-	NS	-	-	112
29	NS	-	-	-	-	-	-	-	-	-	NS	-	-	-
30	NS	-	3063	-	-	4000	-	387	-	1772	NS	-	3592	9275
31	NS	-	-	-	-	3493	-	562	-	-	NS	533	-	7100
32	NS	-	-	-	-	-	-	-	-	-	NS	-	400	6475

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

Table 86: Detection of Coliphages in river Sediments of Bhagirathi/Ganga (22-30 Oct, 2010)

Coliphages (PFU/ g) in strains of EC	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
01	NS	-	12	-	640	-	-	340	1090	-	-	-	590	3200
02	NS	-	-	-	-	-	-	123	654	12	684	-	-	-
03	NS	-	-	-	-	-	-	-	-	14	446	-	-	-
04	NS	-	-	-	-	-	-	-	-	-	-	-	-	-
05	NS	-	-	-	-	-	-	-	-	-	-	-	-	-
06	NS	-	-	-	-	-	-	-	-	-	-	-	-	-
07	NS	-	-	-	-	-	-	-	-	-	-	-	-	-
08	NS	-	-	-	-	-	-	-	-	-	-	-	-	-
09	NS	-	-	-	-	-	-	-	-	-	-	-	-	-
10	NS	-	-	-	-	-	-	-	-	-	-	-	-	-
11	NS	-	-	-	-	-	-	-	-	-	-	-	-	-
12	NS	-	109	-	2674	-	-	-	-	-	-	-	-	-
13	NS	-	-	-	-	-	-	-	24	66	98	-	-	560
14	NS	-	156	-	2770	-	-	-	-	-	1698	-	-	-
15	NS	-	203	-	-	-	-	1978	208	-	-	-	-	-

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

contd...

Table 86 (contd...)

Coliphages (PFU/ g) in strains of EC	Sampling Locations													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
16	NS	-	678	-	-	-	-	-	-	-	-	-	-	-
17	NS	-	-	-	-	-	-	435	-	-	-	-	-	-
18	NS	-	-	-	-	-	-	-	-	-	341	-	-	-
19	NS	-	-	-	-	-	-	-	164	09	-	-	-	-
20	NS	-	-	-	-	-	-	-	-	-	-	-	-	-
21	NS	-	-	-	-	-	-	-	-	-	-	-	-	-
22	NS	-	-	-	-	-	-	-	-	-	-	-	-	-
23	NS	-	-	-	-	-	-	-	-	-	-	-	-	-
24	NS	-	-	-	-	-	-	-	-	-	-	-	-	-
25	NS	-	-	-	-	-	-	-	-	380	-	-	-	-
26	NS	-	-	-	-	-	16	-	-	-	-	-	67	-
27	NS	-	-	-	-	-	-	-	-	-	-	-	-	-
28	NS	-	-	-	-	-	-	-	-	-	-	-	-	-
29	NS	-	-	-	-	-	-	-	-	-	-	-	-	-
30	NS	-	-	-	1100	-	224	-	-	23	-	-	980	-
31	NS	-	-	-	2676	-	-	-	-	234	-	-	668	460
32	NS	-	-	-	2300	-	-	-	-	-	-	-	-	580

1. Gomukh; 2. Gangotri upstream; 3. Gangotri downstream; 4. Uttarkashi upstream; 5. Uttarkashi downstream; 6. Tehri upstream; 7. Bhilangana upstream; 8. Tehri downstream 01; 9. Tehri downstream 02; 10. Bhagirathi upstream (at Devprayag); 11. Alaknanda upstream (at Devprayag); 12. Devprayag downstream; 13. Rishikesh upstream; 14. Rishikesh downstream.

Table 87: Detection of Coliphages in Sediments of Tehri Reservoir (29-31 May, 2008)

Coliphages (PFU/ g) in strains of EC	Sampling Locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
01	-	-	-	-	-	264	28	-	-	-
02	-	-	-	-	-	-	-	-	-	-
03	-	-	-	-	-	-	-	-	-	-
04	-	-	-	-	-	-	-	-	-	-
05	-	-	-	-	-	-	-	-	-	-
06	-	-	-	-	-	-	-	-	-	-
07	-	-	-	-	-	-	-	-	-	-
08	-	-	-	-	-	-	-	-	-	-
09	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-
14	-	78	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-

R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

contd...

Table 87 (contd...)

Coliphages (PFU/ g) in strains of EC	Sampling Locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
16	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	113	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	62	-	-	-	-
21	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-
28	-	-	-	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-
31	-	-	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-	-	-	-

R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

Table 88: Detection of Coliphages in Sediments of Tehri Reservoir (25-30 September, 2008)

Coliphages (PFU/ g) in strains of EC	Sampling Locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
01	-	750	21	-	-	2104	246	-	2592	4866
02	-	981	-	-	1297	-	-	-	33	-
03	-	-	-	-	498	-	-	-	30	-
04	-	-	-	-	-	-	-	-	-	-
05	-	-	-	-	-	-	-	-	-	-
06	-	-	-	-	-	-	-	-	-	-
07	-	-	-	-	-	-	-	-	-	-
08	-	-	-	-	-	-	-	-	-	-
09	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	460	-	-	-
12	-	-	-	-	-	-	-	-	1333	3000
13	-	-	-	-	506	-	-	-	-	-
14	-	-	-	79	-	-	-	3461	1289	2987
15	-	-	-	2284	-	-	-	142	-	3413

R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

contd...

1722

Table 88 (contd...)

Coliphages (PFU/ g) In strains of EC	Sampling Locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
16	-	-	170	2533	-	389	-	-	-	5133
17	-	-	-	-	-	-	-	-	-	-
18	-	-	-	9	-	-	-	-	-	-
19	-	-	-	-	480	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	172	-	-	-	-
25	-	-	244	-	435	-	1224	-	19	-
26	-	-	140	-	-	-	-	-	96	-
27	-	-	-	-	-	-	-	-	-	-
28	-	-	-	-	-	-	2200	-	-	-
29	-	-	-	-	-	-	-	-	-	-
30	39	-	-	-	-	133	-	3365	-	2920
31	165	-	160	-	-	523	-	3913	-	3733
32	-	1396	258	-	-	-	-	2782	-	467

R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

Table 89: Detection of Coliphages in Sediments of Tehri Reservoir (13-16 January, 2009)

Coliphages (PFU/ g) in strains of EC	Sampling Locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
01	-	NS	NS	NS	2542	3410	141	1261	148	134
02	-	NS	NS	NS	-	-	-	-	-	-
03	-	NS	NS	NS	-	-	-	639	-	-
04	-	NS	NS	NS	-	-	-	389	-	-
05	-	NS	NS	NS	-	-	-	-357	-	-
06	-	NS	NS	NS	-	-	-	-	-	-
07	-	NS	NS	NS	-	-	-	-	-	-
08	-	NS	NS	NS	-	-	-	-	-	-
09	-	NS	NS	NS	-	618	-	1145	-	-
10	-	NS	NS	NS	-	688	-	655	-	-
11	-	NS	NS	NS	-	512	-	-	-	-
12	-	NS	NS	NS	3982	470	-	414	122	-
13	-	NS	NS	NS	-	-	-	1096	-	-
14	1603	NS	NS	NS	3128	1726	-	307	133	3
15	2077	NS	NS	NS	76	288	-	-	211	7

R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

Table 89 (contd...)

Coliphages (PFU/ g) in strains of EC	Sampling Locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
16	1176	NS	NS	NS	986	982	-	-	-	-
17	-	NS	NS	NS	-	-	-	1207	-	-
18	-	NS	NS	NS	9	422	-	-	167	-
19	-	NS	NS	NS	-	-	-	-	-	-
20	-	NS	NS	NS	-	-	-	-	-	-
21	-	NS	NS	NS	-	3396	-	359	-	-
22	-	NS	NS	NS	-	2835	-	-	-	-
23	-	NS	NS	NS	36	653	-	-	-	-
24	-	NS	NS	NS	-	-	-	-	-	-
25	-	NS	NS	NS	-	-	-	-	-	-
26	-	NS	NS	NS	-	-	-	-	-	-
27	-	NS	NS	NS	-	1319	-	-	-	-
28	-	NS	NS	NS	-	84	-	-	318	-
29	-	NS	NS	NS	-	-	-	-	-	-
30	-	NS	NS	NS	4472	2933	-	-	-	-
31	-	NS	NS	NS	4897	1193	-	197	593	-
32	1616	NS	NS	NS	3289	2919	-	136	318	-

R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

Table 90: Detection of Coliphages in Sediments of Tehri Reservoir (17-23 May, 2009)

Coliphages (PFU/ g) in strains of EC	Sampling Locations									
	R-001	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
01	1059	-	4510	-	-	4421	89	-	-	-
02	-	-	-	30	22	-	-	-	-	-
03	-	-	3915	151	-	491	1400	-	-	-
04	-	-	-	-	-	-	-	-	-	-
05	-	-	-	-	-	-	-	-	-	-
06	-	-	-	-	-	-	-	-	-	-
07	-	-	-	-	-	-	-	-	-	-
08	-	-	6617	-	-	1248	634	-	-	-
09	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-
12	-	-	-	76	-	12474	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-
14	-	-	2553	10849	-	-	3315	1766	-	-
15	8118	415	-	13151	4733	643	-	-	-	-

R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

Table 90 (contd...)

Coliphages (PFU/ g) in strains of EC	Sampling Locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
16	-	5283	-	-	355	-	5298	-	-	-
17	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-
19	-	-	1702	30	2466	-	294	-	-	-
20	-	-	-	15	-	-	-	-	-	-
21	-	-	5957	424	-	3263	-	-	-	-
22	-	-	-	6833	-	2245	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-	-	-
26	-	-	11489	258	-	-	3333	-	-	-
27	-	-	-	-	-	-	-	-	-	-
28	-	-	-	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-	-	-	-
30	-	-	8936	10606	668	10606	-	7565	4000	8407
31	-	-	-	970	-	-	-	-	888	-
32	-	-	-	4720	2932	9772	8313	-	-	-

R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

Table 91: Detection of Coliphages in Sediments of Tehri Reservoir (22-30 Oct, 2010)

Coliphages (PFU/ g) in strains of EC	Sampling Locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
01	NS	880	56	-	-	3012	342	-	3220	3978
02	NS	573	-	-	1717	-	-	-	46	-
03	NS	-	-	-	3430	-	-	-	12	-
04	NS	-	-	-	-	-	-	-	-	-
05	NS	-	-	-	-	-	-	-	-	-
06	NS	-	-	-	-	-	-	-	-	-
07	NS	-	-	-	-	-	-	-	-	-
08	NS	-	-	-	-	-	-	-	-	-
09	NS	-	-	-	-	-	-	-	-	-
10	NS	-	-	-	-	-	-	-	-	-
11	NS	-	-	-	-	-	438	-	-	-
12	NS	-	-	-	-	-	-	-	1560	4890
13	NS	-	-	-	667	-	-	-	-	-
14	NS	-	-	67	-	-	-	2980	1672	2317
15	NS	-	-	2367	-	-	-	1267	-	2334

R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

contd...

Table 91 (contd...)

Coliphages (PFU/ g) in strains of EC	Sampling Locations									
	R-01	R-02	R-03	R-04	R-05	R-06	R-07	R-08	R-09	R-10
16	NS	-	245	3423	-	235	-	-	-	4987
17	NS	-	-	-	-	-	-	-	-	-
18	NS	-	-	12	-	-	-	-	-	-
19	NS	-	-	-	508	-	-	-	-	-
20	NS	-	-	-	-	-	-	-	-	-
21	NS	-	-	-	-	-	-	-	-	-
22	NS	-	-	-	-	-	-	-	-	-
23	NS	-	-	-	-	-	-	-	-	-
24	NS	-	-	-	-	231	-	-	-	-
25	NS	-	325	-	506	-	1056	-	08	-
26	NS	-	215	-	-	-	-	-	24	-
27	NS	-	-	-	-	-	-	-	-	-
28	NS	-	-	-	-	-	2380	-	-	-
29	NS	-	-	-	-	-	-	-	-	-
30	NS	-	-	-	-	234	-	2390	-	3090
31	NS	-	240	-	-	567	-	4390	-	3980
32	NS	1280	306	-	-	-	-	2343	-	780

R-01. Near Intake point;R-0 2. Near Raj Mahal; R-03. Other side of the bank; R-04. Opposite of koti; R-05. Near Koti; R-06. Maldeval; R-07. Dobra; R-08.Uppu; R-09. Motna; R-10. Bhaldiana

Table 92: Detection of Coliphages in river waters (17-23 May 2009)

Sample Locations	EC (PFU/l)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Badrinath	640	-	-	-	-	-	-	-	-	-	-	-	-	250	-	-
Mandakini (BC) at Rudraprayag	440	-	-	-	-	-	-	1440	-	-	-	1760	-	1240	2800	6720
Alaknanda (A C) at Rudraprayag	7360	-	-	-	-	-	-	1080	-	-	-	-	-	1560	1220	560

PFU: plaque forming unit;

Sample Locations	EC (PFU/l)															
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Badrinath	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mandakini (BC) at Rudraprayag	-	-	-	1480	580	-	-	-	-	3880	-	-	-	3200	-	-
Alaknanda (A C) at Rudraprayag	-	-	-	1740	4000	5440	-	-	-	3360	-	-	-	1340	520	-

PFU: plaque forming unit;

Table 93: Detection of Coliphages in river waters (22-25 October 2010)

Sample Locations	Phage (PFU/l) detected against Hosts															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Badrinath	-	236	-	-	40	-	-	-	-	-	34	60	-	-	-	-
Mandakini (BC) at Rudraprayag	214	222	-	-	-	-	-	-	-	-	-	342	-	-	-	-
Alaknanda (AC) at Rudraprayag	210	162	-	-	886	-	-	-	-	-	42	660	-	2364	-	-

Sample Locations	Phage (PFU/l) detected against Hosts															
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Badrinath	-	34	-	6	-	-	-	-	-	-	-	-	-	16	54	24
Mandakini (BC) at Rudraprayag	-	560	-	48	-	-	-	-	684	-	-	-	-	9	1800	58
Alaknanda (AC) at Rudraprayag	-	44	-	80	-	-	-	-	620	12	-	-	-	34	2480	-

PFU: plaque forming unit;

Table 94: Detection of Coliphages in Ganga River sediments (17-23 May 2009)

Sample Locations	Phage (PFU/g) detected against Hosts															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Badrinath	5585	-	-	-	-	-	-	-	-	-	-	-	1637	-	-	-
Mandakini (BC) at Rudraprayag	7171	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10228
Alaknanda (AC) at Rudraprayag	4763	-	-	-	-	-	-	6658	-	-	-	-	2065	-	-	5316

PFU: plaque forming unit;

Sample Locations	Phage (PFU/g) detected against Hosts															
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Badrinath	-	-	-	-	-	-	-	-	-	-	-	-	-	5268	-	609
Mandakini (BC) at Rudraprayag	-	-	-	-	-	742	-	-	-	-	-	-	-	-	5514	-
Alaknanda (AC) at Rudraprayag	-	-	1210	-	2138	1184	-	-	-	-	-	-	-	-	947	8842

Table 95: Detection of Coliphages in River Sediments (22-30 October 2010)

Sample Locations	Phage (PFU/g) detected against Hosts															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Badrinath	-	216	-	-	32	-	-	-	-	-	14	40	-	-	-	-
Mandakini (BC) at Rudraprayag	321	168	-	-	-	-	-	-	-	-	-	452	-	-	-	-
Alaknanda (AC) at Rudraprayag	380	273	-	-	968	-	-	-	-	-	342	560	-	2650	-	-

Sample Locations	Phage (PFU/g) detected against Hosts															
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Badrinath	-	23	-	4	-	-	-	-	-	-	-	-	-	9	23	45
Mandakini (BC) at Rudraprayag	-	480	-	34	-	-	-	-	870	-	-	-	-	-	1680	49
Alaknanda (AC) at Rudraprayag	-	42	-	78	-	-	-	-	670	34	-	-	-	23	3060	-

PFU: plaque forming unit;

collected for analysis for two seasons *viz.*, May 2009 and Oct 2010. The counts of coliphages detected in river water and sediment samples at three locations are presented in **Tables 92 through 95.** The recorded results amongst the two seasons indicate that the presence of coliphages in water as well as sediments were comparable. This supports that there is homogeneous mixing of water and sediment due to turbulence in this region.

4.3 Radium Equivalent Analysis

Five sediment samples each from rivers Bhagirathi/ Ganga, and water bodies around Nagpur were analyzed through Atomic Minerals Directorate for Exploration and Research, Department of Atomic Energy, Central Region, Nagpur. The concentrations of U_3O_8 (ppm), ThO_2 (ppm) and % K are shown in **Table 96.** It appears that the average levels of U_3O_8, ThO_2 and K are over 500, 275 and 150 percent respectively more in Bhagirathi/ Ganga sediments than those collected in Nagpur (Central India).

Table 96: Gamma Ray Spectrophotometric Analysis of Sediments Samples (Analyzed by Atomic Minerals Directorate)

S.No.	Sampling Locations	U_3O_8 (Ra_{eq}) (ppm)*		ThO_2 (ppm)		%K	
		2003	2008	2003	2008	2003	2008
1	Gomukh	7.0	5.0	17.8	10.0	2.5	2.2
2	Gangotri Downstream	7.5	8.0	10.3	15.0	2.7	2.6
3	Uttarkashi Downstream	6.2	16.0	20.1	35.0	2.2	1.7
4	Devprayag Downstream		5.0		15.0		1.5
5	Alknanda Upstream (Devprayag)		5.0		14.0		1.5
6	Bhagirathi Upstream (Devprayag)		3.0		11.0		1.5
7	Tehri Upstream Bhagirathi		5.0		13.0		2.0
8	Tehri Downstream (Outlet of Powerhouse)	6.8	5.0	22.4	19.0	1.8	2.3
9	R 09 (N 30° 28' 09.9" E 078° 25' 22.3")		8.0		21.0		3.3
10	R 07 (N 30° 26' 29.6" E 078° 26' 12.0")		8.0		26.0		2.9
11	Rishikesh Downstream	5.5	3.0	17.6	11.0	1.9	1.3
12	Kanhan River, Nagpur	1.7	2.0	5.7	6.0	2.3	2.4
13	Ambazari Lake, Nagpur	<1.0	<1.0	4.4	3.0	0.7	<0.2
14	Pili River, Nagpur	1.2	<1.0	3.9	7.0	0.3	0.6
15	Kollar River, near Nagpur	1.5	1.0	4.6	2.0	0.2	0.2
16	Vena Dam, near Nagpur		<1.0		2.0		<0.2

* Radium equivalent

Based on a comprehensive study on the isotopes in the Ganga-Brahmaputra river system, Sarin et al. (1996) reported that the dissolved ^{238}U concentration in these river waters ranges between 0.44 and 8.32 µg/l, and it exhibits a positive correlation with major cations (Na + K + Mg + Ca). The $^{238}U/\Sigma$ Cations ratio in waters is very similar to that measured in the suspended sediments indicating congruent weathering of uranium and major cations. The regional variations observed in the $[^{234}U/^{238}U]$ activity ratio are consistent with the lithology of the drainage basins. The lowland tributaries (Chambal, Betwa, Ken, and Son), draining through the igneous and metamorphic rocks of the Deccan Traps and the Vindhyan-Bundelkhand Plateau, have $[^{234}U/^{238}U]$ ratio in the range 1.16 to 1.84. This range is significantly higher than the near equilibrium ratio (~1.05) observed in the highland rivers which drain through sedimentary terrains. The dissolved ^{226}Ra concentration ranges between 0.03 and 0.22 dpm/l. The striking feature of the radium isotopes data is the distinct difference in the ^{228}Ra and ^{226}Ra abundances between the highland and lowland rivers. The lowland waters are enriched in ^{228}Ra, while the highland waters contain more ^{226}Ra. This difference mainly results from the differences in their weathering regimes. The discharge-weighted mean concentration ^{238}U in the Ganga (at Patna) and in the Brahmaputra (at Goalpara) are 1.81 and 0.3 µg/l, respectively. The Ganga-Brahmaputra river system contributes the major source of dissolved uranium to the Bay of Bengal. These rivers transport annually about 1000 tons of uranium to their estuaries, about 10% of the estimated global supply of dissolved uranium to the oceans via rivers. The transport of uranium by these rivers far exceeds that of the Amazon although their water discharge is only about 20% of that of the Amazon. The high intensity of weathering of uranium in the Ganga-Brahmaputra River system can also be deduced from the $[^{232}Th/^{238}U]$ and $[^{230}Th/^{238}U]$ activity ratios measured in the suspended sediments. ^{230}Th is enriched by about 19% in the suspended sediments relative to its parent ^{238}U. The flux of excess ^{230}Th supplied to the Bay of Bengal via these river sediments is 980 x 1012 dpm/a and is about six times more than its in situ production from seawater in the entire Bay of Bengal.

Literature (Ghosh and Sharma, 1989) reveals that short-lived isotopes of radium are present in higher concentration (80.5 pci) in the Ganga water than other river (65.5 pci). High concentration of radium might play an important role in rapid killing of bacteria, possibly through the interaction of radiation with biological materials present in the Gang water, resulting in the formation of ionized host species (such as H^+, H_2O^-, e^-, e^+ etc.). These ionized particles react with protein and deactivate the enzymes, leading to inhibition of cell multiplication or otherwise damage the cell performance. In general, bacteria are relatively resistant to radiation, requiring 200-800 Gy for killing *E.coli*.

5.0 Self Preservation Capacity of River Bhagirathi / Ganga

For times immemorial, it is observed that Bhagirathi/ Ganga water possesses an unique self preservation capacity. A century ago, Hankin (1896) reported that the waters of the Ganges and Jamuna rivers in India had marked antibacterial action. Edward Twort (1915) and Felix d'Herelle (1917) independently reported isolating filterable entities capable of destroying bacterial cultures and of producing small cleared areas on bacterial lawns seemingly implying that discrete particles were involved. They were jointly given credit for the discovery. It was d'Herelle, a Canadian working at the Pasteur Institute in Paris, who gave them the name "bacteriophages". Several explanations for self purification were put forward, though none of those could justify this unique observation.

Quantification of U_3O_8, ThO_2 and percent K in sediment samples and comparison of these parameters with those present in other river sediment samples and freshwater lake sediment samples show that Bhagirathi/ Ganga sediments collected between Gomukh and Rishikesh are more radioactive than others. The comparative results of 2003 and 2009 are presented in Table 96.

Since suspended particles play a major role towards self preservation of Ganga water, it is, thus, necessitated to have certain levels of suspended solid in the water, downstream of Tehri dam, particularly after confluence with the Alaknanda river at Devprayag. Although about nine-tenth of the existing (31% at downstream of Tehri dam) sediment would be arrested at dam site, there would be ample sediment from the catchment in between Tehri and Devprayag, and also from Alaknanda river

to maintain the self preservation capacity of the Ganga river water during post construction phase of the dam. In order to maintain the self-preservation property of the Bhagirathi River water, a continuous flow, named as *Aviral Dhara*, from upstream of the dam to the downstream is additionally maintained.

6.0 Emission of Green House Gases from Tehri Reservoir

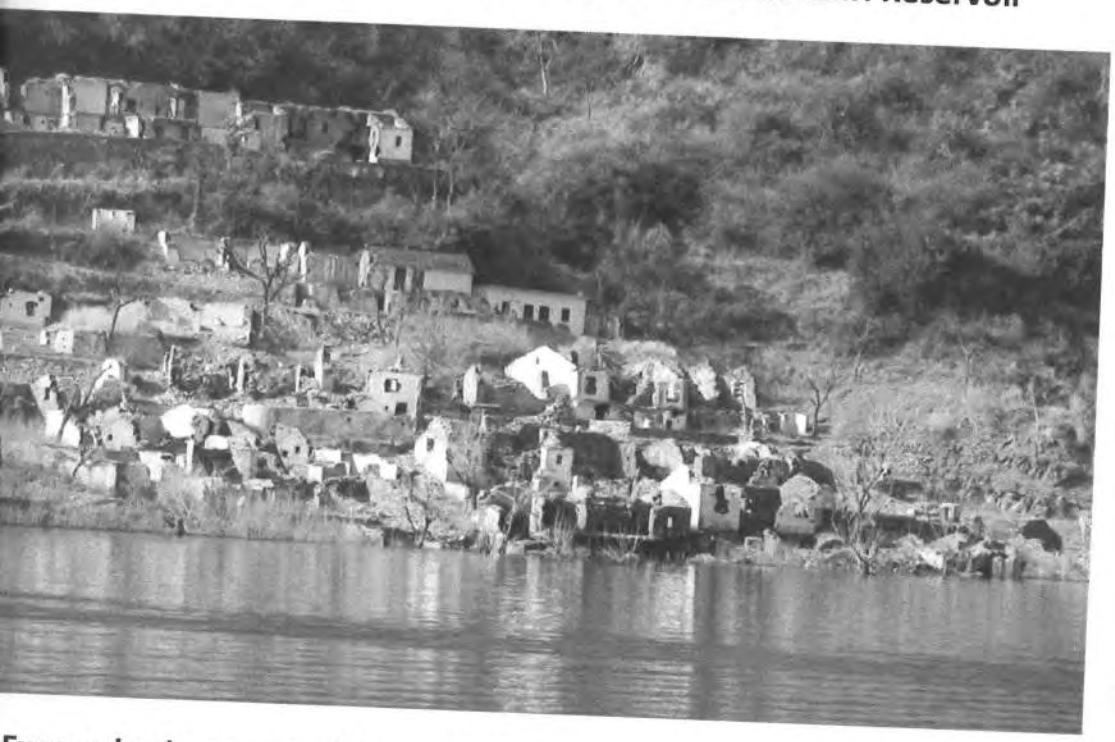
In September 2008 and May 2009, gas samples were collected from sixty four locations, near the periphery of the reservoir, and across the reservoir. The gas trapping domes, fabricated at NEERI, Nagpur, were installed **(Plate 12)** in the reservoir for a period of 24 hours. The accumulated gas in the domes were then transferred to Tedlar gas sampling bags (10 lit capacity) (patent no. 4915356, USA) and carried to Nagpur for Gas Chromatographic analysis. This methodology is adopted world wide. The data reveal that the emission levels of carbon dioxide and methane from the reservoir were 2550 and 24 mg per m^2 per day respectively. The data were compared with those of select tropical reservoirs, as reported elsewhere **(Table 97)**. However, the number of samples was too less in our case as compared to other reported results.

In general, the CO_2 and CH_4 emissions are expected to be more due to decomposition of submerged vegetations in the reservoir as well as incoming organic matters in the reservoir through storm waters. While filling the Tehri Reservoir infrastructures like villages, Rajmahal and vegetation were submerged, resulting in accumulation of organic matters in the water body **(Plates 13 through 15)**. It may be mentioned that present forty nine samples were collected in dam regions of the reservoir where both the factors might have had contributed for fairly lesser values as compared to some of the reservoirs abroad. Obviously, the emissions are dependant on several other factors like temperature, depth of the water column, age of the reservoir, methanogenic activity etc.

Table 97: Fluxes of CO_2 and CH_4 from the surface of tropical reservoirs of different sizes and ages

Location	Reservoir	Area (km^2)	Age (Yr)	Number of measurements	CO_2 ($mg/m^2/d$)	CH_4 ($mg/m^2/d$)	Reference
India	Tehri	42	5	64	2550	24	Present status
Panama	Gatun Lake	430	78	100	Not mentioned	537	Keller and Stallard 1994
Brazil	Curua-Ura	72	21-22	94	2900	65	Vincent et al. 2000
Brazil	Serra de Mese	1784	1	Not given	4000	80	Vincent et al. 2000
Brazil	Tucurui	2800	13	14	Not mentioned	75	Vincent et al. 2000
French Guyana	Petit Saut	300	1-2	10 (CO_2) 40 (CH_4)	4460	1140	Galy-Lacauk et al. 1997

2: Installation of gas dooms for collection of GHGs in Tehri Reservoir



Exposed sub merged villages during summer in Tehri Reservoir

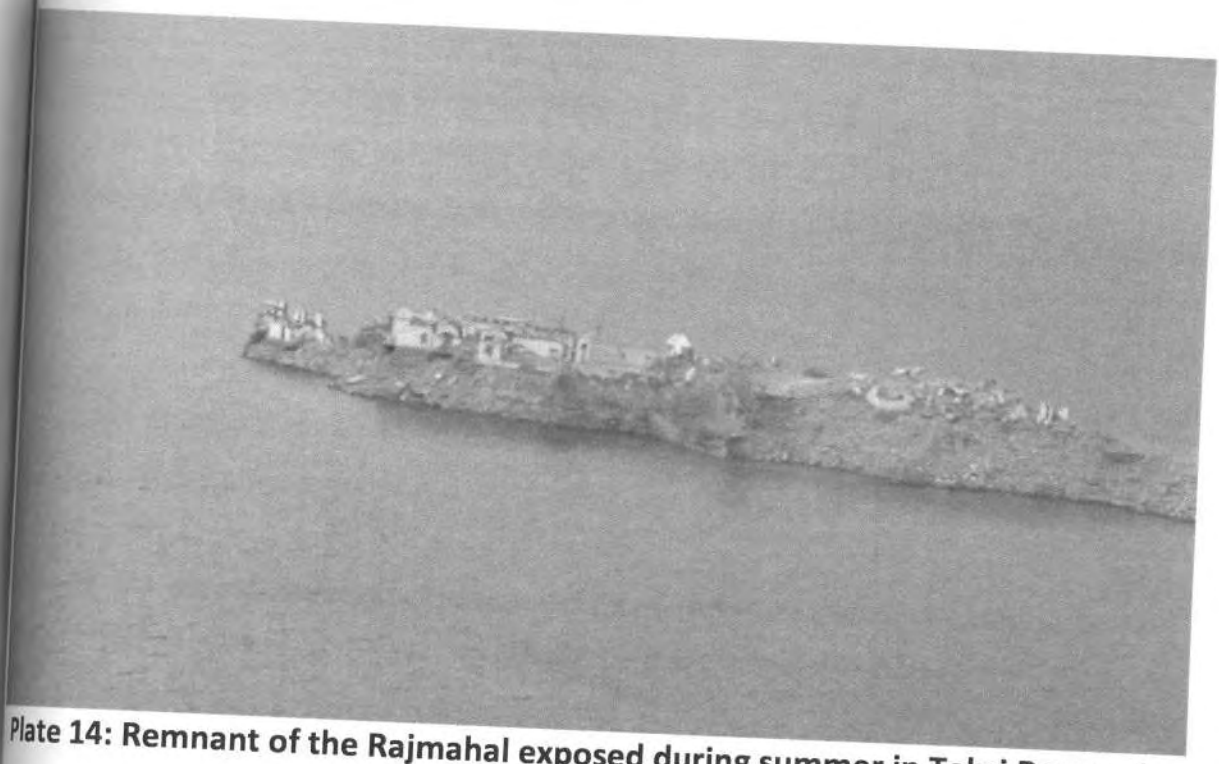


Plate 14: Remnant of the Rajmahal exposed during summer in Tehri Reservoir

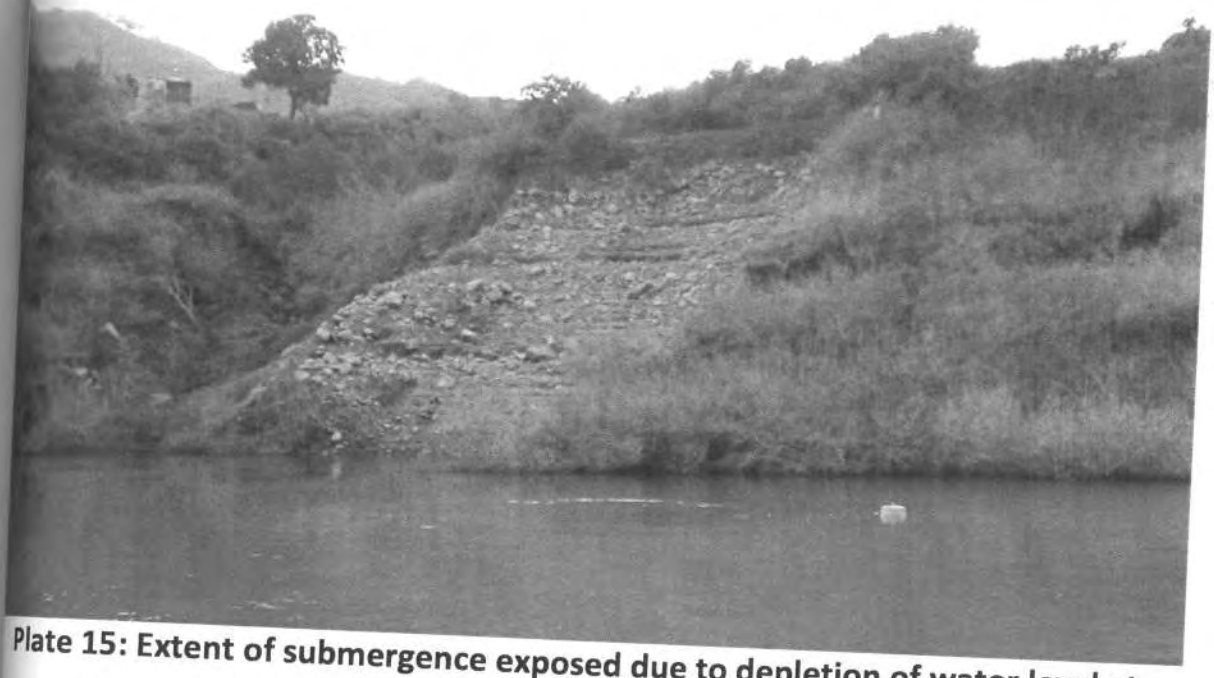


Plate 15: Extent of submergence exposed due to depletion of water level at Tehri dam in summer Season

7.0 Summary of Experimental Results

Physico-Chemical

- In the entire study area, the pH varied between 6.0 and 8.6
- In the study area, the DO varied between 5.16 and 16.8 mg/L
- The total suspended solids varied between 3.4 and 210.0 mg/L
- The total dissolved solids concentration varied between 7.0 and 218 mg/L
- The COD was found to be below 18.4 mg/L along the whole stretch of the study area.
- Total nitrogen in the study area varied between 0.6 and 4.6 mg/L
- Total phosphorus varied between 0.02 and 5.6 mg/L
- Heavy metal concentration was within the desirable limits of drinking water standards
- All the above physico-chemical parameters do not indicate any adverse condition prevailing in the rivers Bhagirathi/ Alaknanda/ Ganga.

Biological

- Water samples from Gomukh, Gangotri and Tehri dam upstream were devoid of phytoplankton
- Studies revealed that role of silt in removing the phytoplankton by settling is remote and nutrient levels may be the factor for absence of phytoplankton
- The river samples from Tapovan to Gomukh were predominantly devoid of zooplankton during the study period. The most dominant group amongst the locations were Nematoda, followed by Copepoda and Plecoptera
- The maximum Shannon Wiener diversity indices ranged from 0.00 to 2.25 at which indicated oligotrophic nature of the Bhagirathi river water
- The benthic fauna of the river was negligible or near to zero throughout the stretch of the study area.

Microbiological

- Water samples for bacteriological analyses were collected from Bhagirathi, Bhilangana and Alaknanda rivers
- The load of bacterial indicators was showing an increasing trend from upstream to downstream which is attributed to increased anthropogenic activities as one moves downstream to Gangotri
- Indicator bacteria were detected from the samples of river sediments also.
- Coliphages were detected in water samples of river Bhagirathi and Ganga. Similarly, coliphages were detected in sediment samples of River Bhagirathi and Ganga. E. coli R9 appeared to be an universal host for the isolated bacteriophages

Self purification aspects

- The experimentation revealed that Ganga/ Bhagirathi sediment has the capability to adsorb coliphages and induce their proliferation. The coliphages adsorbed to the sediment appear to be responsible for predating coliforms in the overlying water column when the sediment and water co-exist in a container under static condition. The Bhagirathi water being stored in the dam mimics such static condition and, therefore, it is not deteriorating the water quality of the river downstream of the Tehri dam.
- Quantification of U_3O_8, ThO_2 and percent K in sediment samples and comparison of these parameters with those present in other river sediment samples and freshwater lake sediment samples show that Bhagirathi/ Ganga sediments collected between Gomukh and Rishikesh are more radioactive than others.

8.0 Conclusions

It is concluded that the uniqueness of river Bhagirathi/ Ganga lies in its sediment content which is more radioactive compared to other river and lake water sediments and of coliphages that reduce and ultimately eliminate coliforms from the overlying water column. Thus, Tehri dam is not affecting the quality or self preservation property of river Bhagirathi/ Ganga, as it mimics a static container which is conducive for conditions responsible to maintain the water quality. In general, coliform count is less in the reservoir during post-commissioning phase of the dam, however, it cannot be nil, since there is continuous input of coliforms from the upstream.

Since suspended particles play a major role towards self preservation of Ganga water, it is, thus, necessitated to have certain levels of suspended solid in the water, downstream of Tehri dam, particularly after confluence with the Alaknanda river at Devprayag. Considering average annual flow of 258 and 467 cubic metre per second respectively in Bhagirathi and Alaknanda rivers, having average suspended solids of 29.5 and 32.2 mg/l in respective river waters, there is ample contribution of sediments from Alaknanda at downstream of Devprayag. Investigation further indicated that particulate matters of Alaknanda river have identical antibacterial property as those of Bhagirathi river.

Annexure I
(11 pages)

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भारतीय मानक

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NEW DELHI 110002

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Price Group 4

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Water Sectional Committee had been approved by the Chemical Division Council.

This standard was originally published in 1983. The current revision has been undertaken to take into account the uptodate information available about the nature and effect of various contaminants as also the new techniques for identifying and determining their concentration. In this revision based on experience gained additional requirements for alkalinity, aluminium and boron have been incorporated and the permissible limits for dissolved solids, nitrate and pesticides residues have been modified.

A report prepared by the World Health Organization in cooperation with the World Bank showed that in 1975, some 1 230 million people were without safe water supplies. These appalling facts were central to the United Nations decision to declare an International Drinking Water Supply and Sanitation decade, beginning in 1981. Further, the VI Five-Year Plan of India had made a special provision for availability of safe drinking water for the masses. Therefore, this standard was prepared with the following objectives:

a) To assess the quality of water resources, and

b) To check the effectiveness of water treatment and supply by the concerned authorities.

During VII Five-Year Plan, 55 mini mission districts were identified with a view to meet supply of water to all the problem villages. The VIII Five-Year Plan intends to provide safe drinking water to the rural mass. It also propose to ensure supply of desired quality and required quantity of drinking water.

While preparing this standard, the Committee had taken note of the limited testing facilities available in the country. This standard, therefore, categories various characteristics as essential or desirable. The standard also mentions the desirable limit and indicates its background so that the implementing authorities may exercise their discretion, keeping in view the health of the people, adequacy of treatment, etc. All essential characteristics should be examined in routine. Besides, all desirable characteristics should be examined either when a doubt arises or the potability of water from a new source is to be established.

It has been recognised that often it is necessary to relax the specifications, especially when no alternate resources are available and therefore, to enable the experts to exercise their discretion a maximum permissible limit has also been given.

In the case of virological examination, if not even one plaque-forming unit (PFU) of virus can be found in 1 litre of water, it can reasonably be assumed that the water is safe to drink. It would, however, be necessary to examine a sample of the order of 10 litres to obtain a proper estimation of the PFUs at this level. Such examinations cannot be made in ordinary control laboratories but there should be at least one laboratory in the country or region capable of carrying out virus examinations and also of pursuing further research on this subject.

The methods of test for various characteristics mentioned in this standard are currently under revision and their latest revision shall be used in testing.

In the formulation of this standard, assistance has been derived from the following publications:

a) International Standards for Drinking Water issued by World Health Organization, 1984 Geneva;

b) Manual of Standards of Quality for Drinking Water Supplies. Indian Council of Medical Research, 1971, New Delhi; and

c) Manual on Water Supply and Treatment (*third revision*), Ministry of Urban Development, 1989, New Delhi.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

IS 10500 : 1991

DRINKING WATER — SPECIFICATION

(First Revision)

1 SCOPE

The standard prescribes the requirements for the essential and desirable characteristics required to be tested for ascertaining the suitability of water for drinking purpose.

2 REFERENCES

The Indian Standard listed in Annex A are necessary adjuncts to this standard.

3 CHARACTERISTICS

3.1 The test characteristics are given in Table 1.

3.2 Bacteriological Examination

3.2.1 *Water in Distribution System*

Ideally, all samples taken from the distribution system including consumers' premises, should be free from coliform organisms. In practice, this is not always attainable, and the following standard for water collected in the distribution system is therefore recommended when tested in accordance with IS 1622 : 1981.

a) Throughout any year, 95 percent of samples should not contain any coliform organisms in 100 ml;

b) No sample should contain E. Coli in 100 ml;

c) No sample should contain more than 10 coliform organisms per 100 ml; and

d) Coliform organisms should not be detectable in 100 ml of any two consecutive samples.

3.2.1.1 If any coliform organisms are found the minimum action required is immediate resampling. The repeated finding of 1 to 10 coliform organisms in 100 ml or the appearance of higher numbers in individual samples suggests that undesirable material is gaining access to the water and measures should at once be taken to discover and remove the source of the pollution.

3.2.2 *Unpiped Water Supplies*

Where it is impracticable to supply water to consumers through a piped distribution network and where untreated sources, such as wells, boreholes and springs which may not be naturally pure, have to be used, the requirements for piped supplies may not be attainable. In such circumstances, disinfection although desirable is not always practicable, and considerable reliance has to be placed on sanitary inspection and not exclusively on the results of bacteriological examination. Everything possible should be done to prevent pollution of the water. Obvious sources of contamination should be removed from the immediate catchment area, special attention being given to the safe disposal of excrement. Wells and storage tanks should be protected by lining and covering, surface drainage should be diverted, erosion prevented and the surrounding area paved. Access of man and animals should be restricted by fencing, and should be so designed that fouling is prevented when drawing water. Although not supplied through pipes, water from such sources is likely to undergo further deterioration in quality during transport or storage before drinking. Containers used for water should be kept clean, covered and clear of the floor. The most important factor in achieving these objectives is to ensure the cooperation of the local community, and the importance of education in simple sanitary hygiene should be strongly stressed. In hospitals or medical clinics with such supplies, the value of some form of treatment is stressed.

3.2.2.1 Bacteriologically, the objective should be to reduce the coliform count to less than 10 per 100 ml, but more importantly, to ensure the absence of faecal coliform organisms. If these organisms are repeatedly found, or if sanitary inspection reveals obvious sources of pollution which cannot be avoided, then an alternative source of drinking water would be sought, whenever possible. Greater use should be made of protected ground-water sources and rain-water catchments which are more likely to meet requirements for potable water quality.

3.2.2.2 Although private sources of drinking water may be outside the jurisdiction of public health and water supply authorities, such supplies should still be of potable quality. The results of bacteriological tests and those of sanitary surveys should therefore be used to encourage improvement. Partial treatment may be necessary to remove turbidity even when coliform counts are low; and other quality criteria may dictate the need for treatment processes.

3.3 Virological Examination

3.3.1 It is theoretically possible that virus disease can be transmitted by water free from coliform organisms, but conclusive evidence, that this has occurred, is lacking.

Table 1 Test Characteristics For Drinking Water

(*Clause* 5.1)

Sl No.	Substance or Characteristic	Requirement (Desirable Limit)	Undesirable Effect Outside the Desirable Limit	Permissible Limit in the Absence of Alternate Source	Methods of Test (Ref to IS)	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Essential Characteristics						
i)	Colour, Hazen units, *Max*	5	Above 5, consumer acceptance decreases	25	3025 (Part 4) : 1983	Extended to 25 only if toxic substances are not suspected, in absence of alternate sources
ii)	Odour	Unobjectionable	—	—	3025 (Part 5) : 1983	a) Test cold and when heated b) Test at several dilutions
iii)	Taste	Agreeable	—	—	3025 (Parts 7 and 8) : 1984	Test to be conducted only after safety has been established
iv)	Turbidity, NTU, *Max*	5	Above 5, consumer acceptance decreases	10	3025 (Part 10) : 1984	—
v)	pH value	6·5 to 8·5	Beyond this range the water will affect the mucous membrane and/ or water supply system	No relaxation	3025 (Part 11) : 1984	—
vi)	Total hardness (as $CaCO_3$) mg/l, *Max*	300	Encrustation in water supply structure and adverse effects on domestic use	600	3025 (Part 21) : 1983	—
vii)	Iron (as Fe) mg/l, *Max*	0·3	Beyond this limit taste/appearance are affected, has adverse effect on domestic uses and water supply structures, and promotes iron bacteria	1·0	32 of 3025 : 1964	—
viii)	Chlorides (as Cl) mg/l, *Max*	250	Beyond this limit, taste, corrosion and palatibility are affected	1 000	3025 (Part 32) : 1988	—
ix)	Residual, free chlorine, mg/l, *Min*	0·2	—	—	3025 (Part 26) : 1986	To be applicable only when water is chlorinated. Tested at consumer end. When protection against viral infection is required, it should be *Min* 0·5 mg/l.
Desirable Characteristics						
x)	Dissolved solids mg/l, *Max*	500	Beyond this palatability decreases and may cause gastro intestinal irritation	2 000	3025 (Part 16) : 1984	—
xi)	Calcium (as Ca) mg/l, *Max*	75	Encrustation in water supply structure and adverse effects on domestic use	200	3025 (Part 40) : 1991	—

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[*Page* 2, *Table* 1, *Sl No.* (xi)] — Insert the following new matter under respective columns after Sl No. (xi) and renumber subsequent rows:

(1)	(2)	(3)	(4)	(5)	(6)	(7)
xii)	Magnesium (as Mg), mg/l, Max	30	Encrustation in water supply structure and adverse effects on domestic use	100	16, 33, 34 of IS 3025 : 1964	—

[*Page* 3, *Table* 1, *Sl No.* (xvi)] — Shift the matter under respective columns and put after Sl No. (ix) under essential characteristics and renumber the subsequent rows.

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Table 1 Test Characteristics for Drinking Water (*Contd*)

Sl No.	Substance or Characteristic	Requirement (Desirable Limit)	Undesirable Effect Outside the Desirable Limit	Permissible Limit in the Absence of Alternate Source	Methods of Test (Ref to IS)	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
xii)	Copper (as Cu) mg/l, *Max*	0·05	Astringent taste, discoloration and corrosion of pipes, fitting and utensils will be caused beyond this	1·5	36 of 3025 : 1964	—
xiii)	Manganese (as Mn) mg/l, *Max*	0·1	Beyond this limit taste/appearance are affected, has adverse effect on domestic uses and water supply structures	0·3	35 of 3025 : 1964	—
xiv)	Sulphate (as SO_4) mg/l, *Max*	200	Beyond this causes gastro intenstinal irritation when magnesium or sodium are present	400 (*see* col 7)	3025 (Part 24) : 1986	May be extended up to 400 provided (as Mg) does not exceed 30
xv)	Nitrate (as NO_3) mg/l, *Max*	45	Beyond this methaemoglobinemia takes place	100	3025 (Part 34) : 1988	—
xvi)	Fluoride (as F) mg/l, *Max*	1·0	Fluoride may be kept as low as possible. High fluoride may cause fluorosis	1·5	23 of 3025 : 1964	—
xvii)	Phenolic compounds (as C_6H_5OH) mg/l, *Max*	0·001	Beyond this, it may cause objectionable taste and odour	0·002	54 of 3025 : 1964	—
xviii)	Mercury (as Hg) mg/l, *Max*	0·001	Beyond this, the water becomes toxic	No relaxation	(*see* Note) Mercury ion analyser	To be tested when pollution is suspected
xix)	Cadmium (as Cd), mg/l, *Max*	0·01	Beyond this, the water becomes toxic	No relaxation	(*see* Note)	To be tested when pollution is suspected
xx)	Selenium (as Se), mg/l, *Max*	0·01	Beyond this, the water becomes toxic	No relaxation	28 of 3025 : 1964	To be tested when pollution is suspected
xxi)	Arsenic (as As), mg/l, *Max*	0·05	Beyond this, the water becomes toxic	No relaxation	3025 (Part 37) : 1988	To be tested when pollution is suspected
xxii)	Cyanide (as CN), mg/l, *Max*	0·05	Beyond this limit, the water becomes toxic	No relaxation	3025 (Part 27) : 1986	To be tested when pollution is suspected
xxiii)	Lead (as Pb), mg/l, *Max*	0·05	Beyond this limit, the water becomes toxic	No relaxation	(*see* Note)	To be tested when pollution/plumbosolvency is suspected
xxiv)	Zinc (as Zn). mg/l, *Max*	5	Beyond this limit it can cause astringent taste and an opalescence in water	15	39 of 3025 : 1964	To be tested when pollution is suspected
xxv)	Anionic detergents (as MBAS) mg/l, *Max*	0·2	Beyond this limit it can cause a light froth in water	1·0	Methylene-blue extraction method	To be tested when pollution is suspected
xxvi)	Chromium (as Cr^{6+}) mg/l, *Max*	0·05	May be carcinogenic above this limit	No relaxation	38 of 3025 : 1964	To be tested when pollution is suspected

(*continued*)

Table 1 Test Characteristics for Drinking Water (*concluded*)

Sl No.	Substance or Characteristic	Requirement (Desirable Limit)	Undesirable Effect Outside the Desirable Limit	Permissible Limit in the Absence of Alternate Source	Methods of Test (Ref to IS)	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
xxvii)	Polynuclear aromatic hydrocarbons (as PAH) g/l, *Max*	—	May be carcinogenic	—	—	—
xxviii)	Mineral oil mg/l, *Max*	0·01	Beyond this limit undesirable taste and odour after chlorination take place	0·03	Gas chromatographic method	To be tested when pollution is suspected
xxix)	Pesticides mg/l, *Max*	Absent	Toxic	0·001	—	—
xxx)	Radioactive materials:				58 of 3025 : 1964	
	a) Alpha emitters Bq/l, *Max*	—	—	0·1	—	—
	b) Beta emitters pci/l, *Max*	—	—	1	—	—
xxxi)	Alkalinity mg/l, *Max*	200	Beyond this limit taste becomes unpleasant	600	13 of 3025 : 1964	—
xxxii)	Aluminium (as Al), mg/l, *Max*	0·03	Cumulative effect is reported to cause dementia	0·2	31 of 3025 : 1964	—
xxxiii)	Boron, mg/l, *Max*	1	—	5	29 of 3025 : 1964	—

NOTE — Atomic absorption spectrophotometric method may be used.

3.3.2 None of the generally accepted sewage treatment methods yield virus-free effluent. Although a number of investigators have found activated sludge treatment to be superior to trickling filters from this point of view, it seems possible that chemical precipitation methods will prove to be the most effective.

3.3.3 Virus can be isolated from raw water and from springs. Enterovirus, reovirus, and adenovirus have been found in water, the first named being the most resistant to chlorination. If enterovirus are absent from chlorinated water, it can be assumed that the water is safe to drink. Some uncertainty still remains about the virus of infectious hepatitis, since it has not so far been isolated but in view of the morphology and resistance of enterovirus it is likely that, if they have been inactivated hepatitis virus will have been inactivated also.

3.3.4 An exponential relationship exists between the rate of virus inactivation and the redox potential. A redox potential of 650 mV (measured between platinum and calomel electrodes) will cause almost instantaneous inactivation of even high concentrations of virus. Such a potential can be obtained with even a low concentration of free chlorine, but only with an extremely high concentration of combined chlorine. This oxidative inactivation may be achieved with a number of other oxidants also, for example, iodine, ozone, and potassium permanganate, but the effect of the oxidants will always be counteracted if reducing components, which are mainly organic, are present. As a consequence, the sensitivity of virus towards desinfectants will depend on the *milieu* just as much as on the particular disinfectant used.

3.3.5 Thus, in a water in which free chlorine is present, active virus will generally be absent if coliform organisms are absent. In contrast, because the difference between the resistance of coliform organisms and of virus to disinfection by oxidants increases with increasing concentration of reducing components, for example, organic matter, it cannot be assumed that the absence of viable coliform organisms implies freedom from active virus under circumstances where a free chlorine residual cannot be maintained. Sedimentation and slow sand filtration in themselves may contribute to the removal of virus from water.

3.3.6 In practice, 0·5 mg/l of free chlorine for one hour is sufficient to inactivate virus, even in water that was originally polluted.

3.4 Biological Examination

3.4.1 Biological examination is of value in determining the causes of objectionable tastes and odours in water and controlling remedial treatments, in helping to interpret the results of various chemical analysis, and in explaining the causes of clogging in distribution pipes and filters. In some instances, it may be of use in demonstrating that water from one source has been mixed with that from another.

3.4.2 The biological qualities of a water are of greater importance when the supply has not undergone the conventional flocculation and filtration processes, since increased growth of methane-utilizing bacteria on biological slimes in pipes may then be expected, and the development of bryozoal growths such as *Plumatella* may cause operational difficulties.

3.4.3 Some of the animalcules found in water mains may be free-living in the water, but others such as *Dreissena* and *Asellus* are more or less firmly attached to the inside of the mains. Although these animalcules are not themselves pathogenic, they may harbour pathogenic organisms or virus in their intestines, thus protecting theses pathogens from destruction by chlorine.

3.4.4 Chlorination, at the dosages normally employed in waterworks, is ineffective against certain parasites, including amoebic cysts; they can be excluded only by effective filtration or by higher chlorine doses than can be tolerated without subsequent dechlorination. *Amoebiasis* can be conveyed by water completely free from enteric bacteria; microscopic examination after concentration is, therefore, the only safe methods of identification.

3.4.5 Strict precautions against back-syphonage and cross-connections are required if amoebic cysts are found in a distribution system containing tested water.

3.4.6 The *cercariae of schistosomiasis* can be detected by similar microscopic examination, but there is, in any case, no evidence to suggest that this disease is normally spread through piped water supplies.

3.4.7 The cyclops vector of the embroys of *Dracunculus medinensis* which causes dracontiasis or Guinea-worm disease can be found in open wells in a number of tropical areas. They are identifiable by microscopic examination. Such well supplies are frequently used untreated, but the parasite can be relatively easily excluded by simple physical improvements in the form of curbs, drainage, and apron surrounds and other measures which prevent physical contact with the water source.

3.4.8 The drinking water shall be free from microscopic organisms such as algae, zooplanktons, flagillates, parasites and toxin-producing organisms. An illustrative (and not exhaustive) list is given in Annex B for guidance.

4 SAMPLING

Representative samples of water shall be drawn as prescribed in IS 1622 : 1981 and IS 3025 (Part 1) : 1987.

ANNEX A

(*Clause 2.1*)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*	*IS No.*	*Title*
1622 : 1981	Methods of sampling and microbiological examination of water (*first revision*)	3025 (Part 5) : 1983	Methods of sampling and test (physical and chemical) for water and waste water : Part 5 Odour (*first revision*)
3025 : 1964	Methods of sampling and test (physical and chemical) for water used in industry	3025 (Part 7) : 1984	Methods of sampling and test (physical and chemical) for water and waste water : Part 7 Taste threshold (*first revision*)
3025 (Part 1) : 1987	Methods of sampling and test (physical and chemical) for water and waste water : Part 1 Sampling (*first revision*)	3025 (Part 8) : 1984	Methods of sampling and test (physical and chemical) for water and waste water : Part 8 Taste rating (*first revision*)
3025 (Part 4) : 1983	Methods of sampling and test (physical and chemical) for water and waste water : Part 4 Colour (*first revision*)		

IS No.	Title	IS No.	Title
3025 (Part 10) : 1984	Methods of sampling and test (physical and chemical) for water and waste water : Part 10 Turbidity (*first revision*)	3025 (Part 26) : 1986	Methods of sampling and test (physical and chemical) for water and waste water : Part 26 Chlorine residual (*first revision*)
3025 (Part 11) : 1983	Methods of sampling and test (physical and chemical) for water and waste water : Part 11 pH value (*first revision*)	3025 (Part 27) : 1986	Methods of sampling and test (physical and chemical) for water and waste water : Part 27 Cyanide (*first revision*)
3025 (Part 16) : 1984	Methods of sampling and test (physical and chemical) for water and waste water : Part 16 Filterable residue (total dissolved solids) (*first revision*)	3025 (Part 32) : 1988	Methods of sampling and test (physical and chemical) for water and waste water : Part 32 Chloride (*first revision*)
3025 (Part 21) : 1983	Methods of sampling and test (physical and chemical) for water and waste water : Part 21 Total hardness (*first revision*)	3025 (Part 34) : 1988	Methods of sampling and test (physical and chemical) for water and waste water : Part 34 Nitrogen (*first revision*)
3025 (Part 24) : 1986	Methods of sampling and test (physical and chemical) for water and waste water : Part 24 Sulphates (*first revision*)	3025 (Part 37) : 1988	Methods of sampling and test (physical and chemical) for water and waste water : Part 37 Arsenic (*first revision*)

ANNEX B

(*Clause* 3.4.8)

ILLUSTRATIVE LIST OF MICROSCOPIC ORGANISMS WHICH MAY BE PRESENT IN WATER

Classification of Microscopic Organism	*Group and Name of the Organism*	*Habitat*	*Effect of the Organisms and Significance*
(1)	(2)	(3)	(4)
1. *ALGAE*	a) *Chlorophyceae*		
	Species of *Coelastrum, Gomphospherium, Micractinium, Mougeotia, oocystis, Euastrum, Scenedesmus, Actinastrum, Genium, Eudorina Pandorina, Pediastrum, Zygnema, Chlamydomonas, Careteria, Chlorella, Chroococcus, Spirogyra, Tetraedron, Chlorogonium, Stigeoclonium*	Polluted water, impounded sources	Impart colouration
	Species of *Pandorina, Volvox, Gomphospherium, Staurastrum, Hydrodictyon, Nitella*	Polluted waters	Produce taste and odour
	Species of *Rhizoclonium, Cladothrix, Ankistrodesmus, Ulothrix, Micrasterias, Chromulina*	Clean water	Indicate clean condition
	Species of *Chlorella, Tribonema, Closterium, Spirogyra, Palmella*	Polluted waters, impounded sources	Clog filters and create operational difficulties

Classification of Microscopic Organism	Group and Name of the Organism	Habitat	Effect of the Organisms and Significance
(1)	(2)	(3)	(4)
	b) *Cyanophyceae*		
	Species of *Anacystis and Cylindrospermum*	Polluted waters	Cause water bloom and impart colour
	Species of *Anabena, Phormidium, Lyngbya, Arthrospira, Oscillatoria*	Polluted waters	Impart colour
	Species of *Anabena, Anacystis, Aphanizomenon*	Polluted waters, impounded sources	Produce taste and odour
	Species of *Anacystis, Anabena, Coelospherium, Gleotrichina, Aphanizomenon*	Polluted waters	Toxin producing
	Species of *Anacystis, Rivularia, Oscillatoria, Anabena*	Polluted waters	Clog filters
	Species of *Rivularia*	Calcareous waters and also rocks	Bores rocks and calcareous strata and causes matted growth
	Species of *Agmenellum, Microcoleus, Lemanea*	Clean waters	Indicators of purification
	c) *Diatoms (Bacillariophyceae)*		
	Species of *Fragillaria, Stephanodiscus, Stauroneis*	—	Cause discoloration
	Species of *Asterionella, Tabellaria*	Hill streams high altitude, torrential and temperate waters	Taste and odour producing clog filters
	Species of *Synedra* and *Fragillavia*	Polluted waters	Taste and odour producing
	Species of *Nitzchia, Gomphonema*	Moderately polluted waters	Cause discoloration
	Species of *Cymbela, Synedra, Melosira, Navicula, Cyclotella, Fragillaria, Diatoma, Pleurogsigma*	Rivers and streams impounded sources	Clog filters and cause operational difficulties
	Species of *Pinnularia, Surinella, Cyclotella, Meridion, Cocconeis*	Clean waters	Indicators of purification
	d) *Xanthophyceae*		
	Species of *Botryococcus*	Hill streams, high altitudes and temperate waters	Produces coloration
2. *ZOOPLANKTON*	a) *Protozoa*		
	Amoeba, Giardia Lamblia Arcella, Difflugia, Actinophrys	Polted waters	Pollution indicators
	Endamoeba, Histolytica	Sewage and activated sludge	Parasitic and pathogenic
	b) *Ciliates*		
	Paramoccium, Vorticella, Carchesium, Stentor, Colpidium, Coleps, Euplotes, Colopoda, Bodo	Highly polluted waters, sewage and activated sludge	Bacteria eaters
	c) *Crustacea*		
	Bosmina, Daphnia	Stagnant polluted waters	Indicators of pollution

Classification of Microscope Organism	*Group and Name of the Organism*	*Habitat*	*Effect of the Organisms and Significance*
(1)	(2)	(3)	(4)
	Cyclops	Step wells in tropical climate	Carrier host of guinea worm
3. *ROTIFERS*	a) *Rotifers*		
	Anurea, Rotaria, Philodina	Polluted and algae laden waters	Feed on algae
	b) *Flagellates*		
	Ceratium, Glenodinium, Peridinium Dinobryon	Rocky strata, iron bearing and acidic waters	Impart colour and fishy taste
	Euglena, Phacus	Polluted waters	Impart colour
	c) *Miscellaneous Organisms Sponges, Hydra*	Fresh water	Clog filters and affect purification systems
	Tubifex, Eristalis, Chironomids	Highly polluted waters, sewage and activated sludge and bottom deposits	Clog filters and render water unaesthetic
	d) *Plumatella*	Polluted waters	Produces biological slimes and causes filter operational difficulties
	Dreissena, Asellus	Polluted waters	Harbour pathogenic organisms

Annexure - II

Microbiological and Biological Quality

Organism	Guideline value (Unit Number/100ml)	Remarks
Microbiological Quality		
A. Piped water supplies		
A1.Treated water entering the distribution system		Turbidity 1 NTU for disinfection with chlorine, pH preferably <8.0, free chlorine residual 0.2 mg/litre following 30 minutes (minimum) contact
Faecal coliforms	0	
Coliform organisms	0	
A2. Untreated water entering the distribution system		In 98% of samples examined throughout the year in the case of large supplies when sufficient samples are examined
Faecal coliforms	0	
Coliform organisms	0	
Coliform organisms	3	In an occasional sample, but not in consecutive samples
A3 Water in the distribution system		In 95% of samples examined throughout the year – in the case of large supplies when sufficient samples are examined
Faecal coliforms	0	
Coliform organisms	0	
Coliform organisms	3	In an occasional sample, but not in consecutive samples
B. Unpiped water supplies		Should not occur repeatedly if occurrence is frequent and if sanitary protection cannot improve, an alternative source must be found it possible
Faecal coliforms	0	
Coliform organisms	10	
C. Bottled drinking-water		Source should be free from faecal contamination
Faecal coliforms	0	
Coliform organisms	0	
D. Emergency water supplies		Advise public to boil water in case of failure to meet guideline values
Faecal coliforms	0	
Coliform organisms	0	
Enteroviruses	no guideline value set	
II. Biological quality		
Protozoa (pathogenic)	No guideline value set	
Helminths (pathogenic)	No guideline value set	
Free-living organisms (algae, others)	No guideline value set	

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Annexure R/9

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आदेश

नई दिल्ली, 9 अक्तूबर, 2018

का.आ. 5195(अ).—गंगा नदी अत्यधिक पवित्र और इस देश के लोगों द्वारा अत्यंत पूज्यनीय है तथा गंगा नदी बेसिन जल ग्रहण क्षेत्र के निबंधनानुसार भारत में वृहत्तम नदी बेसिन है, जिसमें संपूर्ण देश की छब्बीस प्रतिशत भूमि सम्मिलित है तथा जो लगभग पचास करोड़ जनसंख्या के लिए पोषणीय है;

और गंगा नदी विशेष गुणों, विशिष्टताओं तथा महत्व के रूप में अद्वीतीय है जिसका महत्वपूर्ण लौकिक और स्थानिक प्रभाव भिन्नता के साथ जल-विज्ञान, भू-आकृतिविज्ञान, ऐतिहासिक, सामाजिक-सांस्कृतिक और आर्थिक कारण हैं;

और गंगा नदी को राष्ट्रीय नदी का दर्जा दिया गया है तथा नदी-प्रणाली में सिंचाई, घरेलू, औद्योगिक और अन्य प्रयोजनों के लिए बेसिन में सदैव पानी की बढ़ती मांग के साथ घरेलू अपशिष्ट और आद्योगिक अपशिष्ट सहित विभिन्न स्रोतों से प्रदूषण प्रवेश कर रहा है, जो नदी के स्वास्थ्य को लंबे समय से प्रभावित कर रहा है;

और भारत सरकार समुचित पर्यावरण प्रवाह तथा साथ ही नदी में प्रदूषण के प्रवेश के निवारण को सुनिश्चित करने के लिए नदियों की पौष्टिकता की बहाली करने और उसे बनाए रखने के लिए वचनबद्ध है;

और यह सुनिश्चित करना आवश्यक है कि गंगा नदी में हर समय पानी के निर्बाध प्रवाह को पूरी तरह से बनाए रखा जाए, जिससे मौसमी भिन्नताओं को बदले बिना नदी में प्रवाह की निरंतरता सुनिश्चित हो सके;

केंद्रीय सरकार ने पर्यावरण (संरक्षण) अधिनियम, 1986 (1986 का 29) के अधीन अधिसूचना का.आ. 3187 (अ), तारीख 7 अक्तूबर, 2016 द्वारा गंगा नदी जलक्षेत्र के संरक्षण, संरक्षा और प्रबंध तथा निम्नलिखित प्रयोजनों के लिए एक प्राधिकरण अर्थात् राष्ट्रीय स्वच्छ गंगा मिशन का गठन किया था, अर्थात्:-

(क) गंगा नदी और उसकी सहायक नदियों के जल की गुणवत्ता और पर्यावरणीय वहनीय संरक्षण, संरक्षा और प्रबंध को सुनिश्चित करने के उद्देश्य से सतैव विभिन् क्षेत्रों में विभिन्न बिंदुओं पर बनाए रखने के लिए अपेक्षित गंगा नदी और उसकी सहायक नदियों में पारिस्थितिक

प्रवाह के परिमाण को अवधारित करवाने तथा उसे अधिसूचित करवाने और पर्याप्त पारिस्थितिक प्रवाह को बनाए रखने के लिए ऐसे सभी आवश्यक कदम उठाना या निदेशित करना;

(ख) गंगा नदी के जलीय प्रेक्षण स्टेशनों के माध्यम से विनिर्दिष्ट बिंदुओं पर पानी के औसत प्रवाह को विनिर्दिष्ट करना;

(ग) गंगा नदी तथा उसकी सहायक नदियों में जल के प्रवाह की निरंतर मानीटरी के लिए तंत्र विकसित करना;

और केंद्रीय सरकार ने गंगा नदी और उसकी सहायक नदियों में कतिपय प्रवाहों को निर्धारित करने का विनिश्चय किया है।

2. अतः केंद्रीय सरकार, गंगा नदी (संरक्षण, सुरक्षा एंव प्रबंधन) प्राधिकरण आदेश, 2016 के पैरा 39 के उपपैरा (3) और पैरा 41 के उपपैरा (2) की मद (ज) के साथ पठित पर्यावरण संरक्षण अधिनियम, 1986 की धारा 3 की उपधारा (3) द्वारा प्रदत्त शक्तियों का प्रयोग करते हुए, सिंचाई, जल विद्युत्, घरेलू और औद्योगिक प्रयोजनों तथा अन्य अपेक्षाओं के लिए नदी प्रवाह को परिवर्तित करने के लिए संरचनाओं या परियोजनाओं के निम्न प्रवाह अवस्थानों पर न्यूनतम पर्यावरणीय प्रवाहों को बनाए रखने के लिए अधिसूचित करती है, अर्थात्:-

I. देवप्रयाग से हरिद्वार तक अंत में मिलने वाले क्रमवर्तीय सम्मिलनों के माध्यम से और उद्भव वाले ग्लेशियरों से आरंभ होने वाला **उपरी गंगा नदी बेसिन विस्तार**:

क्रम सं.	ऋतु	मास	*प्रत्येक पूर्ववर्ती 10 दैनिक अवधि के दौरान प्रेक्षित मासिक औसत प्रवाह का प्रतिशत(%)*
1.	शुष्क	नवंबर से मार्च	*20*
2.	क्षीण	अक्तूबर, अप्रैल और मई	*25*
3.	*उच्च प्रवाह ऋतु*	*जून से सितंबर*	*30*#*

*#उच्च प्रवाह ऋतु के मासिक प्रवाह का 30%

II. **हरिद्वार, उत्तराखंड से उन्नाव, उत्तर प्रदेश तक गंगा नदी के मुख्य मार्ग का विस्तार**:

क्रम सं.	बैराज की अवस्थिति	बैराजों के सन्निकट निम्न धारा को निर्मुक्त करने वाला न्यूनतम प्रवाह **(क्यूमैक्स में) (अक्तूबर से मई)**	*बैराजों के सन्निकट निम्न धारा को निर्मुक्त करने वाला न्यूनतम प्रवाह* ***(क्यूमैक में) (जून से सितंबर)***
(1)	भीमगौडा (हरिद्वार)	36	*57*
(2)	बिजनौर	24	*48*
(3)	*नरौरा*	24	*48*
(4)	*कानपुर*	*24*	*48*

क्यूमैक-घनमीटर प्रतिसेकंड।

III. उपरोक्त उक्त पारिस्थितिकी प्रवाह निम्न के अध्यधीन हैं, अर्थात्:-

(i) न्यूनतम पर्यावरणीय प्रवाह का अनुपालन सभी विद्यमान, निर्माणाधीन और भविष्य की परियोजनाओं को लागू होता है;

(ii) विद्यमान परियोजनाएं जो वर्तमान में इन पर्यावरणीय प्रवाहों के मानदंडों के अनुरूप नहीं हैं, इनका पालन करेंगी और यह सुनिश्चित करेंगी कि वांछित पर्यावरणीय प्रवाह मानदंडों का पालन इस अधिसूचना के जारी करने की तारीख से तीन वर्ष की अवधि के भीतर किया जाए;

(iii) परियोजना जो सन्निर्माण की विभिन्न प्रक्रम पर हैं, जहां जमीनी भौतिक प्रगति आरंभ हो चुकी है और समुचित प्राधिकारी को रिपोर्ट की गई है, परियोजना को आरंभ करने के पूर्व और उसके पश्चात् अनुबद्ध पर्यावरणीय प्रवाह को बनाए रखने के लिए भी आवश्यक उपबंध करेगी;

(iv) लघु और सूक्ष्म परियोजनाएं जो सारवान रूप से नदी या धारा की प्रवाही विशेषताओं को परिवर्तित नहीं करती हैं, इन परियावरणीय प्रवाहों से छूट प्राप्त हैं;

(v) परियावरणीय प्रवाहों को बनाए रखने के लिए जल की वांछनीय मात्राओं की निर्मुक्ति को सुनिश्चित करने के लिए, इन नदी आगमों में प्रवाह की दशाएं समय-समय पर कालिक अंतरालों पर मानीटर की जाएंगी;

(vi) केंद्रीय जल आयोग अभिहित प्राधिकारी तथा डाटा का संरक्षक होगा तथा प्रवाहों के पर्यवेक्षण, मानीटरिंग, विनियमन तथा जब कभी अपेक्षित हो, समुचित प्राधिकारी को आवश्यक जानकारी रिपोर्ट करने के लिए उत्तरदायी होगा । यह किसी आपात स्थिति की दशा में जल भंडारण मानदंडों के बारे में तत्काल निर्णय लेने के लिए भी प्राधिकृत है । केंद्रीय जल आयोग त्रैमासिक आधार पर राष्ट्रीय स्वच्छ गंगा मिशन को प्रवाह मानीटरी-सह-अनुपालन रिपोर्ट प्रस्तुत करेगा;

(vii) संबंधित परियोजना विकासकर्ता या प्राधिकारी इस अधिसूचना की तारीख से छह मास के भीतर केंद्रीय जल आयोग विनिर्दिष्ट उचित अवस्थानों पर परियोजना स्थलों पर स्वचालित डाटा अर्जन और डाटा प्रेषण प्रसुविधाएं या अपेक्षित आवश्यक अवसंरचना लगाएगा । प्रवाह मानीटरी प्रसुविधा को लगाने, अंशांकन करने, उसे बनाए रखने का उत्तरदायित्व परियोजना विकासकर्ताओं या प्राधिकारियों का होगा और वे समय-समय पर केंद्रीय जल आयोग को डाटा प्रस्तुत करेंगे;

(viii) केंद्रीय सरकार, राष्ट्रीय स्वच्छ गंगा मिशन के माध्यम से, जब कभी अपेक्षित हो, गंगा नदी में विशेष मांग को पूरा करने के लिए अतिरिक्त जल को निर्मुक्त करने का निदेश दे सकेगी ।

IV. संबंधित केंद्रीय और राज्य प्राधिकरण, सिंचाई का प्रभावी ढंग, जल का पुनः उपयोग और पुनः चक्रण, जिसके अंतर्गत विभिन्न प्रयोजनों के लिए भूजल निकालने की मानीटरिंग और विनियमन भी है, जैसे अच्छे और वैज्ञानिक व्यवहारों को अपना कर गंगा नदी के जल निकालने में कमी करने के लिए मांग पक्ष प्रबंध योजना कार्यान्वित करेंगे ।

3. यह आदेश इसके राजपत्र में प्रकाशन की तारीख से प्रवृत्त होगा ।

4. यह आदेश उद्भव वाले ग्लेशियरों से आरंभ होने वाले उपरी गंगा नदी बेसिन तथा देवप्रयाग से हरिद्वार तक और उत्तर प्रदेश के उन्नाव जिले तक गंगा नदी की मुख्य धारा को तथा अंत में मिलने वाली इसकी मुख्य सहायक नदियों के क्रमवर्ती सम्मिलनों पर लागू होगा ।

[फा. सं. - Estt.01/2016-17/111/NMCG (Vol III)]

राजीव किशोर, कार्यकारी निदेशक (प्रशा.)

MINISTRY OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVENATION

(NATIONAL MISSION FOR CLEAN GANGA)

ORDER

New Delhi, the 9th October, 2018

S.O.5195(E).—Whereas, the River Ganga is the most sacred and deeply revered by the people of this country and the Ganga river basin is the largest river basin in India in terms of catchment area, constituting twenty six per cent of the country's land mass and supporting about half a billion population;

And whereas, River Ganga is unique as having special properties, features and importance, holding reasons that are hydrological, geomorphological, historical, socio-cultural and economical with significant temporal and spatial flow variation;

And whereas, River Ganga has been given status of a National river and the ever increasing demand for water in the basin for irrigation, domestic, industrial and other purposes coupled with pollution ingress from different sources including domestic waste, industrial waste, into river system is affecting the health of the said river for long;

And whereas, the Central Government is committed to restore and maintain the wholesomeness of the rivers ensuring appropriate environment flows and simultaneously preventing the pollution ingress into the said river;

And whereas, it is considered necessary to ensure that uninterrupted flows of water are maintained throughout its length at all times in River Ganga to ensure continuity of flows in the river without altering the seasonal variations;

And whereas the Central Government *vide* notification S.O. 3187(E), dated the 7th October, 2016 under the Environment (Protection) Act, 1986 (29 of 1986) has constituted an authority, namely, the National Mission for Clean Ganga for Rejuvenation, Protection and Management of River Ganga basin for the following purposes, namely:-

(a) to determine the magnitude of ecological flow in the River Ganga and its tributaries required to be maintained at different points in different areas at all times with the aim of ensuring water quality and environmentally

sustainable rejuvenation, protection and management of River Ganga and its tributaries and notifying the same and take or direct all such measures necessary to maintain adequate ecological flows;

(b) to specify the average flow of water at specified points through Hydrological Observation Stations of the River Ganga;

(c) to devise a system for continuous monitoring of flow of water in the River Ganga and its tributaries;

And whereas the Central Government has decided to determine certain flows in the River Ganga and its tributaries;

2. Now, therefore, in exercise of the powers conferred by sub-section (3) of section 3 of the Environment (Protection) Act 1986 and read with sub paragraph (3) of paragraph 39 and item(h) of sub-paragraph(2) of paragraph 41 of the River Ganga (Rejuvenation, Protection and Management) Authorities Order, 2016, the Central Government hereby notifies the following minimum environmental flows to be maintained at locations downstream of structures or projects meant for diversion of river flows for purposes like irrigation, hydropower, domestic and industrial and other requirements, namely:-

I. **Upper Ganga River Basin Stretch** starting from originating glaciers and through respective confluences finally meeting at Devaprayag up to Haridwar:

Sl. No.	Season	Months	(%) Percentage of Monthly Average Flow observed during each of preceding 10-daily period
1	Dry	November to March	20
2	Lean	October, April and May	25
3	High Flow season	June to September	30*#

*# 30% of monthly flow of High flow season.

II. **Stretch of main stem of River Ganga from Haridwar, Uttrakhand to Unnao, Uttar Pradesh**

S. No.	Location of Barrage	Minimum flow releases immediately downstream of barrages ***(In Cumecs)*** **Non-Monsoon (October to May)**	Minimum flow releases immediately downstream of barrages ***(In Cumecs)*** **Monsoon (June to September)**
(1)	Bhimgoda (Haridwar)	36	57
(2)	Bijnor	24	48
(3)	Narora	24	48
(4)	Kanpur	24	48

Cumec – Cubic Meter per second.

III. The above said ecological flows are subject to the following, namely:-

(i) the compliance of minimum environmental flow is applicable to all existing, under-construction and future projects;

(ii) the existing projects, which currently do not meet the norms of these environmental flows, shall comply and ensure that the desired environmental flow norms are complied within a period of three years from the date of issue of this order;

(iii) the project which is at different stages of construction, where physical progress on ground has been initiated and made and reported to appropriate authority shall also make necessary provisions to maintain the stipulated environmental flow before and after commissioning of the project;

(iv) the mini and micro projects which do not alter the flow characteristics of the river or stream significantly are exempted from these environmental flows;

(v) to ensure the release of desired quantities of water to maintain environmental flows, flow conditions in these river reaches shall be monitored at hourly intervals from time to time;

(vi) the Central Water Commission shall be the designated authority and the custodian of the data and shall be responsible for supervision, monitoring, regulation of flows and reporting of necessary information to the appropriate authority as and when required and also authorised to take emergent decisions about the water storage norms in case of any emergency. The Central Water Commission shall submit flow monitoring-cum-compliance report on quarterly basis to National Mission for Clean Ganga;

(vii) the concerned project developers or authorities shall install automatic data acquisition and data transmission facilities or required necessary infrastructure at project sites at appropriate locations specified by the Central Water Commission within six months from the date of this order. The installation, calibration, maintenance of flow monitoring facility shall be the responsibility of the project developers or authorities and they shall submit the data to the Central Water Commission from time to time;

(viii) the Central Government through National Mission for Clean Ganga may direct release of additional water in the River Ganga to meet special demand as and when required.

IV. The concerned Central and State authorities shall implement demand side management plans to reduce water withdrawal from River Ganga by adopting good and scientific practices such as efficient method of irrigation, reuse and recycle of water including monitoring and regulation of ground water withdrawals for various purposes.

3. This Order shall come into force on the date of its publication in the Official Gazette.

4. This Order shall apply to the upper Ganga River Basin starting from originating glaciers and through respective confluences of its head tributaries finally meeting at Devaprayag up to Haridwar and the main stem of River Ganga up to Unnao district of Uttar Pradesh

[F. No.- Estt.01/2016-17/111/NMCG(Vol III)]

RAJIV KISHORE, Executive Director(Admn)

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Annexure R/10

UKPCB

LiFE Lifestyle For Environment

HEAD OFFICE
Uttarakhand Pollution Control Board
"Gaura Devi Paryavaran Bhawan"
46B, IT Park, Sahastradhara Road, Dehra Dun
E-mail : msukpcb@yahoo.com, Phone No.-0135-2607092

UKPCB/HO/Con/T-62/2024 / 817

Date : 24.08.2024

REGD. POST

To,

M/s THDC India Ltd.,
Koteshwar Hydro Electric Project
P.O Pokhari, Distt. Tehri Garhwal.

Consolidated Consent to Operate and Authorisation hereinafter referred to as the CCA (Consolidated Consent & authorization) (Renewal) under Section-25 of the "Water (Prevention & Control of Pollution) Act, 1974" and under Section-21 of the "Air (Prevention & Control of Pollution) Act, 1981" and Authorization under "Rule-6(2)" of the "Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016" notified under "Environment (Protection) Act, 1986" as applicable (to be referred hereinafter as Water Act, Air Act and HW Rules respectively).

CAF ID –5885	**Application no.- 4798578**
CCA (Renewal)	
Date :-23-03-2024	

CCA is hereby granted to **M/s THDC India Ltd.** for **Koteshwar Hydro Electric Project, located at Pokhari, Distt-Tehri Garhwal** subject to the provisions of the Water Act, Air Act and **Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016** and the orders that may be made further and subject to following terms and conditions :-

1. This CCA is **granted for the period upto 31-03-2025** and valid for manufacturing of following products with **Capital Investment/Net Assets Values ₹163017 Lakh** :-

S. No.	Last CCA		Present CCA (Renewal)	
	Product	Quantity	Product	Quantity
1	Hydro Power	400 MW	Hydro Power	400 MW

2. **Specific Conditions under Water Act :-**

(i) **The daily quantity of effluent discharge (KLD) :-**

	CTE/Last CCA	Present CCA (Renewal)
Trade Effluent	Nil	Nil
Sewage	9.6	10

(ii) **Trade Effluent Treatment and Disposal :-** Nil

(iii) **Sewage Treatment and Disposal** :- The domestic waste water shall be treated through STP (20.0 KLD) provided by project proponent.

In case of stoppage of functioning of STP, production has to be stopped immediately and this Board has to be intimated by fax/phone/email with a report in this regard to be dispatched immediately.

(iii) The treated sewage shall be reuse in gardening etc. Quality of the treated effluent shall meet to the following standards within five years from the date of notification dated 13.10.2017.

S.No.	Parameters	Standards
1	pH	6.5 to 9.0
2	BOD (mg/L)	Not more than 30
3	TSS (mg/L)	Not more than 100

4	Fecal Coliform (MPN/100ml)	Less than 1000

3. **Conditions under Air Act :-**

(i) The applicant shall use following fuel and install a comprehensive control system consisting of control equipment as is required with reference to generation of emissions and operate and maintain the same continuously so as to achieve the level of pollutants to the following standards :-

S. No	Stack attached with	Stack height (Mt)	Type of Fuel	Fuel Quantity	Emission Control Equipment	Emission standards not to exceed
1	DG Set (1000 KVA) x 2	7	HSD	100 Ltr./Hr.	Natural Draft Acoustic Enclosure	-
2	DG Set (500 KVA) x 4	4	HSD	150 Ltr./Hr.	Natural Draft Acoustic Enclosure	-

In case of stoppage of functioning of air pollution control equipment, production has to be ***stopped immediately*** *and this* ***Board*** *has to be intimated by fax/phone/email with a report in this regard to be dispatched immediately.*

(ii) Noise from the D.G. Set and other source(s) should be controlled by providing an acoustic enclosure as is required for meeting the ambient noise standards for night and day time as prescribed for respective areas/zones (Industrial, Commercial, Residential, Silence) which are as follows :-

Standards for Noise level in db(A) Leq	Industrial Area		Commercial Area		Residential Area		Silence Zone	
	Day time	Night time	Day time	Night time	Day time	Night time	Day time	Night time
	75	70	65	55	55	45	50	40

Day time : from 6.00 a.m. to 10.00 p.m., Night time: from 10.00 p.m. to 6.00 a.m.

4. **Conditions under Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016 :-**

(i) The **Factory Manager** of **M/s THDC India Ltd., Tehri** is hereby granted an authorization to operate a facility for collection and storage of Hazardous wastes.

(ii) The authorization is granted to operate a facility for generation, collection and storage of hazardous wastes within factory premises for following category of wastes :-

S.No.	Category (Schedule-I & Schedule-II)	Quantity of Waste for which authorization is being issued (MTA)	Mode of Disposal
1	Schedule I-5.1	0.500	Recyclable

(iii) The authorization shall be in force **for the period upto 31.03.2025.**

(iv) The authorization is subject to the conditions stated below and such conditions as may be specified in the rules for the time being in force under Environment (Protection) Act, 1986.

Terms and conditions of authorization :-

(i) The authorization shall comply with the provisions of the **Environment (Protection) Act**, 1986, and the rules made there under.

(ii) The authorization and its renewal shall be produced for inspection at the request of an officer authorized by the SPCB/PCC.

(iii) The person authorized shall not rent, lend, sell, transfer or otherwise transport the hazardous wastes without obtaining prior permission of the SPCB/PCC.

(iv) Any unauthorized changes in personnel, equipment as working conditions as mentioned in the application by the person authorized shall constitute a breach of his authorization.
(v) It is the duty of the authorized person to take prior permission of the SPCB/PCC to close down the facility.
(vi) An application for the renewal of an authorization shall be made as laid down under these rules.
(vii) The unit shall comply with any other conditions specified in the guidelines issued by the MoEF&CC or CPCB/SPCB from time to time.

5. This CCA is valid for the production of Hydro Power-400 MW from water of River Bhagirathi only.

6. **Compulsory documents to be submitted by the Industry/Unit** :-
   (i) Annual return in **Form-4** and **Waste Disposal Manifest** in **Form-10** under **Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016** and **Third Party Audit Report**.
   (ii) Environment Statement in **Form-V** of **Environment (Protection) Rules, 1986**.
   (iii) Quarterly **compliance report of the CCA, photograph of ETP/APCs/Waste Storage Area**.

7. Unit has to apply for renewal of CCA well in advance of 60 days of expiry of this CCA.

8. Competent Authority reserves the right to change/modify/add any time any condition of this CCA.

9. **The Unit shall comply the "Approved Fuels" policy in the entire state of Uttarakhand and use the fuel as per the list of Approved Fuels listed in the order issued by the Board vide its letter no. UEPPCB/HO/Gen-183-426/2020/171-331 dated 17.07.2020.**

10. Unit has to comply with the Specific & General conditions which are as follows :-

Specific Conditions:

1. **The Consent to Operate will attract execution of Board's Order dated 02.12.2022 subject to directions of Hon'ble High Court in this regard in the PIL 93/2022 as issued from time to time.**
2. The applicant shall submit audited balance sheet of the unit at the end of each financial year so that fee submitted by the applicant could be assessed.
3. The applicant shall provide ports in the chimney/stack and facilities such as ladder, platform etc. as per requirement for monitoring the air emissions and the same shall be open for inspection and use at all times by the Board's staff. The chimney/stack attached to various sources of emission shall be designated by numbers such as S-1, S-2 etc. and these shall be painted/ displayed to facilitate identification.
4. The industry shall ensure interlocking of air pollution control devices and production processes.
5. Solid wastes generated from the industry has to be disposed in manner so that contamination of surface water bodies/ground water/soil etc. does not take place.
6. The industry shall take adequate measures to control of noise from its own source so as to comply with the standards as may be applicable.
7. The applicant shall develop three rows of green belt on the premises with plant species as suggested by the **Central Pollution Control Board**.
8. The industry shall strictly adhere with the specific and general conditions issued with CCA order. Any violation of stipulated conditions may attract legal action under the provisions of **Water Act, Air Act** and **Environment (Protection) Act** and **Rules** made thereunder.
9. The industry shall ensure **all safety measures** and shall undertake **periodical assessment** by the competent authority.
10. Unit shall ensure manifest system in **Form-10** of **Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016** while disposing hazardous waste.
11. Hazardous waste should not be stored beyond a period **of 90** days.
12. The industry situated nearby the River Ganga and its tributaries shall ensure the treatment facilities and disposal arrangement in such a way so that no waste water is discharged in water stream or water bodies.

13. The project proponent shall maintain minimum environmental flow in downstream of dam/ barrage as prescribed by the Government of Uttarakhand vide order ref. no. 708/U/2018-05/24(writ)/2016 dated 05-06-2018 and prescribed by the Central Govt. from time to time..
14. **The unit shall strictly avoid the usage of single use plastics in the premises as per the list of banned single use plastics mentioned in the notification of MoEF&CC, Government of India dated 12.08.2021 and notification of Uttarakhand Government**
15. **issued vide letter no. 84/XXVIII-1-20-13(II)/2001 dated 16.02.2021.**
16. **The unit shall comply to the letter no. 708/I/2018-05/24(Writ)/2016 dated of Secretary, Uttarakhand Government regarding order of NGT dated 09.08.2017 related to Minimum Environmental Flow in River.**
17. The unit shall strictly comply with the provisions of Water, Air & E (P) Acts and Rules/Notifications made thereunder.

General Conditions

1. The applicant shall get analyse the samples of effluent/emission/hazardous wastes at least once in a three month from the laboratory recognized by the MoEF&CC and shall report to the UKPCB.
2. The applicant shall however, not without the prior consent of the **Board** bring into use any new or altered outlet for the discharge of effluent or gases emission or sewage waste from the unit.
3. Treated waste water and domestic waste water shall be disposed jointly at one disposal point. The applicant shall provide discharge measurement equipment at final disposal point.
4. The applicant shall strictly comply with conditions of this CCA and submit compliance report of stipulated conditions within 30 days of receipt of this CCA. If, at any point of time, it is found that the industry is not complying with stipulated conditions or any further direction/instruction issued by the **Board**, legal action shall be initiated against the applicant.
5. The applicant shall maintain good house keeping. All valves/pipes/sewer/drains etc. must be leak-proof.
6. The industry shall provide uninterrupted entry to the STP's/ETP's inlet and outlet points, Air Pollution Control equipment and stack for smooth sampling/monitoring of efficiency of pollution control measures.
7. The industry shall provide "Inspection Book" at the time of inspection to the Board's officials.
8. Whenever due to any accident or other unforeseen act or event, such emission occurs or is apprehended to occur in excess of standards laid down, such information shall be reported to the Board's offices and all other concerned offices. In case of failure of pollution control equipment, the production process connected to it shall be stopped with immediate effect.
9. The industry shall operate in a manner so that all emissions be emitted through designated chimney/stack only.
10. In case of any damage to the agriculture productivity, human habitation etc. by the operation of industry, it shall be imperative to stop production in the industry with immediate effect and such information shall be reported to Board's offices. The industry shall be liable to pay compensation also in such cases as decided by the Competent Authority.
11. The applicant shall apply before the 60 days of expiry of CCA or any change in production types/ production capacity/manufacturing process/capacity enhancement etc. or any change in effluent discharge point or emission point.
12. The **Board** reserves the right to revoke/add/modify any stipulated condition issued along with CCA, as may be necessary.
13. The person authorized shall not rent, lend, sell, transfer or otherwise transport the hazardous waste without obtaining prior permission of the **Board**.
14. Any unauthorized change in personnel, equipment as working condition as mentioned in the application by the person authorized shall constitute a breach of his authorization.
15. It is the duty of the authorized person to take prior permission of the **Board** to close down the facility.
16. The authorization is valid for temporary storage of Hazardous Waste within premises only.
17. The authorized agency shall ensure that on-line data with regard to quantity and nature of hazardous chemicals being used in the plant as well as air emission and waste generated within premises is displayed on **Display Board of size 6x4 feet** outside the main factory gate within premises.

18. It is duty of the authorized person to take prior permission of this Board to close and cleanup the facility for treatment, storage and disposal of hazardous waste.
19. The applicant shall maintain record of hazardous waste in **Form-3** and shall submit annual return in **Form-4** on or before the 30th day of June following to the financial year to which that return relates.
20. In no case any hazardous waste shall be disposed off on land, in any drain, or into any water stream. All spillage must also be safely collected and stored.
21. Before the hazardous waste is stored or dumped in the facility, applicant must conduct a detailed **physical and chemical analysis of hazardous waste sample** and report to the **Board.**
22. Dried hazardous sludge from the process in the plant shall be **stored in double lined HDPE pit constructed with R.C.C. or such material which does not react with the waste contained in it.**
23. The storage area should be fenced properly and Sign/Notice Board indicating 'Danger' and **'Hazardous'** shall be displayed at appropriate position both in Hindi and English.
24. The industry shall store non-ferrous metal waste, used oil/spent oil waste in sealed drums placed on impervious floor under covered shed. Hazardous waste if required shall be **sold only to Registered Recyclers/Re-processors.**
25. In case of any transportation of hazardous waste, the details in **Form-10** of the **Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016** shall be submitted to the **Board.**

Dr. Parag Madhukar Dhakate
Member Secretary

Letter No. :UKPCB/HO/Con/T-62/2024/ Dated: as above.

Copy to: **Regional Officer, Uttarakhand Pollution Control Board, Dehradun** for information and compliance of the same.

Member Secretary

UKPCB

LiFE Lifestyle For Environment

HEAD OFFICE
Uttarakhand Pollution Control Board
"Gaura Devi Paryavaran Bhawan"
46B, IT Park, Sahastradhara Road, Dehra Dun
E-mail : msukpcb@yahoo.com, Phone No.-0135-2607092

UKPCB/HO/Con/T-36/2024 /818 Date : 21/08.2024

REGD. POST

To,

M/s THDC India Ltd.,
Bhagirathi Puram,
Distt. Tehri Garhwal.

Consolidated Consent to Operate and Authorisation hereinafter referred to as the CCA (Consolidated Consent & authorization) (Renewal) under Section-25 of the "Water (Prevention & Control of Pollution) Act, 1974" and under Section-21 of the "Air (Prevention & Control of Pollution) Act, 1981" and Authorization under "Rule-6(2)" of the "Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016" notified under "Environment (Protection) Act, 1986" as applicable (to be referred hereinafter as **Water Act**, **Air Act** and **HW Rules** respectively).

CAF ID –5775	**Application no.- 4798506**
CCA (Renewal)	
Date :- 23-03-2024	

CCA is hereby granted to **M/s THDC India Ltd.** located at **Bhagirathi Puram, Distt-Tehri Garhwal** subject to the provisions of the **Water Act, Air Act** and **Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016** and the orders that may be made further and subject to following terms and conditions :-

1. This CCA is **granted for the period upto 31-03-2025** and valid for manufacturing of following products with **Capital Investment/Net Assets Values ₹370422.0 Lakh** :-

S. No.	Last CCA		Present CCA (Renewal)	
	Product	Quantity (Per Month)	Product	Quantity (Per Month)
1	Electricity Generation	1000 MWH	Electricity Generation	1000 MWH

2. **Specific Conditions under Water Act :-**

(i) **The daily quantity of effluent discharge (KLD) :-**

	CTE/Last CCA	Present CCA (Fresh)
Trade Effluent	Nil	Nil
Sewage	21	21

(ii) **Trade Effluent Treatment and Disposal :-** Nil

(iii) **Sewage Treatment and Disposal** :- The domestic waste water shall be treated through STP provided by project proponent.

In case of stoppage of functioning of STP, production has to be ***stopped immediately*** *and this* ***Board*** *has to be intimated by fax/phone/email with a report in this regard to be dispatched immediately.*

(iii) The treated sewage shall be reuse in gardening etc. Quality of the treated effluent shall meet to the following standards within five years from the date of notification dated 13.10.2017.

S.No.	Parameters	Standards
1	pH	6.5 to 9.0

2	BOD (mg/L)	Not more than 30
3	TSS (mg/L)	Not more than 100
4	Fecal Coliform (MPN/100ml)	Less than 1000

3. **Conditions under Air Act :-**

(i) The applicant shall use following fuel and install a comprehensive control system consisting of control equipment as is required with reference to generation of emissions and operate and maintain the same continuously so as to achieve the level of pollutants to the following standards :-

S. No	Stack attached with	Stack height (Mt)	Type of Fuel	Fuel Quantity	Emission Control Equipment	Emission standards not to exceed
1	DG Set (1100 KVA) x 2	13	Diesel	100 Ltr./Hr.	Natural Draft Acoustic Enclosure	-

In case of stoppage of functioning of air pollution control equipment, production has to be ***stopped immediately*** *and this* ***Board*** *has to be intimated by fax/phone/email with a report in this regard to be dispatched immediately.*

(ii) Noise from the D.G. Set and other source(s) should be controlled by providing an acoustic enclosure as is required for meeting the ambient noise standards for night and day time as prescribed for respective areas/zones (Industrial, Commercial, Residential, Silence) which are as follows :-

Standards for Noise level in db(A) Leq	Industrial Area		Commercial Area		Residential Area		Silence Zone	
	Day time	Night time	Day time	Night time	Day time	Night time	Day time	Night time
	75	70	65	55	55	45	50	40

Day time : from 6.00 a.m. to 10.00 p.m., Night time: from 10.00 p.m. to 6.00 a.m.

4. **Conditions under Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016 :-**

(i) The **Factory Manager** of **M/s THDC India Ltd., Tehri Garhwal** is hereby granted an authorization to operate a facility for collection and storage of Hazardous wastes.

(ii) The authorization is granted to operate a facility for generation, collection and storage of hazardous wastes within factory premises for following category of wastes :-

S.No.	Category (Schedule-I & Schedule-II)	Quantity of Waste for which authorization is being issued (MTA)	Mode of Disposal
1	Schedule I-5.1	4.000	Recyclable
2	Schedule I-35.3	0.010	Secure land fill

(iii) The authorization shall be in force **for the period upto 31.03.2025.**

(iv) The authorization is subject to the conditions stated below and such conditions as may be specified in the rules for the time being in force under Environment (Protection) Act, 1986.

Terms and conditions of authorization :-

(i) The authorization shall comply with the provisions of the **Environment (Protection) Act**, 1986, and the rules made there under.

(ii) The authorization and its renewal shall be produced for inspection at the request of an officer authorized by the SPCB/PCC.

(iii) The person authorized shall not rent, lend, sell, transfer or otherwise transport the hazardous wastes without obtaining prior permission of the SPCB/PCC.

(iv) Any unauthorized changes in personnel, equipment as working conditions as mentioned in the application by the person authorized shall constitute a breach of his authorization.
(v) It is the duty of the authorized person to take prior permission of the SPCB/PCC to close down the facility.
(vi) An application for the renewal of an authorization shall be made as laid down under these rules.
(vii) The unit shall comply with any other conditions specified in the guidelines issued by the MoEF&CC or CPCB/SPCB from time to time.

5. This CCA is valid for electricity generation only.

6. **Compulsory documents to be submitted by the Industry/Unit :-**
   (i) Annual return in **Form-4** and **Waste Disposal Manifest** in **Form-10** under **Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016** and **Third Party Audit Report**.
   (ii) Environment Statement in **Form-V** of **Environment (Protection) Rules, 1986**.
   (iii) Quarterly **compliance report of the CCA, photograph of ETP/APCs/Waste Storage Area**.

7. Unit has to apply for renewal of CCA well in advance of 60 days of expiry of this CCA.

8. Competent Authority reserves the right to change/modify/add any time any condition of this CCA.

9. **The Unit shall comply the "Approved Fuels" policy in the entire state of Uttarakhand and use the fuel as per the list of Approved Fuels listed in the order issued by the Board vide its letter no. UEPPCB/HO/Gen-183-426/2020/171-331 dated 17.07.2020.**

10. Unit has to comply with the Specific & General conditions which are as follows :-

Specific Conditions:

1. **The Consent to Operate will attract execution of Board's Order dated 02.12.2022 subject to directions of Hon'ble High Court in this regard in the PIL 93/2022 as issued from time to time.**
2. The applicant shall submit audited balance sheet of the unit at the end of each financial year so that fee submitted by the applicant could be assessed.
3. The applicant shall provide ports in the chimney/stack and facilities such as ladder, platform etc. as per requirement for monitoring the air emissions and the same shall be open for inspection and use at all times by the Board's staff. The chimney/stack attached to various sources of emission shall be designated by numbers such as S-1, S-2 etc. and these shall be painted/ displayed to facilitate identification.
4. The industry shall ensure interlocking of air pollution control devices and production processes.
5. Solid wastes generated from the industry has to be disposed in manner so that contamination of surface water bodies/ground water/soil etc. does not take place.
6. The industry shall take adequate measures to control of noise from its own source so as to comply with the standards as may be applicable.
7. The applicant shall develop three rows of green belt on the premises with plant species as suggested by the **Central Pollution Control Board**.
8. The industry shall strictly adhere with the specific and general conditions issued with CCA order. Any violation of stipulated conditions may attract legal action under the provisions of **Water Act, Air Act** and **Environment (Protection) Act** and **Rules** made thereunder.
9. The industry shall ensure **all safety measures** and shall undertake **periodical assessment** by the competent authority.
10. Unit shall ensure manifest system in **Form-10** of **Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016** while disposing hazardous waste.
11. Hazardous waste should not be stored beyond a period **of 90** days.
12. The industry situated nearby the River Ganga and its tributaries shall ensure the treatment facilities and disposal arrangement in such a way so that no waste water is discharged in water stream or water bodies.

13. The project proponent shall maintain minimum environmental flow in downstream of dam/barrage as prescribed by the Government of Uttarakhand vide order ref. no. 708/U/2018-05/24(writ)/2016 dated 05-06-2018 and prescribed by the Central Govt. from time to time.
14. **The unit shall strictly avoid the usage of single use plastics in the premises as per the list of banned single use plastics mentioned in the notification of MoEF&CC, Government of India dated 12.08.2021 and notification of Uttarakhand Government issued vide letter no. 84/XXVIII-1-20-13(II)/2001 dated 16.02.2021.**
15. The unit shall strictly comply with the provisions of Water, Air & E. (P) Acts and Rules/Notifications made thereunder.

General Conditions

1. The applicant shall get analyse the samples of effluent/emission/hazardous wastes at least once in a three month from the laboratory recognized by the MoEF&CC and shall report to the UKPCB.
2. The applicant shall however, not without the prior consent of the **Board** bring into use any new or altered outlet for the discharge of effluent or gases emission or sewage waste from the unit.
3. Treated waste water and domestic waste water shall be disposed jointly at one disposal point. The applicant shall provide discharge measurement equipment at final disposal point.
4. The applicant shall strictly comply with conditions of this CCA and submit compliance report of stipulated conditions within 30 days of receipt of this CCA. If, at any point of time, it is found that the industry is not complying with stipulated conditions or any further direction/instruction issued by the **Board**, legal action shall be initiated against the applicant.
5. The applicant shall maintain good house keeping. All valves/pipes/sewer/drains etc. must be leak-proof.
6. The industry shall provide uninterrupted entry to the STP's/ETP's inlet and outlet points, Air Pollution Control equipment and stack for smooth sampling/monitoring of efficiency of pollution control measures.
7. The industry shall provide "Inspection Book" at the time of inspection to the Board's officials.
8. Whenever due to any accident or other unforeseen act or event, such emission occurs or is apprehended to occur in excess of standards laid down, such information shall be reported to the Board's offices and all other concerned offices. In case of failure of pollution control equipment, the production process connected to it shall be stopped with immediate effect.
9. The industry shall operate in a manner so that all emissions be emitted through designated chimney/stack only.
10. In case of any damage to the agriculture productivity, human habitation etc. by the operation of industry, it shall be imperative to stop production in the industry with immediate effect and such information shall be reported to Board's offices. The industry shall be liable to pay compensation also in such cases as decided by the Competent Authority.
11. The applicant shall apply before the 60 days of expiry of CCA or any change in production types/ production capacity/manufacturing process/capacity enhancement etc. or any change in effluent discharge point or emission point.
12. The **Board** reserves the right to revoke/add/modify any stipulated condition issued along with CCA, as may be necessary.
13. The person authorized shall not rent, lend, sell, transfer or otherwise transport the hazardous waste without obtaining prior permission of the **Board.**
14. Any unauthorized change in personnel, equipment as working condition as mentioned in the application by the person authorized shall constitute a breach of his authorization.
15. It is the duty of the authorized person to take prior permission of the **Board** to close down the facility.
16. The authorization is valid for temporary storage of Hazardous Waste within premises only.
17. The authorized agency shall ensure that on-line data with regard to quantity and nature of hazardous chemicals being used in the plant as well as air emission and waste generated within premises is displayed on **Display Board of size 6x4 feet** outside the main factory gate within premises.
18. It is duty of the authorized person to take prior permission of this Board to close and cleanup the facility for treatment, storage and disposal of hazardous waste.

19. The applicant shall maintain record of hazardous waste in **Form-3** and shall submit annual return in **Form-4** on or before the 30th day of June following to the financial year to which that return relates.
20. In no case any hazardous waste shall be disposed off on land, in any drain, or into any water stream. All spillage must also be safely collected and stored.
21. Before the hazardous waste is stored or dumped in the facility, applicant must conduct a detailed **physical and chemical analysis of hazardous waste sample** and report to the **Board.**
22. Dried hazardous sludge from the process in the plant shall be **stored in double lined HDPE pit constructed with R.C.C. or such material which does not react with the waste contained in it.**
23. The storage area should be fenced properly and Sign/Notice Board indicating 'Danger' and **'Hazardous'** shall be displayed at appropriate position both in Hindi and English.
24. The industry shall store non-ferrous metal waste, used oil/spent oil waste in sealed drums placed on impervious floor under covered shed. Hazardous waste if required shall be **sold only to Registered Recyclers/Re-processors.**
25. In case of any transportation of hazardous waste, the details in **Form-10** of the **Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016** shall be submitted to the **Board.**

Dr. Parag Madhukar Dhakate
Member Secretary

Letter No. :UKPCB/HO/Con/T-36/2024/ Dated: as above.

Copy to: **Regional Officer, Uttarakhand Pollution Control Board, Dehradun** for information and compliance of the same.

Member Secretary