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Integrated Management of Water Resources of Lake Nainital and its Watershed: An Environmental Economics Approach

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Preface

This report considers an environmental economics' perspective into the management of Lake Nainital and its watershed. Located at 1938 m altitude, Nainital is one of the principal tourist stations of India. The tourist number in a year is more than 3 lakhs with over 50% visiting during the summer months. While investigating valuation of water resources and its management the focus was on interconnections between the lake and its watershed. Thus, the lake degradation was considered both in view of the human activities in the watershed as well as direct in-lake activities. The economic valuation reflected both goods such as drinking water, and ecosystem services such as water filtration through a valley-fill. The project took as integrated attempt and to provide social perspective. PRA exercise was carried out to cover perceptions of a range of stakeholder groups, such as boatmen, horsemen, coolies and professionals. Thus, the study considered integrating ecology, economics and social aspects. The environmental economics approach applied was rooted in resource valuation, property right, regimes and institutional arrangements.

The specific objectives of the projects included: estimation of costs and benefits of resource use of Lake Nainital itself and the lake watershed as well, and estimation of cost water quality degradation in Lake Nainital and to workout its relationship, with anthropogenic activities in the watershed. Developing a resource management policy for the Lake Nainital and its watershed was the long-term objective.

This report is organised in seven chapters. Chapter one gives brief background of the project. Chapter 2 primarily describes ecological aspects of lake and its watershed and changes in them in the past. Chapter 3 lists diverse stakeholder groups along with the possible values they derive from the lake. Chapter 4 and 5 describes analyses of individuals' responses, using questionnaire method. The focus on tourists' contribution to the economy based around the lake using travel cost method, and gives an estimate of the amount tourists are willing to pay for lake conservation. The questionnaire method was complemented by undertaking PRA exercise that seeks opinion of diverse stakeholders. The results of this exercise are discussed in Chapter 6. Chapter 7 summaries the measures that could be taken to the lake restoration and for improving watershed and lake condition, keeping in view

the benefits derived from the lake. In this emphasis is on integrated approach that gives value to lake and watershed interconnections.

Officials of Municipal Board Nainital, Jal Sansthan, Jal Nigam and Uttaranchal Tourism provided data pertaining to their departments. The help extended by Advocate Mr. P. Lohani in understanding the administration and management of Lake Nainital is duly acknowledged.

Thanks are due to Prof. B.S. Rajput, Vice Chancellor, Kumaun University who took interest in the entire exercise and also participated in the workshops organised during the course of the study.

Mr. Mukund Kumaiyan contributed to this study in various ways including computerisation of data, organising manuscript and editing.

Several students of Kumaun University provided assistance in the PRA exercise and their assistance is duly acknowledged. Thanks are due to Dr. P.K. Gupta and Dr. Surendra Nagdali of Department of Zoology, Kumaun University, Nainital for easy access of data and other information. Mrs. Veena Pandey, Department of Biotechnology is duly acknowledged for assistance in questionnaire surveys.

And all those who have contributed to this study directly or indirectly are duly acknowledged.

Contents

Executive Summary

This project applies an environmental economics' approach to the management of Lake Nainital and its watershed. While considering the value of water resource and its management the emphasis has been put on dependence of the lake on its watershed. Accordingly, the lake condition was analysed both in relation to human activities in the watershed as well as in-lake activities. The economic estimates we arrived at did not consider all the ecosystem services; however, they were reflected to some extent. The project made an attempt to integrate ecological economics and social perspectives by considering a variety of stakeholders and analysing various geological components.

The specific objectives of the projects included: (i) estimation of costs and benefits of resource use of Lake Nainital itself and the lake watershed as well; and (ii) estimation of cost of water quality degradation in Lake Nainital and to workout its relationship with anthropogenic activities in the watershed; and (iii) developing a resource management policy for the Lake Nainital and its watershed was the long-term objective.

Ecology of the lake and its watershed

Reported first in 1841, Nainital (29°24' latitude and 79°29' longitude at 1938 m above sea level) is one of the major hill resorts of North India, supporting a resident population of about 40,000 and about 4 lakh tourists annually within a small area of 11-12 km^2. Of this, about 5 km^2 area that forms watershed of the lake is densely populated. The climate is temperate with annual rainfall generally ranging between 200-250 cm. The geology of Nainital is extremely complex characterised by landslide scars and fans, and debris cover mostly associated with the Nainital Fault that separates the lake and watershed into two roughly equal parts. Already seven major landslides have occurred during the last century or so.

The lake receives water from its catchment through 21 major drains, springs, runoff and subsurface inflows. Most of the water in the lake owes its origin in the watershed, direct precipitation accounting for only 15% of the total annual inflow. However, much of the water that enters the lake is affected by organic and heavy metal pollutions. For example, the biochemical oxygen demand (BOD) of the drains range between 60-74 mg/l and bacterial population is up to 1218 colony forming

units/ml. The concentration of lead in the lake water often exceeds the permissible level, vehicular traffic and excessive use of lead containing paints particularly on tin roofs being the major sources.

The valley-fill in the catchment is the major source of subsurface water to the lake (accounting for over 40% of total inflow) and is used directly for drinking water supply. The forest cover (mainly oak and cypress) is still substantial accounting for about 48% of the catchment area and providing habitat for nearly 700 plant species and about 200 birds.

During most of its history Nainital has been a city for pedestrians but vehicular traffic has risen steeply during the past decade resulting in summer time traffic jams and problems of parking. The number of light vehicles entering Nainital has increased by 46% during the last 3 years.

The lake is small with the following morphometrics: maximum length of 1423 m, breadth 253-423 m, maximum depth 27.3 m, surface area 48 ha and volume at maximum level 8.58 million m^3. The lake volume is gradually declining due to sedimentation caused by landslides, erosion and illegal dumping of construction waste in drains and on slopes. The young and rising mountains with immature topography are highly vulnerable to destabilising forces. Life expectancy of the lake is generally estimated to be less than 500 years.

The lake is warm monomictic with fairly stable summer time thermal stratification and highly eutrophic with almost opaque water (Secchi disk transparency generally less than a meter). The lake warrants ecological restoration on priority basis and that is a difficult task given the geological sensitivities and insensitivities of administrators and decision makers (so far no Indian lake has been restored).

Eutrophication and phosphate budget

The phosphate budget indicates that the lake has approached the condition of irreversible eutrophication emphasising that the steady state phosphate level cannot be reduced drastically by taking measures that control only the phosphorus input to the lake. The hypolimnion (up to 15 m thick) remains anoxic for much of the year; consequently the phosphorus of the sediment gets readily soluble and recycled. Restoration that involves the treatment of the sediment, which accumulates P at the rate of about 114 kg/yr and the anoxic hypolimnion is necessary to revive the lake to

a healthy condition. Removal of phosphorus from detergents and treatment of the watershed (better network of sewer lines and afforestation) are some of the measure required.

Cost of unsafe water

The fall in lake quality or increased eutrophication has resulted in significant direct costs to the people, as the lake is the principal source of drinking water. The cost of unsafe water includes the cost of buying bottled water, use of water purifying devices and the treatment of waterborne diseases, which are on rapid increase. This amounts to about Rs.5.7 million annually, of which about 60% is on medical expenses alone. Decline in human resource capital and loss of working hours could not be calculated, as that requires a proper socio-economic survey of the local people.

Benefits and economic valuation

The lake and its watershed provide a number of goods and services, many of which have no substitute. Some of the services which are generated from the ecosystems (the lake, forests and the valley-fill) are: lower cost of treatment per unit water; direct water supply without treatment; increased turnover of lake water; increased hill-slope protection; reduced cost of silt removal; and support to activities like bird-watching and the trade of photography. This small town has already produced three nationally acclaimed photographers.

It is the combination of lake and the hills that attract the tourists to Nainital. This is indicated by two-thirds of the 273 tourists that have been interviewed. The consumer surplus arrived at by the use of zonal travel cost method from tourism ranges between Rs.4.3 – 6.5 million depending upon functional form used for calculations. The values obtained are an underestimate of the total value that the people are willing to pay to preserve the lake, as the method captures only the use-value and that too is under represented. The sampling did not consider the foreigners, people on package tours and children.

Given the constraints of further construction, heavy vehicular traffic that restricts tourists to move and walk freely and leisurely, inadequate water supply during summers, vulnerability of hill slopes to landslides, deteriorating water quality and poor garbage disposal system indicate that Nainital has reached its carrying capacity

with regard to tourism. The problem is aggravated by the fact that tourism is getting more and more seasonal, concentrated to a single summer month of June.

Better management with the help of modern techniques can increase the carrying capacity in regard to parameters such as waste disposal and water quality (improved treatment plants, restoration of lake and maintenance of watershed).

Analysis of the responses of the informed citizens of Nainital indicates that the valuation exercise is a step towards conservation of resources and can contribute significantly to the planning for the study of watershed in other areas. The informed citizens have given great importance to the existence value of the lake and pointed out that soil, quality, streams and spring water are the major benefits to humans from the watershed. A majority of citizens are willing to pay for its conservation.

Stakeholders' perceptions

Issues of environment and development warrant integration not only of ecological and economic factors but also social ones. The results of PRA techniques were based on nine stakeholder groups. These include boatmen, horsemen, coolies, rickshaw-puller, vendors, tourists, professionals, hoteliers and citizens. We treated it as a complementary tool to the questionnaire survey to look into the perceptions of different stakeholders. The difference in perception across different stakeholder groups clearly indicates that to achieve participatory management they are to be effectively included in the development of any management plan. For example, while a number of stakeholder groups appear to be lake-centred, horsemen were mainly interested in peaks and view-sites, adding new dimensions to tourist interest and attractions based on nature.

Nearly Rs.57 million (much of which is generated through tourism) is distributed across the poorer stakeholders groups numbering over 1600 individuals comprising rickshaw-pullers, horsemen, boatmen, coolies and vendors. When considered in relation to the lake area the density of money flow is about Rs.1.17 million per hectare annually, which is quite enormous given the fact that this is only a fraction of the total economy of more than Rs.400 million (a crude estimate) based on tourism. High quality school education is another major component of the economy of Nainital. It was initiated and established largely due to the nature, the lake and the climate present.

The approximate value of economy generated annually due to the lake and its watershed comes to about Rs.50 million per hectare. Generation of such a huge amount has heavy environmental cost on the ecogeologically fragile watershed. As a consequence of this the restoration of lake is quite expected and justified.

Conclusions

The travel cost method we used to estimate the value of Lake Nainital and its watershed relates to several ecosystem services such as filtration and storage of water by the Sukhatal valley-fill, and concomitant influence on the lake level, pollution abatement, recreational values, and direct drinking water supply. However, their specific contributions go un-estimated in this method.

Our study, however, makes it abundantly clear that we must give the “natural capital stock” (lake, forests and others) that produces various ecosystem services appropriate weight in decision-making process in the study of the watershed. The health of natural capital stock heavily depends on ecosystem connections, and interactions between ecosystem and connected abiotic components, such as, rocks and valley-fills which store water and release subsequently to the lake and forests.

As Costanza *et al.* (1997) have clearly indicated if ecosystem services were actually paid for, keeping their contributions to the economy, the price system would be very different from that we have. Our study has shown that the ecosystem services of Nainital lake and its watershed have considerable value. The estimates we have arrived at should be incorporated in the regional accounting to have a more sustainable development, and a future that does not drastically suffer on account of ecosystem degradation.

The ecological observations indicate that the lake is highly eutrophic, approaching an irreversible stage, and thus warrants restoration. Measures, such as reduction in input of nutrients and maintenance of a healthy watershed are desired, as they have meaning even when the lake is revived and the steady state P-level is drastically reduced. The restoration cost can be justified, considering the values of ecosystem services over a long horizon. Furthermore, while undertaking a specific project in the watershed, the benefits accruing should be weighed against the loss it may cause to ecosystem services.

Summary of recommendations

1. An integrated unit of development that focuses on the lake and its watershed and their interconnections is required. The focus should be the watershed and consideration all components of the unit.
2. A restoration work that addresses the issues of eutrophication is required. This may warrant a complete documentation of P-budget and recycling from the lake sediment.
3. People's participations should be promoted at all levels: constituting bodies, decisions making, sharing responsibilities, and awareness programs, education, etc.
4. A master plan keeping in view the carrying capacity should be the starting point of management.
5. Pedestrians should be given due place, and arrangement should be made for safe walking. Historically Nainital was city of pedestrians, but now most of the paths and roads have been taken over by vehicles.

Chapter 1: Introduction and Project Background

1.1 Introduction

It is widely recognised that water resources are greatly influenced, both qualitatively and quantitatively, by their catchment (watershed/drainage basin). Human activities, both in the water-body and in its catchment, directly or indirectly affect water quality and various other functions. Though the impacts of water pollution have been discussed from the viewpoint of environmental economics in several studies, the impacts of catchment-based activities have received little attention.

This project takes an integrated approach to understanding the problems of availability of water resources, particularly drinking water. It aims at bringing an environmental economics' perspective into water resources management by evaluating the resources of both the lake and its watershed. It proposed to quantify the level of degradation of lake water quality due to inappropriate practices in the watershed, as well as direct in-lake activities, and assess the economic costs of providing potable water, as well as environmental costs, such as the dissipation of wastes, when the lake and its watershed ceases to provide these services.

The project explores the hypothesis that if catchment-based degradation factors are not taken care of, the cost of water treatment required for drinking water supply would increase multi-fold. The curtailment or proper management of catchment based activities would also provide additional benefits through increased ecosystem services including improved recreational value of the lake, reduction in the incidence of water-borne diseases and a decrease in the siltation rate of the lake. This in turn would prolong the life of the lake.

Lake Nainital along with its watershed in Uttaranchal was selected for the present study in view of its importance for at least two major ecosystem services: (i) as the major drinking water source for the township of Nainital, and (ii) high recreational value for tourists.[1] Other factors that swayed the decision to carry out the study in Nainital were the availability of several decades of background data on the lake, and

[1] Recreation value for tourists may not be as such directly life-supporting, but as the economy of Nainital depends mainly on the tourism, it becomes life-supporting for the local population.

it being one of the few lakes where the lake and its watershed are quite intimately connected.

The project undertook an economic valuation of the resources of the lake and its watershed and of ecosystem services generated by them. It also examined property relations and their importance in the conservation and management of Lake Nainital, and has suggested institutional arrangements thereof. An environmental economics approach rooted in resource valuation, property rights regimes and institutional arrangements were used.

1.2 Project Objectives

The specific objectives as given in the project proposal were:

1.2.1 Short-term objectives

- To estimate costs and benefits of resource use of Lake Nainital itself;
- To estimate costs and benefits of resource use in the watershed of Lake Nainital; and
- To estimate cost of water quality degradation in Lake Nainital and to establish its relationship with anthropogenic activities in the watershed.

1.2.2 Long-term objectives

- To develop a Resource Management Policy for the Lake Nainital and its watershed.

The project has facilitated in capacity building through the training of young researchers in environmental economics and familiarised them with the concepts of integrated water resource management. Though we could only estimate the a part of the total economic value of the lake and its watershed due to limited time, but the learning acquired will certainly facilitate (a) to embark on a larger study that would find the total economic value (TEV) in other such watersheds; and (b) take on valuation of other natural resources say forests, etc. The methodology developed and tested will be useful for similar evaluations in other watersheds.

The project will have a follow up consisting of following two activities:

- Integration of the resultant policy on Lake Nainital and its catchment with cross-sectoral resource management planning of water resources of the region.

- Application of the methodology employed to other similar watersheds.

In order to value resource use of the lake and its watershed the study formally identifies different stakeholder deriving benefits from the lake and its watershed. Once the stakeholders are identified, the study then tries to assign values to the benefits they derive. The benefits derived, in fact, are nothing but the costs to the people of Nainital and to the tourists if lake and its watershed cease to do all the services, which it is currently doing. Any decline in services or increasing costs also implies that the lake and its watershed are deteriorating. Underneath any valuation exercises lies the fact that a natural resource is currently being exploited beyond limit and if the exploitation continues, and once the system reaches a threshold, reversibility would not be assured. The denouement of the valuation exercise is formulation of a proper management plan, the implementation of which would result in the continued flow of benefits by the underlying resource sustainably for the generations to come.

1.3 Organisation of the Report

The present report is organised in seven chapters. Chapter 2 gives in brief the historical sketch of the Lake Nainital and its watershed, the current status of the lake and how the status has changed in the past and what are the factors contributing to these changes. Chapter 3 identifies the stakeholders and the possible values they derive from the lake. The next chapter argues that despite different stakeholders are benefiting from a unique ecology of the lake, the whole is much greater than the individual sum. The clear indication to this synergy effect is the tourism activity in Nainital. The tourists visit for the whole and not for an isolated and individual attribute. What values do they give or in other words how much they are willing to contribute to preserve the ecology of the lake forms Chapter 4. A revealed preference method, i.e., the Travel Cost Method, has been employed to calculate the tourist values.

It is generally argued that most of the stakeholders are quite narrow in their viewpoint. Their views or perceptions are shaped by the profession they are into. For instance, a boatmen would be more concerned with the well being of lake quality; horsemen might wish to concentrate on peaks; tourists visiting Nainital will be more interested in the features around the lake and in the peaks etc., most of them

however, disregard or rather unaware of the services the lake and its watershed provides. It is the informed or aware citizens, who would value a natural resource for its totality not for an individual aspect. Chapter 5 is an attempt that looks into how the informed citizens of Nainital perceive valuation exercise as such and which aspect of the Lake and its watershed they view as the most important for the humankind and to the system.

The questionnaire method adopted in chapters 4 and 5 concentrate on responses from the individuals and it is argued sometimes that they remain passive contributors (see Appendix 1 for format of questionnaires). In order to complement questionnaire method, Participation Rural Appraisal (PRA) exercise was carried out that seeks opinion of different stakeholders. Chapter 6 gives in brief the PRA technique and the results obtained therein from the exercise. Chapter 7 then tries to summarize the benefits derived from the lake and its watershed. The analysis shows that the lake and its watershed are proving innumerable tangible (and intangible) benefits to the local economy. How these benefits continue to flow is the content matter for the last section of Chapter 7 that gives a tentative management plan for the management of lake and its watershed.

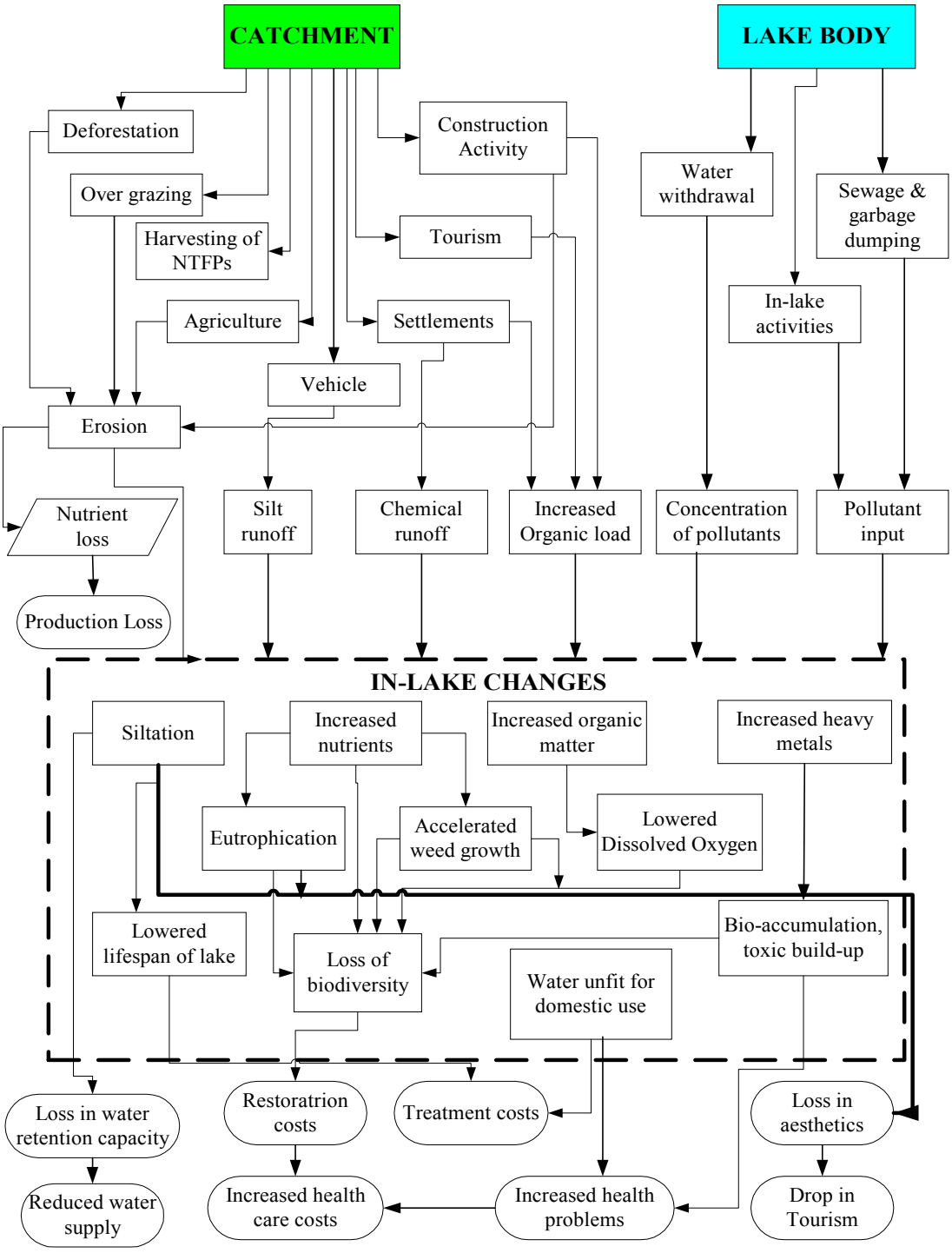

Fig. 1.1 Interconnections of the watershed and the lake and impacts thereof.

Chapter 2 :Nainital Lake and its Watershed – Status and Changes over Time

2.1 Introduction

Fresh water resources and fresh water ecosystems are central to societal and environmental vitality. The quantity, quality, form and timing of precipitation together shape the landscape as well as economics and cultural traits. Short-term water shortages are common in almost all the countries, and over 80% countries are affected by more serious water problems (Naiman *et al.* 1998). The problem is particularly serious in developing countries, where nearly 90% of all illnesses result from waterborne parasites and pathogens (*ibid.*). Many-a-times these problems are a result of anthropogenic pressures or the stresses introduced by humans themselves. The impacts of these pressures are felt in varied ways and from varied directions. This is because the surface freshwaters, such as lakes, wetlands, streams and rivers are not only sources of goods but also provide ecosystem services[2] to humans. They include both direct market goods and services, such as drinking water, irrigation, and transportation as well as those not marketed such as habitat for organisms and satisfaction humans derive from knowing that a lake or river ecosystems exists. The goods and services provided get multiplied if the watershed is also considered along with the water resource.

Lake Nainital and its watershed is one such natural resource, which is providing numerous benefits to a number of stakeholders since it was discovered.[3] The water supply as well as the waste disposal system of Nainital town depends heavily upon the lake and its watershed. During the past few decades, increasing local population and the tourist influx into the Nainital watershed have severely impacted upon the water quality of the lake as well as the water resources in the watershed. A sizable fraction of domestic sewage was entering the lake through open sewers until recently. A large population of domestic animals particularly horses (horse riding is common among tourists) is also contributing to the organic load into the lake. Unauthorized construction in the catchment and around the lake has contributed in

[2] An ecosystem service may be defined as services generated by the interaction and exchange between biotic and abiotic components of the ecosystem and its condition, and that sustain and fulfill human life.

[3] Chapter 3 identifies these different stakeholders, who are deriving benefits from the Lake and its watershed.

the past and is contributing substantially to the input of debris. As a result of these excesses, the lake is facing serious problem of Eutrophication (see Glossary for definition and related terms), heavy metal pollution and siltation. The steep hills surrounding the lake have immature topography and are prone to landslips and landslides. The multitudes of human activities in the watershed have increased the rate of erosion causing further problems of water supply and its quality. Efforts are being made (some since the British period) for the collection and treatment of domestic wastes. But an integrated management plan for the water resources of Lake Nainital and its watershed has not yet been developed or even conceptualised. The present chapter gives the current status of the Lake and how the water quality in the lake has changed in the past and what factors contributed to this change.

In this study, which concerns with aspects of ecology, economics and social factors, a diverse set of methods were used. For lake ecology we collected all information generated in past studies over the years, particularly of Kumaun University group. Apart from these secondary sources, we collected samples of water, particularly for estimating the inputs of PO_4, NO_3 and heavy metals through various sources such as drains and surface run-offs. Both questionnaires based surveys as well as PRA techniques were used to make various economic and socio-economic estimates. Ph.D. theses generated at Kumaun University, Nainital, published research papers, books and journals, reports were consulted to analyse present status of lake ecology and changes overtime. The data given in NIH Report (1992) on various hydrological components were used to throw light on water balance and develop phosphate budget.

The organisation of the chapter is as follows. Section 2.2 gives the history and present status of the Nainital watershed with respect to location, climate, geomorphological setting, drainage, hydrology, population etc. Section 2.3 gives the water-quality of different sources that ultimately feeds the lake, besides giving the nutrient input of the lake. The changes in the lake quality and quantity over time are given in section 2.4. The discussion in the section suggests that the quality of lake water has deteriorated over time. Since lake is the premier source of water to the Nainital town, a clear implication on this will be on the health of the local inhabitants. Section 2.5 explores briefly the impact of quality of water on the health of the people

and what ultimate costs people are paying for this unsafe water. The chapter ends with some concluding remarks in section 2.6.

2.2 History and Present Status of Lake Nainital and its Watershed

Lake Nainital lies in a densely populated valley in the Kumaon Himalaya and is one of the most popular tourist resorts in Northern India. The existence of the Lake Nainital was first reported by P. Baron in 1841 in an English-language periodical.[4] The surroundings, which were first inhabited in the 1850's, grew into a town of 7,500 people by 1901 and to 40,000 by 2001.[5]

Nainital Municipality was established in 1850, even before the concerned act became operative in the then United Provinces. The major landslide of 1880 on Sher-ka-danda ridge (causing death of 151 persons including 43 Europeans) led to various activities relating to the development of watershed management practices such as construction of drainage network. By the 1970s the construction of buildings had become uncontrolled and haphazard. In 1982 a total ban on construction of new commercial buildings was clamped. However, this was bypassed by taking a sanction for a residential building and then later converting into a commercial one. It was felt that the Municipality was incapable of monitoring and restricting the construction work and a more effective body for looking after Nainital and adjoining areas was proposed. As a result Greater Nainital Development Authority (GNDA) came into being in 1984 which had a few people's representatives. However, the scope of GNDA also encompassed the nearby villages and invited resistance from the village communities which led to the abandoning of GNDA in 1989. A new body called the Nainital Lake Regional Special Area Development Authority came into being later that year with the District Magistrate as its president. However, in this body whatever little peoples' representation was there in the past was withdrawn. With all these changes in administrative bodies for checking construction activities a master plan was much needed but never came into being.

[4] He persuaded a guide to take him to Nainital after he heard numerous stories of its existence (as mentioned in Rawat, 1999).

[5] In addition to this, there is a large seasonal tourist population (in the past 5 years the tourist population has hovered above 3 lakhs annually), which severely stresses both the lake and its watershed.

The focus has always been on checking construction activities or on upkeep of the drains but never has there been a concerted effort to consider the lake and its watershed as a whole keeping in view the ecological sensitivities of the entire situation. At present no particular department is responsible for this. The Irrigation Department is concerned only with the water in the lake and maintaining the sluice; the PWD is concerned with the maintenance of only the drains and the roads in the watershed; the Municipal Board is concerned only with cleaning activities and disposal of garbage and issuing of licenses of boats therein; while Jal Sansthan is concerned with supply of drinking water and maintenance of sewer lines, but is not concerned with maintaining the quality of water inside the lake which it pumps. The District Magistrate heading the Hill Side Safety Committee has all these departments under one roof but without having proper coordination among all. This leaves the Lake Nainital in a particularly vulnerable situation where no department is directly connected with its maintenance though all are somehow linked to it.

2.2.1 Location and Climate

Nainital is located at 29°24' N latitude and 79°29' E longitude near the Main Boundary Thrust (MBT) that separates the Siwaliks from the Lesser Himalaya. The elevation at lake level is 1938 m, and encompassing hills (7 in number) rise from 2,139 to 2,611 m above the sea level. The basic pattern of climate is governed by the monsoon. The summer precipitation (June-end to September-end) brought by the monsoon accounts for 75% to 80% of the annual rainfall, which generally ranges between 200 cm and 250 cm (Fig. 2.1). The average annual rainfall for the period 1965-1980 is reported as 207 cm, the highest being 274 cm in 1967 and minimum 159 cm in 1974 (Sharma 1981). Data collected over the past hundred years indicate that the annual rainfall is on decline (Fig. 2.2).[6] Based on the moisture regime, the area comes under humid category. Figure 2.1 also gives the monthly average temperature in Nainital. The mean temperature at Nainital (at 1938 m altitude) ranges between 8°C in January and 20°C in June. Winter snowfall is common (Plate 1).

[6] Since the precipitation rate is falling, it becomes all the more important to manage the water resources.

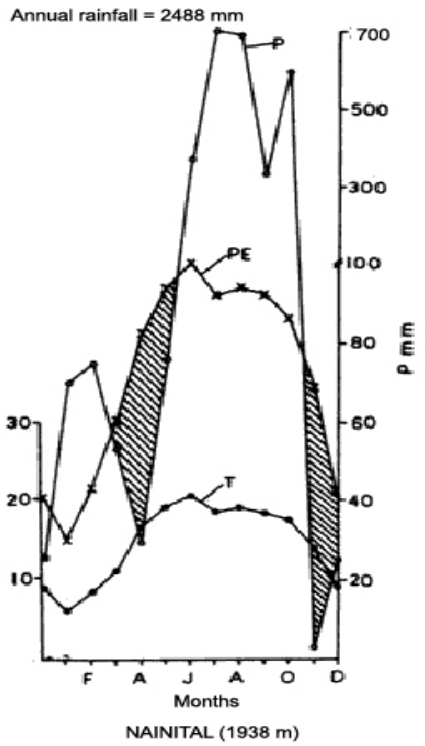

Fig. 2.1 Precipitation in Nainital catchment in the Central Himalaya (p – precipitation; t – temperature)

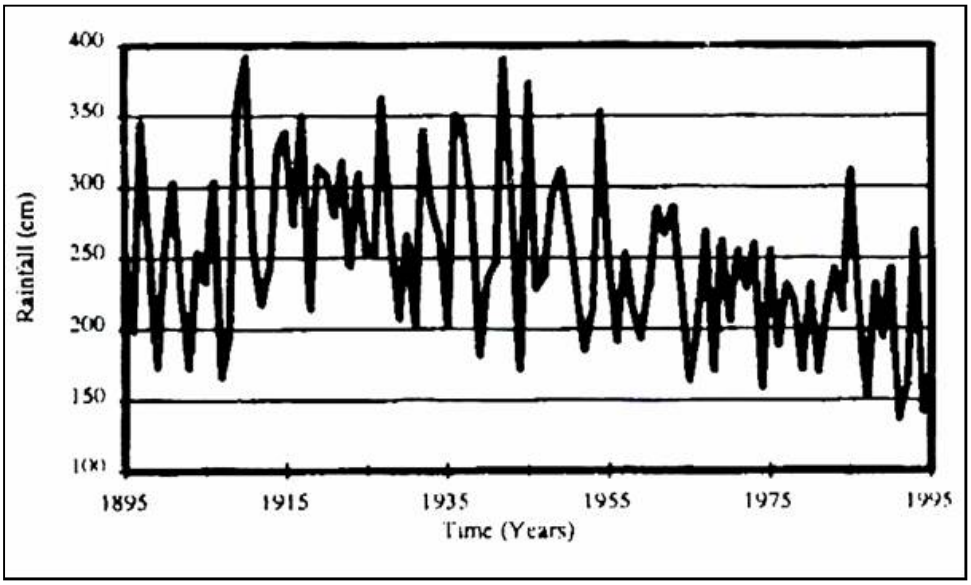

Fig. 2.2 Rainfall pattern over a century in Nainital catchment (Source: NIH, 1999)

2.2.2 Geomorphological setting[7]

The geology of Nainital is extremely complex, that is why its description varies from one researcher to another (Valdiya 1988). The watershed includes three lithostratigraphic units of the Krol Napp. A major fault line, called the Naini Tal fault, separates watershed into two parts (Fig. 2.3). The geomorphological features are many, and include tectonic scarps with 25-100 m heights, landslide scars, landslide fans and debris cover. Scarps are mostly associated with the Nainital fault. The drainage network is greatly influenced by geology, the main stream follows the toe of the Nainital fault, and smaller streams go along fractures, faults and joints. Streams are generally scarce where rocks are massive and are of dolomite and limestone, which are highly permeable. Hills rising generally between 400-600 m altitude from the lake level are composed of shales, marls limestones, dolomites and sandstones. The average slope in different areas of the watershed is 19° to 32°, but some hills can be very steep, 47°-55° in parts of China peak. It drops to 1° at flats and in Sukhatal.

The young and rising Himalayan ranges are highly vulnerable to landslides and erosions. This implies the catchment is highly fragile and prone to land slips and landslides. Already 7 major landslides have occurred during the last century or so (in 1867, 1880, 1890, 1924, 1982, 1987 and 1998) (Figures 2.4 and 2.5). On hills sloping over 45° the rock fall is quite common. A number of debris fans and cones have resulted from the recurring mass-movements in the lake basin (Valdiya 1988). The biggest landslide occurred on 18 September 1880, following a rainfall event of 84 cm in 36 hrs. The fall converted the Northwestern part of the lake into a level tract, which is now called as the ‘flats’.

Nearly half of the human settlements in Nainital are on landslide debris deposited over the years. In fact, Lake Naini originated as a result of differential vertical - rather rotational - movement along the Nainital Fault, which led to the impoundment of water of the stream flowing in the Naini valley (*ibid*.).

[7] This subsection takes heavily from Valdiya (1988).

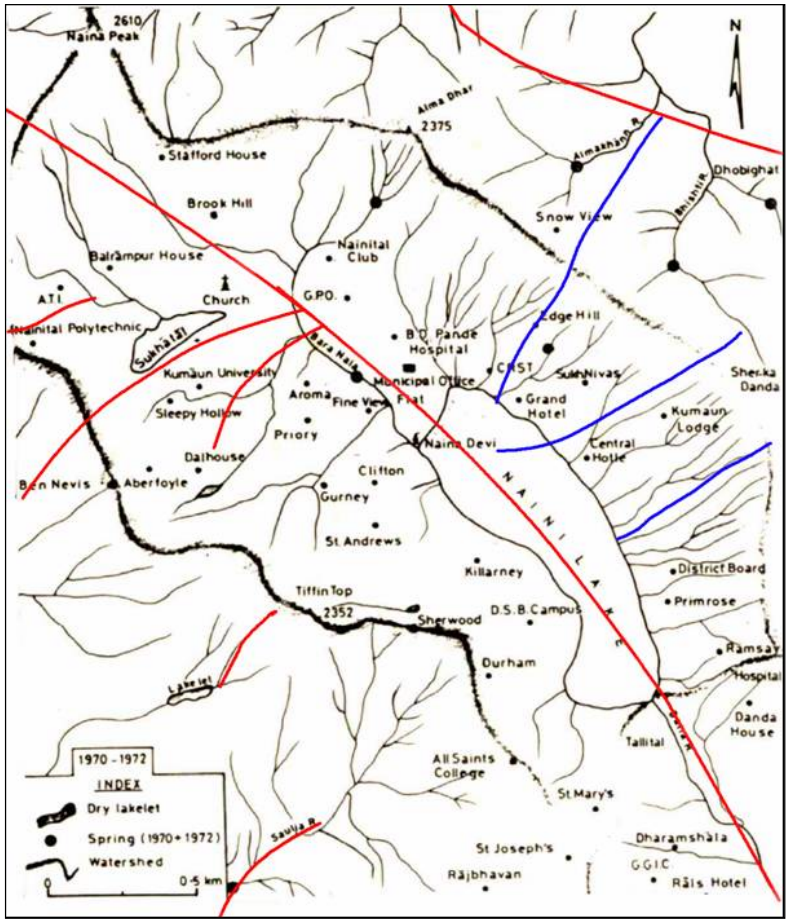

Fig. 2.3 Drainage map of Nainital catchment (Source: Valdiya 1988) (Major faults have been represented by red lines and fractures by blue lines).

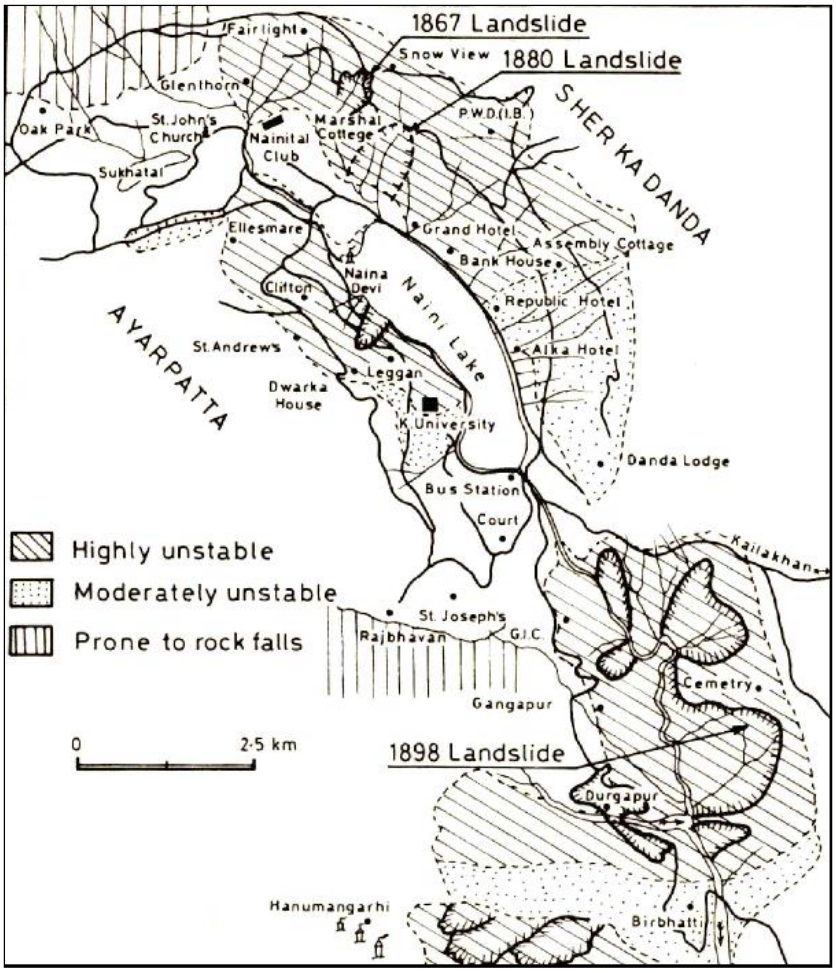

Fig. 2.4 Hazard zoning map of Nainital catchment (Source: Valdiya 1988).

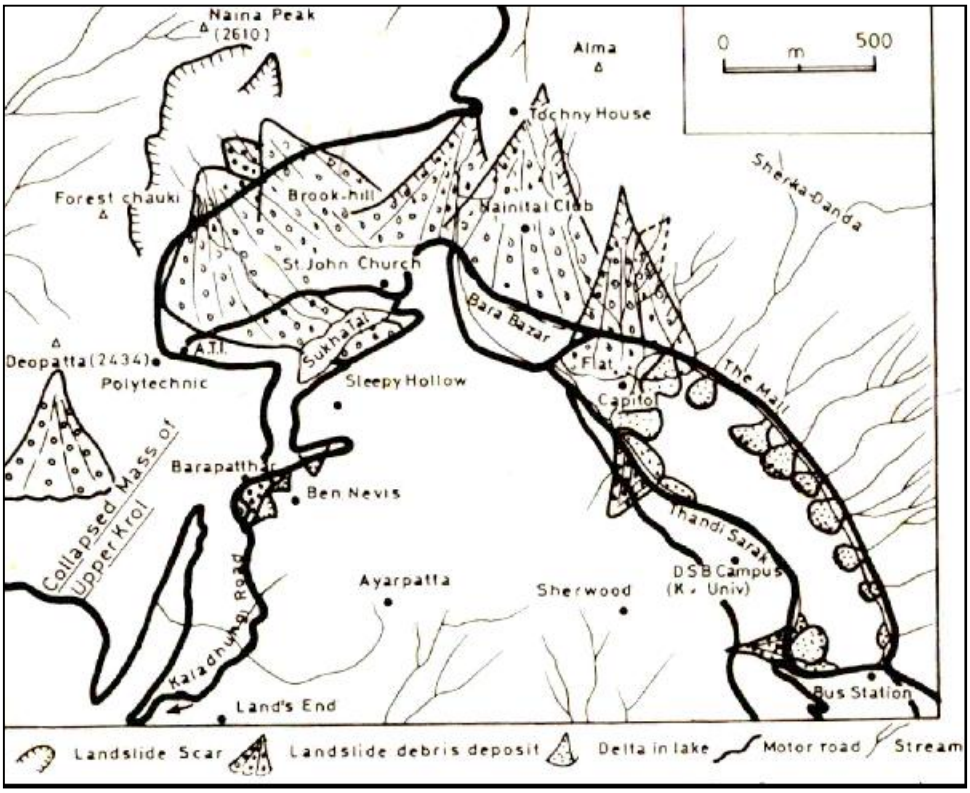

Fig. 2.5 Spatial distribution of debris fans & cones resulting from recurrent mass-movements in the Lake Nainital basin (Source: Valdiya 1988)

2.2.3 Drainage and hydrology

The Nainital catchment is known for its good drainage network. There are 21 major and 3 minor drains joining the lake. Of these 21 major drains, 14 are from Sher-ka-danda side (North-side of catchment) and only 6 are from Ayarpatta side (South-side of the catchment). But by far the largest feeder is the one which collects the drainage and spring waters of the western-end of the valley – called the 'Naina Devi Temple drain' or 'bara nalla'. Only this drain and the one entering the lake near the Mallital rickshaw stand are perennial.

The difference in the two sides of drainage is largely because of rock type. The Ayarpatta mainly consists of limestone and dolomite which are highly permeable to rainwater. Consequently, this catchment side has a sparse drain network. There are a number of springs, generally located on cross / fractures and faults. The 'Parda' spring, as an example, is located at Nainital fault close to its junction with the Sleepy Hollow and Snowdon faults. The main feeder stream passing through Naina Devi

Temple derives a large part of its discharge from the Parda spring, pouring out water at the rate of 2173 litres per minute in September to 534 litres per minute in June (Sharma, 1981). Besides, these there are a large number of gulleys, descending down the steep slopes, carrying discharges from springs.

Sukhatal (Fig. 2.3) is an ephemeral lake-let or a valley-fill, which holds water in its bed from its catchment. The water eventually finds its way through the shattered rocks of the fault zone to the Parda spring, which finally feeds the lake. In the process, however, water gets filtered. There is a direct correlation between the amounts of rainfall and spring discharges.

The morphometric features of Lake Nainital are given in Table 2.1. Presence of a 100m wide ridge in the middle divides the lake into two parts, with different maximum depth. As a consequence, the water of the two parts does not mix during thermal stratification (Rawat, 1987).

Table 2.1 Morphometric features of Lake Nainital

Parameter	
Maximum Length (m)	1423
Breadth (m)	253-423
Maximum depth (m)	27.3 in Northern half and 25.5 in Southern half*
Mean depth (m)	18
Surface area (ha)	48
Lake shoreline (m)	3458
Volume at maximum level (M m^3)	8.58

Note: * - The reason for giving maximum depth in the two halves is because the ridge divides the lake into two parts.

2.2.4 Landuse/landcover

The land-use/land-cover of Nainital watershed and adjacent hills indicates that the hill resort is still substantially covered with forest (Table 2.2). The total area is approximately 14.32 Km^2, of which the built up area is above 20%, and is alarmingly increasing. Oaks (*Quercus leucotrichophora* and *Q. floribunda*), which are hardwood evergreen species, make most of the forests. Only towards China Peak, the noble cypress, a conifer (*Cupressus torulosa*) dominates (Plate 2). The 48 ha forest stand of the noble cypress, occurs on a very steep slope, subjected to recurring erosion and rock fall, and here alone on the outer ranges appears to be indigenous (Atkinson, 1882).

Table 2.2 Landuse/landcover of the Nainital catchment

Landuse/cover	% area
Forest	48.4
Built up	19.7
Barren	18.3
Flats near lake	1.3
Roads	2.5
Lake	9.8

2.2.5 Forest and Biodiversity

Much of the forest in the watershed is of two types of evergreen oaks, *Q. leucotrichophora* in sunny and dry sites and *Q. floribunda* in moist sites with shade. These forests easily attain net primary productivity of about 20 t/ha/yr and biomass of over 500 t/ha in an undisturbed stand (Singh and Singh, 1992). The oaks are known for their massive belowground growth, consisting of roots and ectomycorrhizae (Table 2.3), hence are more effective in generating ecosystems services. A huge amount of the yearly nutrient return through litterfall, and their retention enables to build up a large soil pool, effective in conserving nutrients, carbon and water in its body.

Table 2.3 A comparison of oak forests of the Nainital catchment and pine (*Pinus roxburghii*) forest (occurring outside the catchment) (Usman *et al.* 1999).

Parameter	Forest	
	Oak	Pine
Biomass (t ha^{-1})	400-700	180-250
Net primary productivity (t ha^{-1} yr^{-1})	13-25	16-19
Allocation to roots (%)	24.8-28.3	17.9-18.3
Nitrogen return to soil (kg ha^{-1} yr^{-1})	86-137	59-69
Fine root productivity (t ha^{-1} yr^{-1})	5.16	3.22
Ectomycorrhizal mass (kg ha^{-1})	9.4	4.7
Microarthropods associated with litter (individuals m^{-2})	4672	1171

2.2.5.1 Wild animals

Leopard, *langur,* bear, monkeys, chamois and *jarau*-deer were the common animals found here. But except for monkeys all have become rare. As late as 1845, the site of the present upper bazaar was filled to a great extent with *ringal* (bamboo) jungle, which used to harbour even tigers then.

2.2.5.2 Plants

There are about 700 plant species in the catchment. Amongst the more common trees and other plants are the noble cypress, surai, *Cupressus torulosa*; ash, angu, *Fraxinus micrantha*; horn beam, *Carpinus viminea*; cherry-alder, *Betula alnoides*; alder, *Alnus nepalensis*; various oaks, banj, *Quercus leucotrichophora*; kharsu, *Q. semecarpifolia*, China peak side; rianj, *Q. lanuginosa*; tilonj, *Q. floribunda*; maple, *Acer oblongum*; lodh, *Symplocos paniculata*; burans, *Rhododendron arboreum*; ayar, *Lyonia ovalifolia,* after which Ayarpatta hill is named; holly, *Ilex dipyrena* and *I. odorata*; mehal or pear, *Pyrus pashia*; geala, *Pyrus baccata*; gingaru, *Crataegus pyracantha*; raus, gari *Cotoneaster* spp.; burau, *Albizzia wightii*; chauniya, *Populas ciliata*; makola, *Coriaria nepalensis*; chotra, *Berberis aristata*; set baruwa, *Daphne cannahina*; *Agrimoria*; jhar, *Spireea cuneifolia*; *Rubus tiliaceus*; *Rosa moschata* and *macrophylla*; kagshi, *Cornus macrophylla* and *C. oblonga*; bhuliau, *Rhus vernicifera*; timur, *Xanthoxylon hostilc*; *Desmodium elegans, D. hexagonum* and *D. parvifolinm*; *Astragalus* spp;. banda, *Hedera helix*; *Geranium lucidum, G. nepalense* and *Pinus wallichianum*; chalmori, *Oxalis cirniculata*; chuduea, *Rhamnus virgatus*; bhunguriya, ganiya *Salvia lanata*; bhilmora, *Colquhounia vestita*; kapur-nali, *Strobolanthes glutinosa*; paderiya-lahsan, *Allium wallichianum*; and a dwarf bamboo, *Arudinaria falcata*.

2.2.5.3 Birds

Nearly 200 bird species occur in and around Nainital.[8] Black vulture (*Otogypus calus*), large tawny vulture (*Gyps fulvus*), long billed brown vulture (*G. indicus*), white-backed vulture (*G. begalensis*), white scavenger vulture (*gypaetus barbatus*), bearded vulture (*G. barbatus*), the kestrel (*Tinnunculus alaudarius*), white napped pigmy falcon (*Hoerax eutolmus*), crestless hawk-eagle (*Nisaetus bonelii*) crested hawk-eagle (*Limnaetus cristatellus*), white-eyed buzzard (*Polioris tesea*), common paria kite (*Milvus govinda*), tawny fish-owl (*Ketupa flavipes*), common swallow (*Hirundo rustica*), wire-tailed swallow (*H. ruficeps*), red-rumped swallow (*H. daurica*), common Indian swift (*Cypselus affinis*), alexandrine parakeet (*Palaeornis alexandri*), slaty-headed parakeet (*P. schisticeps*). Of the Picidae or woodpeckers, the brown-fronted woodpecker (*P. brunneifrons*), and the rufous-bellied pied woodpecker

[8] Source: Personal Communication with Anup Sah, the avid nature photographer and ornithologist in the area.

(*Hypopicus hyperythrus*) have been found here. Of the Cuculidae or cuckoos, the European cuckoo (*Cucculus canorus*) and the pied crested cuckoo (*Coccystes melanoleuces*) have been spotted. Of the Nectarinidae or sun-birds the purple honey-sucker (*Archnechira asiatica*), the Himalayan tree creeper (*Certhia himalayana*), the white-tailed nuthatch (*Sitta himalayensis*) and the European hoopoe (*Upupa epops*) are found here. The more remarkable game birds are the pukras and chir pheasants; woodcock; snipe and quail, and the kalij pheasant. Many of them, however, are locally threatened, and of the six vultures none is seen now. *Sher-ka-danda*, Sleepy hollow and adjacent areas are the major centre of bird watching in Nainital.

2.2.6 Population and tourists

The Census of 2001 has estimated the permanent population in the catchment area of Nainital to be 39,840 (Fig. 2.6). This indicates that nearly 1000 people/year were added during the last decade. The catchment also hosts a large floating population of about 5000 persons during the peak tourist season who mostly work as petty vendors, coolies, boatmen, horsemen, etc. Table 2.4 gives the anthropogenic pressure in the Nainital watershed for the year 2001.

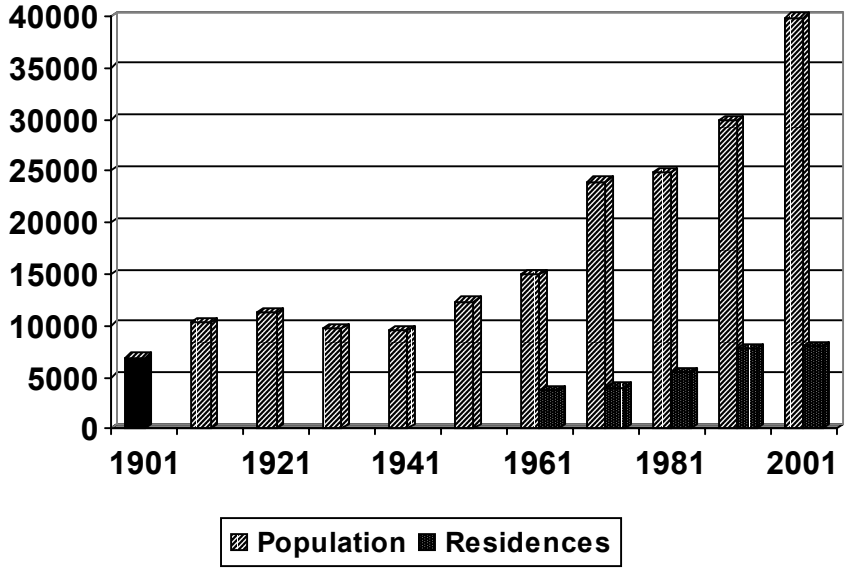

Fig. 2.6 Decadal growth in population from 1901 to 2001.

Table 2.4 Anthropogenic pressure in Nainital watershed during 2001 (Source: Data collected from different government bodies in Nainital)

Permanent	39,840
Tourists no.	≈3,10,000 yr^{-1}
Hotels no.	120
Shops no.	900
Residences no.	8000
Floating Population	≈ 5000*

Note: ***** **-**The floating population comes mainly during the tourist season.

Nainital has been a tourist destination ever since it was discovered in the mid-nineteenth century. The Municipal Board was formally constituted in 1850. In 1862 Nainital became the summer seat of the North Western Provinces which led its rapid extension and by 1900 it was a popular tourist destination. The war with Pakistan in 1965 and 1971 further boosted Nainital's tourism industry as the Kashmir valley closed down. During the late 1980's tourist population were at the peak but thereafter a sudden drop occurred. It may be suggested that the drop in tourist population in the early 1990's occurred due to the opening up of other, possibly cheaper destinations in the surrounding hill districts, and also due the extremely high population density, pollution and drop in (visible) lake water quality in Nainital during the summer season. Though the tourist population is slowly recovering, they are far from the high experienced in the 1980's. Figure 2.7 gives the tourist population since 1983.

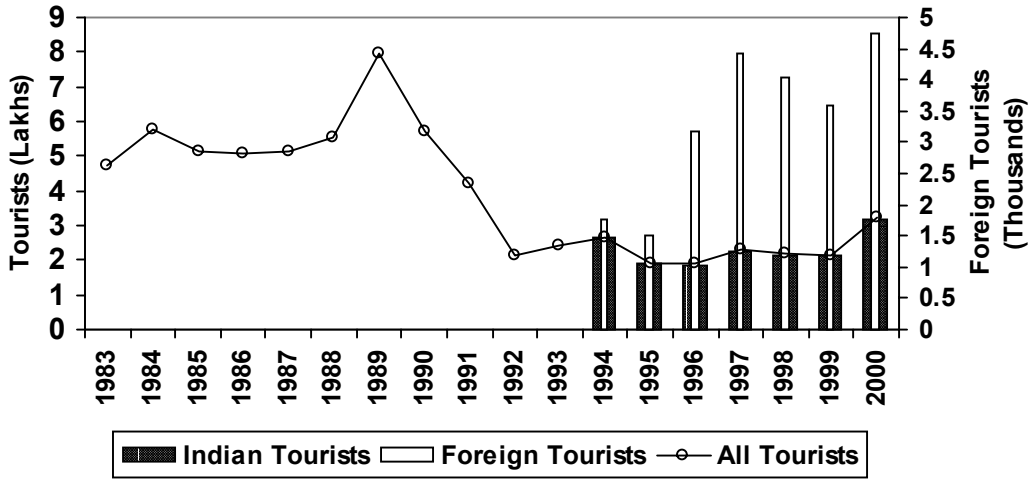

Fig. 2.7 Trend of tourist influx in Nainital town.

The decline in later years actually is not the real decline, but an outcome of change in the method of recording data. The earlier method of recording the tourists was based on the toll collected at the two toll-barriers before entering Nainital. This also included the local visitors or people working in Nainital but staying in the neighbouring areas like Haldwani, Jyolikot etc., thus over-reporting the tourists visiting. However, the current method of reporting grossly under-states the tourist population, as it is based on reporting from the hotels to the tourism department. In order to avoid tax, there exist every possibility for hoteliers not to show the actual occupancy. Also children may not be properly recorded by the hoteliers. As clear from Figure 8, foreigners hardly constitute the tourists population in the Nainital as out of the total tourist population influx only 1-2% are foreigners.

The data shows that a revenue of Rs. 4,980,850/year has been collected through taxes from hoteliers during 1997-2000 (Fig. 2.8). This tax is imposed on all rooms priced above Rs.1000/night. However, like the number of tourists visiting Nainital, the tax collected also grossly under-represents the actual earning of the hoteliers, because many rooms previously priced above Rs.1000/night, were reduced to just below a thousand rupees per night when the tax was implemented. Also, not all hoteliers tend to declare the number of room occupied at all times.

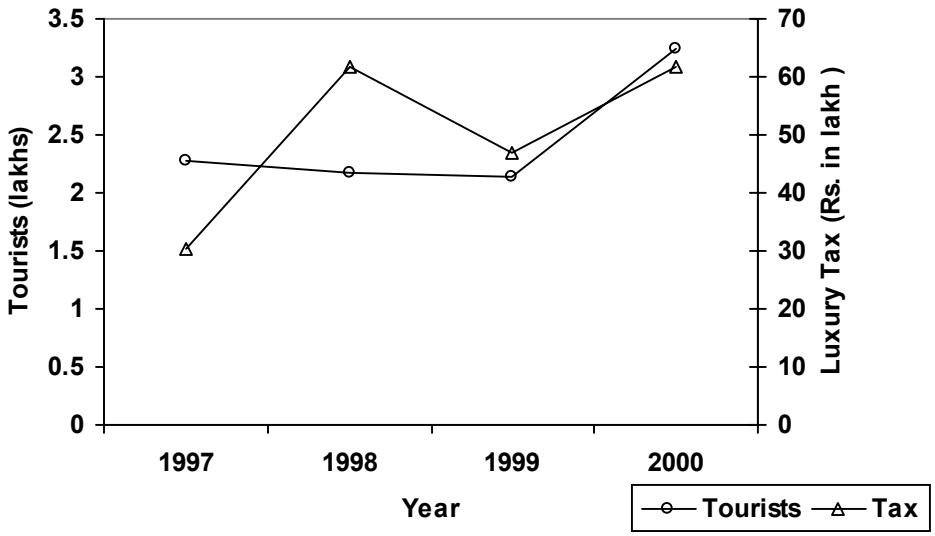

Fig. 2.8 Trend of tourists and luxury tax collected from 1997-2000

An indication of increased tourism in Nainital will be clearly reflected in the property prices adjoining the lake. Since tourism in Nainital is mainly due to the lake,[9] tourists prefer staying in hotels, which are on the lakeside. Predictably, the data shows that the price of land adjoining the lake along the Mall Road is higher than that elsewhere in the catchment. Prices steadily drop with increase in altitude, and distance from the lake. Figure 2.9 gives the variation in property prices with the distance and altitude.

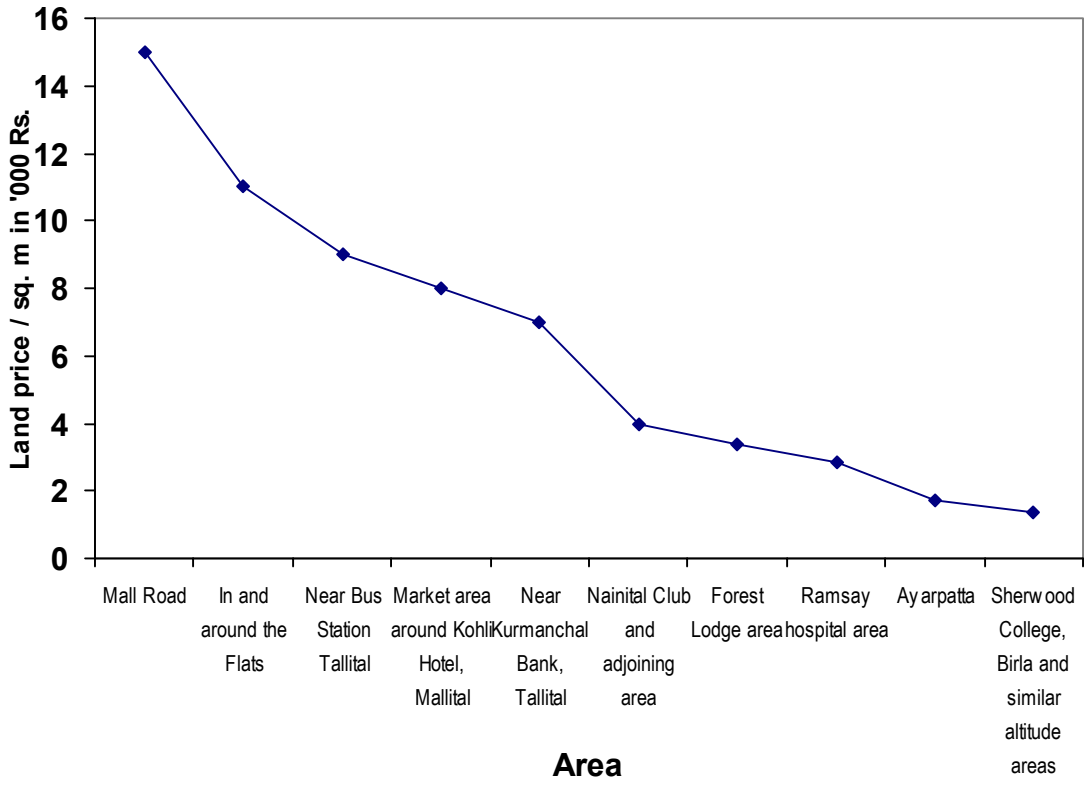

Fig. 2.9 Variation in property prices with the distance from the lake and altitude.

Note: Though first three sites are close to the lake, but the view from the first site i.e., Maill Road is more complete and better, hence the differential property prices.

2.2.6.1 Vehicular traffic

Another indicator reflecting the increased tourism activity in recent past is the number of vehicles entering the town. The data shows that the number of light vehicles that entered the town during the peak tourism month i.e., June has increased by about 46% in the past three years and of the entire summer tourist season (April-June) by about 24% (Fig. 2.10). The revenue earned through toll tax in

[9] This is very well substantiated by our survey of tourists, which finds that more than 90% have come because of the lake (refer Section 4.1, Chapter 4).

June has increased from less than six lakhs in 2000 to close to 8 lakhs in 2002 (Fig. 2.11). Interestingly, the May values have stabilized indicating that the tourists coming by their own vehicles prefer the month of June. In fact the number of cars in June is almost twice as many as in May. In the past tourism in May used to be as important as in the month of June.

The total revenue from toll tax in 2002 is expected to be about Rs. 3.6 million showing an annual increase of about Rs. 0.3 million annually in the past three years. The month of June alone accounts for over 20% of the toll tax revenue generated in a year, and has an annual increase of about 0.1 million Rupees since 2000. This revenue has thus become one of the major sources of income to the Municipal Board of Nainital.

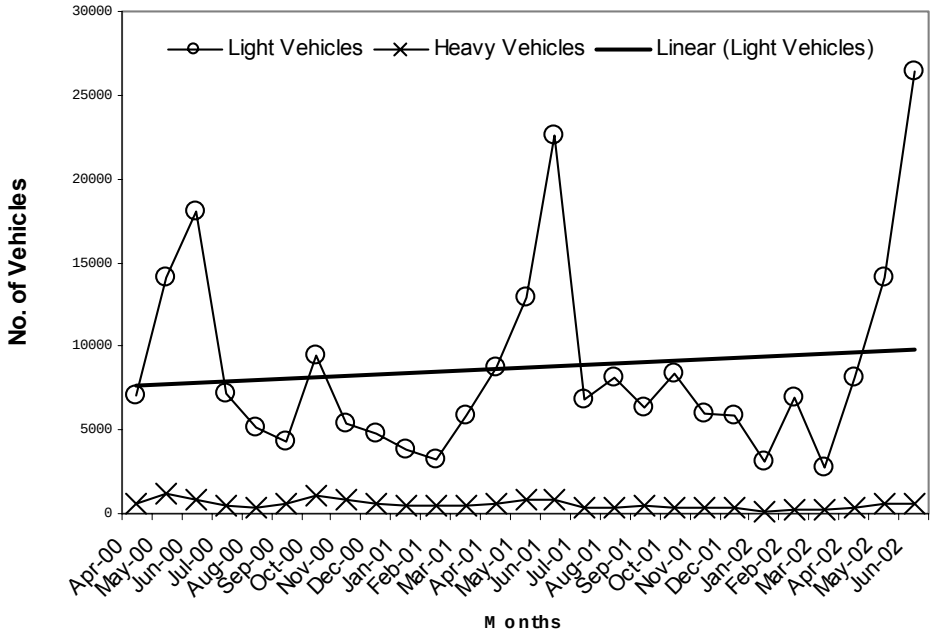

Fig. 2.10 Trend of light and heavy vehicles inflow in Nainital during 2000-2002.

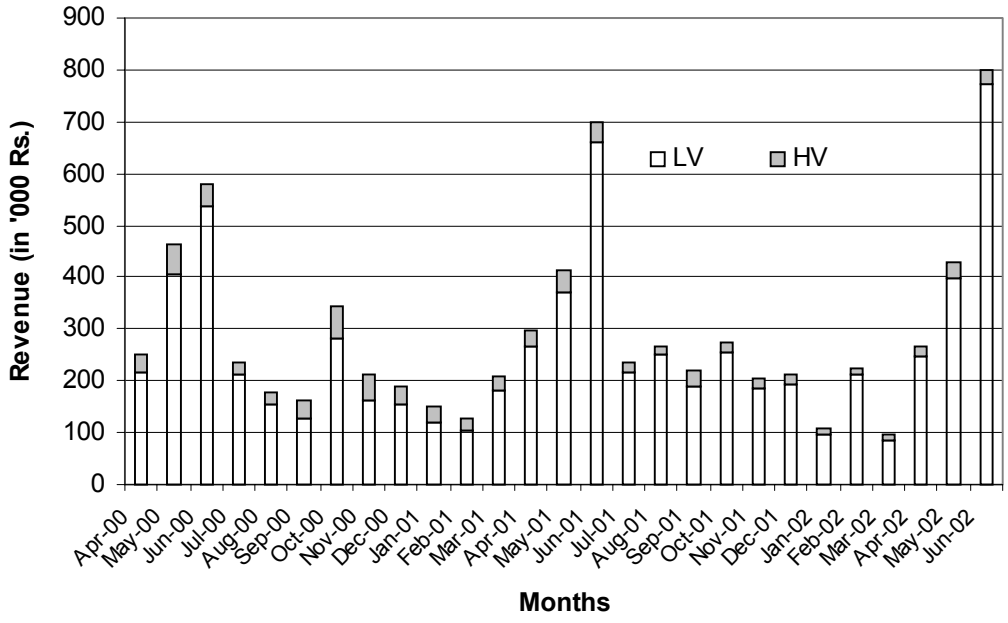

Fig. 2.11 Revenue generation from light and heavy vehicles through toll tax in Nainital during 2000-2002.

One of the implications of increased tourists vehicle is the increased vehicular pollution. This pollution is already being felt, and could become a major problem to human health especially in the month of June in years to come.[10]

2.2.7 Source of Water Supply in Nainital

Each day 15.45 million litres of water is used for drinking and household purposes (Table 2.5). Out of which 40% is directly extracted from the lake and remaining 60% from watershed. Three major water sources as used by inhabitants of the Nainital town and catchment are: a) Springs or Natural subsurface flow; b) Ground storage from the Sukhatal sub-catchment; and c) Lake water from wells adjoining the lake.

The lake water is gravel filtered and chlorinated. The water from watershed includes-spring water, tube well water both from Sukhatal sub-catchment and near-lake site of Flats, while spring water is directly used, the tube well water is chlorinated. The watershed services contribute to saving some cost of water filtration, chlorination and pumping. Safe storage is its additional service that can be valued by estimating cost of storing water in tanks. Apart from these, its services include dilution of lake water pollution and maintenance of water level, which save health cost and add to the

[10] As we shall see later, the tourists in our survey also pointed out that the town needs proper management of vehicles due to increased noise and air pollution.

recreational values (Plate 3), respectively. Thus, the water used by the Nainital town is a mix of lake and ground water. There are 3 tube wells located near the lake in Mallital bank of Nainital. There are 8 tube wells in addition to others.

Table 2.5 Water sources for use in Nainital township (percentage of total water pumped is shown in parentheses).

Source	Water extracted (mld)	Level of treatment
Natural spring	1.00 (6.5%)	Direct use
Lake water	3.45 (22.3%)	Filtration, chlorination
Pressure filter	2.00 (12.9%)	Pressure filtration
Tube wells near lake shoreline	8.00 (51.8%)	Chlorination
Tube well at the bottom of Sub-catchment	1.00 (6.5%)	Chlorination
Total	**14.45 (100%)**	

Costs of using these different water sources differ. Spring water, unless it passes through a polluted area does not require filtration, treatment or even pumping as springs are relatively common, they are not enough to cater to the demand of potable water. The maintenance of springs however requires a vegetative cover over most of the catchment. Groundwater from the Sukhatal sub-catchment requires pumping, though it does not require treatment. Lake water, which is drawn out from wells and pumps adjoining the lake body undergoes a process of natural filtration. However, if the water is pumped out of the wells, the benefits of filtration are reduced due to forcible extraction. In such a case treatment is required. Pumping of lake water is necessary for it to reach residential heights.

2.2.7.1 Hydrological Budget of the Lake

In order to prepare hydrological budget of the lake one needs to know how much inflow is there into the lake and how much flows out of it. The inflow and outflow is derived from the data collected by NIH Roorkee (1999). Inflows include direct precipitation in the lake area, drain water, subsurface flow (mainly spring water, a large proportion of which comes through Sukha Tal). Outflows include water evaporation, water pumped out for drinking purposes, which includes lake water as well as ground water, subsurface outflow and water released through sluice during rainy season.

The main inflows and outflows of water in relation to the lake based on data for the year 1994-95 are shown in Fig. 2.12. The amounts of total outflow (4636 million l/yr) and inflow (4687 million l/yr)[11] are similar, suggesting that a balance is kept with respect to the lake water. Of the total inflow the subsurface flow from the Sukhatal valley-fill accounts for nearly 43%. Though the filtration of water passing through the valley-fill is not effective in brining about substantial removal of nutrients, its lead (Pb) concentration is quite low. Perhaps, by developing a mud layer over the valley-fill rich in bacterial population may contribute to the reduction of both nutrients and Pb. Maintaining a high water level in the Lake Nainital particularly after the rainy season and dilution of pollutants are the major ecosystem services performed by Sukhatal valley-fill.

Surface runoff during the rainy season is the next largest water source. Direct precipitation makes only a small fraction of the lake budget, while water that finds its way through the watershed is more than six times as the direct precipitation. Precipitation in the watershed amounts to 6466.5 million l/yr. Of this amount 3917.5 million l or 60.6% finds its way into the lake as runoff and subsurface flow and drain water. The remaining 1543.15 million l or 39.4% is estimated to be the sum of the water retained in soil, silt deposits and rocks and vegetation and the water lost as transpiration. Some of this water can be used for drinking purpose. Water stored within the bed of Sukhatal is already being used for drinking purpose.

[11] It is to be noted that the year 1995 was rather a dry year as the total rainfall was much below the average. It was less than 150 cm against an average of over 225 cm. This implies the inflow and the outflow are much higher than the one estimated in the budget. Same applies for the PO_4 budget as calculated in the next section.

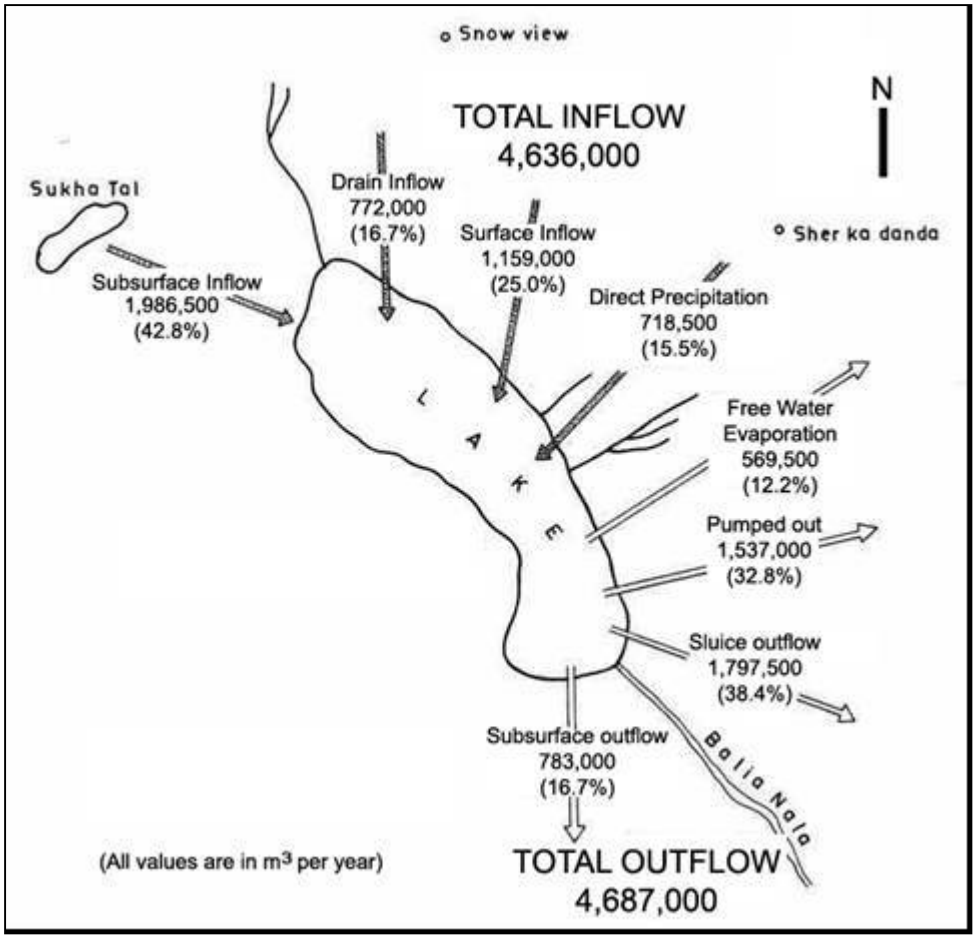

Fig. 2.12 Water budget of Lake Nainital (values are averages of year 1994-1995). Values in parentheses are percentages of inflow/outflow.

2.2.8 Sedimentation Rate

Sedimentation rate, as calculated by ^{210}Pb method[12] indicates that it is far greater in Naini Tal (11.59 mm /yr) than in other lakes of the region (2.99 – 4.70 mm/yr) (refer Tables 2.6 and 2.7). Carbonate rock lithology which is more susceptible to weathering, high precipitation and frequent landslides may account for a higher sedimentation rate in Lake Nainital. Though these natural factors are important causes for high sedimentation rate, but it gets further aggravated by sheer anthropogenic pressure like increased construction and construction- based activities.

The grain size analysis indicates poorly sorted grains (0.98-1.03 φ) pointing to near distance transportation of material. The bathymetric analysis carried out in Lake Nainital has given a sediment accumulation rate of 67m^3/yr between 1895 and 1967

[12] Lead radioisotope method

and 78 m^3/yr during the period between 1967 and 1979 (Rawat 1987). Sharma (1981) has shown the net accumulation of 0.377 million m^3/yr.

Table 2.6 Comparative rates of sedimentation in Nainital and nearby lakes by ^{210}Pb method (from Das *et al.* 1994)

Lake	Rate (mm/yr)
Nainital	11.50
Bhimtal	4.70
Naukuchiyatal	3.72
Sattal	2.99

Sharma (1981) has estimated the life of the lake to be 314 years based on sedimentation deposit of 0.239 million m^3 during 1960-1977 at the rate of 0.22 mm^3/yr (Table 2.7). Using various methods researchers have estimated predicted life of the Lake Nainital between 82 to 2681 yrs (Table 2.8).

Table 2.7 Sedimentation rate estimated by Sediment Balance Method (NIH Report, 1999)

	Suspended sediment concentration	Total suspended sediment load (m^3)
Inflow through drains and during light rains	0.41g/l	1500
Inflow during heavy rains	1.25g/l	5097
Outflow through sluices	0.55g/l	3422
Inflow-outflow (sediment accumulation rate)		3175 (0.69 cm/yr)

Table 2.8 Predicted useful life of Lake Nainital

	Time span	Sedimentation rates (cm/year)	Predicted useful Life of Lake Nainital
U.P PWD, bathymetric data	1960-75	13.705 (3.02-24.39)	82-380 years
NIH, using U.P. PWD data	1965-70	4.53	39-590 years
Using sediment balance method (NIH)	1998-1999	0.69	2681 years
Using radiometric dating			
i. ^{137}Cs method	1994	0.75	2200 years
ii. ^{210}Pb method*	1994	0.86	

Notes: NIH – National Institute of Hydrology, Roorkee; PWD – Public Works Department * Brown *et al.* (1994)

The current section thus has given the basic features of the Lake Nainital and its watershed. The next section looks into the water quality at different sources, which feed into the lake.

2.3 Water Quality of Various Sources

As mentioned earlier in the chapter, the growth of tourism, construction, population etc. is putting lot of stress on the lake and its watershed. This section looks into how this anthropogenic pressure has affected the water quality. In order to establish this, the present study tests the water samples at different locations and calculates the BOD and bacterial counts. Besides this, the study calculates the phosphate budget of the lake i.e., how much phosphate is accumulating in the lake, leading to eutrophication. This is followed by estimation of nitrate and heavy metal concentration in the feeders of the lake (see Appendix 2 for methods used for determination of the physico-chemical parameters).

2.3.1 Biological Oxygen Demand and Bacterial population

At 11 different locations water samples have been collected and tested for BOD and bacterial count. Most of these points form the input to the lake. In a way, they would represent the lake water quality. Table 2.9 gives the values of the samples tested. The BOD values in different samples ranged from 10 mg/l in the water of Sukhatal valley-fill (after-treatment) to 74 mg /l for Mallital rickshaw-stand drain, which is several times higher than the highest desirable limit of 3 mg/l (WHO). The average value of BOD in drains' water is found to be 64.75 mg/l indicating that the drains are heavily polluted. High value of BOD implies a high amount of degradable organic pollution. Sewage effluents and human excreta are known to increase BOD levels. The high pollutant content in the drains is also reflected in the high bacterial content of the drain (816.75 CFU/ml).

Thus, the drain water is highly polluted. According to EPA (2002), with normal techniques more than 500 HPC is difficult to treat for drinking purposes. The bacterial count is significantly related to BOD of the water samples ($r = 0.907$, $P < 0.01$). We expected a relatively lower value for spring water, for it is a kind of filtered water. But surprisingly, the BOD and bacterial count for the treated spring water comes to be higher. One of the reasons for this could be the course through which spring water flows, particularly near the ground surface it may be getting polluted.

Table 2.9 Bacterial population (CFU/ml= colony forming unit/ml) and BOD (mg/l) of water from various sources of Lake Nainital (Source: present study).

Sampled Site No.	Sites of sample collection	BOD (mg/l)	Bacterial population (CFU/ml)
1	Run-off over Thandi Sarak	37	269
2	Spring untreated	11	174
3	Spring treated	32	215
4	Sukhatal valley-fill before treatment	29	85
5	Sukhatal valley-fill after treatment	10	80
6	Water main pump house before treatment, flats	25	210
7	Water main pump house after treatment, flats	20	148
8	Temple drain	60	560
9	Fanshi gadhera drain	65	929
10	Mallital rickshaw stand drain	74	1218
11	Tallital rickshaw stand drain	60	560
	Average of the Drains (Average of 8 to 11)	**64.75**	**816.75**

2.3.2 Phosphate Budget

The excessive input of Phosphorus is the primary cause of eutrophication of lakes (Schindler 1977). The essential dynamics of P input from watershed, and P loss per unit time, include several processes: sedimentation, surface and subsurface outflow, and sequestration in biomass of consumers or benthic plants, rate of P recycling. Several factors can affect the rates of P losses; all of them are proportional to the mass of material in the water column.

In stratified lakes, such as Lake Nainital, recycling also depends on oxygen depletion in the hypolimnion during the stratified period (particularly during summer months). In Nainital hypolimnion remains anoxic during most of the year. In the anoxic condition, iron is reduced and P becomes soluble, leading to an increased recycling. Annual P recycling from hypolimnion of a stratified lake is expected to be directly proportional to the length of the period that the hypolimnion is in a deoxygenated condition. The rate of deoxygenation in the hypolimnion depends on P concentration in the lake, water column, thickness of hypolimnion (up to 15 m in Lake Nainital) and its temperature (Carpenter *et al*., 1999). When P concentration is very high, the hypolimnion is anoxic almost all the time and recycling from the hypolimnion is near maximal (Carpenter *et al.,* 1999) As for P loss, it is expected to be the greatest in

lakes with large flushing and rapid sedimentation. The monsoon-time flushing of Lake Nainital is rapid, but it does not affect P of much of the hypolimnion.

We have attempted to work out a PO_4 budget of the lake by using the hydrological data of NIH, Roorkee (1999) and concentration of PO_4 in various inflows and outflows measured from the samples taken at various places (Fig. 2.13). We could not sample precipitation but one can assume that it could not be a major source of PO_4 input. However, our estimates are gross approximations, and to achieve precise values more frequent samplings of various inflow and outflow waters are required.

Among the inflows, drains had the highest concentration of PO_4 accounting for 33.4% of total PO_4 inflow, vis-à-vis their total water inflow of only 16.7% (Fig. 2.13 & Table 2.10). This implies drains are the net contributor of the PO_4, this is largely because the drain water consists of bathrooms wastewater of clothes washed in detergents, which are rich in PO_4.[13] One of the extreme steps to reduce the input of PO_4 is by clamping a ban on the use of PO_4 containing detergents.

Because of the large volume, however, the subsurface water inflow is the largest source of PO_4 input (34%). The outflow load of PO_4 can be reduced by collecting subsurface inflows before it gets polluted. Detailed investigations are required to duct such points and collect water.

Much of the PO_4 leaves the lake through the sluice during the monsoon months when the lake receives massive water input from the watershed. At this time of the year the lake is still thermally stratified therefore accumulating the PO_4.

[13] Estimates suggest that the proportion of phosphates is 1:3 in the detergents.

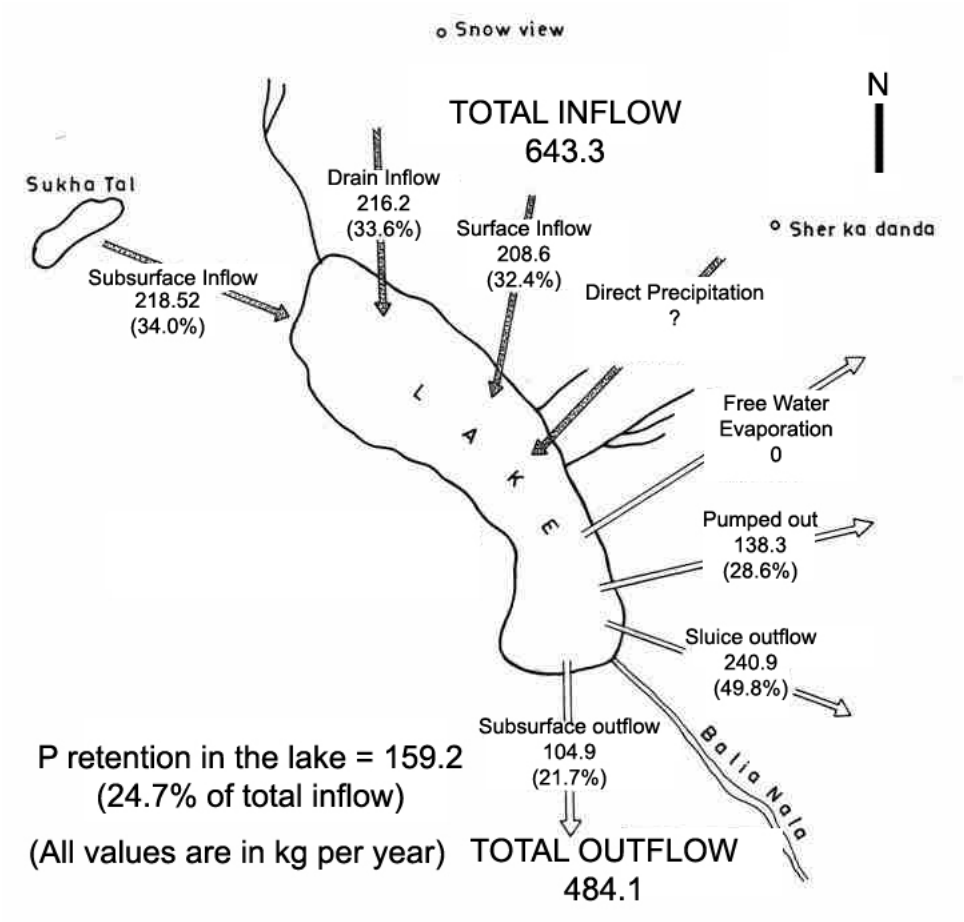

Fig. 2.13 Phosphate budget of Lake Nainital (values are averages of year 1994-1995).

Table 2.10 PO_4 concentration (mg/l) at various water sources. Data on water volume is based on the average for 1994 and 1995 (Source: NIH Report, 1999).

Sample Site No.	Sites of sample collection	PO_4 (mg/l)
1	Sukhatal Parking Site - Run-off	0.385
2	Sukhatal Petrol Pump Site - Run-off	0.225
3	Sukhatal Pump House Site - Run-off	0.155
4	Malli Tal road run-off	0.170
5	Talli Tal road run-off	0.005
6	Flats - run-off	0.130
7	Forest - run-off	0.010
	Average of run-offs	***0.154***
8	Mallital rickshaw stand drain	0.247
9	Tallital rickshaw stand drain	0.067
10	Temple drain	0.120
11	Fanshi gadhera drain	0.457
12	Library drain	0.045
13	Everest hotel drain	0.343
14	Alka hotel drain	0.207
	Average of drains	***0.212***
15	Sukhatal valley-fill before treatment	0.110
16	Sukhatal valley-fill after treatment	0.263
17	Water main pump hose before treatment, flats	0.063
18	Water main pump hose after treatment, flats	0.087
19	Spring untreated – Masjid	0.193
20	Spring treated – Masjid	0.103
21	Rain water	-

Note: Concentration of PO_4 (mg/l) are averages of periodical sampling of water (3 samples at each site, each sample is after every 3 months).

We assume that 50% of drain PO_4 has source in detergents, and the remaining 50% in hill slope soils. Most of the remaining PO_4 that enters the lake from the watershed through surface and subsurface flow is derived from soil and rocks. Thus, the loss of watershed fertility in terms of PO_4 loss (50% drain water inflow + surface inflow + subsurface inflow) is 553.9 kg/yr. Much of this leaves the lake through various outflows (Fig. 2.13) and 159.2 kg is the yearly net accumulation in the lake. Since the average increase of P in the lake water was 45 kg/yr during the last 20 years, a large amount of P (114.2 kg/yr) can be assumed to accumulate in the sediment (Table 2.11).

Table 2.11 Loss of P from watershed and its accumulation in the lake

Parameter	Amount of P
Total P inflow (through drains, surface and subsurface), kg/yr (A)	643.3[a]
Inflow in the lake through detergents, kg/yr	64.3
Inflow of P from the watershed to the lake, kg/yr	579.0
Outflow of P from the lake (pumping out + sluice + subsurface outflow), kg/yr (B)	484.1[a]
Net accumulation of P in the lake, kg/yr (A-B)	159.2[b]
Increase in P-concentration over past 20 years, µg/l	119[c]
Increase of amount of P in lake water during past 20 years, kg	900[d]
Rate of P accumulation in the lake water, kg/yr	45
P accumulation in lake sediment, kg/yr	114.2

Note: [a] see in Fig. 2.13 ; [b] difference of P-inflow and P-outflow; [c] see the section on temporal changes; [d] estimated using P-concentration and volume of lake water.

Thus, from Figure 2.13 and Table 2.11, we can say that at present the lake's P-output is smaller than the P-input. This implies that the watershed is causing P-accumulation.

2.3.2.1 Phosphorus enrichment and the problem of lake eutrophication

The excessive input of phosphorus is the primary cause of eutrophication of lakes (Schindler 1977). The Lake Nainital has been eutrophic for the last three decades and the lake bed seems to have a large P-accumulation. The essential dynamics of P-input from watershed, and P-loss per unit time, include several processes: sedimentation, surface and subsurface outflow, and sequestration in biomass of consumers or benthic plants, rate of P-recycling the main source of which is sediment. Several factors can affect the rates of P-losses, all of them are proportional to the mass of material in the water column.

In stratified lakes, such as Lake Nainital, P-recycling is enhanced due to the oxygen depletion in the hypolimnion during the stratified period (particularly during summer months). In Nainital hypolimnion remains anoxic during much of the year. In the anoxic condition, iron is reduced and P becomes soluble, leading to an increased recycling. Annual P-recycling from hypolimnion of a stratified lake is expected to be directly proportional to the length of the period that the hypolimnion is in a deoxygenated condition. The rate of deoxygenation in the hypolimnion depends on P

concentration in the lake, water-column, thickness of hypolimnion (up to 15 m in Lake Nainital) and its temperature (Carpenter *et al.* 1999). When P concentration is very high, the hypolimnion is anoxic almost all the time and recycling from the hypolimnion is near maximal (Carpenter *et al.* 1999) As for P-loss, it is expected to be the greatest in lakes with large flushing and rapid sedimentation. The monsoon-time flushing of Lake Nainital is rapid, but it does not affect P of much of the hypolimnion.

Lakes are divisible into three types with respect to reversibility of eutrophication (Carpenter *et al.* 1999):

I. Reversible lakes – generally deep and cold lakes, rapid flushing, eutrophied for a short period. Eutrophication of these lakes could be restored by P input control alone.

II. Hysteretic lakes – often small or shallow lakes, with rapid P recycling, therefore, eutrophication cannot be reversed by P input controls alone. Temporary intervention such as aluminium sulphate treatment and biomanipulations are required to bring about shift from a high-P steady state to low-P steady state.

III. Irreversible lakes – includes lakes of P-rich regions, or lakes that have received extreme P-inputs for an extended period of time. Their eutrophication is so high that even severe reduction in P input and temporary manipulations may not shift the lake out of the eutrophic state. The lake of Nainital with a large anoxic hypolimnion and the associated rapid P-cycling and an extended time period of eutrophication has almost reached the irreversible eutrophication stage.

The adverse effects of eutrophication on the lake are many: increased phytoplankton biomass, and increase in the proportion of bloom-forming species that are often toxic and/or inedible, shift in macrophytic species to those that can withstand pollution (*Potamogeton pectinatus*), reduced water transparency, problem of taste, odour and water treatment, oxygen depletion, loss of desirable fish, and decrease in aesthetic value of the lake (Smith, 1998). Almost all these adverse effects are visible in Lake Nainital.

2.3.3. Nitrate

In order to find out the status of Nitrate, samples were taken from 21 places. Table 2.12 gives the Nitrate concentration at these places for the months of July, August

and September 2001 and February 2002. It can be seen that the Nitrate concentration in water inflows of the Lake Nainital varied widely across sources and month of sample. However, for more reliable data more frequent sampling is required. The concentration exceeded the permissible limit of 3.16 mg/l (EPA, 2001) at many places. In three drains in one month each, values were also higher (above 5 mg/l) in the water of the wells near the flats (Table 2.12). It is possible because the highly polluted water of hypolimnion gets mixed with the wells' water. The spring water was relatively clean and run-off water does not appear to be a major source of nitrate. Surprisingly the concentration of nitrate in rainwater was relatively high indicating the effect of vehicular emissions. It seems the residence period of pollutants is quite long in the narrow valley of Nainital.

Table 2.12 Nitrate concentration in different sources of water inflows into the Lake Nainital (runoff is overland or surface inflow that occurs during an event of rainfall).

Sample Site No.	**Sites of sample collection**	**Nitrate (mg/l)**				**NO_3**
		July	**Aug.**	**Sept.**	**Feb.**	**Average**
1	Sukhatal Parking Site - Run-off	1.50	0.88	0.19	-	0.86
2	Sukhatal Petrol Pump Site - Run-off	1.40	0.88	0.89	-	1.06
3	Sukhatal Water Pump-house Site – Run-off	0.21	0.32	0.19	-	0.24
4	Malli Tal road run-off	0.50	-	0.52	0.02	0.35
5	Talli Tal road run-off	0.00	-	0.12	0.00	0.04
6	Flats - run-off	0.30	-	0.15	0.02	0.16
7	Forest - run-off	-	-	0.21	0.01	0.11
	Average - run-off	***0.65***	***0.69***	***0.32***	***0.01***	***0.40***
8	Mallital rickshaw stand drain	0.50	2.24	5.97	2.04	2.69
9	Tallital rickshaw stand drain	1.10	0.84	0.27	0.72	0.73
10	Temple drain	5.90	1.36	3.10	1.28	2.91
11	Fanshi gadhera drain	0.10	0.16	0.64	0.28	0.30
12	Library drain	0.10	-	-	1.52	0.81
13	Everest hotel drain	1.10	0.36	7.23	1.01	2.43
14	Alka hotel drain	1.00	0.12	-	0.92	0.68
	Average – drains	***1.40***	***0.85***	***3.44***	***1.11***	***1.20***
15	Sukhatal valley-fill before treatment	0.50	2.48	2.68	2.08	1.94
16	Sukhatal valley-fill after treatment	-	1.56	1.53	1.48	1.52
17	Water main pump house before treatment, flats	0.50	5.84	5.37	0.56	3.07
18	Water main pump house after treatment, flats	0.60	5.08	5.64	0.64	2.99
19	Spring untreated – Masjid	1.30	0.88	0.05	0.23	0.61
20	Rain water	-	-	2.33	1.01	1.67

Notes: Except for the Naina Devi temple drain and Mallital rickshaw-stand drain which are perennial; all others are seasonal (each data is average of three samples at the same site). * It is the weighted average. The temple drain is given 0.8 weightage, Mallital rickshaw-stand 0.1, and remaining together 0.1. Weights are given arbitrarily.

2.3.4 Heavy Metal Concentration

We have also tried to calculate the heavy metal concentration in the water reaching the lake. Table 2.13 gives the concentration of lead in the two months (February i.e. before the start of tourist season and September i.e. after the tourist season and cleansing by the monsoon rainfall). The increase in metal concentration is a recent problem. At least in certain parts of the lake during certain periods of the year concentration of Pb exceeds the permissible levels of 0.01 mg/l (Table 2.13). Among other metals studied Fe, Cu and Mn exceeded the highest desirable level in several seasons. Fe and Mn occasionally exceeded even the permissible levels.

Among all the metals studied lead is the one posing greatest health hazard by polluting the lake. A substantial amount of this until recently used to be caused by vehicles. Now also, though unleaded petrol is sold everywhere, it is yet not lead-free. Thus, besides vehicles, other sources contributing largely to Pb include lead containing paints and perhaps rocks. The number of vehicles has increased dramatically during the last 5-7 years, particularly during the summer tourist season (Plate 4). Once released in atmosphere from fumes of burnt fuel, it settles down in the soil and enters into the lake through the rainwater. Since the monsoon follows immediately the peak tourist activity, this results in a massive Pb input. A substantial concentration of Pb in spring water indicates rocks and soils could also be a Pb source.

All houses have slanting tin roofs (as a protection against heavy rain and snow), which are painted regularly during the summers. The roof area is approximately 2.5 km^2, and this could be a major Pb source.[14]

[14] Pb is deposited mostly in bones and tissues of liver, kidney, muscles and others. Insomnia, headache, abdominal pain, fatigue, anaemia, irritability, degradation of bone marrow, dysfunction of gastrointestinal tract and urine troubles are major effects of lead poisoning.

Table 2.13 Lead concentration (ppm or mg/l) at various water sources of Nainital catchment (Source: present study).

Sample Site No.	Sites of sample collection	Pb Concentration Feb.	Sept.	Average
1	Sukhatal Parking Site - Run-off	0.00001	-	0.00001
2	Sukhatal Petrol Pump Site - Run-off	0.00640	-	0.00640
3	Sukhatal Pump House Site - Run-off	0.00140	-	0.00140
4	Malli Tal road run-off	-	0.00760	0.00760
5	Talli Tal road run-off	0.00640	0.00580	0.00610
6	Flats - run-off	0.01600	-	0.01600
7	Forest - run-off	0.00057	-	0.00057
	Average of run-offs	***0.00513***	***0.00670***	**0.00592**
8	Mallital rickshaw stand drain	0.01100	0.00250	0.00675
9	Tallital rickshaw stand drain	0.00690	0.00210	0.00450
10	Temple drain	0.01800	0.00380	0.01090
11	Fanshi gadhera drain	0.00690	0.00580	0.00635
12	Library drain	0.00067	-	0.00067
13	Everest hotel drain	0.01100	0.00280	0.00690
14	Alka hotel drain	0.01200	0.00310	0.00755
	Average of drains	***0.00950***	***0.00335***	**0.00642**
15	Sukhatal valley-fill before treatment	0.00140	0.00180	0.00160
16	Sukhatal valley-fill after treatment	0.00370	-	0.00370
17	Water main pump hose before treatment, flats	-	0.00340	0.00340
18	Water main pump hose after treatment, flats	0.00001	-	0.00001
19	Spring untreated – Masjid	0.00039	-	0.00039
20	Spring treated – Masjid	0.00220	-	0.00220
21	Rain water	0.00220	-	0.00220

From above data, it seems the lake is highly eutrophic with phosphate getting accumulated. Besides, lead is another problem. Many of the drains, feeding into the lake have high BOD and bacterial count, thus indicating poor state of the lake. The next section compares some of the changes in lake with the pristine state.

2.4 Changes in the Lake Over Time

The kidney-shaped Lake Nainital (Plate 5) is warm monomictic lake, with strong summer time thermal stratification, with temperature difference of 17°C between surface water and at 9 m depth (Fig. 2.14). The stratification, however, breaks down in autumn and by winter the entire water column has the same temperature (Purohit, 1981).

It is highly eutrophic with Secchi disc transparency of less than 2m, NO_3 and PO_4 concentration of 1.11 mg l^{-1} and 0.16 mg l^{-1}, respectively. It has a total P of 127.25 µg/l (other lakes 3-26.4 µg/l). The dominant algal form is blue green algae and Microcystis blooms. The dominant macrophyte is *Potamogeton pectinatus*. The lower limit of dissolved O_2 in epilimnion is less than 2 mg/l during mixing of water of epilimnion and hypolimnion.

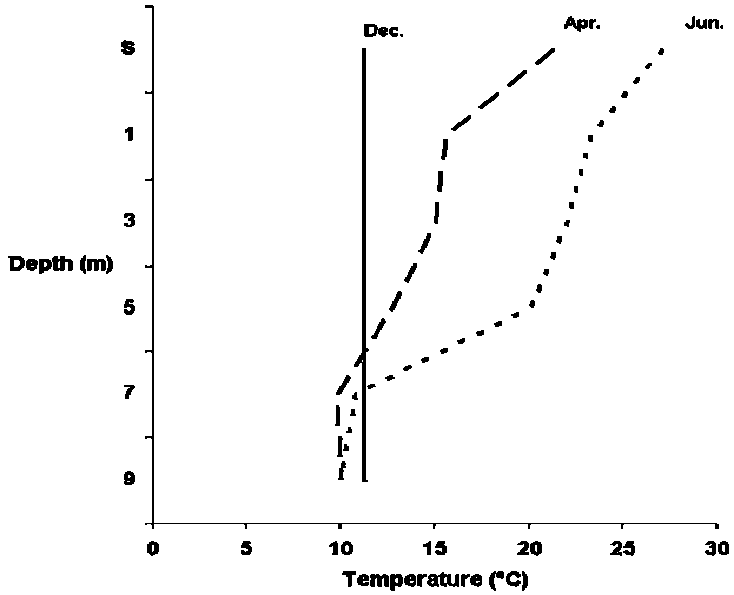

Fig. 2.14 Thermal stratification in Lake Nainital.

Note: S – means Lake Surface

2.4.1 Pristine stage

Description of the lake given by Atkinson (1882) when human settlements had just begun indicates that the lake was clean with bluish-green water, except when *Ceratium kumaonense* formed dense population. This horned peridinea, allied to that found in Baltic sea, Red sea, Indian ocean, the Swiss lakes and freshwater ponds of Mumbai and Kolkatta turned the lake water rusty brown. In the pristine lake of that time the concentration of total solids was just 4 mg/l compared to 300 mg/l at present and B.O.D. of filtered water below 1 mg/l compared to 20 mg/l in the present. Among the macrophytes that occurred in those days, *Myriophyllum* and *Chara* are no longer found as a consequence of pollution. *Potamogeton pectinatus,* which has more capacity to tolerate pollution, has increased in the lake in the recent times.

2.4.2 Changes in Mean and Maximum Depth

In the next 84 years, after the first time its depth was measured, the mean depth has reduced by 2.88 m (i.e., a fall of over 13%) from 1895 to 1979 (Table 2.14 and Fig. 2.15). The total volume has reduced in these 84 years by 7682.5m^3 (i.e., by one-fifth) and the sedimentation deposition rate is 91.46 m^3/yr. It is estimated that with this rate of sedimentation deposit, the lake would be filled up in about 325 yrs (Table 2.14).

Table 2.14 Changes in the depth of the lake from 1895 to 1979 (Rawat, 1987).

Year	Depth (m)			
	1895	1969	1979	% Reduction from 1895 to 1979
Maximum depth(m)	27.45	26.95	25.70	1.75 (6.38)
Mean depth(m)	21.43	20.64	18.55	2.88 (13.44)

Note: Figures in parentheses are reduction in percentage terms

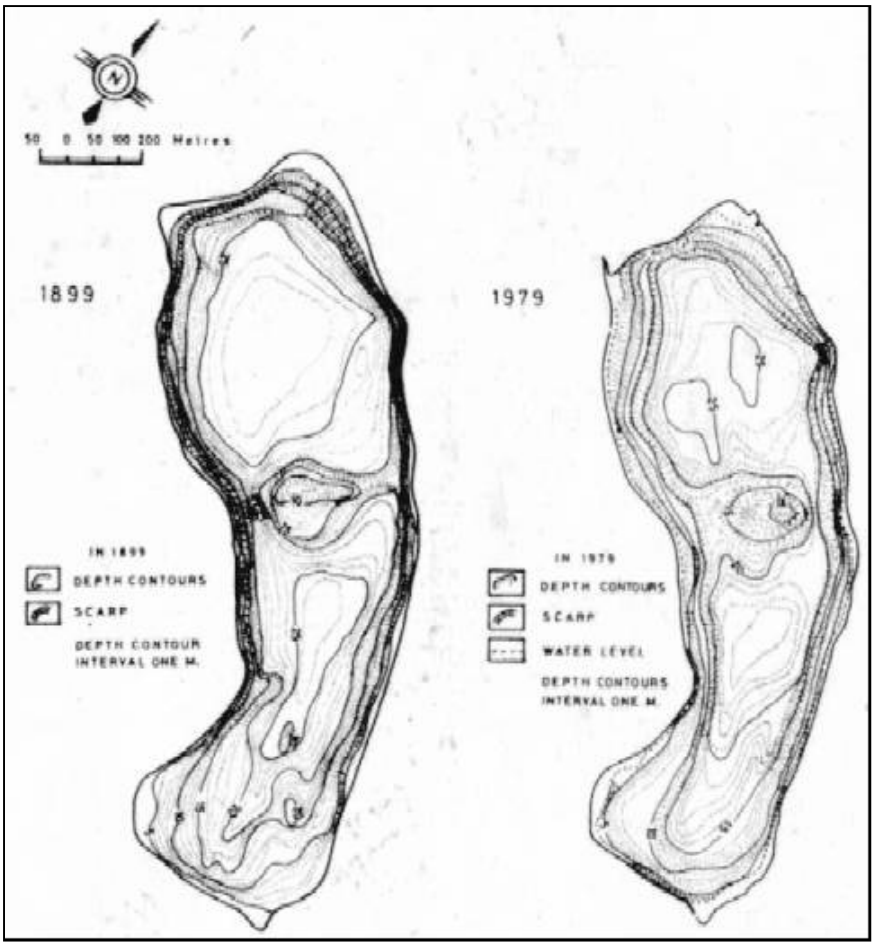

Fig. 2.15 Comparison of the hydrographic contour maps 1899 and 1979 (Source: Rawat 1982)

2.4.3 Lake water

Table 2.15 gives the nutrient content and other changes in the lake since 1954. It is clear from the table that the lake had become eutrophic by the 1970s and eutrophication increased further during the subsequent two decades. At present the lake water has become almost opaque, NO_3-N has increased by 1.6 times, and BOD by 2 times in the last two decades. But the most alarming rise has occurred in PO_4-P, which has risen by 13.6 times. In recent years though the sewer connections have improved considerably, bathroom and kitchen waste water of many houses still finds its way into the lake through the drains. Since detergents used for washing clothes contain PO_4, the bathroom water is the major source of PO_4 enrichment of the lake water. The consumption of detergents has increased several folds because of the change in preference, the increase in population and tourists, and also increases in the per capita consumption of detergents. Furthermore, the use of services of washermen who used to wash clothes outside the catchment has declined considerably. Though household wastes are transported periodically to the dumping grounds located away from the lake catchment, a small fraction of it finds its way into the lake because of the inefficient collection system. Other sources of nutrients include soil erosion and dumping of construction materials into the drains.

The extent of deterioration in water condition of Lake Nainital can be evaluated also by comparing the lake with other two major lakes, with less anthropogenic pressure. This comparison indicates that the lake Nainital is hyper-eutrophic, displaying 0.7 times lower DO, 5.7 times greater NO_3, and 42 times greater P than in Naukuchiatal lake, which is classified as oligotrophic[15] (NIH Report, 1999).

Table 2.15 Temporal changes in the water quality of Lake Nainital.

Mean littoral zone	**Pant *et al.* (1980) as referred in Valdiya (1988)**				**Sharma (1982)**	**Nagdali (2002)**
	1954	**1960**	**1965**	**1970**	**1977-79**	**1999-2000**
NO_2-N(µg/l)	t	t	14	20	25	41
NO_3-N(µg/l)	t	t	40	300	336	535
NH_4-N(µg/l)	15	20	60	90	190	805
PO_4-P(µg/l)	-	-	-	-	15	134
Transparency (m)	-	-	-	-	1.10	0.80
BOD (mg/l)	-	-	-	-	11.0	22.0
TDS (mg/l)	-	-	-	-	90	350

[15] There exist three kinds of trophic lakes – oligotrophic, meso-eutrophic and hyper-eutrophic.

Note: The study of Pant *et al.* (1980) did not consider the values for PO_4-P, transparency, BOD and TDS; All values are seasonal means of several stations in littoral zone; t- traces.

2.4.4 Biotic Components of Lake Nainital

Potamogeton pectinatus (*P. pectinatus*) is the dominant macrophyte of the lake Nainital. Its proportion has increased sharply with eutrophication as indicated by comparison of three major lakes differing in eutrophication level (Table 2.16). The net primary productivity of *P. pectinatus* (582 m^2 /yr) is about 8 times of that in the meso-eutrophic lake Bhimtal. This pollution tolerant macrophyte is scarcely present in oligotrohic Lake Naukuchiyatal.

As mentioned earlier, the lake Nainital lost *Myriophyllum spicatum* and *Hydrilla verticillata* during the last two decades, and *Chara*, perhaps even earlier.[16] Data collected about two decades ago indicate that the phytoplankton community is dominated by chlorophyceae followed by bacillariophyceae in terms of species members (Table 2.17). However, in terms of biomass chlorophyceae and cyanophyceae are dominant groups (13.2 g/m^2 and 10.4 g/m^2). The major species are *Chlorella vulgaris, Chlamydomonas* sp., *Chloroccum humicola, Eudorina elegense*, *Ankisrodesmus* sp., *Cloestriopsis longissima* and *Closterium acerosum*, in chlorophyceae, and *Microcystis* sp., *Anabaena* sp. and *Aphanocapsa* sp. in cyanophyceae (Table 2.17). The phytoplankton mass has increased considerably during the last two decades and composition has shifted towards a greater domination of cyanophyceae and some diminution in the importance of chlorophyceae (Table 2.18). The zooplankton did not show rise because of the weed fish, *Gabusia affinis* which feeds on them. Both gross and net primary productivity continues to increase in the lake (Tables 2.19 and 2.20).

The zooplankton community of Lake Nainital consisted of 59 species belonging to 33 genera. In terms of species richness, Rotifera is dominant, while Copepoda has more cell density than other groups (Table 2.19). In terms of density, the Copepods dominate. The dominant zooplanktons species are as following: *H. brehmi, F. longiseta, A. brightwelli, K. topica* of Rotifera, *M. leuk, E. serrulatus, P. blanci* of Copepoda, and *D. excisum* of Cladocera (Table 2.21) (Sharma, 1980).

[16] There does not exist any study or conclusive evidence to indicate when *Chara* got extinct.

Table 2.16 Macrophytes, their biomass and productivity in Lake Nainital vis-à-vis other lakes (Singh and Gopal, 1999 and Gupta *et al.*, 1999).

	Nainital Hyper-eutrophic	**Bhimtal Meso-eutrophic**	**Naukuchiyatal Oligotrophic**
Depth up to which macrophytes occur	6	8	12
Total no. of species	5	13	13
Major floating and submerged species	*Polygonum amphibium, Potamogeton pectinatus, P. crispus*	*Myriophyllum spicatum, Vallisneria spiralis*	*Nelumbium nucifera, Myriophyllum spicatum, Ceratophyllum demersum*
Submerged community annual net primary productivity (g / m^2)	766	599	582
Potamogeton pectinatus peak biomass (g)	578	69	3

Note: Values of other two lakes of the region are given to indicate changes that have occurred partly due to excessive eutrophication

Table 2.17 Phytoplankton species richness in Lake Nainital vis-à-vis Lake Bhimtal.

	Nainital (Sharma, 1980)	**Bhimtal (Joshi, 1983)**
Total no. of species	69	54
Chlorophyceae	33	31
Bacillariophyceae	19	16
Cyanophyceae	12	3
Rhodophyceae	1	0
Dinophyceae	2	4
Others	2	-

Note: Data of Lake Bhimtal, a lake of a similar size of the region with less eutrophication are given to indicate changes that accompany hyper-eutrophication.

Table 2.18 Changes in phytoplankton group composition (in terms of biomass) during the last two decades (Figures in %).

Group	**1977-1979 (Sharma, 1980)**	**1999-2000 (Nagdali, 2002)**
Chlorophyceae	53	41.7
Cyanophyceae	41	51.4
Bacillariophyceae	5.6	6.9
Others	0.4	0
TOTAL	**10000.00%**	**10000.00%**

Table 2.19 Changes in density and biomass of phytoplankton and zooplankton community over a period of two decades.

	1977-1979 (Sharma, 1980)	**1999-2000 (Nagdali, 2002)**
Phytoplankton density (cells/litre)	13.0×10^6	14.5×10^6
Zooplankton density (individual/litre)	10-480	46-350
Phytoplankton biomass (mg/m^2)	17.4	34.0

Table 2.20 Temporal changes in gross and net primary productivity, and respiration (mg/C/m^3/d) in surface water of Lake Nainital.

	1978-1979 (Sharma, 1980)	**1998-1999 (Gupta and Nagdali, 1997-1999)**
Gross primary productivity	790	1000.8
Respiration	445	396.5
Net primary productivity	302	604.3

2.4.5 Macrozoobenthos

Gupta (1981) records 30 species belonging to 9 taxonomic groups, of which *Diptera* was most important Ephemeroptera, Decapoda and Lepidoptera were absent, though they occur in the nearby Bhimtal lake.

2.4.6 Fish

Lake Nainital which once had rich Mahseer population is presently devoid of this species due to high water pollution. The winter fish morality is getting more common, largely because of the oxygen depletion at the time of turnover of lake water. As temperature stratification disrupts anoxic hypoliminon mixes with epiliminon having some oxygen, resulting in overall oxygen depletion. Furthermore, in the mixed water column organic matter of the bottom layer creates oxygen demand as it comes in contact of the air dissolved in water.

With increasing pollution incidents of fungal diseases on fishes have increased in the recent years (Khulbe and Sati, 1999). Nearly 100 species of aquatic fungi belonging to Blastocladiales, Saprolegniales, Leptomitales, Lagenidiales and Peronosporales occur in water. Most of the pathogenic fungi belong to *Achlya*, *Aphanomyces*, *Saprolegnia*, *Leptolegnia* and *Pythium*.

Table 2.21 Zooplankton community of Lake Nainital: species richness and percent density by groups (Source: Sharma, 1980).

Groups	Species richness	% of total density
Rotifera	48	42.5
Copepoda	6	54.0
Cladpcera	5	3.5
Total	**59**	**100.0**

2.5 Water borne diseases and its Cost

As we have seen in previous section that the Lake Nainital is hyper-eutrophic and the nutrient load is continuously increasing. As a consequence, the quality of water is degrading; a clear impact of this should get reflected in the health status of the people in Nainital. The current section looks into whether there is any perceptible increase in water-borne diseases or not. This is followed by what preventive measures people have taken and how does this translate to cost for the people.

2.5.1 Water borne diseases

Data based on cases admitted to the hospital indicate that infective diarrhoea, dehydration and vomiting constitute the major diseases and are steadily on the rise, showing nearly a fourfold increase from 1995 to 1999 (Fig. 2.16). Jaundice and infective hepatitis are also on the rise, but are less important in comparison. These diseases show a definite seasonal pattern, with a peak during the summer and rains, and a sharp decline during the winters.

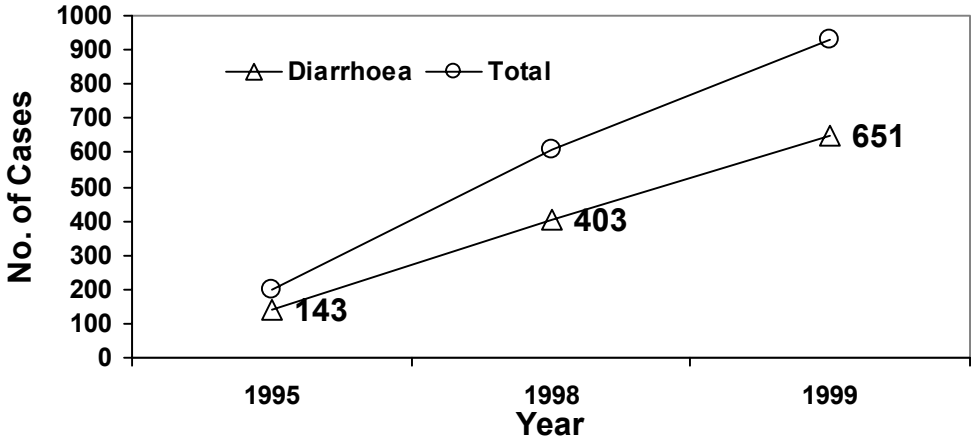

Fig. 2.16 Trend of water-borne diseases (individuals admitted to the district hospital of Nainital during 1996-98)

2.5.2 Cost of Unsafe Water

The cost of unsafe water has been estimated by considering the sale of bottled water, household devices such as filtering and boiling of water, expenses on treatment of water borne diseases. The annual cost of bottled water, filter and boiling of water and treatment of water borne disease is about Rs.5.7 million (Table 2.22) of which more than 60% is on the medical expenses alone.

Table 2.22 Cost of unsafe water (Source: Present study).

Safe water/Treatment method	Cost (Rs.)
Filtration[1]	640,000
Boiling[2]	300,000
Bottled water[3]	1,180,000
Medical treatment[4]	3,630,080
TOTAL	**5,750,080**

Notes:

1. Rs. 640,000 is spent annually on filtering of drinking water assuming that about 20% of the total 8,000 households do it @Rs.400/- per family annually (Rs.400 is spent annually on use of each water filter assuming that a new water filter costs Rs.1500 and lasts for 15 years and the annual cost of replacing filter candle is Rs.300). This is one of the preventive measures taken by the local population.
2. Rs. 300,000 is spent annually on boiling of drinking water assuming that only 10% of the total population of 8,000 families do it @Rs.375/- per family annually. This is another water purification method followed by the local population.
3. Total annual expenditure on bottled water was Rs.1.18 million for the year 2000-2001. The expenditure on bottled water is mainly by the tourists.

    a) Mineral water sale started in the town in 1990, since then an annual increase of approximately 10% has been recorded till 1995 and thereafter an increment of 25% annually.

    b) 70% consumption during peak tourist period (May, June, October) and 30% in low tourist-activity period.

    c) Brand-wise sale was 65% for Bisleri (Acqua Minerals Ltd.), 15% Nestle (Nestle), 10% for Kinley (Coca Cola Ltd.), 10% for Aquafina (Pepsi Ltd.) and 5-10% for others for the period 2000-2001.

    d) The medical expenses of about Rs. 3.63 million (as per the estimates from hospitals and chemists for the period 2000-2001) is incurred on treatment. This includes both the local and tourist populations.

The value is underestimate of the cost of unsafe water, as the study could not capture the loss in man-hours and loss of human capital.

2.6 Conclusions

The present chapter gives the basic features of the Lake Nainital and its watershed. Since its discovery, Nainital is a tourist destination. Over time, with increase in population, tourism activity and commensurate increase in construction activity led to severe anthropogenic pressures. This ultimately has affected the water quality of the lake. The lake has become highly eutrophic and has become a pool of phosphate also despite continuous outflow. Even the geology of the rocks and watershed is contributing to this eutrophication.

Analysis of samples at different sites, which are feeding to the lake, indicates that most of the sources especially drains and run-offs, are high in terms of BOD load, bacterial count, nitrate, phosphate and lead. The chapter then looks into the changes in the lake with respect to nutrients, TDS, BOD and transparency over time and across other lakes in the region. This is followed by calculation of the cost of unsafe water to the local people, who are incurring preventive expenditure. The data reveals that the water-borne diseases are on the rise and nearly Rs. 5.75 million is being spent by the people and tourists as a result of deterioration in the lake water quality.

Chapter 3 :Benefits/Values derived from the Watershed by various Stakeholders

3.1 Introduction

The previous chapter by analysing the water samples at different feeding points (Plate 6) to the Lake Nainital and using secondary sources comes to the conclusion that the lake is hypereutrophic. The catchment-based activities have contributed adversely to the current state. If the lake continues to get polluted, the first and foremost impact will be felt by the local population, who are dependent on the lake for the water supply. Any further eutrophication leading to reduction in transparency level caused by green algae bloom will have the second casualty in the form of reduction in tourism. This will affect the local population even more severely as the local economy depends mainly on the tourism. Are these the only two stakeholders that depend on the lake or there are few others? The present chapter attempts to identify different stakeholders who are benefiting from one or other aspect of the lake and its watershed. The chapter also enumerates the benefits these stakeholders are deriving.

The chapter is organized into four sections. Section 3.2 identifies the stakeholders followed by part identification of services by the watershed in Section 3.3. The chapter concludes in Section 3.4.

3.2 Stakeholders in the Lake Nainital and its Watershed[17]

3.2.1 Type of Values

It is well acknowledged that natural systems / resources provide several use values and non-use values to enhance human welfare and render sustainability to all species (Kadekodi, 2001). Conceptually, the total value of a system/resource is the sum of Use values (UV) and Non-use values (NUV). The use values are nothing but the good and services to the users for their current or future benefits or welfare (*ibid*.), e.g., fuel-wood or fodder from the forests or water from the lake etc. Society also has the *option* of postponing any decision on the use of any natural resource. Accordingly, the use values can be broadly classified into three groups – direct, indirect and option values.

[17] Part of this section has been taken from Kadekodi (2001).

Direct use values can either be consumptive or non-consumptive. In the Lake Nainital and its Watershed, taking water from the lake for drinking or other purpose is clearly a consumptive use, whereas boating in the lake is an example of non-consumptive use value. An alternate to 'consumptive use value' is the 'productive use value'. It constitutes values of products that are harvested and sold in commercial markets. Fish harvested from the lake can be a good example of productive use value.[18]

On the other hand, indirect use values are generally referred to the ecological functions that natural resource (e.g., Lake and its watershed) provides., without harvesting, depletion or degradation. Indirect use values are further classified into three categories – watershed values, ecosystem services and evolutionary process. Watershed values in the case of Lake Nainital include regulation of stream flows, natural filtering of water etc.; fixing of nutrients, assimilation of waste, carbon sequestration etc. are the ecosystem services from the Lake and its watershed; and evolutionary process include life support (by providing drinking water), religious, cultural and aesthetic concerns, biodiversity preservation, etc.

Non-use values are entirely different from the use values and are generated without any direct link with the use of natural resource under question. An example is the values that people of Tamil Nadu may be putting on the Lake and its watershed. Existence and bequest are the two significant non-use values. The bequest value originates when people are willing to pay to conserve a resource for the use of future generations; whereas, existence values are associated with people's willingness to pay simply for the pleasure they derive from knowing that the Lake Nainital is preserved irrespective of their plans to visit Nainital.

Lastly, the Option Value (OV) relates to the future benefits of conserving the Lake and its watershed for being able to use them in the future, irrespective of their current use. Table 3.1 gives a comprehensive total value from the Lake and its watershed.

[18] Currently, due to ban in fishing, this cannot be considered as a productive use value from the Lake. But timber, fuel-wood, medicinal plants, etc. are clear examples of productive use value from the watershed.

Table 3.1: Total Value from the Lake and its Watershed

USE VALUE			NON-USE VALUE
Direct Use Value (1)	**Indirect Use Value (2)**	**Option Value (3)**	**(4)**
Drinking Water	Nutrient Recycling	Future Use as per 1 and 2	Existence Value
Recreation and Tourism	Watershed Protection		Cultural Value
Fuelwood, Fodder, Fish	Natural Filtration		Bequest Value
Medicinal Plants	Waste Assimilation		Biodiversity
Plant Genetics	Carbon Sequestration		Intrinsic Value
Education, Human Habitat	Biodiversity		Religious Value
Non-timber Forest Products	Micro-climatic Functions		Heritage Value
Timber	Soil erosion Protection		

Note: Adapted from Pearce and Moran (1994)

Thus, the Lake Nainital and its watershed offer a variety of consumptive and non-consumptive direct and indirect use value. Besides, it has a significance option and non-use values. It is these use and non-use values, which is facilitating sustenance of Nainital economy. Table 3.2 gives a comprehensive list of stakeholders, who are dependent on lake for direct and indirect use, and non-use values.

Table 3.2: Stakeholders in the Nainital Lake and its Watershed and the Benefits / Values Derived

No.	Stakeholders	Benefit or Value Stakeholders deriving	Type of Value
1	Local population	Benefiting from the incomes generated by hotel and tourism industries	Non-consumptive Use value
2	Tourists	Derive services of recreation, education and tourism	Non-consumptive Use value
3	Boatmen	Benefiting from the lake through the income generated from tourism	Non-consumptive Use value
4	Horsemen	Benefiting from the surrounding peaks / hills through the income generated from tourism	Non-consumptive Use value
5	Rickshaw-pullers, Taxi-owners, etc.	Benefiting from the income generated from tourism	Non-consumptive Use value
6	Petty Traders, Shop-owners, Vendors	Benefiting from the income generated from tourism	Non-consumptive Use value
7	Population of Nainital Town	Benefiting from the Lake Nainital as the source of drinking & other water supply	Consumptive Use value
8	Local Municipality	Derive benefit from the income/ revenue from the Toll charged from the tourists and saving in water-treatment plant costs because of natural cleansing property of lake and its watershed.	Non-consumptive Use value
9	Lake Management Authority	Which is responsible for the maintenance of the ecological health of the lake and its watershed such that the economic benefits continue to accrue.	Non-consumptive Use value
10	Low-income Group	Benefits from the income or saving in expenditure mainly through the collection of fuel wood, fodder, medicinal plants etc.	Consumptive use or Productive use value
11	Community of Scientists and Ecologists	By putting a premium on the existence value of the lake and its watershed as the Lake and watershed is being used extensively for research purposes.	Non-Consumptive, non-use value
12	Non-users in the rest of the country	Who value the existence of lake Nainital and its watershed and other places of similar nature.	Non-Consumptive, non-use value

Note: Many of the stakeholders like petty vendors, rickshaw-pullers, horse-owners, Boat-owners etc. are not the local inhabitants; they migrate during the tourist season. Hence they are given separately.

Thus a large number of stakeholders depend on the Lake and its watershed for a number of goods and services. It is quite ironical that some of these are in fact cause of anthropogenic pressures also. On the one hand, they are getting benefits from the ecosystem, on the other hand by putting enough stress on the system, they are contributing to reduction in future services of the ecosystem. Following Figure 3.1 gives a simplified summary of anthropogenic pressures on the Lake Nainital and its watershed.

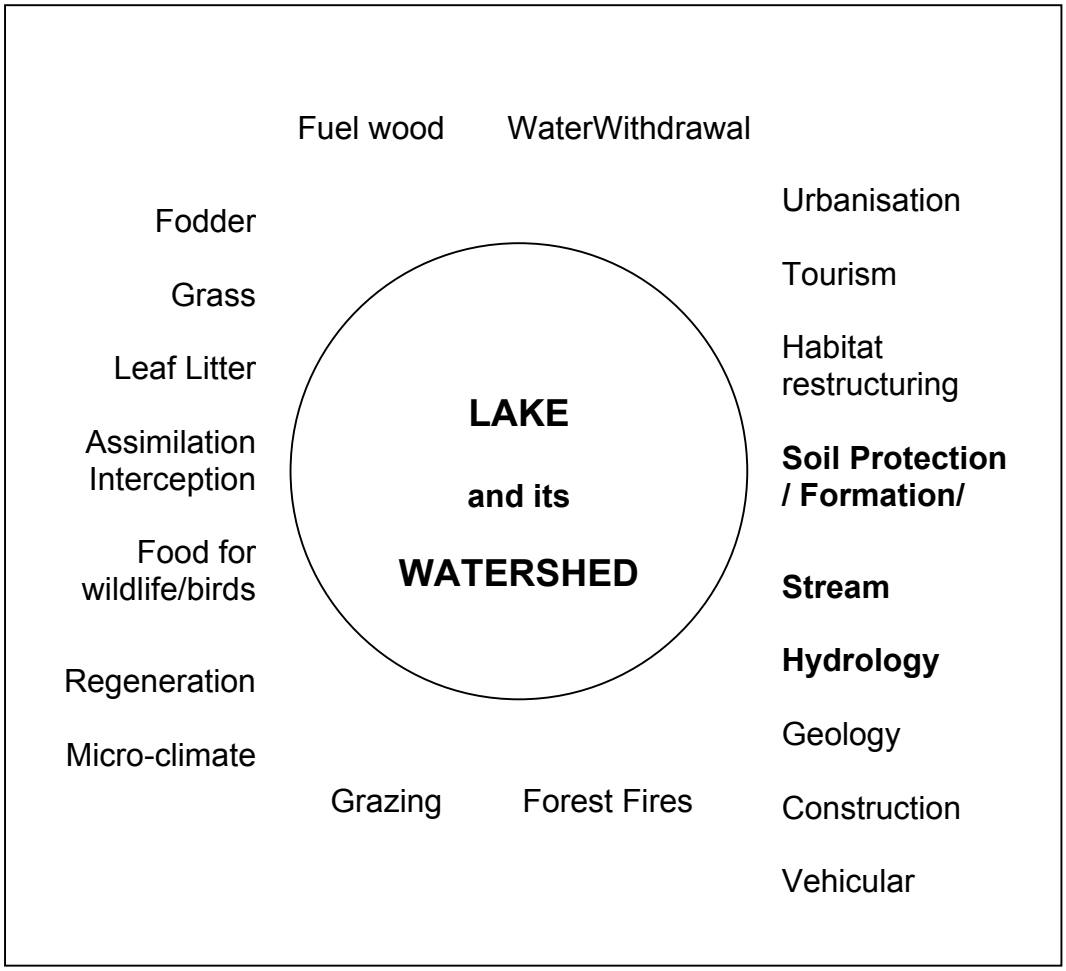

Figure 3.1: A simplified summary of Anthropogenic Pressures on the Lake and its Watershed (Adapted from Pandit, 1997)

3.3 Ecosystem-services by the Lake Nainital's Watershed (Reduction in silt load due to forest) – An Illustrative Example

As we have enumerated in the previous section that the Lake Nainital and its watershed is providing a lot of direct and indirect use values. The current section

gives an illustrative example of one such eco-service i.e., reduction in silt load due to forests and the cost savings from that.

Estimates suggest that the soil and silt loss during rainy season in forested area is only 12.1% that of non-forested areas. This implies, the forest does the service of controlling soil loss, which is about 3175 t from the entire forested area (Table 3.3). The cost of removal of silt from the delta formed in the lake is minimum Rs.2 lakhs annually for this amount of deposition of silt. However, not the entire soil lost is accumulated as delta, a certain portion accumulates in the deeper beds of the lake, reducing its capacity and quality of water. Obviously, the total cost that the forest saves is much bigger. In much of the catchment oak forest dominates, which is characterized by deep root system, strong mycorrhizal association and high capacity for water retention in its body. Table 3.4 gives the features of the Oak forests in the watershed.

Table 3.3: Reduction in silt load due to forest

Parameter	**Value**
Silt erosion from forest area	0.045 t ha^{-1} yr^{-1}
Silt erosion from non-forest area	3.72 ha^{-1} yr^{-1}
Amount saved by the forested area	3.675 t ha^{-1} yr^{-1} (3157 t)
Removal cost of 3157 t of silt	1.92 lakh yr^{-1}#

Note: # This is the lower estimate of the removal of cost. In actual practice, the amount would be much higher, as the marginal cost of removing silt would increase non-linearly with every kg of silt removed.

Table 3.4: Oak forest characters (derived from Singh and Singh, 1992; Singh, 2002)

Mainly evergreen oaks (*Quercus* spp.)	about 170 ha
Cypress (*Cupressus torulosa*)	about 48 ha
Net primary productivity close	20 t ha^{-1} yr^{-1}
Biomass	> 400 t ha^{-1}
Litterfall in forested area	720 t yr^{-1}
N from litterfall in forested area	10.08 t yr^{-1}
P from litterfall in forested area	0.60 t yr^{-1}
Soil loss from the forested watershed	45 kg ha^{-1} yr^{-1} or 10.8 t
Root : shoot ratio for oak.	0.28
Root : shoot for other species	< 0.22
Deep roots, abundance of mycorrhizae	

The previous chapter and the discussion so far in the current chapter refer to a large number of services provided by the ecosystems and the geological components of

the Lake Nainital and its watershed. Table 3.5 summarises the services and the saving in costs from those services. The supply of naturally filtered water without any treatment for the drinking purpose is a good example of cost saving that is already in practice. However, the ban on swimming and fishing subsequent to the water pollution can be considered to the cost of not managing the lake properly.

Table 3.5: Ecosystem processes and services generated from the forests

Hydrological regulation	**Services**	**Possible valuation examples**
Water filtration (forest, valley-fill, pervious rocks)	Reduced cost of water treatment	• Lower cost of treatment per unit water • Direct water supply without treatment
Water retention within watershed (forest, valley-fill, pervious rocks)	Increased extra-monsoon water availability and the tree growth Higher water level in the lake	Increased turnover of water, increased hill protection More boating, can lead to revival of swimming and fishing • Can be measured as importance given by tourists to springs, high water level in the lake and lower pollution
Forest canopy interceptions and Reduced overland flow	Less siltation Dampened flood peaks	Reduced cost of silt removal
Forest-direct	Beauty, biodiversity, soil formation	Activities related to photography, bird watching, etc. can be measured as importance given by tourists to them.

3.4 Conclusions

The present chapter looks into different use and non-values (or benefits) that one can have from a natural resource like Nainital Lake and its watershed. This is followed by enumeration of list of stakeholders dependent on the lake for varied

benefits. The discussion in the chapter indicates that the lake ecosystem is providing innumerable goods and services, most of which are life-supporting and may not have any substitute. The chapter then gives an illustrative example of one such service provided by the forests in the watershed i.e., removal of silt by the forests and a commensurate savings in costs.

Chapter 4: Economic Valuation of Nainital Lake and its watershed – Travel Cost Method

4.1 Introduction

As we have seen in previous chapter, the Lake Nainital and its watershed is immensely important to a number of stakeholders – be it the local population or the tourists or the community dependent on the watershed for fuel wood, fodder etc. (and other eco-services) or the town's population dependent on the lake for the water supply etc. The Table 3.1 in Chapter 3 has given a comprehensive list of stakeholders in the Lake Nainital and its watershed and the benefits / values they derive from it.

It is evident from Table 3.1 that different categories of stakeholder benefit from the unique ecology of the Lake and its watershed. This reflects a clear case for preserving the ecology. However, the extent to which different users will be able to reap the benefits from the lake and its watershed in future depends on the ongoing anthropogenic pressure created by continuous use / catchment-based activities, which may result in change in the ecology. Though the individual components in the Lake Nainital and its watershed have a use value like the fuel wood and fodder for the low income group; water for drinking purpose for the town's population; lake and flora for research and so on, but the system as a whole has a distinct use value in the form of tourism. This value emanates out of the existence of the Lake and its watershed as a distinct unit. The tourists in Nainital visit the Nainital because of the sum total of the ambience i.e., the Lake and its watershed together not due to one single aspect. This is clearly substantiated by our survey of 273 visitors, which find that more than two-third (67%) tourists have come for the sum, not for the individual resource (Table 4.1).

Such a synergy between different aspects of the lake and its watershed also suggests that the approximate value of the lake is reflected in the 'travel cost' incurred by tourists to visit. This cost of travel essentially expresses the revealed preference of people interested in deriving tourism and recreation value from the lake and its watershed i.e., how much people are willing to contribute to preserve the ecology of the lake.

Table 4.1 Reason for Visiting Nainital

Reason to Visit Nainital	No. of Visitors Responded
Combination of Lake and Mountains	183 (67.03)
Presence of Lake	62 (22.71)
Presence of Mountains	11 (4.03)
Presence of number of nearby tourist places e.g., Bhimtal, Sattal, etc.	11 (4.03)
Opportunity for Exercise, like hiking, horse-riding, boating etc.	6 (2.20)
Total	**273 (100.00)**

Note: Figure in parentheses gives the percentage of the total tourists surveyed.

In this chapter attempt has been made to put economic value to the lake and its watershed from the tourism. Assigning a proper value to the lake and its watershed from tourism is also a *sine quo non* from the policy-makers point of view if they aim at restricting / curtailing catchment-based anthropogenic activity in the watershed. The structure of the chapter is as follows. Section 4.2 gives a brief outline of the methodology. Section 4.3 discusses in short the sample and the descriptive features of the sampled tourists. This is followed by how important variables were constructed. The estimation of the demand function and the value of Lake Nainital and its watershed from tourism is given in section 4.4. The section also compares the estimates arrived with other studies done in India using almost similar methodology. The chapter concludes with section 4.5.

4.2 Estimation of Recreation value

When the preferences are expressed on a market, it is easy to estimate the demand for a good or a service, provided the market price is not the distorted one. However, as we have seen in Chapter 3 that most of the natural resources and the functions they do, have no market value. Carbon sequestration potential of forests is one such example, the services provided by the Lake Nainital and its watershed is other such example. For such cases, which do not have any market, two alternate approaches are usually adopted. In one approach, called as stated preference method, hypothetical market situation is created and individuals are asked their willingness to preserve the natural resource. The second approach, known as revealed preference

methods, uses the behaviour of the individuals to approximate the price of a natural resource.[19]

To estimate the recreational value of Lake Nainital, the present study uses a revealed preference method i.e., the travel cost method (TCM).[20] In the method, the expenditure incurred on visiting the Lake Nainital will be treated as a revelation of a tourist's preference for the (environmental) services provided by it. The variation in travel costs and visitation rate is being used to estimate a demand curve, which is then used to compute the consumer surplus of the activity i.e., the recreational value. The basic premise is to use the cost of travel as surrogate for the willingness to pay for using the Nainital site. Besides actual transportation costs, the travel costs may also include tariffs paid at hotels and the opportunity cost of travel time spent on journey, as a proxy for asset value of the recreation site.

Before embarking on the exact methodology, it needs to be stressed that these non-consumptive direct use values are lower estimates of the total social benefits of the lake and its watershed. This is because the total economic value (TEV) of the natural resource requires estimation of both use and non-use value (refer to Table 3.1). Incidentally, in the present study the focus is only on the use value.[21] The travel cost method focuses on estimating the following demand function:

$$V = f(TC, X) \qquad (4.1)$$

Where, V = Number of visits to the lake; TC = Travel cost to reach the lake; and X = Other socio-economic variables like income, education etc. affecting choice of visits to the lake.

In the TCM also, there exist two approaches to estimate the demand function – the Zonal Travel Cost Method (ZTCM) and the Individual Travel Cost Method (ITCM). In

[19] Revealed preference method are also known as subjective valuation approaches mainly applied for maintenance costing of natural assets. Travel Cost Method, hedonic price method, property value and production function, are few techniques in this approach. Refer Kadekodi (2001) for description of these and other different methods to value natural resource and a summary of application of these methods for different resources in case of India.

[20] TCM was first suggested by Hotelling in 1947 to value a National Park in USA, thus it already has had five decades of development since the idea was germinated. Refer Ward and Beal (2000) for an historic sketch of the TCM.

[21] The non-use value can be captured by interviewing the non-visitors. Given the time frame of the study and the budget, it was not feasible to estimate the non-use values. However, some efforts are made to capture how the informed citizens or intellectuals value lake and its watershed, as we shall see in the next chapter.

the ZTCM, the unit of analysis is the Zone. Under this method the visitors are divided into different zones of origin.[22] A visitation rate is then calculated for each zone given by Number of visits to the Lake per year from a zone to the total population of the zone i.e., the rate of participation per capita (Walsh, 1986; p. 217).[23] On the other hand, the dependent variable in the ITCM is the number of trips per period made to a site by each individual. Practically, ITCM works best when individuals take a highly variable number of trips in the period to the site e.g., a park or zoo in the city. However, when recreation sites are greater than 2-3 hours driving time distant from their homes, multiple visits to a site by an individual become less common.[24] Under the situation, the ZTCM is better.

In the case of Nainital, though visitors are predominantly from North Zone (nearly 75%) but in general they have to travel more than 3-4 hours to reach Nainital. This implies multiple visits to Nainital by an individual won't be there. Freeman (1985) argues that when most individuals take a single trip per year to a site, i.e., the dependent variable does not exhibit sufficient variation to estimate a statistical demand function, ITCM cannot be used. This is also substantiated by our data on 273 surveyed visitors (Table 4.2). More than 55% visitors were visiting Nainital for the first time. Of the 122 visitors, that had visited Nainital earlier, only 18% had multiple visits during the year, rest 82% had visited Nainital two or more years ago.

Table 4.2 Whether the tourist has visited Nainital earlier – If yes then when

Last when	No. Of Tourists (%)
First Visit	151 (55.31)
Last Visit in 2001-02	22 (8.06)
Last Visit before 2001	100 (36.63)
Total	**273 (100.00)**

Note: Figure in parentheses gives the percentage of the total tourists surveyed.

[22] In the present study, each district has been assumed to be a zone.

[23] The use of per capita specification also has an added advantage as it adjusts for differences in population sizes of zones of visitors' origin.

[24] Recently, hybrid TCM have become rather popular that incorporates the salient features of both ITCM and ZTCM (see Navrud and Mungatana, 1994 for application of hybrid TCM in the case of Kenya). In the present study also, the attempts were first made to estimate the recreation demand function using hybrid TCM, however the results came out quite contrary to the demand theory forcing us to use ZTCM. The results, though not reported, showed that the visitation rate increased with increase in travel cost. Under only one condition this can happen i.e., the income effect dominates the price effect, which makes the function upward sloping. The data also gives some indication of this as nearly one-fourth of the tourists visit by their own vehicle, which makes the per capita travel expenditure to be extremely low due to high occupancy rate. The problem is partly taken care when we use Zonal method, as it takes average of the travel expenses by the visitors from the zone.

Another advantage of ZTCM is that it has lesser data requirements and adjusts automatically for the frequency of participation by recreationist i.e., the zones that are farther away from the site of interest will produce fewer trips for given individuals and smaller frequencies of households taking trips (Bergstrom and Cordell, 1991). This is well corroborated by our data also, which finds that of the 22 tourists who visited Nainital earlier during the year, all are from the North zone – the zone nearest to the Lake Nainital. Given a very low frequency of visits by tourists during the year, the present study, thus uses ZTCM.

Clawson and Knetsch (1966) who were the first ones to use Zonal methodology to derive demand for a particular recreation site, argued that the methodology suffers from two major limitations: a) First, it is difficult to account for the effects of travel time on individuals, because there is a high correlation between travel cost and travel time when individual experiences are averaged to estimate the zonal values. Thus to overcome multicollinearity in the regression analysis, travel time has to be omitted. Secondly, there is a loss of informational efficiency, as the aggregation and averaging process makes some demand determinants, particularly the socio-economic variables, statistically insignificant[25] (Ward and Beal, 2000: p. 34).

Model Specification

A major problem in specifying any demand function is the choice of an appropriate set of independent variables. Both economic theory and previous demand studies are still not unanimous in what are the common factors that could influence the demand for a recreation site (i.e., the visitation rate). The price of the recreational experience (i.e., the travel costs to Nainital), household income, opportunity cost of travelling and other socio-economic variables (age, sex and educational level) have been included as independent variables in the regression models.

The literature argues that neither previous studies nor economic theory can provide the general recommendations about which functional form to use and which independent variables to use (see Navrud and Mungatana, 1994 for a brief discussion on this). This leaves ample scope for sensitivity analysis. Regressions

[25] Perhaps that may be the reason for some of the socio-economic variables like Age, Personal-Income have not attained significance in any variants of the model (refer Tables 4.10 and 4.11 in Section 4.4).

based on three different functional forms (linear, semi-log and linear-log) and different combinations of independent variables were used in the analysis. However, the general form of the demand function can be written as:

V_j = *f(Trvl_cost (or Totl_cost), Pers_Inc, Hhd_Inc, Ocost, Edu, Age)* (4.2)

Where V_j = Visitation Rate from a zone = Total Tourists from a zone to the total Population of the zone.

Trvl_cost = Total return travel cost incurred from place of residence to Nainital and back including the travel time cost.

Totl_cost = Total Travel Cost including the Local cost in boarding and lodging.

Pers_Inc = Average Personal income of the Visitors

Hhd_Inc = Average Household income of the Visitors

Ocost = Opportunity cost of travelling to Nainital – per capita Household income per day corrected for number of days spent in visiting Nainital.

Edu = Average Education profile (as represented by the school years) of the tourists from the Zone

Age = Average Age of the respondents from the Zone

Once the model is estimated, the demand function are used to make the second stage benefit estimates i.e., the calculation of consumer surplus (Sutherland, 1982). As mentioned above, there does not exist any specific functional form (and the choice of variables), the model will be estimated in three forms – linear, semi-log and linear-log form. The model in these forms will be:

Linear: $V_j = a_j + b_{tc1j} TC_j + b_j' X_{kj} + v_j$ (4.3)

Semilog: $\ln V_j = a_j + b_{tc2j} TC_j + b_j' X_{kj} + v_j$ (4.4)

Linear-log: $V_j = a_j + b_{tc4j} \ln TC_j + b_j' \ln X_{kj} + v_j$ (4.5)

where TC is the average travel cost from the zone and X is other variables like education, income etc. affecting visitation rate from the zone.

The consumer surplus (CS) for each of these two functional forms (Adamowicz *et al*., 1989) will be:

Linear: $CS1 = V_j^2 / (-2*b_{tc1j})$ (4.3a)

Semi-log: $CS2 = V_j / (-b_{tc2j})$ (4.4a)

Linear-log: $CS3 = Max\ (TC_j)\ (Max\ (V_j) - b_{tc4j}\ )) - TC_j\ (V_j - b_{tc4j})$ (4.5a)

Where TC_j is the average travel cost used in estimating equations 3 to 5, V_j is the actual average visitation rate from the zone. Max (TC_j) and Max (V_j) refer to the maximum travel cost observed over the sample and the corresponding visitation rate.

4.3 Sample Selection and Descriptive Statistics

In order to do the ZTCM analysis, a random sample of 273 tourists was selected in the month of May and June 2002. In order to have proper representation of tourists, all the important spots in the Nainital watershed were identified and interviews were carried out at these spots. The selection of spots was also warranted so as to capture different strata of visitors (society). For example, spots like Tiffin Top are approachable either by foot or by pony – so only those visitors who are not very old and would have sufficient time at their disposal would prefer visiting these sites. Similarly, tourists do not frequent sites like Kilbury, etc., since to visit these places, the tourists need to have their own vehicle. Interviews were carried out by research scholars pursuing Ph.D. in different ecological aspects of the Lake Nainital and its watershed. Since they were quite aware of the issues, the quality of responses received was very high. In order to avoid interviewer bias – the interviewers were rotated among different spots. Thus, most of the interviewer interviewed tourists at almost all the sites.

Since Nainital is few hours drive from Delhi, Ghaziabad, Meerut, Moradabad etc., many of the tourists from these neighbouring towns/cities reach Nainital on Friday evening (or Saturday morning) and leave on Monday morning (or Sunday evening) – a weekend effect. This effect is captured by interviewing tourists during weekends also. Table 4.3 gives the ten places from where most visitors in our sample had come.

Table 4.3 Districts/Cities Topping in terms of Number of Tourists

District/City	Tourists Interviewed
Delhi	57 (20.88)
Lucknow	33 (12.09)
Mumbai	22 (8.06)
Uddham Singh Nagar	10 (3.66)
Kolkatta	10 (3.66)
Moradabad	8 (2.93)
Kanpur	8(2.93)
Chandigarh	7 (2.56)
Bareilley	7 (2.56)
Aligarh	7 (2.56)
Meerut	7 (2.56)
Sub Total	**176 (64.47)**
Total	**273 (100.00)**

Note: Barring Mumbai, it is mainly from the North Zone that most of the tourists have come; Figures in parentheses are the percentage of total visitors.

As we have seen in Chapter 2, the visitor statistics in the past 4-5 years indicate that foreigner account for only 1-2% of the total tourists visiting Nainital. This implies the Nainital has a limited attraction for the foreign tourists.[26] Given their low overall percentage, the present survey concentrated only on Indian tourists and no foreign tourist was interviewed. Of these 273 tourists, significant proportion (i.e., nearly 90%) hail from the two zones – North and the West and remaining 10% from other four zones of the country. Table 4.4 gives the zone wise origin of tourists.

Table 4.4 Zone-wise break-up of Tourists

Zone	Tourists
Northern	203 (74.36)
Western	42 (15.38)
Southern	6 (2.20)
Eastern	15 (5.49)
Central	6 (2.20)
North-East	1 (0.37)
Total	**273 (100.00)**

Note: Figures in parentheses are the percentage of total visitors.

The other reason for not considering foreigners is because the resident visitors were/are in general on single destination trips to Lake Nainital, whereas the tourists

[26] The limited attraction of Nainital for the foreigners could be due to poor advertising by local government in projecting Nainital as a tourist destination, or difficulty in reaching Nainital by air / road etc.

hailing from foreign countries are on multiple destination trips to India including Nainital. Apportioning part of their total costs to Nainital is little cumbersome as our earlier experience shows that in terms of visiting different places, the foreign tourists are rather flexible and they are mostly unsure what other places they would be visiting.[27] Moreover, we expect that resident and non-resident to have different preferences for recreation.[28]

Table 4.5 gives the occupation profile of the visitors. Over 13% of the visitors interviewed are housewives. It can be seen from the table that no student has been interviewed - though students also have a recreational value of visiting the lake, only adult employed (Table 4.6 gives the age structure of the tourists surveyed), who had a definite source of income and housewives were interviewed as they are considered to be more realistic in making personal valuations of their recreational experiences at Nainital vis-à-vis their budget constraints (Brown and Henry, 1989).

Table 4.5 Top seven occupations of the respondents

Occupation	No. of Tourists
Government Service	81 (29.67)
Businessman / Trader	76 (27.84)
Private Service	35 (12.82)
Teacher/Hostel Warden	8 (2.93)
Lawyer/Advocate	6 (2.20)
Doctor/Nursing Home	5 (1.83)
Remaining	*40 (14.66)*
Housewives	*36 (13.19)*
Total	**273 (100.00)**

Note: The remaining 40 tourists forming 14.7% of the tourists surveyed have the following occupations – Industrialist (2); Farming (4); Consultancy / Chartered Firm (2); Contractor / Builder (3); Defense (3); Lecturer/Reader/Professor (4)); Retired – Govt. service (2); Semi-Govt. (3); and 3 persons did not mention - whether they are in a government job or private Job. Figure in parentheses are percentages of total in that category.

[27] Though they are flexible about the places to be visited, the duration of their trip is usually fixed.

[28] It has been generally observed that foreigners visit Nainital not only for the lake and its watershed but also for bird-watching at *sher-ka-danda*, Ayarpatta and (nearby) Kilbury. On the other hand, none of the Indian tourists interviewed mentioned bird-watching as the motive for visiting Nainital. This depicts the difference in the preference of the two. This is further substantiated by our interview of two restaurants owners at Tiffin-top (the second highest peak in the Nainital watershed). According to them, whenever foreigner tourists visit the spot, they usually spend the whole day on the spot admiring the scenery and beauty of the place, whereas Indian tourists come, eat, take-photographs and leave immediately (Source: Interviewed on 22.05.2002).

Table 4.6 Classification of Respondents by Age Group

Age group	No. of Tourists
24-25	3 (1.1)
26-30	40 (14.65)
31-35	63 (23.07)
36-40	78 (28.57)
41-45	47 (17.23)
46-50	22 (8.05)
51-55	10 (3.67)
56-60	3 (1.1)
61-65	4 (1.46)
65+	3 (1.1)
Total	**273 (100.00)**

Note: Figures in parentheses are the percentage of total visitors.

One interesting feature of the visitors surveyed is that none of them was illiterate – in fact, majority of them (over 80%) were Graduate or more as is indicated in Table 4.7 that gives the education status of the tourists surveyed. The high qualification is also reflected in the high personal income and the household income of the tourists surveyed (refer Table 4.8). Nearly 90% of the tourists surveyed have household income of more than Rs. 10,000 per month. The figure of Rs. 10,000 per month is much higher than the average per-capita household income of India or even Nainital.

Table 4.7 Classification of Respondents by level of Education

Education	No. of Tourists
Upto 10	13 (4.76)
Intermediate	26 (9.52)
Diploma	13 (4.76)
Graduate	97 (35.53)
Post-graduate	56 (20.51)
Professional Degree / B.Ed. / C.A.	58 (21.25)
Doctor (M.B.B.S.)	4 (1.46)
Ph.D.	6 (2.20)
Total	**273 (100.00)**

Note: Figures in parentheses are the percentage of total visitors.

Table 4.8 Classification of Respondents by Monthly Personal and Household Income

Income Category	Personal Income Frequency (%)	Household Income Frequency (%)
0 (For Housewives)	36 (13.19)	N.A.
< 5,000	8 (2.93)	2 (0.73)
Rs. 5,000 – 10,000	51 (18.68)	26 (9.52)
Rs. 10,000 – 20,000	116 (42.49)	114 (41.76)
Rs. 20,000 – 50,000	59 (21.61)	107 (39.19)
Rs. 50,000 – 100,000	2 (0.73)	20 (7.33)
Rs. 100,000 – 200,000	1 (0.37)	3 (1.10)
> 200,000	@	1 (0.37)
Total	**273 (100.00)**	**273 (100.00)**

Note: N.A. – Not applicable; @ - We did not have this category in our questionnaire.

4.3.1 Construction of Variables

While constructing the variables, three major issues arose – (a) how to account costs for the persons who have come by car, but they could not elicit precisely how much they spent on travel; (b) how to value housewives time; and (c) how to assign value to the travel time. This subsection briefly explains how these issues were circumvented in the present analysis.

4.3.1.1 Calculation of Transport cost

The survey finds that there exist two categories of tourists – one who came by their own vehicle and others who had come by public transport. The data shows that nearly 22% (i.e., 60) tourists interviewed came by their own vehicle.[29] Out of these sixty tourists, 90% are from zone 1 i.e., the North Zone. In our questionnaire we specifically asked the type of the vehicle – whether it is Indica or Maruti or Qualis etc., then based on the distance from where the tourist originated and assuming certain mileage for each model of car, we derived the total cost of travelling from residence to Nainital.[30] If x_i is the distance between home-town and Nainital of i^{th}

[29] These 60 tourists also include three tourists, who had come from far-off places, but to arrive Nainital they had used public transport till Delhi or Lucknow and thereafter hired a taxi.

[30] Though we had also asked how much the tourist paid on fuel charges during the course of their journey from home to Nainital, this information however could not be effectively used for the simple two biases – (i) many a times, the vehicle already has some unused fuel at the time when the tourist embarks on journey, any non-accounting of this would underestimate the total transport cost; (ii) secondly, the same fuel may be used for local travel also, this would inflate the total transport cost.

tourist, y_i is the type of the vehicle, with which the tourist has come, then assuming m_i is the mileage for distinct y_i, the total transport cost of i^{th} person will be

$$\text{Trans\_cost}_i = x_i * m_i * 17 \quad (4.6)$$

$$= x_i * m_i * 27$$

where 17 and 27 are the approximate prevailing diesel and petrol prices per litre during the time survey was conducted. This cost along with the toll amount paid during the journey gives the total transport cost, which a family has incurred on the travel. The per-capita transport cost is obtained by dividing the sum of transport and toll charges by the number of people accompanying[31] i.e.,

$$\text{PC Trvl\_cost} = (\text{Travel Cost} + \text{Toll\_tax})/\text{Person\_accompanying} \quad (4.7)$$

4.3.1.2 Calculation of Housewives Earnings

There does not exist any unanimity on how to account for opportunity cost of housewives time. The present study takes a very arbitrary rule while assigning value to the non-working females' opportunity time. If the household earning is less than Rs. 20,000 per month, then female earning has been assumed 10% of the household income; however if the household income is more than Rs. 20,000 per month, then the personal income of household is assumed to be 5% of total household earnings.[32]

4.3.1.3 Calculation of Value of Travel Time

Travel time costs need to be added to round trip transportation costs to make up total travel costs. Travel time costs were estimated as the product of the round trip travel time from different places as taken by the visitors, their hourly wage rate and a factor of 0.3 to reflect that the value of time while going on vacation is less than the gross wage rate. Factors close to 0.3 are commonly used in travel cost recreation

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Thus to avoid these two biases, an alternate method was selected to calculate the total transport cost of reaching Nainital. This too would have introduced some bias as we did not ask the model (i.e., the year of make) of the vehicle and whether the vehicle has air-conditioning system or not. Both of these may have affected the mileage in either direction.

[31] While interviewing, we specifically asked the number of children accompanying. Since children below 5 do not have to pay in the public transport and in hotels also, there is no charge for them, we adjusted the accompanying person downward by looking into children and parents age, so as to have proper calculation of per capita travel cost.

[32] The differential rate is based on the assumption that the housewives of lower income group may be doing more household work then housewives of high-income group.

demand models (see Smith and Kaoru, 1990; Navrud and Mungatana, 1994 etc.). Thus, the total travel cost has been estimated as

Trvl_cost = 2 * Per capita Transport Cost +

0.3* Round-trip travel time * Wage Rate/Day (4.8)

The visitors hourly wage rate was derived from their statement of annual income assuming that they worked an average of 250 eight-hour days annually.[33] Thus, the Total travel cost will be:

= 2 * Per capita Transport Cost + 0.3* Round-trip travel time * P_Income/250*8

Though initial sample consisted of 273 cases, 27 cases had to be dropped, as in 7 cases the tourists were on package tours and had a plan to visit a number of places. In few cases, there was some discrepancy in the responses of the tourists. In few other cases, tourists were on sponsored tours. In one case, the travel cost was found to be extremely high, more than double the travel cost of the next tourist – thus an outlier. As a result, only 246 tourists were found to be of use. These 246 tourists fall into 56 zones, with visitors varying from 1 to 54 in different zones. Table 4.9 gives the descriptive statistics of the variables used in the model for these 246 tourists / 56 zones.

Table 4.9 Descriptive Statistics of various variables used for final sample of 246 tourists belonging to 56 zones

Variable	Mean	S.D.	Min.	Max.	Median
Trvl_cost	904.56	539.60	136.93	3078.3	792.03
Ln (Trvl_cost)	6.627	0.642	4.92	8.032	6.68
Totl_cost	1336.22	636.77	300.93	3938.8	1242.41
Ln (Totl_cost)	7.091	0.476	5.71	8.28	7.12
PC_locst	431.66	156.38	164	884	396.83
Ln (pc_locst)	6.01	0.344	5.10	6.78	5.98
Age	37.52	5.38	28	54	38
Ln (Age)	3.62	0.142	3.33	3.99	3.64
Schol_yr	15.85	2.01	10	21	15.54
Ln (Schol_yr)	2.76	0.128	2.30	3.04	2.74

[33] The experience shows that in India people do not reveal their true income. As a result categories were formed to elicit the range in which the income of a particular tourist falls. Few tourists exactly specified their incomes, however, for others, assumptions based on education level, age and type of job were made to estimate the true incomes. In our questionnaire we asked the number of earning members in the family. Since we knew the category in which household earnings were falling, based on similar assumptions as made above, household earnings were approximated.

Variable	Mean	S.D.	Min.	Max.	Median
Pers_Inc_cat	11.79	0.763	9.17	12.61	12.01
Pers_Inc	158989.2	73721.09	9600	300000	164280
Hhd_Inc	261975.3	103239.9	105600	660000	240000
Vij = Visit Rate from the zone	0.002	0.003	0.00023	0.014	0.001
Ln (Vij)	-6.56	1.04	-8.40	-4.29	-6.68

4.4 Results from ZTCM

The models given in equations 4.3-4.5 are estimated using ordinary least squares (OLS). Since the zones are effectively the cities/districts, some cities being highly developed, people more literate and richer like Delhi, Noida, Mumbai etc, can have high visit rate from them. In other words, there exists possibility of heteroscedasticitiy. As a result, the models are run with correction for heteroscedasticity. Table 4.10 gives the demand estimates for different specification of models with travel cost as the independent variable. From the table, one can see that the models clearly reflect the demand theory, as the travel cost of visiting Nainital increases, the visit rate from the zone decreases.

Table 4.10 Demand Function for Lake Nainital Visitation Rate (Heteroscedasticity Corrected Ordinary Least Squares, OLS Estimates) (with only Travel Cost as Explanatory Variable)

Variable	Linear Model	Semi-Log Model	Linear Log Model
	Coefficient (1)	**Coefficient (3)**	**Coefficient (5)**
Trvl_cost	-2.27×10^{-6}***	-9.65×10^{-4}***	-2.07×10^{-3}***
	(-3.391)	(-5.516)	(-3.546)
Age	3.39×10^{-5}	0.0118	0.0015
	(0.595)	(0.64)	(0.713)
Schol_yr	-2.76×10^{-4}*	-0.124*	-3.66×10^{-3}*
	(-2.012)	(-1.922)	(-1.805)
Pers_In	8.22×10^{-9}	1.67×10^{-6}	7.27×10^{-4}*
	(1.374)	(0.811)	(1.729)
Constant	6.3×10^{-3}**	-4.437***	0.012
	(2.235)	(-3.171)	(1.489)
F	3.75	10.81	4.01
	(4, 51)	(4, 51)	(4, 51)
R-squared	0.2252	0.3277	0.2645
N	56	56	56

Note: The figures in parentheses give t-values. ***, **, and * implies significance at 1%, 5% and 10% level. The models were tried with different independent variables like average household income (hhd_inco) from the zone, average opportunity cost (Ocost) of travellers, etc., but none of the variables come out to be significant and the overall fitness of the model does not improve with inclusion of those variables. The results presented are the best fit among different variants.

Row 3 gives the coefficient of age variable, which has come out to be insignificant in all the variants of the model. One surprising result is that the more educated people are less likely to visit. The effect is highly significant also. One probable reason for this negative relationship is that the sample consists of tourists of high education profile (refer Table 4.7), and for such a sample, a marginal increase in levels of education would not result in an impact on visitation rate. The role of personal income in inducing more visits is positive, though it has not attained significance in either model.

Table 4.11 reports the results with Total Travel cost as an explanatory variable that includes the local cost also rather than the transport cost only.[34] Most of the variables retain the same sign and significance level, except the slight change in parameters. Based on the coefficients, one can say that any increase in the cost – be it the transport or total travel cost would lead to reduced visitation from a particular place.

Table 4.11: Demand Function for Lake Nainital Visitation Rate (Heteroscedasticity Corrected Ordinary Least Squares, OLS Estimates) (With Total Travel Cost as Explanatory Variable)

Variable	Linear Model	Semi-Log Model	Linear Log Model
	Coefficient (1)	**Coefficient (2)**	**Coefficient (3)**
Totl_cost	-1.76×10^{-6}***	-7.3×10^{-4}***	-2.47×10^{-3}***
	(-3.194)	(-5.187)	(-3.047)
Age	3.54×10^{-5}	0.012	0.0017
	(0.588)	(0.602)	(0.614)
Schol_yr	-2.79×10^{-4}*	-0.126*	-3.90×10^{-3}
	(-2.044)	(-1.942)	(-1.293)

[34] The results though not reported, the models are run with per capita local cost by the tourists also. However, the explanatory power fell drastically and even the main variable did not attain significance when we used local cost instead of total travel cost. One probable reason is that the survey was conducted during the peak tourist season, during that time, if the tourists do not have a prior booking of hotels etc., they may have to shelve more money for the same services. This may exaggerate the local cost. However, the effect might get diluted if local cost forms only a part of the total cost as in the present case. Navrud and Mungatana (1994) also disregard local cost while estimating the model for recreation demand.

Variable	Linear Model	Semi-Log Model	Linear Log Model
	Coefficient	Coefficient	Coefficient
	(1)	(2)	(3)
Pers_Inc	7.96×10^{-9}	1.55×10^{-6}	7.60×10^{-4}
	(1.296)	(0.725)	(1.44)
Constant	6.63×10^{-3}**	-4.29***	0.0156
	(2.303)	(-3.014)	(1.216)
F	3.35	9.05	3.69
	(4, 51)	(4, 51)	(4, 51)
R^2	0.1998	0.2778	0.2244
N	56	56	56

Note: Same as Table 4.10.

The next stage is finding the consumer surplus from the estimated models. Table 4.12 gives the consumer surplus from different models. At the level of average travel cost, the area under the demand curve and above the line of average cost represents the consumer surplus enjoyed by the tourist. This is nothing but a measure of willingness to pay for the services provided by the Lake Nainital and its watershed. In order to calculate the consumer surplus, an estimated 400,000 tourists visiting Nainital for the year 2001-02 has been considered.[35]

From Table 4.9, however, one can see that in case of travel cost variable, there exist wide variation in the average value and the median. This could be due to some outliers in the data. The data shows that there exist some visitors from two zones who have spent more than thrice the average transport cost of the sample. This implies these outliers may have jacked up the average travel cost. One alternate is to use both – the mean and the median travel costs have been employed to calculate the consumer surplus. Table 4.12 reports the consumer surplus as calculated from different models with both mean and median travel cost as reservation price.

[35] This figure is little higher than the recorded tourists during the year, but we have already mentioned in Section 2.2 of Chapter 2 that the recorded figures understates the true tourist population.

Table 4.12 Consumer Surplus as obtained from different variants of Demand Functions (In Rs.)

Linear Form		Semi-log Form		Linear-log Form	
Mean as reservation price (1)	Median as reservation price (3)	Mean as reservation price (4)	Median as reservation price (4)	Mean as reservation price (5)	Median as reservation price (6)
4,327,179	5,275,367	4,386,309	4,934,330	4,422,465	5,235,798
5,599,515	6,377,363	6,100,703	6,548,218	5,783,854	6,481,558

Based on the values, it can be said that the willingness to pay to preserve the Lake Nainital and its watershed varies from Rs. 4.3 million to Rs. 5.27 million depending on the functional form used. However, when travel cost consists of local cost also, the consumer surplus increases to 5.60 million (for the linear model) to 6.55 million (for the semi-log model). Since the lake and its watershed is spread over an area of 14.32 Km^2, the recreation value per unit hectare would be Rs. 3,022 for the linear model and Rs. 4,260 for the semi-log model.

Table 4.13 compares the values obtained in the present study with other recreation valuation studies carried out elsewhere but using similar methodology. From the table, one can see that the values are quite comparable with what others have received in their analysis, though in the present analysis only local tourists were considered, whereas study no. 1 and 3 also include foreigners.

Table 4.13 Comparison of Consumer Surplus with other studies (In Rs.)

No.	Location	Annual Value	Source
1	Keoladeo National Park, Bharatpur	Rs. 16,197 per hectare	Chopra (1998)
2	Periyar Tiger Reserve, Periyar	Rs. 676 per hectare (for locals)	Manoharan (1996)*
3	Khecheopalri Lake, Sikkim	Rs. 1,604 per hectare	Maharana *et al*. (2000)*
4	Nainital Lake, Nainital	Rs. 3,022 – 4,260 per hectare (only Indian Tourists)	Present Study

Note: * - As referred in Kadekodi (2001)

4.5 Concluding Remarks

The present chapter employs a revealed preference method, i.e., Travel Cost incurred by the tourists, to estimate the recreation value for the Lake Nainital. In

order to estimate value, a random sample of 273 tourists was selected for the primary questionnaire survey in the month of May 2002 and June 2002.

The analysis and results based on 246 tourists falling in 56 zones show that the value derived from tourism in the Lake Nainital and its watershed is to the tune of Rs. 4.3 million (i.e., Rs. 3.020 per hectare) to Rs. 6.5 million (i.e., Rs. 4,260 per hectare) depending upon which functional form we take and whether only travel cost is taken as an independent variable or even local costs are included.

The analysis thus shows the applicability of ZTCM in the case of Nainital and its watershed. Though the values obtained are underestimate of the total value which people are willing to pay to preserve the lake, as the method captures only the use value. Even within the use value, it is an under-representation as foreigners and people on package tours and children were excluded from the analysis. As mentioned earlier in section 4.2, the model has some problems in the treatment of time, there are two more problems associated with TCM. The first problem is the truncation bias. Since data in the TCM is collected through on-site survey, only the users i.e., the tourists who can pay for the travel and other things are included. Non-users – the people whose visitation rate is zero as a result of higher travel costs – are automatically excluded in the analysis. This truncation bias leads to faulty demand estimate and hence the consumer surplus estimates.[36] Another problem with TCM is that the identical preferences are assumed for all the individuals. As the TCM constructs a single demand curve for a large number of individuals, this assumes identical preference for all of them.

Though Nainital is primarily dependent on tourism, there is a limit to which the lake and its watershed can support tourism. In fact, it will be quite interesting to know the carrying capacity of the Nainital i.e., what is the optimum number of tourists that can be taken in without affecting the lake ecosystem adversely. Any effort to estimate optimum number essentially requires information on the effect of tourist (disturbance) on the lake watershed.

[36] It has been suggested to use maximum likelihood estimation rather than the OLS in order to avoid the problem of truncation bias. However, the literature has not conclusively proved whether ML estimation performs significantly better than the OLS or not (Chopra 1998).

Chapter 5 :Non-use Value from the Lake and its watershed

5.1 Introduction

Ample evidence exists that people attach value to natural resources and systems even if they do not have any direct use for them. Evidence also exist that most of the stakeholders in am eco-system are concerned with only that aspect of natural resource, on which their livelihood depends. For instance, boatmen, whose livelihood depends on lake, would be more concerned with the well being of lake quality; horsemen might wish to concentrate only on peaks; tourists visiting Nainital regard most the features around the lake and the peaks etc.,[37] most of them however, disregard or rather unaware of the services the lake and its watershed provides. The present chapter attempts to value Nainital and its watershed from the informed citizens' point of view. It can be easily conjectured that the informed citizens, by virtue of their profession, education, awareness etc. will look the problem in totality rather than stressing any individual aspect of the lake and its watershed. The citizens consist of people engaged in academics, professionals, private medical practitioners and others engaged in government jobs at respectable positions in Nainital, say lawyers, forest officers etc. This group in the present chapter is called as informed citizens.

The chapter in general uses an ordinal approach to value; however, some monitory estimates of Willingness to pay to preserve the lake ecology and the system are also presented in the chapter. The chapter is organised in 5 sections. Since valuation has its root in preserving a particular ecosystem, but the valuation exercise may itself be motivated by different concerns. One may wish to value the ecosystem from the point of view of services they provide. Few others may value it for its sheer existence, while some other may value the resource from the livelihood point of view. On the other hand, few may value the resource as it may have a possibility of future use e.g., medicinal plants from tropical or rain forests. Section 5.2 gives an overview of the respondents, followed by the perception of the informed citizens and scientists – why should we value the ecosystem? As we have seen in Chapter 3, the Lake Nainital and its watershed provides a number of consumptive goods and non-

[37] This is also evident from our Participatory Rural Appraisal (PRA) exercise, as we shall see in the next chapter.

consumptive services, section 5.3 explores which of these aspects these citizens value most by giving an ordinal ranking. The willingness to pay towards the upkeep of the lake is explored in section 5.4. The chapter concludes with section 5.5.

5.2 Informed Citizens – overview and their perceptions about valuation

For the exercise, 30 informed citizens of Nainital were consulted. The interviews were held during the months of March to July 2002. In order to avoid interviewer-bias, one researcher only, a Ph.D. scholar, interviewed all the respondents. Of these 30 responses, one had to discard, as in this case the questionnaire was filled by the respondent himself. Among remaining 29 respondents, 11 (37.93%) are academicians,[38] 2 (6.90%) professionals, 8 (27.59%) medical practitioners and remaining 8 (27.59%) engaged in government jobs in fields like law, forestry etc.

One of the important reasons, which catapulted the valuation into lime-light is that valuation of a particular threatened resource/system will provide strong motivation to conserve/preserve it. We have already seen in Chapter 2 that Lake Nainital is one such threatened natural resource and its given the services it is providing, the valuation should lead to efforts towards its conservation. But do the informed citizens of Nainital also view valuation as first step towards conservation? Table 5.1 indicates that nearly 21% do not support the notion that by valuing we can conserve the system.

Table 5.1 Does valuation help in conservation? – Informed Citizens' opinion

Does valuation help in conservation?	No. of Informed Citizens
No	6 (20.69)
Yes	23 (79.31)
Total	**29 (100)**

Note: Figures in parentheses are the percentage of total responses.

Neither all the ecosystems of the world are fragile, nor threatened. However, given the burgeoning population and changing consumption pattern, which are becoming more resource intensive, such possibility that most ecosystems will be threatened in the long run cannot be ruled out. Table 5.2 gives the perception of the informed citizens on the extent of importance of valuation in the long-run and their utility in evolving conservation strategies at regional or national level.

[38] Among these 11, two were scientists. They have been clubbed with the academicians because part of their time is also spent in academics.

From Table 5.2 one can see correspondence between the responses received earlier in Table 5.1 and in this table. Here also nearly 20% informed citizens are quite cautious of the long-term utility of the valuation and their usefulness in evolving conservation strategies. The distribution of the respondents, who are quite restrained in putting faith in valuation show that they belong to all those three categories, which have large representation in our sample i.e., academics, medical practitioners and government servants.

Table 5.2 Is Valuation important in the long run and in evolving conservation strategies?

Scale	Importance of valuation in the long run	Importance of Valuation in evolving conservation strategies
1	11 (37.93)	5 (17.24)
2	4 (13.79)	9 (31.03)
3	9 (31.03)	9 (31.03)
4	3 (10.34)	3 (10.34)
5	2 (6.9)	3 (10.34)
Total	**29 (100)**	**29 (100)**

Note: Scale is in decreasing order of importance: 1 – means important, 5 means unimportant; Figures in parentheses are the percentage of total responses.

As mentioned earlier, the valuation exercise may itself be motivated by different concerns. Table 5.3 gives the first three concerns, which the respondents thought are quite important for an ecosystem valuation. Column 4 gives the overall ranking. The overall ranking has been obtained by giving weights to the first three ranks. If an aspect has been given rank 1, it is given 100% weightage, rank 2 – 50% weightage and rank 3 – 25% weightage.[39]

[39] The weightage is arbitrary. However, with different weighting scheme of 100%, 75% and 50% or 100%, 60% and 40%, the final first three ordinal rankings remain the same.

Table 5.3 Ordinal Rankings of different aspects of valuation

Value to a system / species	Rank 1 (1)	Rank 2 (2)	Rank 3 (3)	Overall Rank (4)
According to the service they provide	16 (55.17)	5 (17.24)	5 (17.24)	19.75 [1]
For its existence	6 (20.69)	10 (34.48)	7 (24.14)	12.75 [2]
For its rarity	3 (10.34)	3 (10.34)	4 (13.79)	5.5 [3]
For its use in generating items of consumption like fuel, fodder, fish etc.	1 (3.45)	2 (6.90)	7 (24.14)	3.75 [5]
For its use in generating livelihood	1 (3.45)	5 (17.24)	1 (3.45)	3.75 [5]
For possibility of future use	2 (6.90)	4 (13.79)	3 (10.34)	4.75 [4]
Total	**29 (100)**	**29 (100)**	**27 (100)**	

Note: Figures in parentheses are the percentages of the total responses. Figure in brackets is the overall rank based on the weightage.

From the final ranking, it becomes clear that informed citizens value the valuation exercise most from the services aspect. The existence value and the rarity of a specie or system are the next two important reasons for the valuation. It is quite interesting to note that the relevance of a system/specie in generating livelihood or its consumptive use is not motivating enough to carry out the valuation. One probable reason for livelihood and consumptive usefulness not figuring in the most important reasons is that the first option i.e., services provided by a system, partly encompasses these two options.

5.3 Aspects Relevant for Valuation – Perception of Informed Citizens

As we have seen above, a sizeable proportion of scientist/informed citizen value valuation and this valuation could be merely for systems' existence or rarity or the services it provides. If we talk about the services of an ecosystem, then all services may not be of equal relevance to either humankind or to the system. A natural system may have aesthetic value, but may pale into insignificance compared to their immediate economic value. This section explores which services are of utmost importance to the humans and which services are relevant to the system. Table 5.4 gives the ranking of the different services in order of decreasing relevance for the humankind as given by the informed citizens. To compute the overall rank, here also rank 1 is given 100% weightage, rank 2 – 50% weightage and rank 3 – 25% weightage.

Table 5.4 Ordinal Rankings of Services deemed important for the Humankind

Services	Rank 1	Rank 2	Rank 3	Overall Rank
Immediate economic value e.g., water, tourism, fuel, fodder etc.	7 (24.14)	8 (27.59)	11 (37.93)	13.75 [3]
Future value for humankind	11 (37.93)	12 (41.38)	3 (10.34)	17.75 [1]
Ritual and Cultural Values	1 (3.45)	3 (10.34)	6 (20.69)	4.0 [4]
Value as an ecosystem – i.e., includes eco-services	9 (31.03)	6 (20.90)	8 (27.59)	14.00 [2]
Aesthetic Value	1 (3.45)	0 (0.00)	1 (3.45)	1.25 [5]
Total	**29 (100)**	**29 (100)**	**29 (100)**	

Note: Figures in parentheses are the percentages of the total responses. Figure in brackets is the overall rank based on the weightage.

Based on the final rankings, it becomes clear that it is the future value of a natural system that holds the maximum importance for humankind. The eco-services and immediate economic value are the next two important aspects that have relevance for the humankind. The ecosystem and economic value however swap places when a litter higher weight is given to rank three.

5.3.1 Lake Nainital and its catchment – Aspects Relevant to the System and to Humans

Chapter 3 identifies that the lake and its watershed is providing a number of consumptive and non-consumptive use values like water, aesthetic value, dead wood, fodder, soil quality, etc. Some of these use values are specific to the lake and some are derived from the watershed. In this subsection, the opinion of the informed citizens is sought to find out which of these are extremely relevant to the eco-system and which are important to humans. In the questionnaire, opinion was asked to rank in order of importance the following ten aspects from the watershed. The aspects include dead wood (fuel wood), fodder, dry grass (thatch, fuel), wood (construction timber), wood (furniture), soil quality, spring water, stream water, medicinal plants, and flowers etc. as decorative items. Table 5.5 tabulate the responses for these watershed resources in both cases – systems and humans.

Table 5.5 Rankings of Important Services from the Watershed to the system and humans

	Value to the System					Value to the Humans				
Resource	**Rank 1**	**Rank 2**	**Rank 3**	**Rank 4**	**Rank 5**	**Rank 1**	**Rank 2**	**Rank 3**	**Rank 4**	**Rank 5**
Dead wood (fuel)	6 (20.69)	1 (3.45)	11 (37.93)	4 (13.79)	7 (24.14)	2 (6.9)	2 (6.9)	13 (44.83)	9 (31.03)	3 (10.34)
Fodder	3 (10.34)	0 (0.0)	11 (37.93)	14 (48.28)	1 (3.45)	1 (3.45)	3 (10.34)	13 (44.83)	11 (37.93)	1 (3.45)
Dry Grass (thatch, fuel)	2 (6.9)	4 (13.79)	13 (44.83)	7 (24.14)	3 (10.34)	2 (6.9)	3 (10.34)	12 (41.38)	6 (20.69)	6 (20.69)
Wood (construction timber)	3 (10.34)	3 (10.34)	7 (24.14)	5 (17.24)	11 (37.93)	1 (3.45)	5 (17.24)	13 (44.83)	7 (24.14)	3 (10.34)
Wood (furniture)	0 (0.0)	3 (10.34)	8 (27.59)	6 (20.68)	12 (41.38)	2 (6.9)	8 (27.59)	9 (31.03)	7 (24.14)	3 (10.34)
Soil Quality	16 (55.17)	9 (31.03)	0 (0.0)	0 (0.0)	4 (13.79)	15 (51.72)	7 (24.14)	2 (6.9)	2 (6.9)	3 (10.34)
Spring Water	20 (68.97)	3 (10.34)	2 (6.9)	2 (6.9)	2 (6.9)	24 (82.76)	1 (3.45)	1 (3.45)	2 (6.9)	1 (3.45)
Stream Water	15 (51.72)	7 (24.14)	2 (6.9)	5 (17.24)	0 (0.00)	20 (68.97)	4 (6.9)	0 (0.0)	3 (10.34)	2 (6.9)
Medicinal Plants	10 (34.48)	4 (13.79)	10 (34.48)	3 (10.34)	2 (6.9)	16 (55.17)	7 (24.14)	0 (0.0)	3 (10.34)	3 (10.34)
Wood, grass, flowers as decorative items	2 (6.9)	2 (6.9)	11 (37.93)	13 (44.83)	1 (3.45)	1 (3.45)	5 (17.24)	10 (34.48)	12 (41.38)	1 (3.45)

Note: Figures in parentheses are the percentage of total responses i.e., 29.

Water, fish, aesthetic value and ritual and cultural value are the benefits from the lake, for which informed citizens have been asked to opine the relative importance. Table 5.6 gives the responses for these resources in both cases – systems and humans.

Table 5.6 Rankings of Important Services from the Lake to the system and humans

	Value to the System					Value to the Humans				
Resource	**Rank 1**	**Rank 2**	**Rank 3**	**Rank 4**	**Rank 5**	**Rank 1**	**Rank 2**	**Rank 3**	**Rank 4**	**Rank 5**
Water	21 (72.41)	6 (20.69)	0 (0.0)	0 (0.0)	2 (6.9)	27 (93.10)	0 (0.0)	0 (0.0)	0 (0.0)	2 (6.9)
Fish	5 (17.24)	11 (37.93)	8 (27.59)	3 (10.34)	2 (6.9)	4 (13.79)	10 (34.48)	11 (37.93)	2 (6.9)	2 (6.9)
Aesthetic Value	3 (10.34)	4 (13.79)	16 (55.17)	5 (17.24)	1 (3.45)	4 (13.79)	2 (6.9)	22 (75.86)	1 (3.45)	0 (0.0)
Ritual & cultural value	2 (6.9)	0 (0.0)	11 (37.93)	10 (34.48)	6 (20.69)	2 (6.9)	4 (13.79)	11 (37.93)	12 (41.38)	0 (0.0)

Note: Figures in parentheses are the percentage of total responses.

From Table 5.5, we find that the informed citizens perceive spring water, soil quality and the stream water as the most important natural resource/service from the watershed of Lake Nainital. None of the consumption good items like fuel wood, fodder, dry grass, wood etc. figured high in the list of the informed citizens. This is also substantiated by our survey, which finds that not more than 50-60 households depend on watershed for the consumptive use.

As expected, Table 5.6 suggests that the drinking water is the most significant resource from the Lake to both the system and to humankind.

5.4 Willingness to Pay of Scientists – Some Indications

Before going into how the informed citizens responded to their willingness to pay for the upkeep of the lake, the subsection seeks the opinion of the informed citizens whether commercial establishments be charged for the use of the resource or not. It is a common knowledge that many commercial establishments use the available natural resource for their benefit. A very prominent example in the Nainital lake watershed is the candle industry that uses dyes to make candles. The discharge from these units ultimately goes to the lake. Another example is the hotels on the catchment, which may be discharging their wastewater in the lake.[40] Should these units be closed down or they are asked to contribute some amount so that whatever harm they have created can be compensated by proper management of the lake? Table 5.7 gives the response to this question by the informed citizens. More than 82% (24) of the respondents are in favour of charges on the exploiters of the natural resource.

Table 5.7 Should commercial establishments using Natural Resource for their personal benefit be charged for their use? – Informed Citizens' opinion

Should Commercial Establishments be charged?	Informed Citizens' Opinion
No	5 (20.69)
Yes	24 (79.31)
Total	**29 (100)**

Note: Same as Table 5.6.

[40] A third important group, which is not a commercial establishment, but uses the natural resource to its benefit is the households, who use detergents rich in phosphorous, leading to eutrophication of the lake (refer Section 2.3, Chapter 2).

As we have seen in the last two sections, the informed citizens rate very high the systems for the services they provide and for their existence. According to them valuation as such is a useful exercise for both long-term point of view and for evolving a conservation strategy at the regional/national level. Given the fact that they value the lake ecosystem so highly, they must be willingness to pay for the upkeep of the lake and its watershed. The current section looks into the willingness of informed citizens so that lake and its watershed be conserved. Responses suggest that of the 29 people, 26 (i.e., nearly 90%) are willing to pay for the management the Lake and its watershed.

Interestingly, all the people who have refused to contribute cite the dissatisfaction with the present management as the sole important reason for not paying. With respect to the mode of payment, the people who are willing to contribute do not wish to pay as a lump-sum and would prefer paying an annual contribution. Table 5.8 gives a summary of respondents based on their willingness to pay, whereas Table 5.9 gives the category-wise annual willingness to pay.

Table 5.8: Willingness to Pay – Summary Table

Sr. No.		Number of Respondents
1	No of responses to WTP question	29
	Not willing to pay	3 (10.34%)
	Yes	26 (89.66%)
2	Reason for not Willingness to pay – Dissatisfaction with the present management	3
3	Willingness to pay – By lump-sum payment	0
	By annual payment	26 (100.00%)
4	Average Annual Payment	Rs. 1061.54 per capita

Table 5.9: Category-wise Willingness to Pay

Category	Mean	S.D.	Min.	Max.	N
Academicians	822.22	746.287	200	2500	9
Professionals	500	0.0	500	500	2
Medical practitioners	1275	625.07	500	2000	8
Government Employee	1285.71	487.95	500	2000	7
Total	**1061.54**	**647.50**	**200**	**2500**	**26**

From Table 5.8 it can be seen that the WTP for government employee is maximum followed by that of medical practitioners and then of academicians. The t-test suggests that the two subgroups – medical practitioners and government employees have identical willingness to pay.

5.5 Conclusions

This chapter carried out a limited exercise, where 29 informed citizens of Nainital belonging to different fields – academics, research, medicine, law, forestry, information technology etc. were asked their view-point about utility of valuation exercise in general and which of the aspects is important from the valuation point of view. The chapter then sought their opinion about relevance of aspects specific to the Lake Nainital and its watershed. This is followed by asking their willingness to pay for the upkeep of the lake.

The responses suggest that a significant proportion of informed citizens view valuation exercise as a step towards conservation of the resource and can facilitate planning at the regional or may be at the national level. However, it is the existence, and future value besides the services from the natural eco-system that is extremely relevant for valuation. With respect to the Lake, water is the most important aspect to the system and to the humans. From the watershed – the soil quality, stream and spring water are the three most important benefits to humans and to the system.

Most of the citizens are willing to contribute for the upkeep of the lake. The small group who do not wish to pay cite the mismanagement as the reason desisting them to contribute.

Chapter 6 :Participatory Rural Appraisal of the Lake and its watershed

6.1 Introduction

Issues of environment and development warrant integrating not only ecological and economic factors, but also social aspects. The questionnaire method adopted in chapters 4 and 5 concentrate on responses from the individuals and it is argued that they remain passive contributors. In order to complement questionnaire method, Participation Rural Appraisal (PRA) exercise was carried out that seeks opinion of different stakeholders. This chapter gives in brief the PRA technique and the results obtained therein from the exercise. The structure of the Chapter is as follows: section 6.2 gives a brief idea of the PRA technique and its utility. Section 6.3 gives a profile of different stakeholders who have been considered in this exercise. The responses of the stakeholders are analysed in section 6.4, whereas section 6.5 tries to ordinate the stakeholders based on similarities in their responses. The estimation of average earnings of some of the low-income stakeholders from the lake and its watershed is done in section 6.6. The chapter concludes with section 6.7 that summarises the results obtained from the PRA exercise.

6.2 Participatory Rural Appraisal (PRA)

Participatory Rural Appraisal (PRA), also called Rapid Rural Appraisal (RRA) is a way of organizing people for collecting and analysing information within a short time span. Rapid rural appraisal or PRA developed as a methodology in the 1970s, influenced by farming system research (FSR) and other methods. Some of the early works in PRA methodology were by Chambers (1981, 1986), Hildebrand (1981), Rhodes (1979) and Collinson (1981). As the name PRA indicates, it is a participatory approach in which individuals of a particular group are active respondents. Generally it is a methodology of interacting with relatively low-income people, understanding them and learning from them. It is a means of collecting data, identifying and mobilising involved groups and their participation in decision-making, project design, execution and monitoring (Mukherjee 1993). The PRA technique provides an alternative framework for data collection and analysis. Because of its participatory nature, it is a powerful methodology to focus attention on people, their livelihoods and their interrelationship with socioeconomic and ecological factors.

6.2.1 How PRA exercise was carried out?

The subsection briefly mentions how the PRA exercise was carried out in the present study. Before giving the exact methodology followed, it needs to be mentioned at the outset that PRA and questionnaire survey are complementary techniques not a substitute. The questionnaire survey is more exact but PRA gives a broad indication of the extent of the benefits that different stakeholders derive from a particular resource (lake and its watershed have) besides perception of the stakeholder about different components of the watershed. A PRA workshop[41] explaining the relevance of PRA tool was held at Kumaun University, Nainital in April 2001. In the evening of day 3, basic data collected from nine groups of stakeholders, viz., rickshaw-pullers, horsemen, boatmen, street vendors (petty traders), hoteliers, coolies, professional, tourists and households were assessed and discussed.[42] The methods of data collection included mapping, damage assessment, and ranking of values.[43] The trainees continued to collect information in the field and covered different stakeholders during subsequent 3-4 months.

Table 6.1 lists the specific low-income groups targeted in the present PRA exercise. The reason as stated to the stakeholders by the PRA team was for the purpose of research in order to know more about them, their perception, their problems and opportunities. Generally they appeared quite enthusiastic to assemble together and meet the PRA team.

Table 6.1 Stakeholders of low-income groups and their numbers in the Nainital Lake watershed.

Stakeholders	Nos.
Boatmen (row-boats)	233
Horsemen	164
Coolies	1000
Vendors	150
Rickshaws	76

(**Source:** Municipal Record Nainital, 2001)

[41] Dr. Neela Mukherjee and Dr. Amitava Mukherjee were the experts who spent a day in classroom exercises and two days in the field with the students. Students' response was unusually enthusiastic.

[42] It is to be noted that not all the groups were low-income. Groups like professionals, tourists, hoteliers and households belonged to middle to high-income groups.

[43] Assessment methods were also taught to the trainees, including Cost-Benefit Analysis, Willingness to Pay, and the Damage Functions.

As we shall see later, the stakeholders differed in their perceptions from one another with regard to many parameters such as importance they give to lake, forest, hills, water sources, nature and others. Our PRA experience gives an estimate of the share of the benefits derived from tourism in Nainital by poor stakeholders like boatmen and horsemen. We started with a rapport building session in which the formal introduction between the stakeholders and the PRA team took place. This was followed by informing the members of the stakeholder groups about the purpose of visit by the PRA team. They were asked about their day-to-day living so that team could get more information about them. Gradually the stakeholders gained confidence in the team and the exercise. This led to start of map-drawing exercise. On an average some 2-4 hours were taken by them to draw the map of the entire town. In case of differences of opinion, the stakeholders were able to sort out them amongst themselves through intense discussions. In total 68 maps were drawn varying from 3 (for Professional groups) to 17 (for Household groups) across the stakeholders. The maps drawn by stakeholders were analysed for understanding their perceptions, knowledge relating to lake, its degradation and various features of the watersheds such as forests and peaks, and drains bringing water and pollutants to the lake (Plates 9 & 10). Equal weights were given to different parameters within a map.

6.3 Profile of different stakeholders

To study the use of the lake and its watershed various stakeholder groups from low income and less educated (like horsemen and coolies) to those with high income and high education (hoteliers and professionals) were identified. Most of them are local residents and have intimate associations with the lake and its watershed. A brief description of these stakeholders is given in Table 6.2. Inputs from these stakeholders were taken using the following PRA techniques: semi-structured interviewing; participatory mapping; participatory seasonality analysis and visual analysis methods. Appendix 3 gives a brief introduction of these techniques.

Table 6.2 Profile of the stakeholders.

Group name	Description	No. of subgroups (and No. of participants in each subgroup)
Professionals	This group included people having higher education, some of the members having scientific professional background	3 (1-2)
Tourists	This group consisted of the tourists visiting Nainital at different times of the year and were generally rich and literate.	4 (2)
Rickshaw-puller	This group mostly consists of individuals who are very poor, and have migrated from Nepal and Bihar. Their association with the city is generally of temporary nature as they migrate mainly in the tourist season.	6 (4)
Horsemen	They are mostly illiterate Muslims of adjacent plains, many return to their home towns after the summer tourism season ends. Recently, the horsemen have been shifted to Lands-end to keep horses' dung (rich in nutrients) away from the watershed.	6 (4)
Boatmen	Boatmen generally come from the rural Kumaun, are poor and semi-literate.	5 (4)
Vendors	The vendors represented a mixed group consisting of the permanent residents, as well as seasonal traders.	14 (4-5)
Hoteliers	The hoteliers make the richest group, who take a very high proportion of the income from tourism activities. However, variations across the individual earning could be quite wide.	8 (1)
Coolies	Coolies are mostly poor Nepalese who hail from the remote hills of Humla and Jumla. Migrating in groups, they have maintained their Nepalese connection. They usually live under harsh conditions on the footpaths, any public shed or godowns of the residents.	5 (4-5)
Households	All members of the group were literate, with varying levels of education.	17 (1)

6.4 Analysis of the responses of stakeholders

The analysis of the numerous maps drawn by the stakeholders yielded certain common features that were used later for making comparisons. Further within each feature a number of objects were considered and equal weights to all objects within a feature were assigned (Table 6.3). Some of these features were marked as present or absent in a map and this formed the basis of converting these into percentage for a particular stakeholder (Appendix Tables 1-9).

Table 6.3 Features considered while analysing the PRA maps

Feature	Considered Objects
Facilities/infrastructure	Hospital, Bus station, Mall road, School / College, Pump house, Nagar Palika, Rickshaw stand, Religious places
Tops and views	Tiffin Top, China Peak, Snow View, Lake View
Roads	Bhowali, Haldwani, Mall Road + High Court road, Thandi Sarak
Environment Status Indicator	Erosion/slide/siltation, Pollution, Forest/trees, Drains, Deforestation
Major drains	Nanda Devi temple drain, Malli Tal drain, Nanak Restaurant drain, Municipal Library drain, Alka Hotel drain, Tallital drain, Phanshi Gadhera drain
Inside-the-lake features	Boat, Duck, Fish, Garbage, Vegetation, Others

Note: All the objects considered have been given equal weightage in the respective categories.

6.4.1 Stakeholders' Maps Analyses

In the present study Participatory Mapping method was used to determine the perception of the nine categories of stakeholders towards the lake and its watershed. This was further strengthened by using the Visual Analysis Method. Table 6.4 summarises the perceptions of various stakeholder groups based on the maps drawn by them. Following inferences can be drawn based on the analysis of these maps by various stakeholders:

6.4.1.1 Professionals

The lake was shown in three shapes - oval, kidney and circular, and occupied 30-40% of the catchment area; whereas the proportion that the lake actually occupies is 10-11%. The maps of this group focussed on inside-lake features (e.g. boats and actual ducks). They have also given importance to trees/forests, and hills/tops. This group also showed a high level of environmental awareness (50-80%).

6.4.1.2 Tourists

The tourists gave importance to the lake, but not to the details within the lake. Most of the tourists rightly drew the kidney shaped lake in their maps. As these people generally have seen tourist maps, so they were rather aware of the correct shape of the lake. Except for two maps, which included only boat, inside lake features were missing. Most of the subgroups gave importance to temple, roads and other facilities.

In brief, though lake is the primary attraction, adjoining hills and forests are also important components of Nainital as far as tourists are concerned.

6.4.1.3 Rickshaw-pullers

In four of the six maps made by rickshaw-pullers, the lake was circular in shape, and of the remaining two, one showed oval and the other kidney-shaped lake. The lake generally accounted for nearly 50% of the area in their maps. This group paid attention to garbage, as garbage was the only inside-lake feature marked by all except one subgroup. Only one subgroup showed fish and ducks. This stakeholder category gave comparatively less importance to trees, forests and hilltops/views.

6.4.1.4 Horsemen

In all maps made by horsemen the lake was oval (though it is actually kidney-shaped). Three out of six subgroups of horsemen either did not show lake or it was inconspicuously shown. In maps of other three subgroups, the lake occupied 25-50% of map area. Inside-the-lake features were absent except for garbage. Features around lake (lake edge) were shown by only few of the subgroups. In the three maps in which lake was shown the number of drains ranged from 2-4 and generally the Mallital rickshaw drain was shown. Horsemen gave the highest importance to sites located away from the lake with views of snow-clad mountains and valleys. Three out of six subgroups showed mainly the view-sites and the connecting paths. In their maps, roads were prominently shown.

To conclude, horsemen were mainly interested in peaks and view-sites. In a way, they have added new dimensions to the tourist interest and have increased the range of attractions based on nature.

6.4.1.5 Boatmen

In maps of all the subgroups of boatmen the lake was highly prominent and occupied 40-50% of map area, which is much more than the actual proportion (actually, the lake occupies 10% of the area). Three out of five maps showed kidney-shaped lake. All maps had some inside-lake features that included boats, ducks, fish, aquatic plants and garbage. In this respect, however, intra-group variations were considerable. Because of their intimate association with the lake, lake pollution was quite marked in their mind. In general, the boatmen showed high awareness of the environmental threats faced by the lake. The lake edge was quite prominent in

majority of subgroups Some of the maps included as many as 12-16 drains, indicating that drains and the waste matter that these drains carry are prominent in the boatmen's perceptions. Facilities and structures located around the lake, such as hospital and rickshaw-stands, and roads also figured prominently. Forests were shown by a few subgroups, however, tops and other view sites were generally missing.

6.4.1.6 Vendors

Out of the 14 maps of the vendors, six showed the lake oval, two kidney-shaped, and six circular. In most of the maps made by vendors, the lake was prominently occupying 50-70% map area and inside-the-lake features were present in all the maps. As most of these vendors have shops/stalls along the lake-edge, they were familiar with inside-lake features. The lake-edge was most prominently marked by this group, extent of marking ranged from 15-100%. All subgroups, except one showed drains, with the maximum number being nine. Forest/trees were also given importance. In general, they showed a high environmental awareness.

6.4.1.7 Hoteliers

Out of 8 subgroups 6 showed the correct kidney-shaped lake. Five out of 8 maps showed the presence of inside-lake features ranging from 2 to 4 in number, and all but one subgroup showed the lake-edge, and drains numbering up to 28. The Nanda Devi drain was the correctly located drain in six cases. Five maps showed the presence of the forest/trees while only one map showed the presence of hills. Only two subgroups showed the presence of tops/view sites. Out of 8 maps, 6 showed the presence of the temple.

6.4.1.8 Coolies

Eighty percent of coolies gave a circular shape to the lake and 20% oval. Only two out of the 5 maps showed the presence of inside-lake features (showed only fish). The group on an average showed 27% of the lake edge. Only 3 maps showed the presence of drains, with the Nanda Devi drain being shown in the 3 maps. Only 2 maps showed the presence of trees/forests while the presence of hills and top/view sites was absent in all the maps. All the maps showed the presence of the temple, a number of other facilities and roads.

6.4.1.9 Households

Nine subgroups out of 17 showed the correct kidney-shaped lake. Eleven maps showed presence of inside-lake features with boat and garbage being the prominent objects. All maps showed the lake-edge and the presence of drains numbering from 2 to 7 with Nanda Devi temple and Mallital rickshaw stand drain being the most named drains. Forest/trees, hills and tops/view were shown in 9 maps. Facilities were shown in all maps and ranged from 20-80%. All maps, except one, showed roads ranging from 10-100% while only 13 maps showed the presence of temple. Environmental awareness was shown by all except one subgroup ranging from 20-80%.

6.4.2 Stakeholders' responses to individual features

After analysing the maps drawn by different subgroups of the stakeholders we have tried to see the perception of the individual stakeholders towards the identified features of the lake and its watershed. Table 6.4 summarises the perception of these stakeholders.

6.4.2.1 Lake shape

The percent subgroups showing lake as kidney-shaped was high in the case of tourists (75%), hoteliers (75%) and boatmen (60%), in contrast to the maps of horsemen (0%) and coolies (0%) (Table 6.4). Tourists and hoteliers are generally familiar with the maps published in the tourist brochures, thus correctly drawing the kidney-shaped figure of the lake. Boatmen seem to get familiarity with the kidney-shape of the lake because of their occupation, especially the round-trips they make. Horsemen and coolies, whose activities are mostly located away from the lake, seem to be hardly interested in the details of the lake. The ignorance is partly compounded by their low literacy level. As a result, the lake was never kidney shaped in their maps.

Surprisingly, the vendors, whose activities are also concentrated around the lake also seldom showed kidney-shaped lake (14.4%). Perhaps, location at a point of the lake-edge gave only a restricted view of the shape of the lake. The rickshaw-pullers were also not correct in their perception of the lake shape, only 16.6% maps showing a kidney shaped lake.

Thus, level of literacy and consequent familiarity with the published maps and working experience (boatmen) determined this particular aspect of the lake.

6.4.2.2 Lake area as percent of total map area

Most of the stakeholder maps showed the lake disproportionately large, except the professionals (20.0%) who have the knowledge, and horsemen (20.3%) whose professional interest is away from the lake (Table 6.4). The lake actually occupies about 10% of its watershed, but in majority of maps it occupied 40-75% of the map area. This lake-centric perception is a common feature of various groups ranging from rickshaw-puller and coolies to hoteliers.

6.4.2.3 Inside-lake features

The garbage dumped into and around the lake is the most prominent feature. This clearly indicates that the people are affected by the pollution problem (Table 6.4). The other lake features which different stakeholders showed were boat, duck, fish and plants inside the lake. Vendors who work around the lake, boatmen who work inside the lake, and the professionals who have gathered sufficient information about the lake showed most of these features. Coolies, rickshaw-pullers, horsemen and tourists did not pay attention to many inside-the-lake features.

6.4.2.4 Lake edge as the percent of different sites of the lake boundary

Across the different stakeholders it ranged from 15% for horsemen to 56.6% for professionals (Table 6.4). Most of the maps focused the mall roadside of the lake. Again the horsemen and coolies who were occupationally not attached with the lake gave little importance to the lake edges. Not only did these stakeholders give little importance to lake edges, they were also highly incorrect in drawing the correct shape and area of the lake.

6.4.2.5 Drains shown and drains named

The average percent of the total 28 drains shown was high in the case of hoteliers (27.2%), many of whose hotels are located around the lake, boatmen (25.7%) who work inside the lake and professionals (22.6%) who have some knowledge about the lake (Table 4). The percentage was very low in the maps drawn by tourists (4.5%), horsemen (6.0%) and coolies (7.9%). The low number in case of tourists may be because they are usually unfamiliar to the details of the Nainital township. While

horsemen and coolies again showed that they paid less attention to all aspects pertaining to the lake. Nanda Devi temple drain figured most commonly because of its size and location. A maximum of 7 drains were named by the stakeholders who could show drains on a map. Professionals (81.0%) named most of the drains due to their greater awareness, while hoteliers (57.1%) and vendors (52%) named about half the drains. The tourists' percentage was very low (14.3%) in naming the drains due to their obvious ignorance about the lake and its watershed.

6.4.2.6 Trees and forests

All tourist maps showed forest/ trees indicating that they also give importance to this important feature of watershed (Table 6.4). Among the other groups vendors (about 79%) gave high importance to trees, particularly at the lake edge and where they have stalls. Rickshaw-pullers were least concerned with the trees and forests. The horsemen who gave importance to tops/views also ignored forest and trees just as they ignored lake and its features. Remaining groups showed moderate interest in trees and forests.

6.4.2.7 Hills

The percent of maps showing hills surrounding lake varied from zero in the case of coolies and vendors to 66.7% in case of professionals (Table 6.4). Interestingly the groups with low literacy, such as boatmen and horsemen gave a substantial importance to the adjoining hills while hoteliers' perception resembled that of coolies and vendors. It seems that occupational linkage is an overriding factor in certain perceptions.

6.4.2.8 Tops and views

Only horsemen among the stakeholders gave importance to tops and view sites (Table 6.4). About 66% of their maps showed tops and view sites compared to 0-26.6% across other groups. This is the best example showing relationship between occupational interest and perception.

6.4.2.9 Facilities and roads

Facilities were generally given low (20.0-26.2%) to moderate importance (31.2-55%) (Table 6.4). Interestingly the tourists and the hoteliers have given rather similar and relatively low importance to facilities which indicates that their stay (tourist) or

profession (hoteliers) is unrelated to facilities like hospitals, schools, post-office, municipal board and bus station, etc. Roads as the percent of the major roads ranged from 21.7% for rickshaw-pullers to 50% for professionals. For rickshaw-pullers only the Mall road, where they ply the rickshaw, is important and other roads are irrelevant. Hoteliers and tourists were similar in having comparatively low values; they too are interested only in major roads. Higher values (over 40%) were recorded for coolies, horsemen and boatmen. The profession of both horsemen and coolies is connected with a number of bridle-paths and roads. Boatmen seem to be more focussed on various features of the city than other groups, therefore, having a more balanced view. In their perception many aspects are important. They give high values to the area of the lake, its shape, inside-the-lake features, lake-edge, drains, trees/forests, hills, tops and views and facilities, etc. Their profession is such that they have more time to contemplate and have leisurely talks with the entire cross-section of stakeholders.

6.4.2.10 Temple

Naina Devi Temple was a common feature in all maps across all stakeholders, ranging from 50% in case of horsemen to 100% in case of professionals, boatmen and coolies (Table 6.4).

6.4.2.11 Environmental awareness

Overall environmental awareness ranged from 20% among coolies to 63.3% among professionals (Table 6.4). Values were relatively high also for tourists, boatmen, household and vendors.

Table 6.4 A summary of stakeholder-wise map analysis.

Stakeholder	Map features												
	% maps with kidney shape	Lake shown as %age of map area	% of inside-lake features shown	Lake edge, % of all sides	% of drains shown	% of drains named	% with Trees/ Forest	% with Hills	% of Top/View sites	Average % of Facilities shown	Average % of Roads shown	% with Temple	Average Awareness– Environment, % of maximum scale
Professionals	33.3	20.0	77.8	56.6	22.6	81	66.7	66.7	26.6	43.3	50.0	100.0	63.3
Tourists	75.0	42.5	12.5	40.0	4.5	14.3	100.0	50.0	7.4	31.2	37.5	75.0	53.7
Rickshaw-puller	16.6	40.8	13.9	32.5	8.9	23.8	16.7	20.8	3.3	20.8	21.7	83.3	33.3
Horsemen	0	20.33	13.9	15.0	6.0	21.4	33.3	50.0	65.8	20.0	41.7	50.0	33.3
Boatmen	60.0	46.0	36.7	40.0	25.7	31.4	40.0	60.0	4	55.0	46.0	100.0	48.0
Vendors	14.4	41.1	42.9	48.6	16.1	52.0	78.9	0	10.7	43.9	24.6	92.8	48.6
Hoteliers	75.0	75.0	27.1	40.0	27.2	57.1	62.5	12.5	6.3	26.2	30.6	75.0	40.0
Coolies	0	41.0	3.3	27.0	7.9	31.4	40.0	0	0	41.0	44.0	100.0	20.0
Households	53.0	36.8	20.6	43.2	14.1	40.3	53.0	53.0	19.1	50.3	33.8	76.5	50.6

Notes: Values are based on features shown in maps. They either represent average across all maps of a stakeholder (e.g. % area of map under lake) or percentage of maps with a give feature (e.g. temple).

6.5 Ordination of Stakeholders

The different stakeholder groups were ordinated[44] (polar ordination of Bray and Curtis, 1957) on the basis of the features shown on maps drawn by them. Distance between the locations of stakeholders in the ordination graph is inversely proportional to their similarity. Stakeholders groups similar in their perceptions are located close to each other in the ordination graph. Low range of X-values (40% dissimilarity) and Y-values (33% dissimilarity), indicates that the stakeholders share several common perceptions, largely centred on lake features. For example, the proportion allocated to the lake of the total area across the 9 stakeholders ranged between 20-46%, though lake occupied only about 10% of the catchment, and a smaller percentage of the town. However, within the space of ordination, stakeholders' positions are scattered, emphasising that each group differed from the remaining groups in a significant way in certain features. The main feature of their relationships is that horsemen, coolies and vendors are highly isolated both from one another and the remaining stakeholder groups (Fig. 6.1). Only two groups could be outlined: one consisting of four stakeholders (professionals, tourists, boatmen and households), and the other of hoteliers and rickshaw-pullers.

Of the outliers the horsemen differ from the remaining groups because of their focus on peaks and view-sites located from the lake. The stakeholder vendors that makes other pole of x-axis is characterised by its focus on lake and inside-the-lake features and little importance to the surrounding hills. The other outlier group coolies resembles vendors in showing no interest in hills but it differs clearly from them also in having no or little knowledge of the shape of the lake, inside-the-lake features as well as of tops and view-sites.

[44] Ordination is a method for arranging individuals (or sometimes attributes) in order along one or more lines. The method is used, with many techniques, in biological and earth sciences and especially in ecology. There are many methods of arranging individuals / species, such as constellation diagram, gradient analysis, inverse analysis, hypothesis-generating method and reciprocal averaging (Allaby, 1998). In the present exercise we have used constellation diagram to find the association among stakeholders and about their perceptions towards the lake, its watershed and attributes. Constellation diagram is a representation of species/stakeholders affinities based on high correlation or χ^2 as a measure of association between species/stakeholders. The reciprocal of the χ^2 for each species/stakeholder pair is used to plot the diagram so that highly positively associated species with high χ^2 values are positioned closely together. As a result the clusters of similarly distributed species/ stakeholders may emerge.

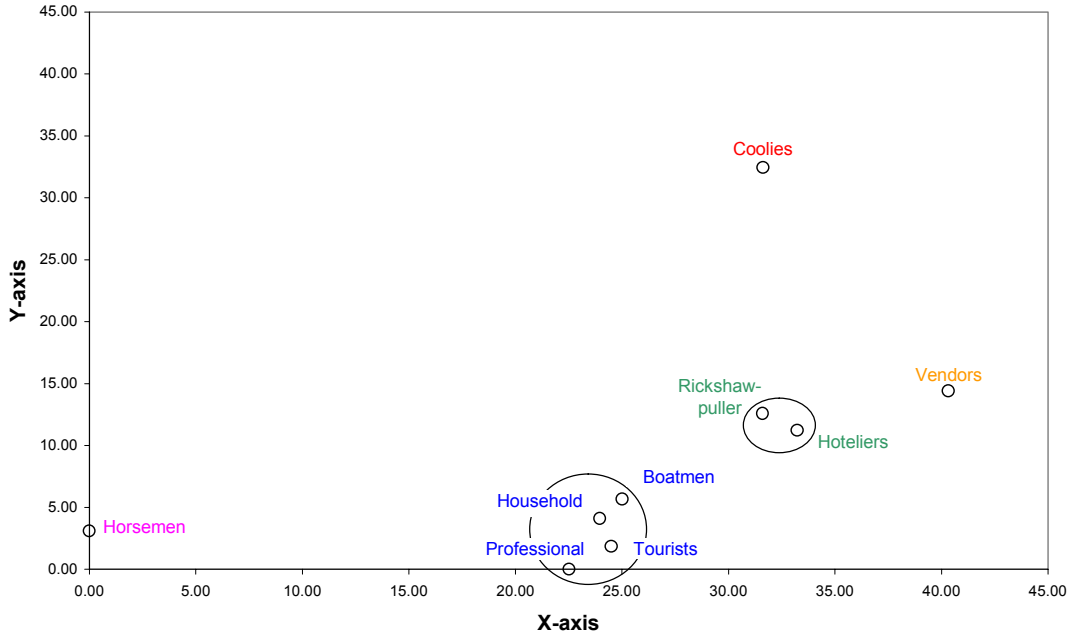

Fig. 6.1 Relationships among different stakeholder groups in regard to their perceptions and management implications using Ordination

The cluster consisting of 4 stakeholder groups is characterised by better knowledge about the lake and its catchment and more sensitivity to environmental issues. Generally they have better education also, except in case of boatmen, who are not highly literate. But the boatmen due to their dependence on the lake for livelihood show sensitivity towards issues of lake and its catchment. Moreover, while boating, they find adequate time for long interactions with most of other stakeholders. They appear to enjoy themselves the status of “lake specialists”. It may be noted that two different groups may have similar response to an issue despite having different backgrounds and reasons. For example, both rickshaw-puller and hoteliers form a cluster though they have widely different backgrounds. Both groups show moderate interest towards the lake-edge, and both ignore tops and views. Furthermore, both show low interest in facilities but for different reasons, the hoteliers because they depend less on public facilities, and rickshaw-pullers because of ignorance and poor access to facilities such as hospital and schools.

6.6 Monetary Benefit to stakeholders

The PRA method of semi-structured interviewing was applied considering the fact that the present PRA exercise was the first of its kind in Nainital. This was complemented by participatory seasonality analysis method to estimate the monetary benefits that accrue to some of the stakeholders in the Nainital watershed. On the basis of these two methods earnings of different stakeholders in peak season (May-June and October) and off-peak season (remaining months of the year) were calculated.

A significant proportion of recreation expenditure of tourists goes to the lower section of the society consisting of boatmen, horsemen, vendors, coolies, and rickshaw-puller. PRA technique is used to estimate their earnings from both tourist and local population. The total amount of earnings of these five SGs (stakeholder category) amounts Rs. 56.6 millions annually, of which 53.4% is earned during the Peak Tourist Period (PTP) months (Table 6.5). The stakeholder group-wise amount varies from Rs. 27.3 millions for coolies (1000 individuals) to Rs. 1.24 million for rickshaw-pullers (76 individuals) annually, and Rs. 0.513 million for rickshaw-puller to 13.5 millions for coolies during PTP (Table 6.5). This amount varies across SGs group depending upon the size of the SGs and individuals monthly earning capability.

Table 6.5: Peak-season and off-peak season earning of stakeholder groups in a typical year (see Appendix Tables 10-14 for details).

Stakeholder group	Number of persons in the group	Peak-season earning in Rupees	Off-peak season earning in Rupees	Total annual earning
Rickshaw-pullers	76	513,000	730,800	**1,243,876**
Horsemen	164	5,166,000	3,645,000	**8,811,164**
Boatmen	233	8,388,000	4,399,200	**12,787,433**
Vendors	150	2,700,000	3,735,000	**6,435,150**
Coolies	1000	13,500,000	13,860,000	**27,361,000**
TOTAL	***1623***	***30,267,000***	***26,370,000***	***56,638,623***

Table 6.6: verage monthly earning of stakeholders who do not change their occupation throughout the year.

Stakeholder group	No. of stakeholders employed in their respective occupation throughout the year	Peak-season earning per stakeholder in Rupees	Off-peak season earning per stakeholder in Rupees	Total annual earning per stakeholder in Rupees	Average monthly income in Rupees
Rickshaw-pullers	17	6750	10800	**17567**	**900**
Horsemen	81	31500	27000	**58581**	**2250**
Boatmen	58	36000	32400	**68458**	**2700**
Vendors	120	18000	13500	**31620**	**1125**
Coolies	200	13500	18900	**32600**	**1575**
TOTAL		***105750***	***102600***	***208826***	***1710***

When we compared the earnings of the permanent individuals, it was highest for boatmen (Rs. 5,700 p.m.) followed by horsemen (Rs. 4,875 p.m.), vendors (Rs. 2,625 p.m.), coolies (Rs. 2,700 p.m.) and rickshaw-pullers (Rs. 1,462 p.m.) (Table 6.6). The sensitivity to environment was lowest amongst the rickshaw-pullers who form the poorest of the lot. It seems that hard work and low earnings are associated with low sensitivity to environment. Vendors have better appreciation to environmental issues than coolies do.

6.7 Summary and Conclusion

The present chapter uses PRA technique, as a complementary tool to questionnaire survey, to look into the perception of different stakeholders in the Lake Nainital and its watershed. The stakeholders covered for the exercise were coolies, vendors, rickshaw-puller, hoteliers, tourists, boatmen, horseman, professional and households. Different aspects of the lake and its watershed were considered while evaluating the preferences. The chapter then tries to ordinate different stakeholders based on the similar and dissimilar perceptions. The chapter ends with the calculation of average earnings of some of these low-income stakeholders from the tourism activity.

It may be suggested that PRA should not be limited to one time activity as the participatory approach warrants a continuous and elaborate exercises to understand

the reasons behind the perceptions and formulating solutions. As our exercise indicates PRA approach can be useful also where stakeholder groups are many and varied. Further exercises may require how to make different stakeholder groups to interact in a positive manner. The case study of Nainital provides an opportunity to improve upon PRA techniques dealing with stakeholders of different socio-economic background and hence their stakes.

Chapter 7 : Conclusions and Recommendations for Management of Lake Nainital and its Watershed

7.1 Introduction

Resilience or the capacity of a non-linear system to remain within a stability domain is a central concept (Holling, 1973; Ludwig *et al*., 1997).[45] However, when an ecosystem shifts between stability domains, the end result is a crisis.[46] Though crisis may provide opportunities for learning, introduction of novel approaches, or reorganization, it may also prompt more rigid policies for ecosystem management (Gunderson *et al*., 1995).[47] Lake Nainital is one such ecosystem that has almost reached a stage, from where crisis is imminent unless some drastic policy measures are adopted. This is essentially because the lake has become highly eutrophic and phosphorous (P) inflow is more than the outflow i.e., it is P accumulating at the moment (section 2.3.2, Chapter 2).

Though Nainital Municipality was established way back in 1950 and some major attempts were made during the last three decades to improve the organisation structure of management and administration of lake and its watershed, conditions continued to deteriorate until a couple of years ago. One of the important reasons was lack of any focus on lake and its watershed as an interconnected unit of conservation and management. In brief all these years the issue of environmental degradation was being addressed on peace-meal basis or rather causally without looking lake and its watershed in totality and that too using antiquated practices of restoration and not considering participatory management. As we have seen earlier, the watershed cannot be detached from the lake. This makes it imperative that there should be a single unified body for the upkeep of the lake and also maintenance of the watershed. This would certainly check the further deterioration.

The present project was aimed to look into dependence of different stakeholders on the lake and its watershed and what benefits they are deriving from it, besides looking into the current status of the lake. If the lake is degrading, then the study was to propose possible management action plan so that the lake continues to yield

[45] As referred in Carpenter *et al*. (1999).

[46] Collapse of fishery is one such often quoted example; global warming is another.

[47] Same as 1.

benefits sustainably. Section 7.2 of the present chapter summarizes the benefits obtained from the lake and its watershed as estimated in different chapters. Section 7.3 looks into current initiatives taken by different authorities for maintaining the lake and its watershed. Obviously, the current initiatives are not enough as the lake is continually facing threat of degradation, section 7.4 looks this from tourists and informed citizens / professionals perspective. Measures for restoration of lake and its watershed are discussed in section 7.5. The chapter ends with some concluding remarks in Section 7.6.

7.2 Benefits from the Lake and its Watershed

Chapters 3 to 6 have amply demonstrated that Lake Nainital is having a high economic value to a number of stakeholders as it is one of the most popular tourist destinations in North India. Nainital will cease to exist as a major tourist destination, if lake degrades considerably. This is well supported by the tourist survey, which finds that more than two-third of tourists would not visit or would not have visited, had there been no lake (Table 7.1).

Table 7.1 Visitors option of not visiting if lake is not there

Will you visit Nainital if lake is not there?	No. of Tourists
No	188 (68.86)
Yes	83 (30.40)
No reply	2 (0.73)
Total	**273 (100)**

Note: Figures in parentheses are the percentage of the total tourists.

As mentioned in Chapter 3, tourists are only one of the stakeholders in the Lake Nainital and its watershed; there exist other stakeholders like boat-owners, vendors, local population, scientists etc. who are enjoying use and non-use values from the lake. Murty and Menkhaus (1994) categorise the benefits obtained from a natural resource / ecosystem in two categories – primary benefit and secondary benefits. Primary benefits include recreation benefit, income from forest produce / watershed and non-use. The secondary benefits are income to the hoteliers, boatmen, coolies and other stakeholders. Table 7.2 gives a summary of the tentative benefits that have been estimated in the present study.

Table 7.2 Summary of Benefit to Different Stakeholders as found in the present study.

Type of Benefits	Beneficiary	Amount (In Rs. Million)
Primary[#]	Recreation Benefits[*]	4.3 – 6.55
Secondary[§]	Rickshaw-pullers	1.24
	Horsemen	8.81
	Boatmen	12.78
	Vendors	6.43
	Coolies	27.36
	Total	**60.92 – 63.17**

Notes: [#] - Primary benefits also include non-use values and income from forests use, which current study could not estimate.

[*] - Recreation benefits are only to the domestic nationals who are not on package tour. Benefits to foreigners and to locals, who are on package tour were not estimated. Recreation benefits have been given as a range as the value depends on the model specification.

[§] - Income to Hoteliers, transporters etc. have not been estimated.

From the table and notes therein, it is quite clear that the Lake and its watershed is providing huge benefits to a number of stakeholders. The table does not give the total economic value (TEV) of the Lake Nainital and its watershed, as the study could not estimate benefits value to all the stakeholders. However, it is quite apparent that all the benefits mentioned in Table 7.2 are lake-centred, the continuity of these benefits from the lake would necessitate that the lake should not get polluted. Next section looks, what preventive expenditure has been incurred by different authorities so as to maintain the lake.

7.3 Current initiatives for maintaining the lake and its watershed

More than Rs.10 million has already been spent in the past six years (i.e., Rs. 1.66 million/year) on maintenance of lake and catchment (Plates 7 and 8). The expenditure has been incurred on following main activities: desilting of silt deltas near shoreline; the repair, expansion and construction of sewer lines and toilets; repair of drainages and research on different aspects of lake limnology. Table 7.3 gives a summary of expenditure for each activity in the past 5-6 years.

As is evident from the table, a substantial amount of the expenditure has been incurred so that the nutrient input to the lake is reduced. At present the total length of sewer lines is 32 km and there are 3320 sewer connections; this is not enough even for reducing the inputs of nutrients and silt to the lake as we have found there exist evidence of increase of nutrients over the years (see Chapter 2). This implies a

special package is required to revive the lake and suitable management strategies to retain the pristine status of the lake.

Table 7.3 A summary of expenditure on the conservation of lake & its watershed during 1995-2001

Purpose	Agency	Amount in Rs. Million	Year
Desilting of lake	Lake Development Authority	1.1 (10.74)	1997-2001
Construction of drainage nets	PWD	2.1 (20.51)	1995-1998
Maintenance of sewer system	Jal Sansthan and Jal Nigam	3.65 (35.64)	1997-2001
Research on lake	Kumaun University	1.59 (15.53)	1997-2001
Construction of public toilets	Jal Nigam	1.8 (17.58)	1997-2001
Total		**(89.76)**	

Note: Figures in parentheses are the percentage of the total amount spent.

7.4 Is Nainital managed well – Tourists and Informed Citizens perception.

There is no gainsaying to the fact that the current initiatives are inadequate for maintaining and restoring the lake as the quality of lake is continues to decline. Before moving into what management steps we need to take to restore the lake, we look into what the informed citizens and tourists perceive about management of Nainital town and lake. If the town / lake is not managed well, what are the reasons for mismanagement. Tables 7.4, which give the opinion of the tourists, find that more than half of the tourists surveyed are dissatisfied with the town management. This figure rises up to 100% in case of informed citizens, 65% of whom are of the opinion that the town is poorly managed (Table 7.5).

Table 7.4 Is Nainital being Managed Well? Tourists Opinion

How well is Nainital being managed	No. of Tourists
Not Well	5 (1.88)
Ok Type	51 (18.68)
Could do better	90 (32.97)
Fairly Well	81 (29.67)
Very Well	46 (16.85)
Total	**273 (100)**

Note: Figures in parentheses are the percentage of total tourists interviewed.

Table 7.5 Is Lake Nainital being Managed Well? Informed Citizens Opinion

How well is Nainital being managed	Informed Citizens
Poorly Managed	19 (65.52)
Adequately Managed	10 (34.48)
Good	0 (0.00)
Excellent	0 (0.00)
Total	**29 (100)**

Note: Figures in parentheses are the percentage of total informed citizens interviewed.

The tourists' survey has also sought the perception of the tourists that which aspects of Nainital mismanagement require most attention. The responses vary from vehicular pollution to lake pollution to noise. However, excess vehicles and the tourist population are the two most important aspects that need immediate attention.[48] Table 7.6 reproduce the responses of the tourists indicating their perception of the problem.

Table 7.6 Which Aspect Needs Most Attention? – Tourists Perception

Aspect Needing Maximum Attention	First Most Concern	Second Most Concern	Third Most Important Concern	Most Important Concern
Tourist Population	36 (24.66)	25 (17.12)	12 (8.22)	63.2 [2]
Excessive Vehicles	45 (30.82)	50 (34.25)	12 (8.22)	92.2 [1]
Excessive Construction	31 (21.23)	22 (15.07)	21 (14.38)	61.2 [3]
Solid Waste Problem	8 (5.48)	8 (5.48)	20 (13.70)	26.4 [5]
Noise	2 (1.37)	3 (2.05)	3 (2.05)	6.2 [8]
Non-availability of Drinking water	2 (1.37)	10 (6.85)	12 (8.22)	17.2 [7]
Lake Pollution	12 (8.22)	15 (10.27)	34 (23.29)	44.4 [4]
Lack of Public Amenities	6 (4.11)	7 (4.79)	22 (15.07)	24.8 [6]
Did not reply?	4 (2.74)	6 (4.11)	10 (6.85)	
Total	**146 (100)**	**146 (100)**	**146 (100)**	

Note: Figures in parentheses are the percentages of the total. The total 146 comprises of those tourists who responded that Nainital is not being managed well. Figure in bracket is the overall rank of the most important concern. The Most important concern has been obtained by giving weights to different concerns with first, second and third most getting 1, 0.8 and 0.6 respectively.[49]

Table 7.7 gives the opinion of the professionals / informed citizens of Nainital about causes of mismanagement of the lake. It is interesting to see that funds and

[48] It needs to be mentioned that excess vehicles and tourists' population are indirect contributor to the lake pollution.

[49] The overall rank does not change with other weighting scheme.

mismanagement are not the two most important factors. Rather it is the lack of public support and lack of awareness among general public that are the chief reasons for deterioration of Lake Nainital and its watershed (Table 7.7).

Table 7.7 Why Lake is not managed well? – Informed Citizens View

Why Lake is not being managed well?	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Overall Rank
Inadequate funds for maintenance	9 (31.03)	13 (44.83)	4 (13.79)	2 (6.9)	1 (3.45)	22.8 [4]
Mismanagement	18 (62.07)	2 (6.9)	7 (24.14)	1 (3.45)	1 (3.45)	24.4 [3]
Lack of public support	18 (62.07)	6 (20.69)	3 (10.34)	2 (6.9)		25.4 [1]
Lack of awareness among general public	17 (58.62)	5 (17.24)	5 (17.24)	2 (6.9)		24.8 [2]

Note: Ranks are in order of decreasing importance. Figures in parentheses are the percentage of the total. Figure in brackets give the overall rank based on following weightage – Rank 1 – 100%, Rank 2 – 80%, Rank 3 – 60%, Rank 4 – 40% and Rank 5 – 20%. The overall rank does not change with other weighting scheme.

7.5 Measures for Restoration of Lake and its Watershed

This section explores different management options to restore the lake and its watershed. Before venturing into exact measures, it is imperative to know whether options adopted would immediately lead to reversal of eutrophication or not. Eutrophy is one of the two states of the lake, other is oligotrophy.[50] Oligotrophic state of the lake flips to the eutrophic state with increase in nutrient (especially phosphorous) input. Figure 7.1 gives a framework for policy choice to the management of lake eutrophication.

Chapter 2 has already emphasised that the ultimate cause of eutrophication is excessive inputs of nutrients. Nutrient input is a by-product of activities such as construction, urbanisation, forestry etc., but benefits from these activities are directly related to inputs. For instance, use of detergents rich in phosphate make the

[50] Oligotrophic lakes are characterised by low nutrient inputs, low to moderate level of plant production, relatively clear water, and relatively high value of ecosystem services. On the other hand, eutrophic lakes have high nutrient inputs, high plant production, murky water, anoxia, toxicity and relatively low value of ecosystem services. This implies, eutrophication diminishes the net value derived from the lakes (Wilson and Carpenter, 1999).

washing of clothes faster and easier. Thus there is a trade-off between benefits from polluting activities and costs of ecosystem services foregone due to consequences of pollution (Fig. 7.1). This implies a proper analysis will be required if different policies are to be compared for use and management that evaluate the net flow of benefits.

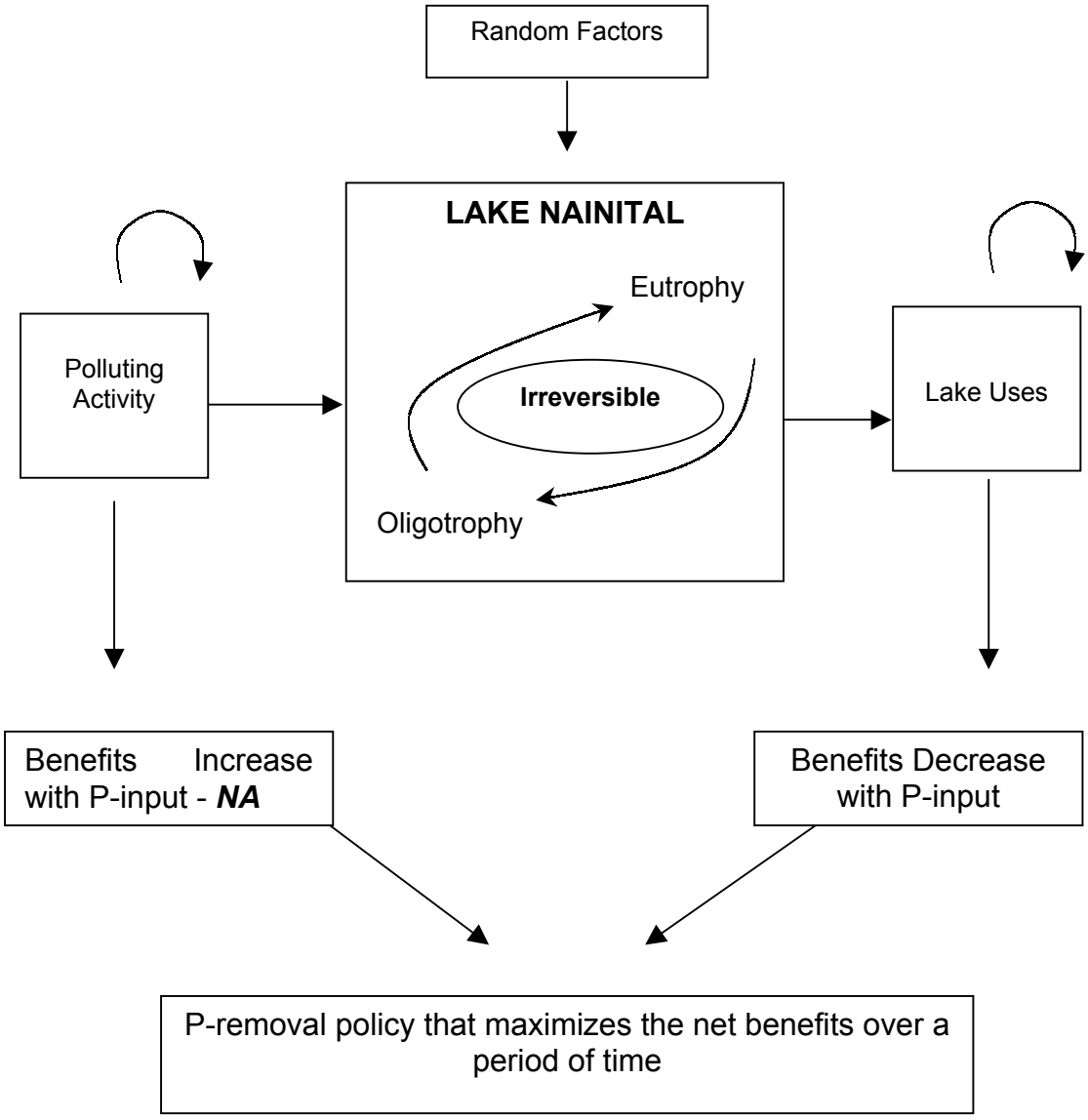

Figure 7.1 Framework for Policy Choice to the management of Lake Nainital's Eutrophication. NA – not applicable to Lake Nainital (derived from Carpenter *et al*., 1999).

Negative effects of eutrophication include increased plant growth; shifts in phytoplankton to bloom-forming species that are often toxic or inedible; decrease in water transparency; problems with taste, odour and water treatment; oxygen depletion; and fish kills (Smith, 1998).[51] While nutrient addition may lead to immediate increase in symptoms of eutrophication, decreased nutrient input does not always result in complete reversal of eutrophication (Sas, 1989). Studies indicate considerable variability in lake responses to reduced P inputs. Based on their responses, lakes can be classified in three categories – 'reversible', 'hysteretic' and 'irreversible'. Reversible lakes are those where eutrophication can be reversed by P input controls only. Lakes where eutrophication can be reversed by combining P input controls with temporary interventions such as chemical treatments to immobilize P or bio-manipulation are called as hysteretic lakes. The lakes where eutrophication cannot be reversed by even severe reduction in P inputs are called the irreversible lakes. The irreversibility is most likely to occur in lakes in P-rich regions or lakes that have received extreme P inputs for an extended period of time (NRC 1992 as referred in Carpenter *et al*., 1999).

The explanation for this irreversibility or delayed response lies in the recycling of P. As lakes are enriched, P accumulates in sediments, which then lead to increase in 'internal loading' i.e., recycling of P from sediments to the overlying water (Carpenter *et al*., 1999). As mentioned, culturally such lakes receive excessive P inputs for decades or longer. Lake Nainital is a clear example of this P accumulation and internal loading. In such lakes including the Lake Nainital, the eutrophication cannot be reversed by decreasing P input alone, additional interventions that decrease recycling, accelerate sedimentation, or increase inputs of P such as sediment treatment, hypolimnetic oxygenation, or biomanipulation are needed.

7.5.1 Managing P, eutrophication and aspects of management

P-input can be reduced by resorting to a number of measures aimed at both – the watershed and in-lake. The watershed measures include clamping a ban on P-containing detergents, keeping hill slopes clean (maintenance of sewer lines, provision of toilets for all, control of domestic animals, garbage disposal, etc.) and

[51] Eutrophication is a widespread problem in US and Scandinavia also. It accounts for about half the impaired lake area, 60 per cent of the impaired river reaches and is the most widespread pollution problem of estuaries in US (USEPA 1996 as referred in Carpenter *et al*., 1999). Baltic sea in Scandinavia also suffers from widespread eutrophication.

improving forest cover. Interventions such as aluminium sulphate treatment and bio-manipulation can also reduce available-P. However, these measures alone would not bring about reversal of the lake-eutrophication because of the rapid recycling of P, the source of which is the sediment and hypolimnion under anoxic condition during most of the year. Removal of the anoxic hypolimnion water (up to 15 m thick) from the sluice and periodical oxygenation may help drastically reducing the P-status of the lake. But to bring about P-level to the low steady-state level that shifts the lake from eutrophic to oligotrophic status, the treatment of lake sediment would also be required. Treating the lake sediment may be costly, but the gains which include sustenance and continuity of tourism, improvement in the aesthetic and recreational values of the lake, revival of swimming and fishing, and fewer water-borne diseases, will surely outstrip the expenditure in the long run. Following are the measures with increasing costs and difficulty:

7.5.1.1 Watershed Measures to reduce P-inputs to the lake

1. Banning sale of detergents containing PO_4 (allow the use of only those detergents which have no PO_4).[52]
2. Construct more public toilets for the labour class people (about 1000 in number) who are using godowns and temporary hutments for residence and hence do not have access to proper toilets. Though there does not exist any data of how many of these are using toilets and how many use open space for defecation, but such a move would surely facilitate checking the input of human excreta (rich in nutrients) into the lake.
3. Improve and maintain sewer network and also connect bathroom and kitchen drainage to it.
4. Control construction-related erosion.
5. Improve forest cover and capacity of watershed to retain rainwater.

[52] Banning detergents containing PO_4 may not be very difficult. This is because Nainital already has a successful history of banning polythene bags and now none of the shopkeepers use polythene bag.

7.5.1.2 In-lake measures to reduce P

1. Use biomanipulation for reducing algal blooms by using techniques such as altering the fish community to reduce predation on certain zooplankton (cladocerans such as *daphnia*) that can most efficiently graze on algae.
2. Carryout periodical oxygenation of hypolimnion using (up to 15 m thick) suitable aeration techniques.
3. Remove hypolimnion water in place of epilimnion water from the sluice.
4. Remove lake sediment.

However, for an effective treatment investigations are required to synthesize phosphorous budget of the lake considering the details of P-input from different sources, its seasonality, sediment chemistry with particular reference to changes in P-concentration in lake water, particularly at the time of turnover, and rate of P-recycling from sediment in relation to oxygen condition.

7.5.2 Watershed treatment to reduce pollutants

As we have seen in Chapter 2, watershed is contributing not only Phosphorous but also some other pollutants like lead etc.

I. All designated motor vehicle parking places should have proper drainage system to ensure that oil and other pollutants are directed to sewer lines. Since these sewer lines are directed out of the watershed, oil and other pollutants will not enter the lake.

II. The problem of lead contamination of the lake and its watershed associated with the heavy inflow of motor vehicles especially during the tourist season needs immediate attention. The following measure is suggested for the same: check the emission levels of the vehicles coming into the town and in case, if pollutant level is high, vehicle entry be restricted.

III. Use of lead-free paints on boats and tin rooftops of the houses be promoted.

IV. Investigate the role of forests in lead input to the lake from the watershed.

V. Investigate the role of bacterial population and metalophytes in removing lead from the water of Sukhatal valley-fill.

7.5.3 Improvement of forest cover in watershed

The following administrative measures need to be taken to improve the watershed of Lake Nainital:

I. Improve forest cover in the watershed, the ban on tree cutting to be extended to all the stages of tree, and make punitive measures severe enough to act as deterrent. The advantages yield by these steps would include:

- reduction of water run-off, soil erosion and concomitant reduction in siltation of the lake and further eutrophication;
- restriction on construction activities, since construction work cannot be done on sites having trees as per existing laws; and
- since Nainital has been identified as one of the centres of bird-watching, improving forest cover will certainly boost the tourist (especially foreigner) influx.

II. Impose a ban on firewood extraction from the forest, and replace this subsidy by providing electricity/LPG at affordable costs to the poor stakeholders groups. This subsidy is clearly justified in terms of services of forests in checking soil erosion and nutrients, and the importance tourists give to its aesthetics.

7.5.4 Importance to valley-fill and rocks that store and filter water

The maintenance of Sukhatal sub-catchment is required for continued, round-the-year supply of subsurface water to the lake and direct water supply to the lake. This valley-fill by providing water subsequent to monsoon rainfall contributes to the maintenance of lake level, its recreational value, and abatement of pollution. Somehow, people have not been educated of the value of this major component of watershed.

7.5.5 Initiate participatory approach to the watershed management

Participatory approach to the watershed management has been found superior and more effective than top-down, coercive approach, particularly where stakeholders are many and diverse (Farrington and Lobo, 1997).[53] Participation, however, should

[53] It also dovetails with the national and international objectives of effective democratisation.

not be considered merely an “add-on” or for token use. It warrants detailed and thorough exercises, and long and hard thinking at conceptual and operational levels.[54]

Our study has clearly demonstrated how people differed in their perceptions, though living within a small area and rooted around a common resource, the lake. The vocational needs play a significant role in determining the perception and involvement of the stakeholders. The poorest stakeholder, rickshaw-puller, as an example, showed the lowest sensitivity to environmental issues while the horsemen, showed the lowest interest in the lake, as their earning from tourists depended on peaks and other view-sites. Their responses contrasted with responses of other stakeholders, which were more lake-centred.

Further exercise is required to address the issue of enabling different stakeholders to interact positively. PRA technique could be enriched by considering management that involves diverse stakeholders, but differing in socio-economic background. The PRA exercise brought out a simple fact that different stakeholders view-point need to be considered while formulating a management plan, and outlier stakeholders such as horsemen and coolies should not be ignored.

The more the stakeholders, the larger the probability of conflicts, and this reality runs counter to the participatory rhetoric. To deal with this issue, there would be need to build a new institution capable of mediating and communicating with diverse stakeholders. This may consist of representatives of the various stakeholder groups and government as a “collaborator” not merely a bureaucratic component. Both the tourists and the informed citizens are of the view that the local people in some form or other be involved, if lake and its watershed is to be managed (Tables 7.9 and 7.10).

[54] The token use of participation has rather devalued it (Fisher, 1995).

Table 7.9 Tourists perception - who should maintain the Lake Nainital and its Watershed

Who should maintain the Lake and its watershed?	Tourists
Government (municipality or any development authority)	36 (13.19)
NGO/Voluntary Organisations	11 (4.03)
People	12 (4.40)
Government and People	124 (45.42)
People and NGO	16 (5.86)
Government and NGO	29 (10.62)
Government, People and NGO / Voluntary Organisations	44 (16.12)
Not responded	1 (0.37)
Total	**273 (100)**

Note: Figures in parentheses are the percentage of total tourists surveyed.

Table 7.10 Informed Citizens Views - who should maintain the Lake Nainital and its Watershed

Who should maintain the Lake and its watershed?	Informed Citizens First Choice	Informed Citizens Second Choice	Most Preferred Choice
Another autonomous government body	3 (10.34)	12 (41.38)	12 [3]
A local peoples society	9 (31.03)	7 (24.14)	14.25 [2]
A local non-government organisation	0 (0.00)	0 (0.00)	0
An international managed NGO	2 (6.90)	8 (27.59)	8 [4]
A local NGO with monitoring by an international body	15 (51.72)	2 (6.90)	16.5 [1]
Total	**29 (100)**	**29 (100)**	**29**

Note: To find the most preferred choice, first choice has been given 100% weight and second as 75%. Figure in bracket is the most preferred choice.

7.6 Concluding Remarks

The amount of money that is generated around the 48 ha of the lake and its watershed is huge. The present exercise could account for a certain fraction of it and several values remain unestimated. For example, many people living in India for whom the lake has high existence value could not be considered. Even recreation value for foreigners was not considered. Similarly, the amount of filtration done by *Sukha Tal* could not be valued. Still, the present study has made it possible to put

certain economic value while accounting the various aspects of costs and benefits which planners would find useful in taking decisions.

The study also finds that the Lake Nainital is highly eutrophic and is rather P-accumulating. The present chapter looks into different options that can be adopted to restore the lake. Since the lake has already reached irreversible state, besides controlling P inputs, other interventions are needed that would facilitate restoration of the lake. However, there is still no guarantee that other interventions will yield desirable results. This is because in lakes with large surface area, oxygenation and aluminium sulphate treatment are extremely costly (Cooke et al., 1993).[55] But when considered on a long-term basis the cost of lake restoration could be justified.

After having examined various aspects of management of Lake Nainital and its watershed we can conclude by stating that for an effective management the lake and its watershed be recognised as a single unit with the managing body having peoples' representatives being responsible not only for improving the quality and maintenance of the lake but it should also look after the watershed.

[55] As referred in Carpenter *et al*. (1999).

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Appendix 1

Questionnaire – 1

Project: ***Integrated Management of Water Resources of Lake Nainital and its Watershed: An Environmental Economics Approach***

Kumaun University, Nainital & National Institute of Ecology, New Delhi
Sponsored by IGIDR, Mumbai

Name & Code of interviewer

_____

Date: _____ Time: _____ Place:

_____

Name:

_____

_ Gender: M/F

Place of Residence: _____ When did you arrive at Nainital

_____

Occupation:_____ Age: _____ Last qualification:

_____

Monthly personal income: Rs. **_____**

<Rs.5,000	Rs.5,000-10,000	Rs.10,000-Rs.20,000	Rs.20,000-Rs.50,000	Rs.50,000-Rs.1,00,000	> Rs.1,00,000

Approximate monthly household income (from all sources):

Rs._____

<Rs.5,000	Rs.5,000-10,000	Rs.10,000-Rs.20,000	Rs.20,000-Rs.50,000	Rs.50,000-Rs.1,00,000	Rs.1,00,000-Rs.2,00,000	> Rs.2,00,000

Number of members in household: **_____ &** Number of **earning members** in household: _____

Q1. Have you come **directly from your hometown**/place of residence? **Y/N**

Q2. If **NOT,** then from where? _____

Q3. How many **members of your household are on this trip**?

_____

Q4. Have you come on a package tour? **Y/N**

Q5. (If response to Q4 is Y)

(i) Number of total tour days? _____

(ii) Number of days to be spent at Nainital _____

(iii) How many places are you visiting on this tour? _____

(iv) The places visited/visiting _____

(v) Total cost of package tour (including food expenses) Rs. _____

Q6. (If response to Q4 is N)

(i) Total number of days on this trip _____

(ii) Number of days to be spent at Nainital

_____

(iii) Where are you **staying** (hotel/guest house/other)

_____

(iv) How much are you spending on **accommodation** daily (per family) Rs._____

(v) How much is your daily expenditure on **food** (per family) Rs._____

(vi) How many places do you intend to visit – name them: local places _____

_____ other places _____

Q7. How much are you spending on speciality recreations within Nainital?

(i) Boating /yachting Rs._____

(ii) Horse riding Rs._____

(iii) Ropeway Rs._____

Q8. How much are you spending daily on **transport during Nainital visit**?

(i) Rickshaw Rs._____
(ii) Taxi Rs._____
(iii) If in personal vehicle, **type** _____
daily kilometres travelled _____ km x Rs.____ / km = Rs._____
daily parking and toll charges Rs._____

Q9. How much you are spending/intend to spend on **excursions during Nainital visit?** Rs._____

Q10. If coming by own vehicle the total toll tax paid on the way and fuel cost: Rs._____

Q11. How much did you spend on transportation to reach Nainital from your hometown (total for family)? Rs. _____
Modes of transportation used in reaching Nainital from your residence/ last destination
_____

Q12. Is your travel funded? (for example by the LTC/any other organization) **Y/N**

Q13. Is this your first visit? **Y/N**
How many times have you visited Nainital earlier? _____
If No, when was your last visit? _____ year

Q14. What is the main reason you have come to Nainital other than its climate (tick one)?
i. The presence of the lake
ii. The presence of the mountains
iii. The combination of hills and lake
iv. The opportunity for exercise e.g., hiking, boating, riding
v. Presence of number of nearby tourist places e.g. Bhimtal, Sattal, etc.

Q15. Had you not been able come to Nainital where would you have gone? _____

Q16. If No to Q13, do you think Nainital has become polluted or improved since your last visit (tick one)?
(i) Polluted/Degrades/Deteriorated
(ii) The same
(iii) Improved

NOTE: IF RESPONSE (i) TO Q15 THEN ANSWER Q17 – Q19

Q17. If response (i) to Q15, has there been a reduction of greenery/forest cover? **Y/N**

Q18. If response (i) to Q15, can you rank the form of damages to the lake, if any
i. Change in water quality (transparency, colour, smell, garbage, etc) _____
ii. Presence of large populations of water plants and algae (*Kai*) _____

Q19. If response (i) to Q15, what do you think are the causes of damage? (**Rank first three**)
i. Absence of proper management by the municipality _____
ii. Excessive tourism _____
iii. Lack of interest on the part of local population _____
iv. Lack of civic sense on the part of tourists _____

Q20. Would you extend your stay at Nainital beyond what you had planned initially? **Y/N/Not sure**

Q21. What do you feel makes Nainital a unique tourist destination _____
If **Not Lake**, why not? _____

OR

If **Lake** is the main attraction then what else are the other attractions?
i. _____
ii. _____
iii. _____

Q22. How do you think Nainital (the entity including the lake, forests and town) is managed? **(tick one)**

(i) Not well
(ii) Ok type
(iii) Could do better
(iv) Fairly well
(v) Very well

If you think the town management is below rank (iii) please answer the following:

Q23. Which management aspect required most attention (rank 1st to **3rd**)?

i. Excess tourist population _____
ii. Excessive vehicles/ traffic _____
iii. Excessive construction _____
iv. Solid wastes (irresponsible garbage dumping) _____
v. Excessive noise pollution _____
vi. Non-availability of drinking water _____
vii. Pollution / degradation of the lake _____

Q24. Who should maintain Nainital? **(tick one)**

i. Govt. (municipality or any Development Authority)
ii. NGOs/Voluntary Organisations
iii. People
iv. Govt. and people
v. People and NGO/Voluntary Organisations
vi. Govt. and NGO/Voluntary Organisations
vii. Govt., people and NGO/Voluntary Organisations

Q25. The management of the lake, town and surrounding forests involve a considerable expense (more than Rs.20 Crores annually) but no regular source of income is available to the local body. Would you be willing to pay a certain amount towards the conservation of the lake and its surroundings? **Y/N**

Q26. If No, why not?

i. Unable to pay as income is limited
ii. Government should meet the expenses
iii. Local people should pay the expenses
iv. Other reasons _____

Q27. If response (i) to Q28, if your income were increased say by Rs. 1000/- month, would you then be willing to contribute? **Y/N**

Q28. If yes, how much would you like to contribute on per visit basis so that the lake and its environs may be conserved (**tick one**)?

<50	50	100	200	250	500	750	1000	>1000

Q29. How should else this money could be generated? (tick one)

(i) As a cess from local people
(ii) As a tax on tourists
(iii) Both from local people and tourists
(iv) As aid by central/state govt.
(v) Reallocation of existing Luxury Tax imposed in hotels
(vi) Voluntary contributions and donations from tourists.
(vii) Any other means _____

Q30. Will you visit Nainital again? **Y/N/Not sure**

Q31. If yes, how soon do you think you will visit, in

i. the next 12 months
ii. in the next 3 yrs
iii. in the next 5 yrs
iv. Not sure when

Q32. Will you still visit Nainital if the lake was heavily polluted or dried-up but the climate/forest/hills and other beauty remains the same? **Y/N**

Q33. If not, why will you not be visiting again? (Details) _____
_____
_

Q34. Considering your experience on this trip & total costs you have incurred. After what maximum cost (budget) would you decide not to come to Nainital. Rs. _____

Questionnaire – 2
ECONOMIC VALUATION OF NAINITAL LAKE AND ITS CATCHMENT

(Questionnaire for Professionals/Scientists)

1. Name of Scientist/Professional _____.
2. Nationality _____.
3. Specialisation _____.
4. Title on study/paper if any (any subject) on Nainital Lake_____
5. Any project on Nainital Lake_____
6. Remarks (if any) _____
7. Name of interviewer _____
8. Date/time _____

What this project is trying to achieve and what we request of you :

Research in the field of environmental economics today aims at estimating the value of our natural resources, including mineral, aquatic and biological resources. Although some direct uses of these resources are relatively easy to evaluate, others are more difficult to quantify. These include the social, aesthetic and future values that a resource may have for a population.

With a view to understanding, (and estimating, as far as possible) these values in relation to Nainital Lake, an attempt is being made to collect information on scientific perceptions.

We require from you responses in the format specified. Although ranking and scoring may appear an inadequate manner to settle questions scientists are still poring over, your responses will help our study arrive at conclusions.

Whenever the term '**Any Other**' appears, you are requested to put in an item which you think should be included but has been ignored, and further to rank/score/mark it as the question specifies.

Thank you

This study is being carried out by the Botany Department, Kumaon University, Nainital and NIE, Delhi and is funded by the Indira Gandhi Institute of Developmental Research, Mumbai.

Q1. How would you like to value the functions and benefits accruing to us from Nainital Lake and its catchment-

- As the value of one whole system which would include the lake and its catchment _____
- As two different systems - the lake and catchment separately _____
- Both ways, depending upon the situation _____

Q2. How would you rank the following aspects of valuation? (Rank alternatives in order of precedence i.e. 1 for the highest etc.)

- Putting monetary value to a system/species according to the services they provide
- According a monetary value to the system/species for its existence alone, as part of the ecosystem on this earth
- According a value to it depending upon its rarity
- Ascribing a value (monetary or otherwise) because of its use in generating items of consumption (fuel, fodder, fish etc)
- Ascribing a value (monetary or otherwise) to it for its use in generating livelihoods (providing inputs for local industry, tourism, fisheries etc.)
- Ascribing a value because of the possibility of future use
- Any other

Q3. Do you think that putting an economic/monetary value to a threatened system (e.g. Nainital lake) could help conserve it? **Y/N**

Q4. How important do you think can the economic valuation of systems prove to be in the long run?

Important 1 2 3 4 5 **Unimportant**

Q5. On a regional/national level, how effective do you think can economic valuation prove in evolving conservation strategies?

Important 1 2 3 4 5 **Unimportant**

Q6. Rank the following in terms of relative importance to humankind (examples quoted of Nainital lake and catchment)-

- The systems present/immediate economic value for humankind (water, tourism, fuel, fodder) ____
- The systems future value for humankind ____
- The systems ritual and cultural value in the lives of people (Naini devi temple, religious implications of the lake) ____
- The systems value as an ecosystem - including the ecological functions it provides ____
- Its aesthetic value ____

Q7. The following question is specific to the context of the catchment ecosystem of Lake Nainital. Kindly respond only if you are familiar with the ecosystem.

The following listed natural resources from the catchment are of value both to the ecosystm itself and to the people living in and around the area. How important do you think each resource is, in terms of its value to the ecosystem and to humans respectively-

Resource	Value to the system	Value to humans
1. Dead wood (fuel)	1 2 3 4 5	1 2 3 4 5
2. Fodder	1 2 3 4 5	1 2 3 4 5
3. Dry grass (thatch, fuel)	1 2 3 4 5	1 2 3 4 5
4. Wood (construction timber)	1 2 3 4 5	1 2 3 4 5
5. Wood (furniture)	1 2 3 4 5	1 2 3 4 5
6. Soil quality	1 2 3 4 5	1 2 3 4 5
7. Spring water	1 2 3 4 5	1 2 3 4 5
8. Stream water	1 2 3 4 5	1 2 3 4 5
9. Medicinal plants	1 2 3 4 5	1 2 3 4 5
10. Wood, grass, flowers (as decorative items)	1 2 3 4 5	1 2 3 4 5
11. Any other	1 2 3 4 5	1 2 3 4 5

Q8. The following question is specific to the context of the Lake Nainital. Kindly respond only if you are familiar with the ecosystem.

The following listed resources/benefits from the lake which are of value both to the ecosystem itself and to the people living in and around the area. How important do you think each resource is, in terms of its value to the system and to humans respectively-

Benefit/Resource	Value to the system	Value to humans
1. Water	1 2 3 4 5	1 2 3 4 5
2. Fish	1 2 3 4 5	1 2 3 4 5
3. Aesthetic value	1 2 3 4 5	1 2 3 4 5
4. Ritual and cultural value	1 2 3 4 5	1 2 3 4 5
5. Any other	1 2 3 4 5	1 2 3 4 5

Q9. As a scientist/professional you are aware of the economic importance of Nainital lake and its catchment. You are also aware that at present efforts to manage the lake are in progress. The present expenditure on the upkeep of the lake is Rs.------ annually.

(a) As you live here and observe management efforts in progress, do you think it is - Poor/Adequate/Good/Excellent

(b) If the answer to the previous question falls in the first three, why do you think so? Kindly rank your answers.

- Inadequate funds for maintenance (highest) 1 2 3 4 5 (lowest)

- Mis-management 1 2 3 4 5
- Lack of public support 1 2 3 4 5
- Lack of awareness among general public 1 2 3 4 5
- Any other 1 2 3 4 5

Q10. Should commercial establishments using the available natural resources for their personal benefit be charged for their use (in this case the lake and its catchment) **Y/N**

Q11. As you also benefit, directly or indirectly from the resources of the Lake and its catchment would you be willing to contribute some amount towards its management?
If **Yes**:

- Would you prefer a lump sum payment **Y/N** Amount = Rs._____
- An annual contribution **Y/N** Amount = Rs._____

If **No**, is it due to-(rank reasons in order which best explains your reluctance.)

- Income constraint _____
- Dissatisfaction with present management _____
- Any other _____

Q12. If income constraint is a reason for not contributing, please answer the following-
If your income were increased by Rs 10000/year, would you be willing to contribute? **Y/N**
Amount = Rs._____

Q13. If you find the present management not upto mark, which of the following options would you suggest as an alternative. (Rank them if you have a preference ordering.)

- Another autonomous government body _____
- A local peoples society _____
- A local non-governmental organization _____
- An internationally managed NGO _____
- A local NGO, with monitoring by an international body _____

Appendix 2

Determination of Physico-chemical parameters

1 Biochemical Oxygen Demand (BOD):

A measure of the amount of oxygen removed (respired) from aquatic environments by aerobic microorganisms either in the water column or in the sediments. The parameter BOD uses the maximum rate of O_2 consumption over a 5 day period in the dark at 20 0 to estimate the total amount of "biodegradable" organic matter in the system. Typically too insensitive to be useful for pristine lakes and so is used primarily for wastewater "streams" or systems impacted by organic pollution.

Biological oxygen demand was determined using standard method following APHA (1989). 300 ml of diluted water sample was incubated at 20°C for 5 days in a B.O.D. incubator. Initial and final concentrations were measured using B.O.D. Analyzer Model YSI 5100. The following formula was used:

$$\text{B.O.D. mg/l} = \frac{D_1 - D_2 - (B_1 - B_2)}{p} \times f$$

Where, D_1 = initial Dissolved Oxygen (D.O.) in the sample

D_2 = D.O. after 5 days of incubation of the sample

B_1 = Initial D.O. in blank

B_2 = D.O. in blank after 5 days of incubation

p = decimal fraction of the sample used

f = ratio of blank to sample

2 Bacterial population

Heterotropic bacterial density (HPC) was determined by pour plate technique (Trivedy and Goel, 1986; Benson 1990). The diluted water samples were inoculated in sterilised nutrient agar medium in the sterilised Petri dishes and incubated at 37°C. After 48 hours of incubation the colonies were counted using a colony counter. The total colonies number in 1 ml in original sample was calculated by the following formula:

HPC (CFU/ml) = No. of colonies counted on plate x dilution of sample.

3 PO_4 and NO_3

Phosphorus (P) is the key nutrient influencing plant growth in lakes. Soluble reactive phosphorus (PO_4) is the amount of P in solution that is available to plants. Total phosphorus includes the amount of phosphorus in solution (reactive) and in particulate form.

For the analysis of PO_4-P and NO_3-N Microprocessor based photometer model-YSI-9100 with the direct display was used.

4 Pb Concentration

For determining the concentration of lead (Pb), a heavy metal, 100 ml of water sample was taken in 150 ml conical flask was taken and then added 3 ml concentrated HNO_3 was added and kept overnight. After digestion with HNO_3 one ml perchloric acid was added till a clear solution was obtained. 10 ml of double distilled water was added and left for 24 hours. The solution was filtered through Whatman filter paper No. 40 and was analysed using Perkin Elmer Atomic Absorption Spectrophotometer (AAS-2380). A direct reading of Pb concentration in ppm was obtained.

Appendix 3

Following techniques were used in the PRA exercise:

a. Semi-structured interviewing – participatory method based on open questions and hence, has a great deal of flexibility and further questions can be designed on the spot for probing the issue.
b. Participatory mapping – involves spatial drawing of any area, by local people. Such mapping can be theme specific, such as resource map indicating natural resources of the locality or social map showing households and other buildings.
c. Participatory seasonality analysis – Seasons tend to influence lives and livelihoods of local communities in major ways. Seasonality analysis reflects seasonal dependency of local communities on natural resources and highlight seasonal dimensions. The seasons bring changes in climate and rainfall, soil conditions, days of labour, wages, disease incidence, income and expenditure, etc.
d. Visual analysis methods – Visual methods encourage participation, enable local people to offer their views, facilitate discussions, allow more information at a glance, helps in cross checking and provides a logical framework for description, analysis and assessment of benefits.

Appendix Table 10 Benefit value matrix of Rickshaw-pullers in Nainital

Nature of livelihood	Season	No. of stakeholders	Days employed	Employed @ Rs./day	Total Earning in Rs.
Rickshaw-puller	May-June, Oct	76	90	75	**513,000**
Rickshaw-puller Cat. A	Remaining year	17	270	40	183,600
Rickshaw-puller Cat. B	Remaining year	76	180	40	547,200
From Bihar		40			
From Nepal		15			
From Almora		4			
			Off-peak season total		**7,30,800**
			Grand total		**12,43,800**

Note:
Categories within stakeholder group rickshaw-pullers. All the stakeholders spend their time in Nainital during the peak tourist period during summer and autumn. The description given below is generally in relation to the remaining months of the year.

A. **Permanent Rickshaw-pullers** – Work as Rickshaw-puller throughout the year (23%).

B. **Temporary Rickshaw-pullers** – Work as Rickshaw puller (77%) for 6 months of LTP, and returning to their homes to take up other works such farming.

Rickshaw-pullers
From Bihar-70%
From Nepal-20%
From Almora-5% From Nainital-5% PTP = Peak tourist-activity period LTP = Low tourist-activity period

Appendix Table 11 Benefit value matrix of Horsemen in Nainital

Nature of livelihood	Season	No. of stakeholders	Days employed	Employed @ Rs./day	Total Earning in Rs.
Horsemen	May-June,Oct	164	90	350	**5,166,000**
Horsemen Cat. A	Remaining year	81	270	100	2,187,000
Horsemen Cat. B	Remaining year	81	180	100	1,458,000
			Off-peak season total		**3,645,000**
			Grand total		**8,811,000**

Note:
Categories within stakeholder group horsemen. All the stakeholders spend their time in Nainital during the peak tourist period during summer and autumn. The description given below is generally in relation to the remaining months of the year.

A. Permanent horsemen – Occupied as horsemen throughout the year (50%) at Nainital.

B. Temporary horsemen – Occupied as horsemen (50%) during 9 months of LTP and returning to their home to take up farming during 3 months of LTP (Nov., Dec. and Jan).
PTP = Peak tourist-activity period
LTP = Low tourist-activity period

Appendix Table 12 Benefit value matrix of Boatmen (rowing) in Nainital

Nature of livelihood	Season	No. of stakeholders	Days employed	Employed @ Rs./day	Total Earning in Rs.
Boatmen	May-June,Oct	233	90	400	**8,388,000**
Boatmen Cat. A	Remaining year	58	270	120	1,879,200
Boatmen Cat. B	Remaining year	58	120	120	835,200
Boatmen Cat. C	Remaining year	117	120	120	1,684,800
			Off-peak season total		**4,399,200**
			Grand total		**12,787,200**

Note:

Categories within stakeholder group boatmen. All the stakeholders spend their time in Nainital during the peak tourist period during summer and autumn. The description given below is generally in relation to the remaining months of the year.

A. Permanent boatmen-occupied as boatmen throughout the year (25% of boatmen).

B. Nainital based temporary boatmen occupied as boatmen for four months of LTP (Low Tourist-activity Period), doing other work, such as selling newspapers or driving taxi driving the remaining four months.

C. Outsider temporary boatmen occupied as boatmen for four months of LTP, and returning to their home to take-up other works such as farming during remaining five months; (50% of boatmen).

PTP = Peak tourist-activity period LTP = Low tourist-activity period

Appendix Table 13 Benefit value matrix of Vendors in Nainital

Nature of livelihood	Season	No. of stakeholders	Days employed	Employed @ Rs./day	Total Earning in Rs.
Vendors	May-June,Oct	150	90	200	**2,700,000**
Vendors Cat. A	Remaining year	120	270	50	1,620,000
Vendors Cat. B	Remaining year	30	210	50	315,000
Vendors Cat. C	Remaining year	150	60	200	1,800,000
			Off-peak season total		**3,735,000**
			Grand total		**6,435,000**

Note:

Categories within stakeholder group vendors. All the stakeholders spend their time in Nainital during the peak tourist period during summer and autumn. The description given below is generally in relation to the remaining months of the year.

A. **Permanent Vendors** – Occupied as vendors throughout the year (80% of vendors).

B. **Permanent Vendors** – Occupied as vendors throughout the year (20% of vendors), work in candle factory during winters (3 months).

C. **Outstation seasonal Vendors**- Staying in Nainital during PTP.

PTP = Peak tourist-activity period
LTP = Low tourist-activity period

Appendix Table 14 Benefit value matrix of Coolies in Nainital

Nature of livelihood	Season	No. of stakeholders	Days employed	Employed @ Rs./day	Total Earning in Rs.
Coolies	May-June,Oct	1000	90	150	**13,500,000**
Coolies Cat. A	Remaining year	200	270	70	3,780,000
Coolies Cat. B	Remaining year	800	180	70	10,080,000
			Off-peak season total		**13,860,000**
			Grand total		**27,360,000**

Note:

Coolies are mostly Nepalese from remote districts of Humla and Jumla.

Categories within stakeholder group coolies. All the stakeholders spend their time in Nainital during the peak tourist period during summer and autumn. The description given below is generally in relation to the remaining months of the year.

A. Permanent Coolies – Occupied as coolies throughout the year (20% of coolies) at Nainital

B. Temporary Coolies – Occupied as coolies during 6 months of LTP (80%) and returning to their home to take up farming during 3 months of LTP (July, August and September).
Out of 800 coolies (80%) going back to their home only 100 (12.5%) earn (average Rs.1500/month) during rainy season, others (700) do not earn but do farming at their homes.
PTP = Peak tourist-activity period
LTP = Low tourist-activity period

Glossary of Terms

Compensation level: The depth at which light penetration in aquatic ecosystems is so reduced that oxygen production by photosynthesis just balances oxygen consumption by respiration. Generally this implies a light intensity of about 1 percent of full daylight.

Epilimnion: The upper, warm circulating water in a thermally stratified lake in summer. Usually it forms a layer that is thin compared to the hypolimnion.

Eutrophication: Even pollution that is not toxic can kill. While PO_4-rich detergents are essential to modern living, their use can have harmful effects on aquatic plants and water quality leading to problems such as eutrophication, by causing excessive growth of vegetation. Phosphates and nitrates, usually harmless, can fertilize the algae that grow in lakes or rivers. When algae grow, in the presence of sunlight, they produce oxygen. But if algae grow too much or too fast, they consume great amounts of oxygen, both when the sun is not shining and when the algae die and begin to decay. Lack of oxygen eventually suffocates other life; some living things may be poisoned by toxins contained in the algae. This process of algal overgrowth, called eutrophication, can kill life in lakes and rivers. In some cases, particular algae can also poison the drinking water of people and livestock.

Hyper-eutrophic/ Hypertrophic: A very nutrient-rich lake characterized by frequent and severe nuisance algal blooms and low transparency.

Hypolimnion: The lower, cooler, non-circulating water in a thermally stratified lake in summer. If, as often occurs, the thermocline is below the compensation level, the dissolved oxygen supply of the hypolimnion depletes gradually; replenishment by photosynthesis and by contact with the atmosphere is prevented. Re-oxygenation is possible only when the thermal stratification breaks down in autumn.

Limnology: is the scientific study of the physical, geographical, chemical, and biological aspects of inland freshwater systems. The factors studied in such bodies of water as lakes, rivers, swamps, and reservoirs include productivity, interactions among organisms and between organisms and their environment, characteristics of the water and of the water bottom, and pollution problems.

Meso-eutrophic/ Mesotrophic: Applied to waters having levels of plant nutrients intermediate between those of oligotrophic and eutrophic waters.

Metalimnion: The middle or transitional zone between the well mixed epilimnion and the colder hypolimnion layers in a stratified lake. This layer contains the thermocline, but is loosely defined depending on the shape of the temperature profile.

Oligotrophic: Waters that are relatively low in nutrients and cannot support much plant life.

Secchi disc Transparency: Transparency; routinely estimated by the depth at which you can no longer see a Secchi disk. The Secchi disk is a 20 cm (8 inch)

diameter weighted metal plate with alternating quadrants painted black and white that is used to estimate water clarity (light penetration). The disc is lowered into water until it disappears from view. It is then raised until just visible. An average of the two depths, taken from the shaded side of the boat, is recorded as the Secchi depth.

Thermal stratification: In the water column of a lake, a condition that may develop during the summer in which the thermocline and pycnocline change over a short vertical distance, at the metalimnion. This prevents mixing between the waters of the epilimnion and hypolimnion. It occurs because of the limited depth to which solar radiation penetrates and wind movement mixed the water. There is almost no temperature gradient within the epilimnion, but in the metalimnion it may be up to 1° C/m; temperature is fairly constant throughout the hypolimnion. Photosynthesis occurs in the epilimnion; organisms residing in the hypolimnion subsist on detrital rain falling from the epilimnion, but dissolved oxygen is rapidly used and is not replenished. As solar warming decreased, thermal stratification breaks down, water mixes fully, and the hypolimnion is recharged with oxygen. This is called 'over-turn' and occurs in autumn or winter. Inverse stratification occurs where the epilimnion surface freezes. Dense water at 4°C, sinks to the bottom, and water that is less dense but cooler (about 3.94°C) floats above it. Fish can, therefore, survive the winter in hypolimnion water at temperatures above freezing.

Thermocline: A gradient of thermal change applied more particularly to the zone of rapid temperature change between the warm surface water (epilimnion) and the cooler deep waters (hypolimnion) in a thermally stratified lake in summer.

Plate 1 A view of snowfall. The lake, however, does not freeze.

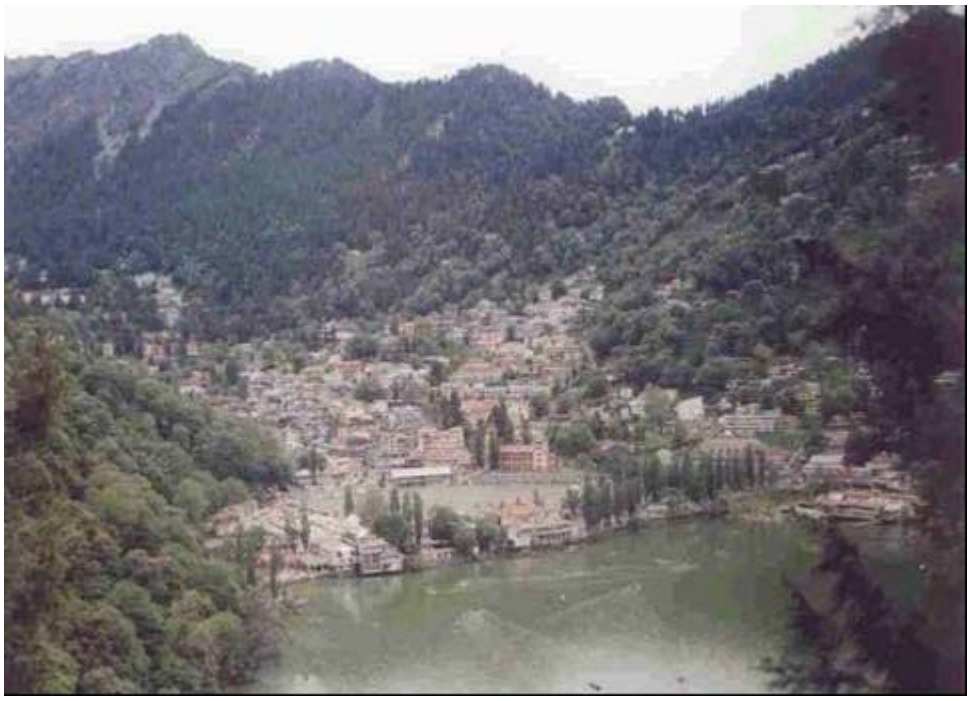

Plate 2 Peaks (the tallest is China Peak, about 2600 m asl) and forest cover are the main features of the watershed. The forest of around China Peak (conspicuously bald) is of cypress (*Cupressus torulosa*) and that in the foreground on the two sides are of oak (*Quercus* spp.). The bare slopes on the right side are the site where the massive landslides of 1880 occurred. The base of hill on the south-west side is one of the major constructed areas.

Plate 3 Boating is still a common recreational activity (swimming and fishing are no more in practice due ban).

Plate 4 Car parking in “flats” near the west-end of Lake Nainital during the peak tourist period.

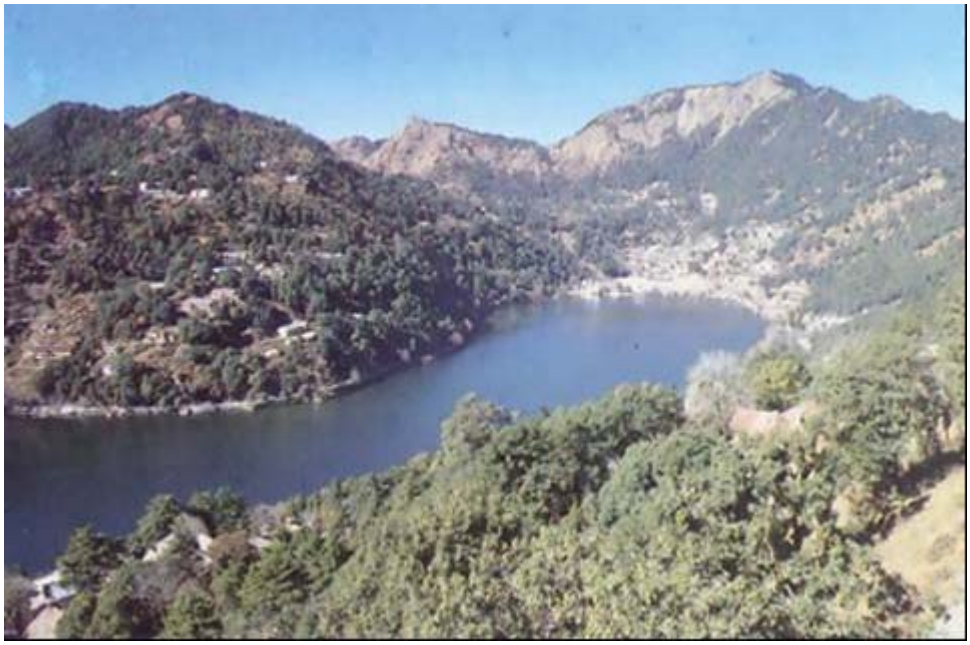

Plate 5 An overview of the kidney-shaped lake and its watershed.

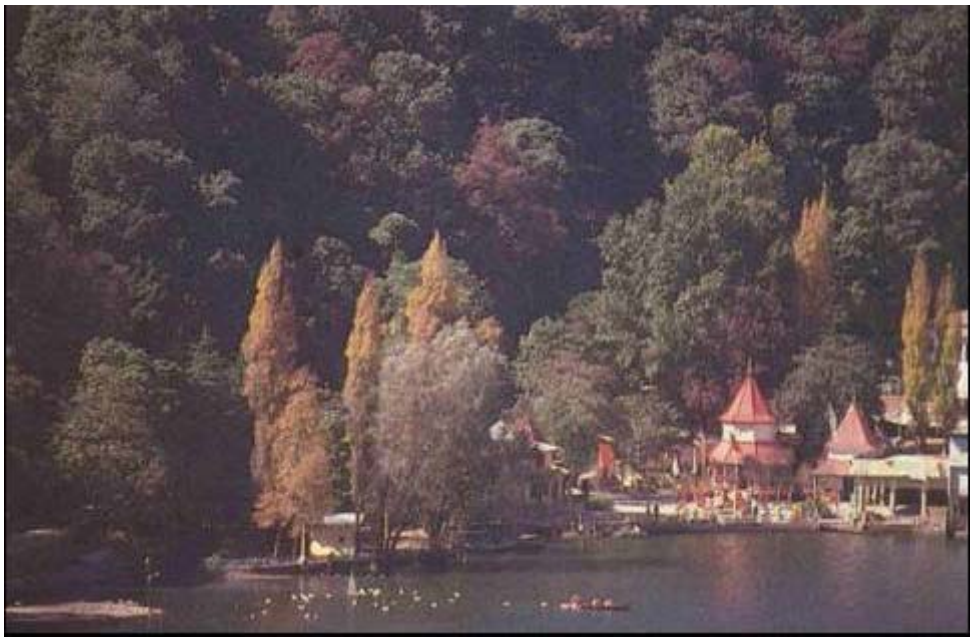

Plate 6 A view of the temple (at the west end of the lake) and land formed near it due to the silt deposition through the temple drain the largest drain feeding the lake. Ducks are seen in the foreground.

Plate 7 Removal of silt and soil from the island formed near temple, along the principal drain.

Plate 8 Removal of silt and soil from the island formed near temple, along the principal drain.

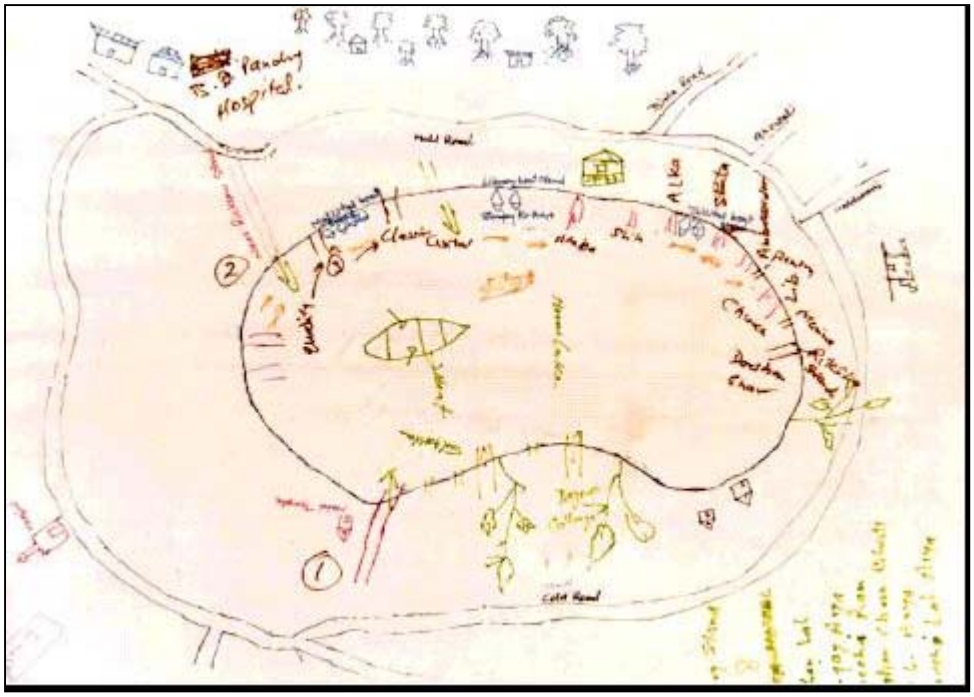

Plate 9 A map drawn by subgroup of boatmen comprising of 4 individuals who are most connected with the lake.

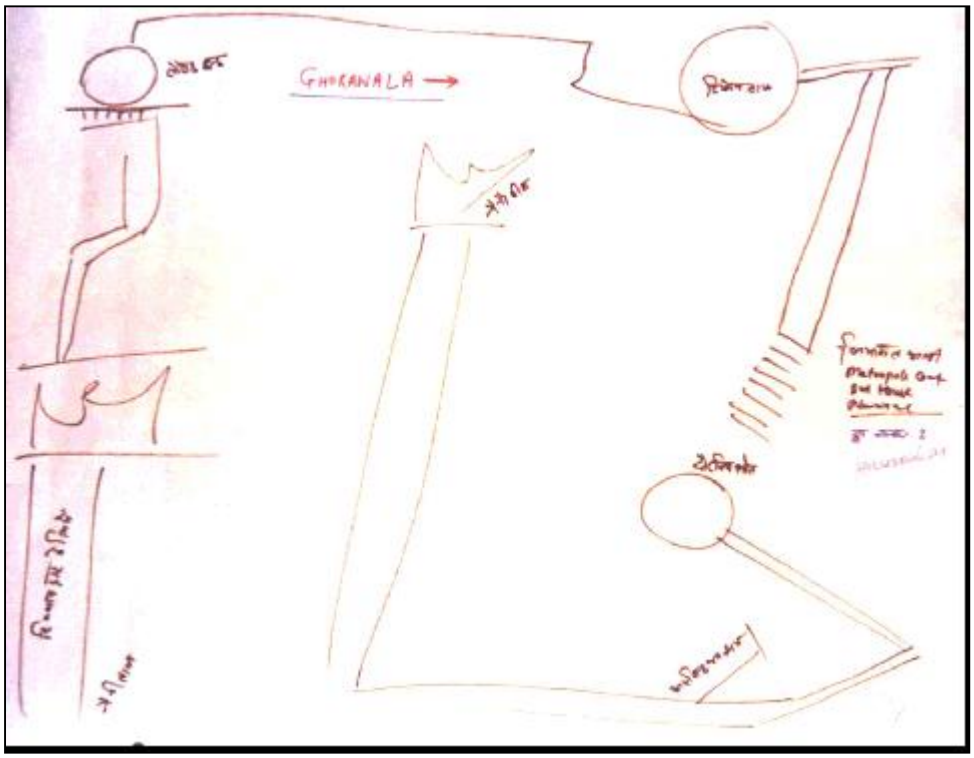

Plate 10 A map drawn by subgroup of horsemen comprising of 4 individuals who are least connected with the lake.