ANTHROPOGENIC IMPACTS ON THE NATURAL ENVIRONMENT OF NAINITAL TOWN

DISSERTATION THESIS

By

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For the fulfillment of the requirement for the degree of
Masters of Science in Environmental Science
(Natural Resource Management)
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CERTIFICATE

This is to certify that this dissertation report entitled **Anthropogenic Impacts on the Natural Environment of Nainital Town** submitted to Doon University Dehradun in the partial fulfilment for requirement of degree of Master of Science in Natural Resource Management. The work is compilation of bonafide and original work completed by **Akansha Joshi.**

The work has been carried out under the supervision of Dr. Suneet Naithani, Assistant Professor, School of Environment of Natural Resources, Doon University, Dehradun. The candidate has fulfilled all prescribed requirements for the thesis, which is based on candidate's own work and has not been submitted elsewhere.

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This is to certify that **Ms. Akansha Joshi** has carried out her dissertation project in partial fulfilment of the requirement of the degree Master of Science in Natural Resource Management on the topic "**Anthropogenic Impacts on the Natural Environment of Nainital town"** from **January 2017 to June 2017** at the Centre for Ecology Development and Research, Dehradun.

It gives us extreme pleasure to state that Akansha has very diligently carried out all the work that was assigned to her. We have witnessed a very positive growth in her personality, professional development and skill set. Akansha's decorum both in the office and in the field has been of high standard. We hope that the experience she has gathered here will hold her in good stead in her work elsewhere. We would like to wish her the best in her future endeavours!

Vishal Singh
(External Supervisor)

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I am extremely grateful to my family for their unconditional love, especially my father and sister for helping me in the field work and my mother for always being there with me.

DECLARATION

I declare that the dissertation work entitled "Anthropogenic Impacts on the Natural Environment of Nainital Town" submitted by me, Akansha Joshi, for partial fulfillment for the award of the M.Sc. Environmental Science (Natural Resource Management), is my own work. This work has not been submitted for any other degree/certificate in any institute/university, what so ever.

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Chapter 1 INTRODUCTION

"*A gem in perfect setting, this charming lake resort with its graceful willows encircling the emerald mountain lake. During the day, the city with brightly colored villas, bungalows, ponies, rickshaws and sail boats beckons the visitors to discover the town in a special way. And as the sun sinks behind the mountains, the hill station turns into an enchanting, alluring fairyland. The lake reflecting the row of lights dancing in the water weaves a mysterious fantasy. That is how is Nainital- the lake town.***"**

-Giri Raj Shah

The hill station of Nainital is the creation of the British. The individual history of Nainital can be traced from the year 1834, though the first recorded discovery of Nainital was made on 18th November 1841 by Peter Barron, a European merchant from Rosa, near Shahjahanpur, who had been touring in the Kumaon hills with his two companions (Shah 1999). Barron in his book **"Notes of Wandering in the Himmala"** however mentions that Mr. Traill, the commissioner of Kumaun was the first European to visit the site in 1817.

The legend behind the name- According to the 'Manas Khand' of the ancient Hindu scripture 'Skanda Purana', the place was known as ***Tri-Rishi Sarovar,*** named after the three sages Atri, Pulastya and Pulaha.Tri means 'three', Rishi means 'Sage', and Sarovar means 'Lake'. The legend says that on their way for pilgrimage to Chitrasila the sages reached this place and started looking for water to quench their thirst. On finding no water they dig a large hole and prayed to Lord Brahma for water who filled it from the Mansarovar(the sacred lake of Tibet), thereby giving rise to the lake. Another legend says that Goddess Sati was very angry with her father King Daksha for not inviting her and her husband Lord Shiva to a sacrifice in honour of the gods. She took it as an insult and leapt into the sacrificial fire. While the grieving Lord Shiva was carrying her half-burnt dead body to Mt. Kailash, her left eye dropped at a place known as "Smugglers' Rock" and forthwith ***goddess Narayani*** sprang up. The lake became her abode and she is supposed to live at the bottom of the lake. Thus the lake got its name Nainital, as Nain means 'an eye'.

Kumaon division was under Gorkha rule till 1803. It was acceded to British rule in 1815. Nainital was an unpopulated forested area with Nanda Devi temple at Mallital and known only to local tribal 1841 – 1900. Nainital was discovered by European merchant P.Barron in 1841. Pilgrim lodge was the first building to be constructed. Nainital Nagar Palika Parishad was established in 1845 and many of important buildings came up during this period. 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 (Fig 1). The landslides of 1880 on the slopes of China Peak (also known as Naina Peak) caused substantial damage and created Flats ground on Mallital, which is used as public space for residents and tourists in the present times. Nainital District was created in 1891. Boat Club house was built in 1897. During the 1900s it became the Eastern command army headquarters and summer capital of Northwest Province. After it was made the summer capital, a remarkable expansion of the town occurred with the growth of magnificent bungalows, construction of facilities such as marketing areas, rest houses, recreation centres, clubs etc together with the secretariat and other administrative units. It also became an important centre of education for the British. The 36 km long Kathgodam – Nainital road was completed and also electric supply came to the town. Almost 925 buildings were constructed during this period.

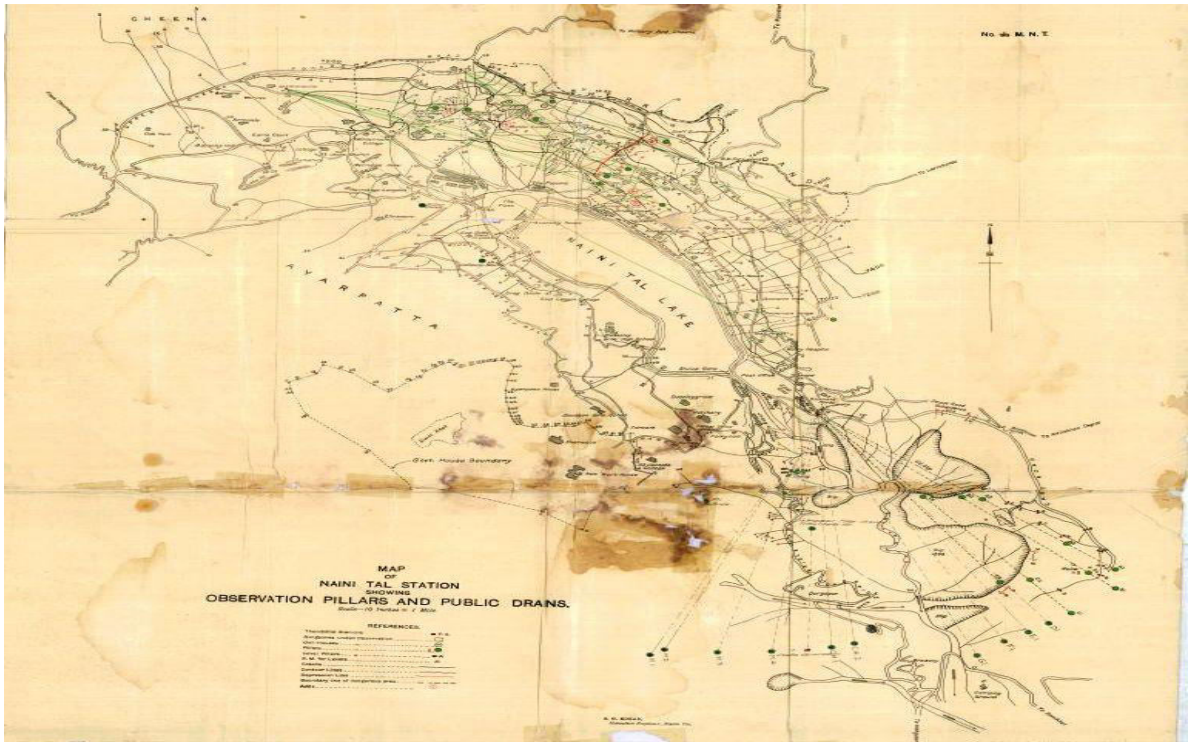


Fig 1. Drainage map of Nainital circa 1919 (Source: Nagar Palika, Nainital)

After independence, Nainital continued to function as UP Government's summer capital. The towns' growing popularity as tourist centre spurted construction of numerous hotels along Mall Road and Sher ka Danda area. The Greater Nainital Development Authority (GNDA) was established in 1984 to regulate development of the town. In 1989, GNDA was dissolved and Nainital Lake Region Special Area Development Authority (NLRSADA) was established. The

year 2000 saw the creation of Uttarakhand State and the setting up of the High Court in Nainital (Source: CEDAR- ESPA Water Security and Livelihoods in the Himalayas Project).

The township of Nainital is located in close proximity of a major regional tectonic discontinuity of the Himalayan orogen; the Main Boundary Thrust (MBT) along which the Lesser Himalayan meta - sedimentary rocks override the sedimentary rocks of Siwalik Group. This tectonic boundary is recognised as being seismically active and this fact enhances vulnerability of the township of Nainital. Rocks of Lesser Himalaya are observed to be exposed in the area around Nainital. To the west of the lake most exposures are of calcareous rocks and these have been subject to erosion by the action of water. Formation of sink holes and cavities and their subsequent slumping has given this area its peculiar geomorphic signature. In many areas the rocks are observed to be slumped and dislodged and have a number of joint and fracture sets. These pose threat of rock fall in many areas and such incidences in the past have taken toll of human lives. Towards the east of the lake the rocks are predominantly shales and slates that are highly fissile. The slopes on this side of the lake also show evidences of creep and enhanced pore water pressure during prolonged rains can trigger large scale mass movement. The township has so far not been affected by any major seismic tremor. The area however falls in Zone IV of Earthquake Zoning Map of India (IS 1893, Part 1, 2002) and there exist records of ground fissures and cracks being observed in the city during earthquake events in the past. The township of Nainital has witnessed massive mass movements in 1867, 1880, 1893, 1898, 1924, 1989 and 1998.

The area around Nainital is observed to be dissected by several ridges and the ground elevations vary between 1694 to 2611.5 meters above mean sea level (msl). Naini peak (earlier known as China peak) with height of 2611.5 meters above msl is the highest point of the area while Sher ka Danda, Deopatha and Ayarpatha respectively have altitude of 2402, 2435.1 and 2352 meters above msl. Naini and Khurpatal lakes respectively have elevations of 1935.5 and 1570 meters above msl. The area is prone to landslides due to high relief, presence of overburden and high precipitation.

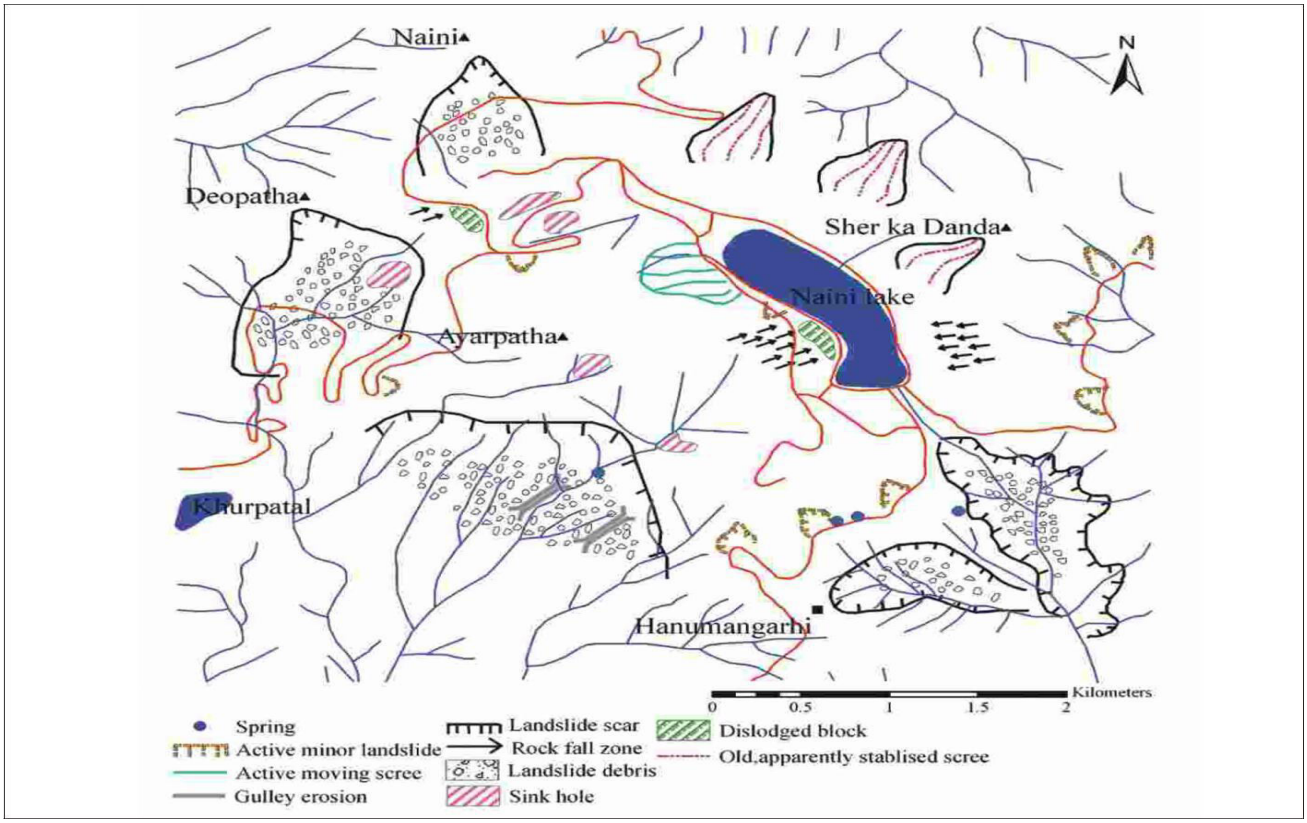


Fig. 2. Map showing important geomorphic features in the area around Nainital (Source: DMMC 2011)

General lithostratigraphic succession of the area in and around Nainital is as given in Table 1.

Table 1: Lithostratigraphic succession in and around Nainital.

Group / Formation	Lithology
Siwalik Group	Sandstone and shale
	MBF/ Krol Thrust
Tal Group	Carbonaceous pyritic shale with subordinate grey stromatolitic limestone,

		purple shale and siltstone interbedded with fine grained brownish to muddy sandstone and mudstone
Krol Group		**Unconformity**
		Red, purple and black shale, light yellowish, green - grey and light brown calcareous slate, massive grey and blue dolomitic limestone and argillaceous limestone with greywacke and purple and brown siltstone with subordinate slate of same colour and muddy fine grained Sandstone
Baliana Group	**Infra Krol Formation**	Purple slate associated with ash - grey and black shale with limonitic staining
	Blaini Formation	Conglomerate associated with purple slate, sandstone and dolomitic limestone. The pebble to cobble sized, rounded to sub rounded clasts of quartzites, slates and dolomites are embedded in the matrix of green to brownish sandstone or limestone

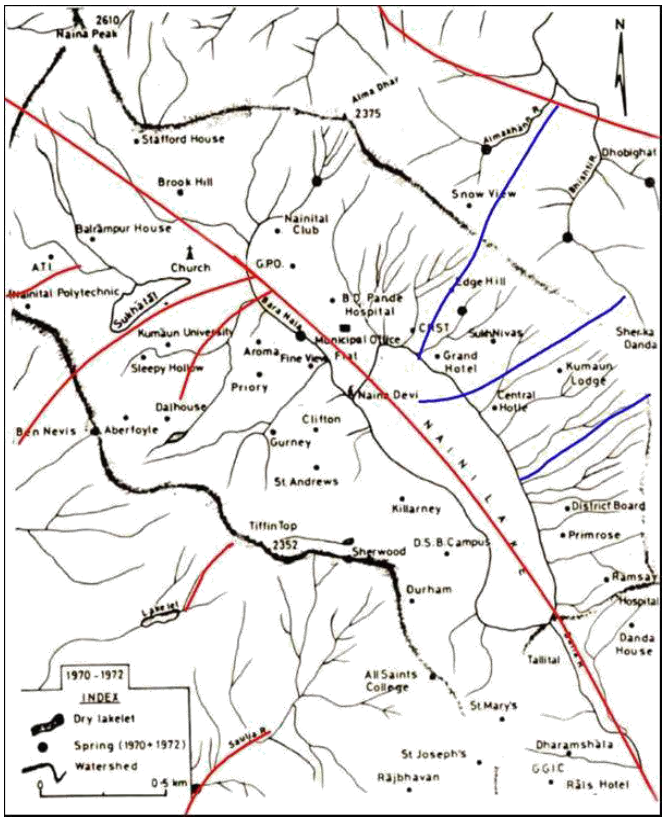


Fig.3 Drainage map of Nainital catchment (Source: Valdiya 1988) (Major faults have been represented by red lines and fractures by blue lines)

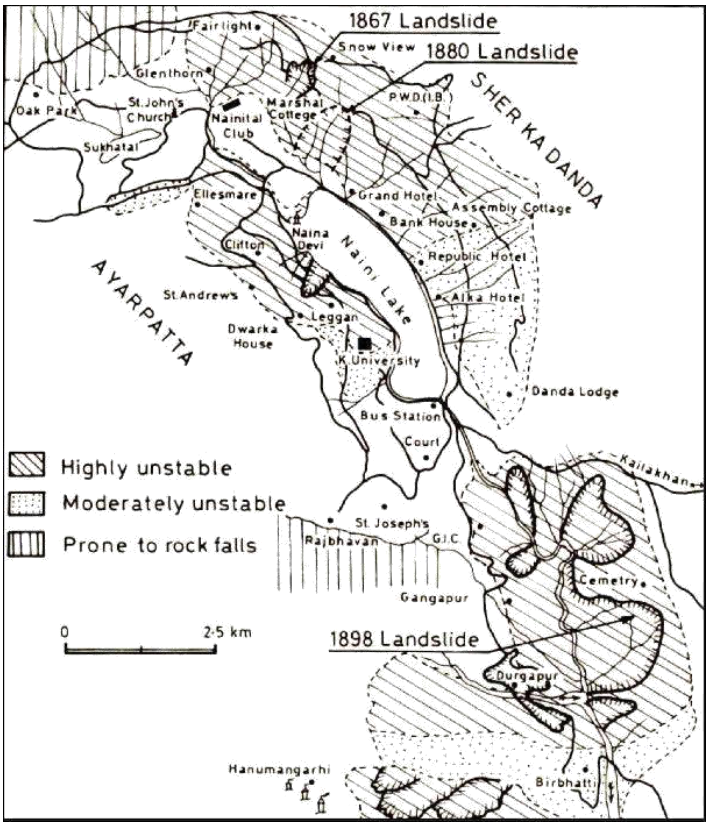


Fig.4 Hazard zoning map of Nainital catchment (Source: Valdiya 1988).

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.

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.

There are about 700 plant species in the catchment (EERC: WB-8). 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, *Strobolanthesglutinosa*; paderiya-lahsan, *Allium wallichianum*; and a dwarf bamboo, *Arudinaria falcata*.

Nearly 200 bird species occur in and around Nainital (EERC: WB-8). Black vulture (*Otogypuscalus*), 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 (*Hypopicus hyperythrus*) have been found here. Of the Cuculidae or cuckoos, the European cuckoo (*Cucculus canorus*) and the pied crested cuckoo (*Coccystesmelanoleuces*) have been spotted. Of the Nectarinidae or sun-birds the purplehoney-sucker (*Archnechira asiatica*), the Himalayan tree creeper (*Certhiahimalayana*), the white-tailed nuthatch (*Sitta himalayensis*) and the Europeanhoopoe (*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 birdwatching in Nainital.

As per the 2011 census the population of the town is 42,775 with a floating population between 5-7 lakh every year. Approximately 21% of the total population of the city fall below poverty line (CEDAR- ESPA Water Security and Livelihoods in the Himalayas Project).

Table 2: Population of Nainital Town 1901-2011

S.No.	Year	Popoulation	Growth rate
1	1901	6903	0
2	1911	10270	48.77
3	1921	11230	9.35
4	1931	9741	-13.3
5	1941	9539	-2.07
6	1951	12350	29.47
7	1961	14495	21.42
8	1971	23986	59.96
9	1981	24835	3.54
10	1991	29837	20.14
11	2001	38630	29.5
12	2011	41377	7.11

Source: censusindia.gov.in

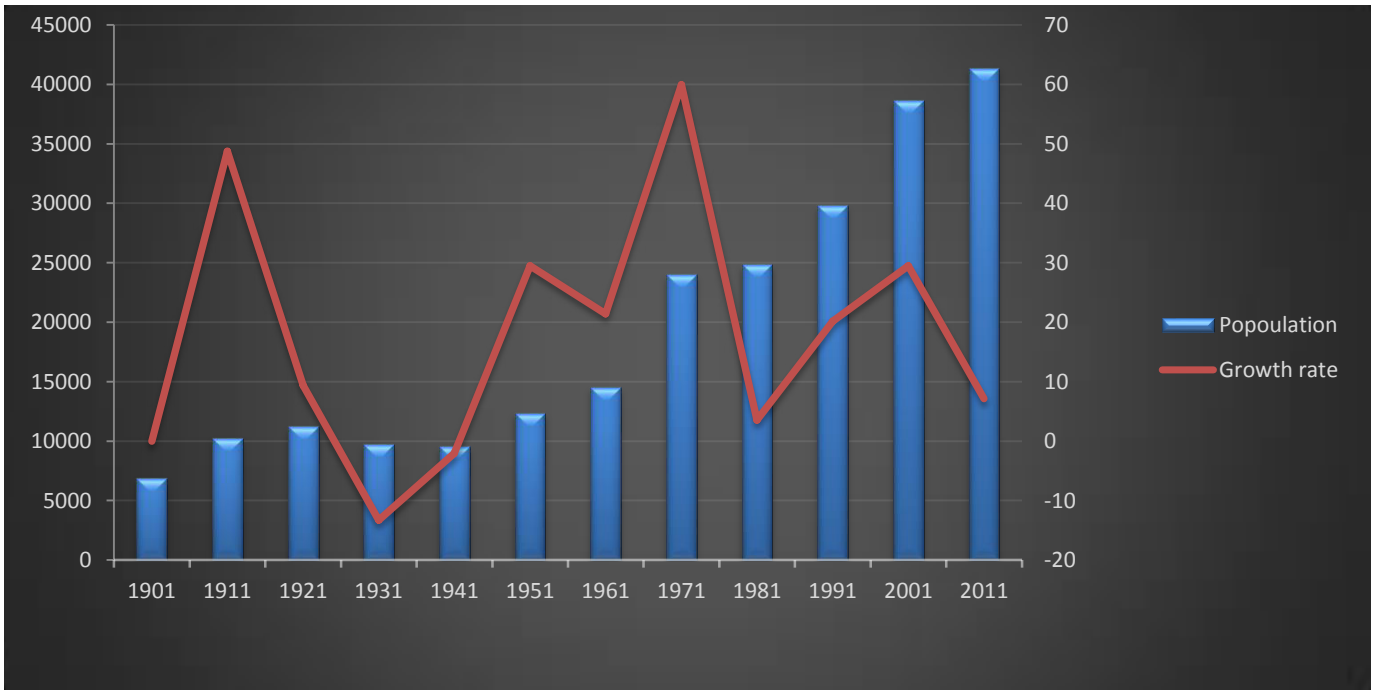


Fig. 5: Graph showing population trend of Nainital town 1901-2011

Nainital has been a tourist destination ever since it was discovered in the mid-nineteenth century. The influx of tourists in the region, of which the majority arrive in the summer months, has been estimated to be as much as 400,000 per year (Gopal, Singh, 2002).This degree of oscillating population has put massive strain on Nainital's infrastructure leading to significant water quality degradation, vehicle congestion on the roads and unregulated urban sprawl. 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.(EERC: WB-8).

There rests a lake in the middle of the town. The lake, a kidney shaped water body, is a big tourist attraction as well as a source of drinking water. It is fed by around 20 water channels. Only 2 of them are perennial open drains. Besides these surface drains, internal and underwater **springs** also feed into the lake at several locations. To regulate the water level in the lake particularly during the rainy season, a dam has been constructed at the lower end of the lake. Excess water is discharged from the dam through 5 sluices, which then joins the Balia River (Dash et al. 2008).

Chapter 2 LITERATURE REVIEW

Shah, et al, (2009) studied the impacts of human activities on the Nainital catchment area. The impacts of these pressures are felt in varied ways and from varied sources. During the few decades increasing local population 6903 (1901) to 38559 (2001) and the logarithmic increase in tourist influx into the watershed has effected the water resources and biodiversity of the area. A significant number of water resources have dried up in the past two to three decades. The study is an attempt to document and relate the population rise and increase in the jungles of concrete in the past 50 years in the Nainital catchments to its impact on the forest cover forest density, biodiversity and water resources. Certain herb and shrub species that were abundant in the oak forests (*Q. leucotrichophora* and *Q. floribunda*) have now disappeared. In Nainital catchment area in un-disturbed sites the tree richness is 11, shrub richness is 19 and herb richness is 51, whereas in disturbed forest the richness is declining and is 7 for tree species, 19 for shrubs and 31 for herb species. The study is important as it indicates the changes that are occurring in forests that are degrading because of relentless biotic pressure.

O'Hanlon (2014) provided evidence to support the theory that continued construction and material dumping directly onto the Sukhatal 'Dry' Lakebed has caused a reduction in the maximum volume of the Sukhatal Lake and the rate of sub---‑ surface flow between the Sukhatal Dry Lake and the Nainital Main Lake in the Uttarakhand State of India. This report has demonstrated that anthropological presence, including uncontrolled construction and the dumping of waste material, has caused a significant volume reduction of the Sukhatal Lakebed. A sustainable solution must be found to prevent further degradation of the Sukhatal Lake area. If construction and waste dumping continues at the current rate, recharge from Sukhatal to the aquifer that provides drinking water for the local community will continue to diminish. The community of Nainital rely heavily on the sub---‑ surface recharge from Sukhatal Lake to provide potable water that is abstracted from both the aquifer that lies between the Sukhatal and Nainital Lakes and from Nainital itself.

Dash, et al, (2008)analyzed the water samples from the lake and tube-wells in monsoon and non-monsoon periods from 1997 to 2006. Total dissolved solids, EC, alkalinity and hardness were found to be marginally greater in tube-well waters. The difference in hydro-chemistry of tube-well water was mainly due to variation in flow regimes during monsoon and non-monsoon periods. Results clearly indicate that lake water as such is not potable as it contains unacceptable levels of organic matter in terms of COD (~44 mg/L), coliforms (~15.6× 10^4 MPN/100 mL) and nutrients. Coliform bacteria and COD have not been detected in any of the tube-well water samples over the years. Lake water, treated by sand filters did not conform to drinking water standards. These investigations have led to the closure of the treatment facility and installation of two tube-wells in addition to the existing five tube-wells.

Gupta, et al, (2008) studied the water chemistry of Nainital lake and analzed that the lake has become eutrophic. The paper provides information on the water quality of the lake during 2006 at various depths wit the main objective of presenting the baseline data before the proposed hypolimnetic aeration to restore the lake. It was also observed that the water was hard and the concentration of dissolved oxygen in epilimnion was high but hypolimnion was anoxic almost for the whole year.

Gupta, et al, (2010) studied the heavy metal pollution status of Nainital lake and analyzed 48 samples of water collected from different depths. The results of the study suggested that concentration of all the analyzed metals were within the prescribed limit of WHO and Indian Standard Drinking Water Specification.

Chapter 3 METHODOLOGY

1) **Study Area-** Nainital town 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 existence of a kidney bean shaped lake is the most prominent feature of the town.

Presence of 100 m wide ridge in the middle divides the lake into two parts with different maximum depths (Table 3).

Table: 3 Morphological features of Lake Nainital

a)	Maximum Length (m)	1423
b)	Maximum Width (m)	253-423
c)	Maximum Depth (m)	27.3 in Northern half 25.5 in Southern half
d)	Mean Depth (m)	18
e)	Surface Area (ha)	48
f)	Watershed Area (km^2)	5

Source: (EERC: WB-8)

The lake is of monomictic type and the water retention time of lake Nainital estimated by isotopic mass balance, chloride mass balance and conventional water balance methods is about 1.93, 1.77 and 1.92 respectively (Niclhapan and Kumar 2002)

STUDY AREA

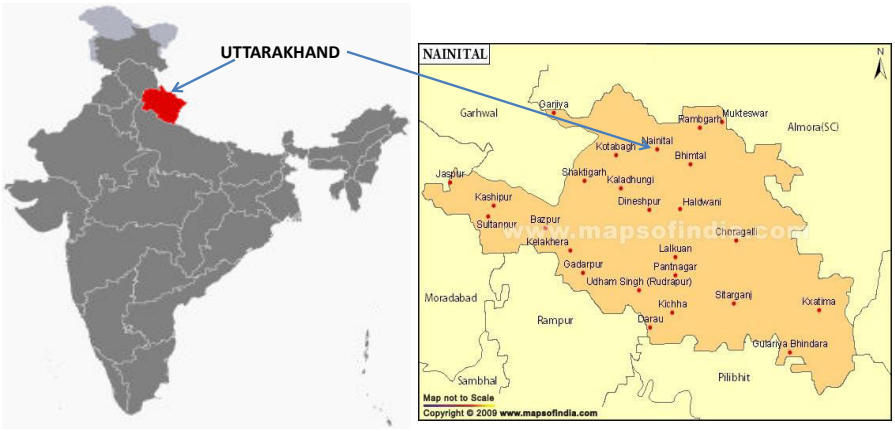
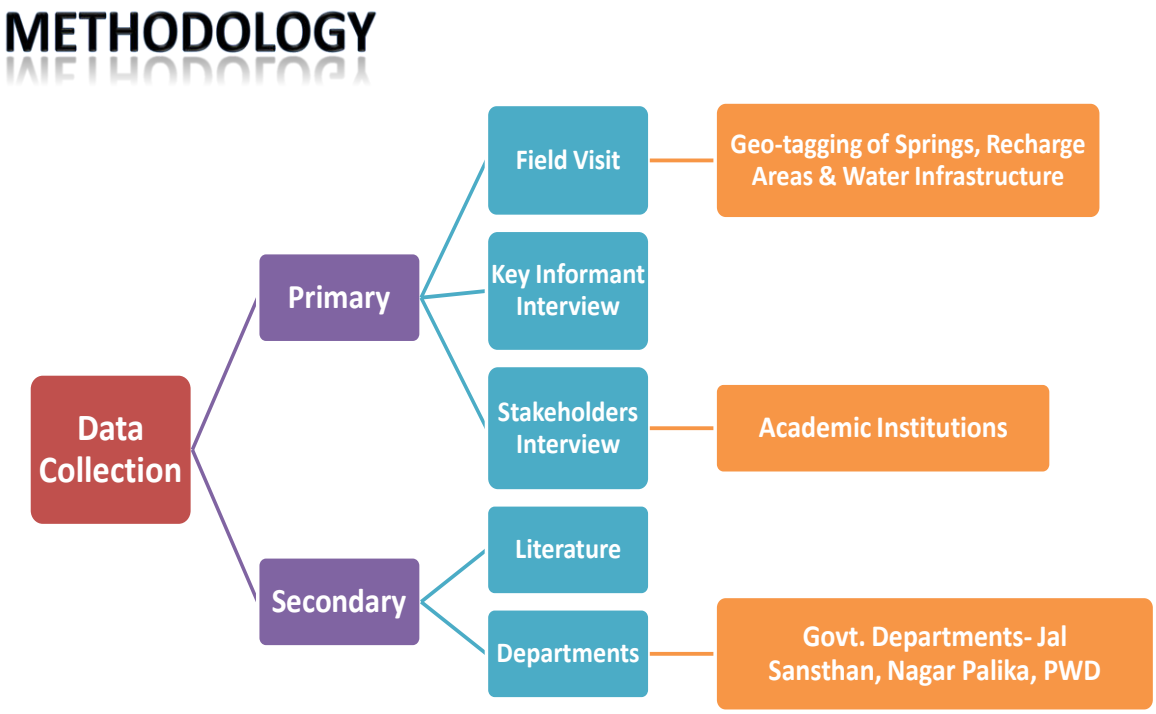


Fig 6: Location map of Nainital town (blue colour showing the municipal boundary)

2) Data Collection-



Data collection was done by two methods- primary and secondary.

Primary Data Collection- This included field visit, in which the springs, recharge areas and water infrastructure of the town were geo-tagged and demarcated with the help of a GPS device. Also, interviews of the key informants and stakeholders (from various academic institutions) were also taken.

Secondary Data Collection- This included review and analysis of different scientific literature and data collection from various government departments (Jal Sansthan, Nagar Palika, Pump houses and PWD).

Formats of Spring Water Inventory and Water Consumption Inventory Questionnaire Used in the Field:

SPRING WATER INVENTORY QUESTIONNAIRE

A. General Questions:

1) Name/Location of spring:
2) Ward no. :
3) GPS location of spring: N- E- Elev. (m)-
4) For how many years you have been residing here?
5) Nature of spring: perennial/ seasonal/ dry
6) Type of primary water supply used (presently): pipeline/ spring water
7) If pipeline supply, then for how many years you have been using it?
8) Name of the person interviewed:
9) Sex: M/F

B. Dependency on the spring source:

1) Your dependency on this specific spring source?
    1- No dependence
    2- Very low dependence
    3- Low dependence
    4- Moderately dependent
    5- Highly dependent
2) If you are dependent, then for what purpose you collect the water?
3) How many times in a day water is collected?
4) How many days in the week water is collected?
5) For how many years have you been collecting water from this spring source?
6) On a scale of 1-5, what is the condition of the following:
    1= fair
    2= good
    3= very good
    4= poor
    5= very poor

source spring-
collection tank/s (if any)-
#Note: Mention the reason if the condition is poor or very poor:

7) Distance between your house and the spring?

C. Quantity:

1) Perception on spring discharge over the year (presently)-Maximum Discharge Months:
    Minimum Discharge Months:

2) Has the spring discharge changed over past 5/10 years:

a. increased b. decreased c. no change

3) If the quantity has changed, what were the reasons?

D. Quality:

1) Perception on quality of spring water (presently)-

2) Has the quality of spring water changed over the past 5/10 years?

a. Improved b. Declined c. No change

3) Do you treat this water before using?

4) If the quality has changed, what were the reasons?

E. Additional/Other Available Sources of Water:

1) In the past 5/10 years have you changed the source from which you collect water?

a. Yes b. No

2) If yes, then why?

3) Apart from this primary spring source do you also get water from other spring sources?

a. Yes b. No

4) If yes, name these springs:

F. Water Scarcity and Water Crisis Perception:

1) Overall, do you think there is a water crisis/problem in your locality?

a. Yes b. No

2) If yes, what are the best practices you/community/government has adopted to cope up with water scarcity?

3) Any suggestions on how to improve the water supply from existing springs?

WATER CONSUMPTION INVENTORY QUESTIONNAIRE

1) Name of the school:
2) Area/Ward no. :
3) Name/ Designation of the person interviewed:
4) Total no. of students:
   4.1) No. of residential students: 4.2) No. of non-residential students:
5) Total no. of staff:
   5.1) No. of residential staff: 5.2) No. of non-residential staff:
6) Water storage capacity:
7) How many times a day the water tanks are filled?
8) Any additional water storage facility?
9) Overall quality of water:
10) Is the drinking water treated before consumption?
11) If yes, then type of treatment:
12) If R.O. is used, then how many?
13) Type of toilets:
   13.1) No. of western toilets: 13.2) No. of Indian toilets:
14) Type of laundry system: In-house/Outside
   14.1) No. of times laundry done in a week:
15) Grey water drainage system:
16) Time period/Months when there is least no. of students and staff:
17) Water consumption per day:
18) Is the overall water demand being met?
19) Is there any water crisis/problem in the school?
20) Is any water conservation technique being practiced in the school?
21) Any water conservation awareness activity/workshop held in the school:

Some Glimpses of the field:

Springs

Recharge Areas

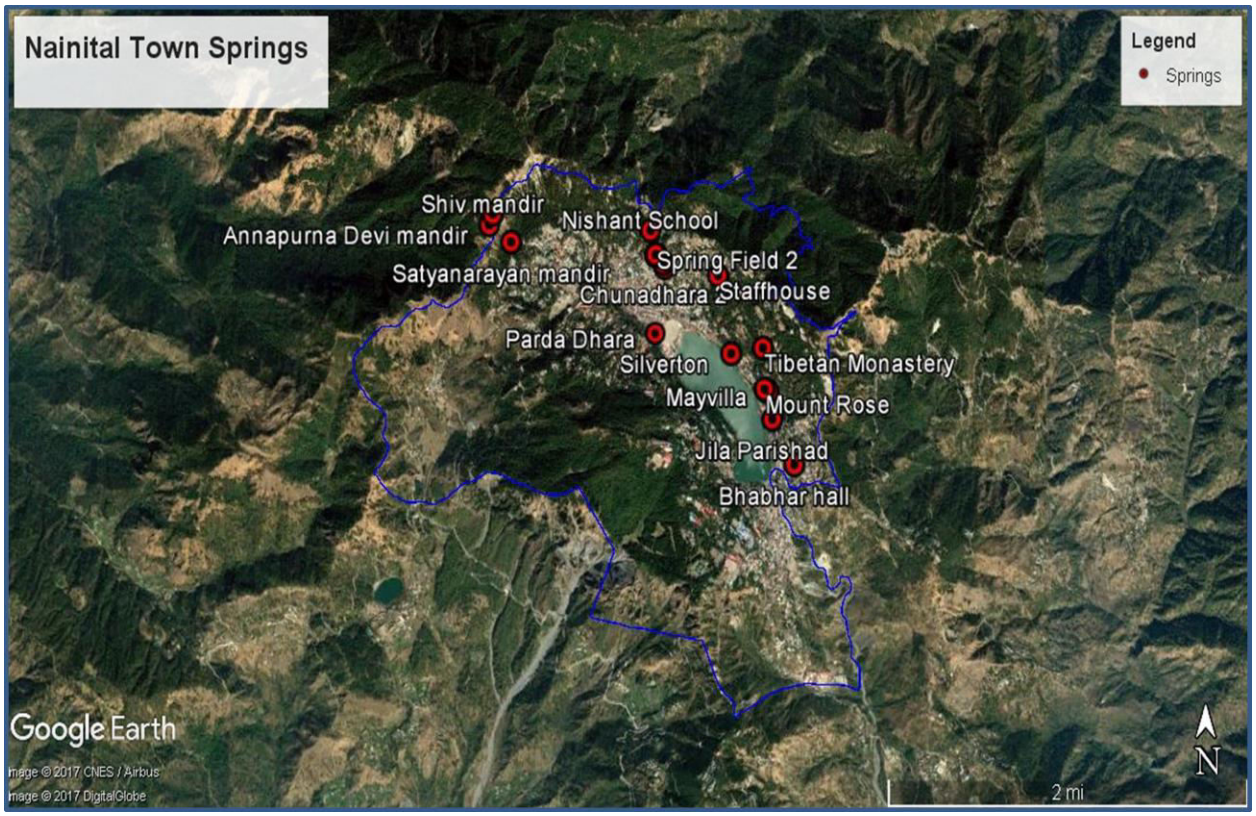
Water Infrastructure

Pump Houses

Chapter 4 RESULTS & DISCUSSIONS

1) **Identification & Geo-tagging of Springs-**In Nainital catchment area the following 20 springs were identified**:**

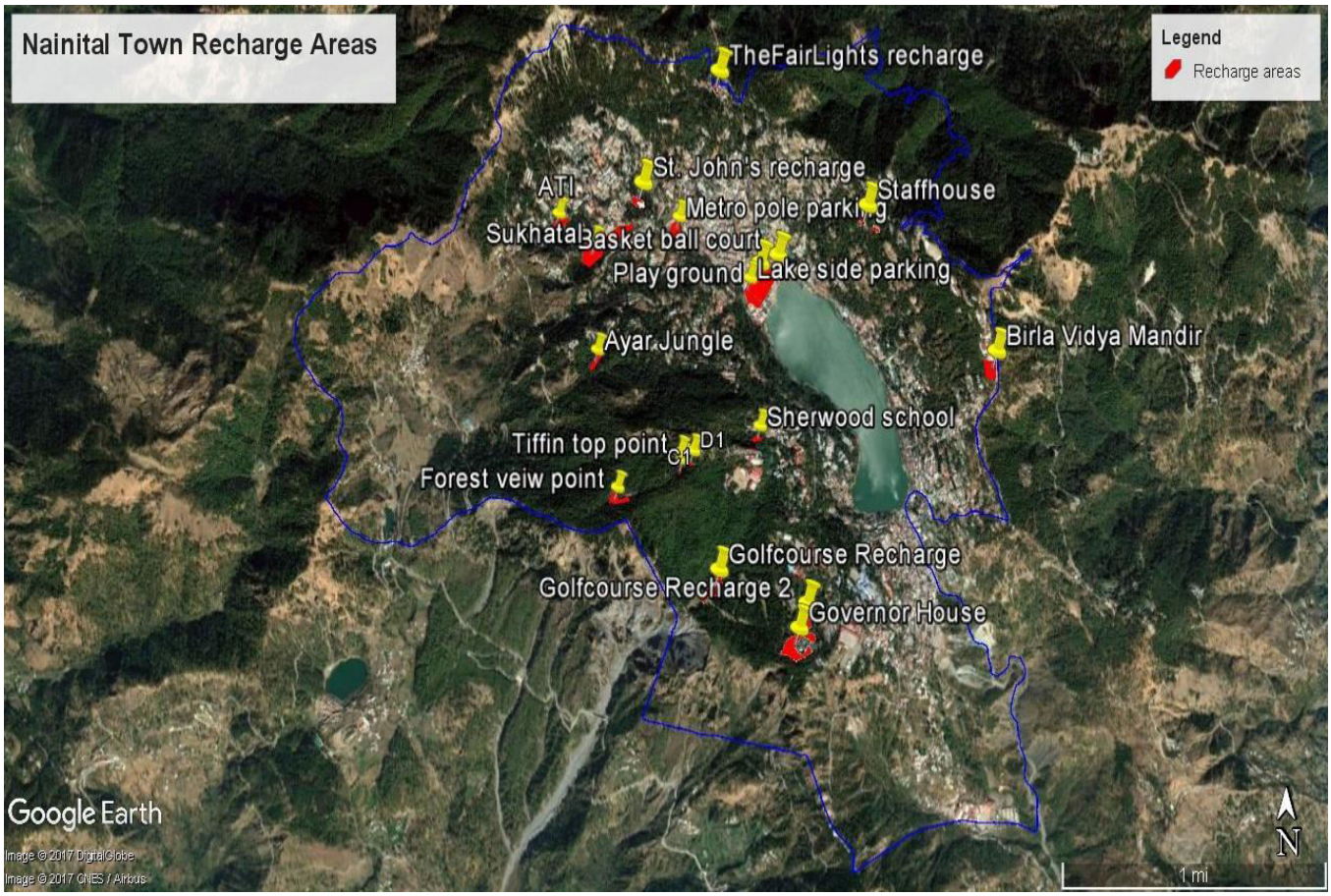
1) Spring Field (3 springs) 2) Chunadhara (2 springs) 3) Pardadhara 4) Annapurna Devi Mandir Spring 5) Shiv Mandir Spring 6) Satyanarayan Mandir Spring	7) Nishant School (3 springs) 8) Staffhouse Spring 9) Bhabhar Hall Spring 10) Jila Parishad Spring 11) Mount Rose Spring 12) Mayvilla Spring 13) Hotel Silverton Spring 14) Tibetan Monastery (2 springs)



2) **Identification, Geo-tagging & Demarcation of Recharge Zones-** On the basis of literature and geological analysis total 15 probable recharge areas were identified**:**

1) The Fair Light Hotel Parking 2) Staffhouse * 3) Birla Vidya Mandir 4) Golf Course * 5) St. John's Church 6) Governor House 7) Tiffin Top * 8) Forest View Point	9) Sherwood School Parking 10) Ayar Jungle 11) Sukhatal- largest recharge area 12) ATI 13) Metropole Parking 14) Flats 15) Sleepy Hollow

#Note- (*) signifies more than one recharge grounds



S.No.	Name	Area (square metre)
1.	The Fair Light	688
2.	Staffhouse *	1,691
3.	Birla Vidya Mandir	6,155
4.	Golf Course*	15,707
5.	Governor House	15,546
6.	Forest View Point	3,162
7.	Tiffin Top*	812
8.	Sherwood parking	945
9.	Ayar Jungle	3,078
10.	Sukhatal	21,467
11.	ATI	3,860
12.	Metropole	3,793
13.	Flats	22,163
14.	St. John's	2,315
	TOTAL	**1,01,382**

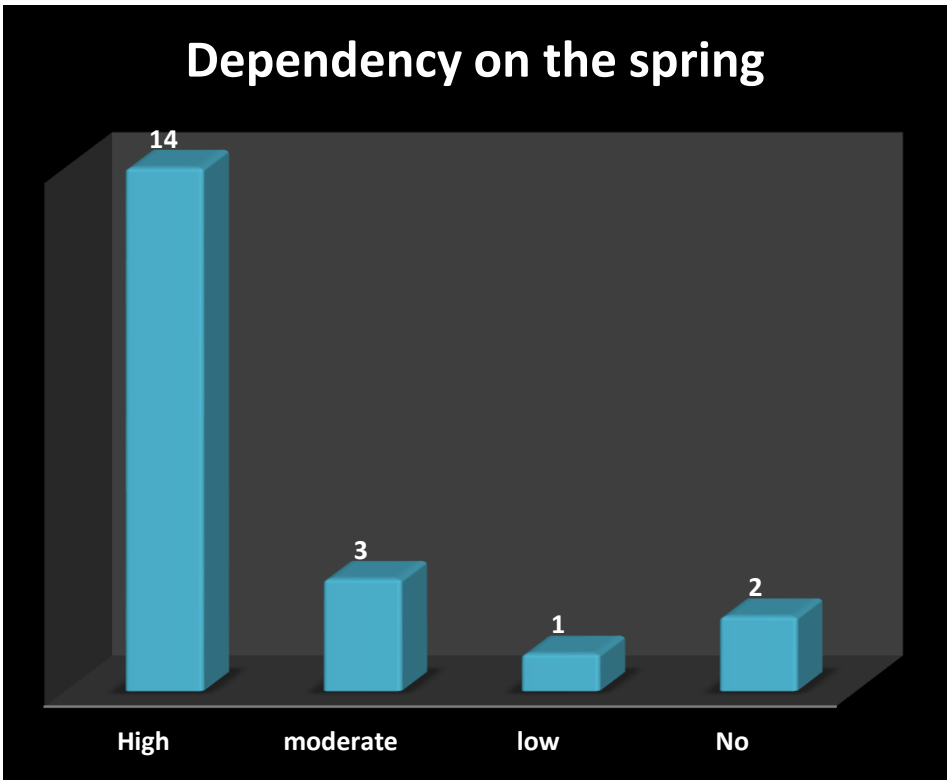
It was analyzed that 14 recharge zones cover a total area of **1,01,382 m^2**or **10.1382 ha** or **25.05 acre** (approx.).

#Note- area of Sleepy Hollow recharge zone could not be calculated.

3) **Status of Springs-** Out of 20 identified springs- 15 are perennial, 4 are seasonal and 1 is completely dry.

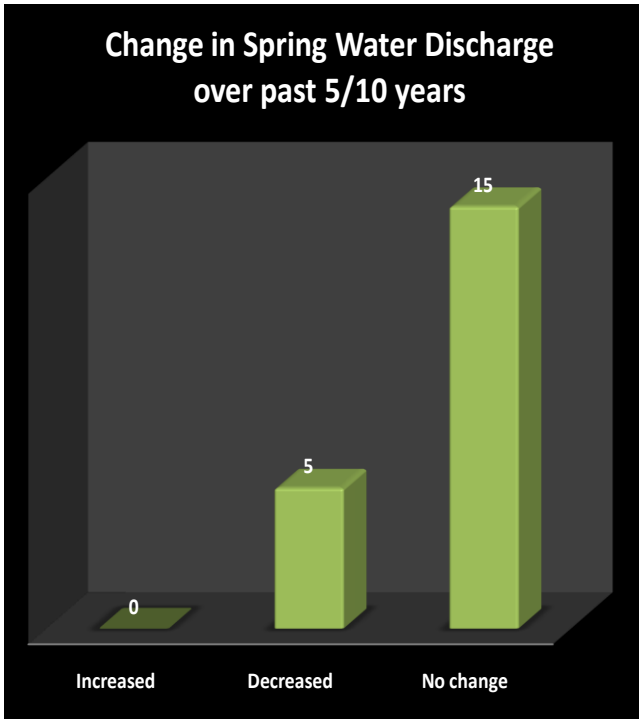
S.No.	Name	Nature of Spring (Perennial/Dry/Seasonal)
1.	Spring Field (3)	1 P, 2 S
2.	Chunadhara (2)	P
3.	Pardadhara	P
4.	Annapurna Devi Mandir	P
5.	Shiv Mandir	P
6.	Satyanarayan Mandir	P
7.	Nishant School (3)	P
8.	Staffhouse	P
9.	Bhabhar Hall	D
10.	Jila Parishad	P
11.	Mount Rose	P
12.	Mayvilla	P
13.	Silverton Hotel	S
14.	Tibetan Monastery (2)	1 P, 1 S

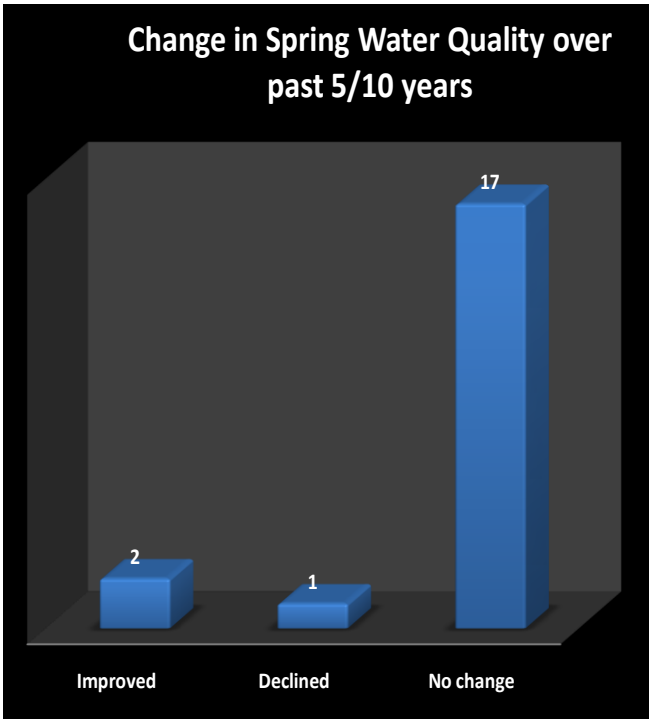
20 key informants were interviewed from 9 spring locations, out of which 6 informants walk/drive 1-5 km for collecting the spring water.



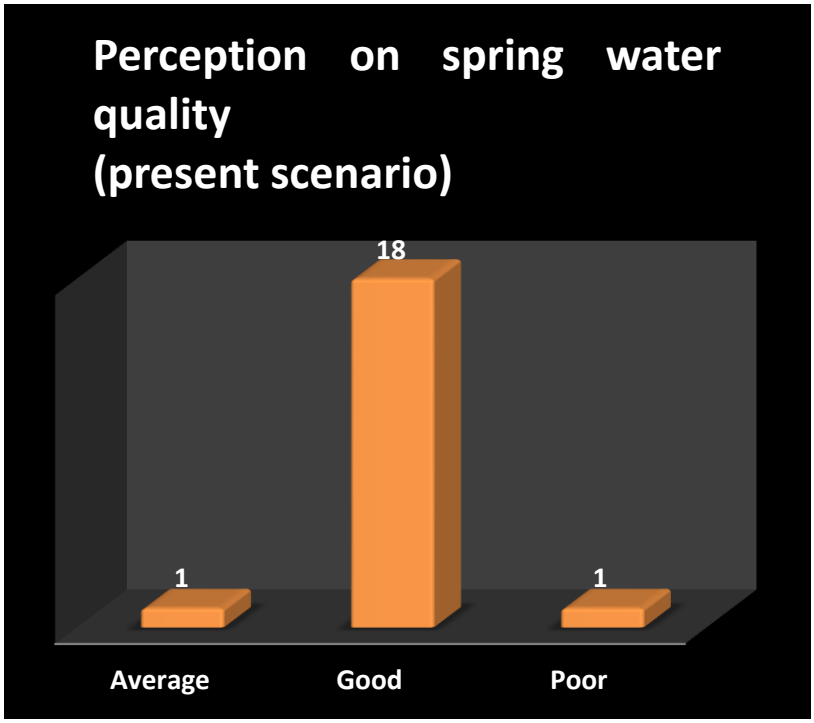
The graph shows the high dependency of the informants on the spring water. Out of 20 key informants 14 said that they are highly dependent on the springs while 2 said that they are not at all dependent on the spring water.

Then out of 18 dependent informants 12 used the spring water for drinking/cooking purposes, 1 for washing and cleaning purposes and 5 for every purpose.



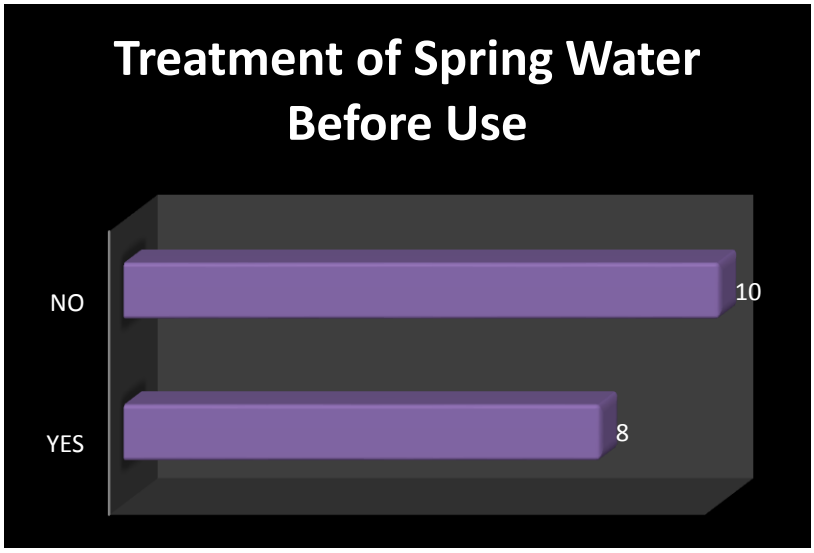


Out of 20 key informants- 15 said that there is no change in the spring water discharge over past 5 or 10 years; 17 said there is no change in the spring water quality over past 5 or 10 years

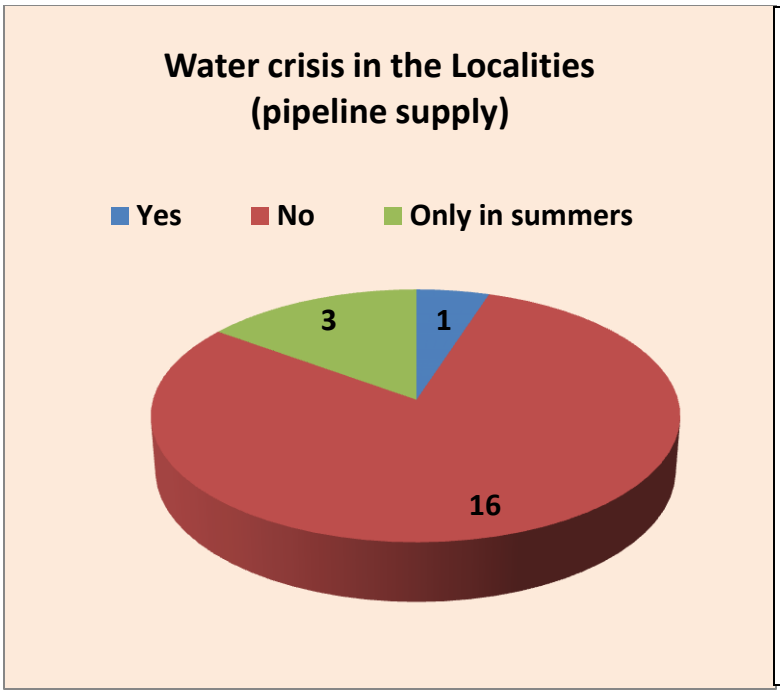


Out of 20 key informants 18 said that presently, the quality of spring water is good in their respective water collection points.

#Note: Here the quality analysis of the spring water is totally based on the perception of the informants and not on the scientific water quality analysis methods.



Out of 18 dependent informants 10 do not treat the spring water before use and 8 boil/filter/sieve the water before use.



Out of 20 key informants 16 said that there is no pipeline water supply crisis in their area, while only 3 said that there is a shortage in the summer.

This probably points out that the water is over extracted from the lake/aquifers for the pipeline supply.

It was observed that 9 out of 20 springs are facing anthropogenic pressure due to **:**

- Construction activities- on the recharge areas and areas nearby the springs.
- Garbage dumping- in the recharge areas and spring sites(fig. 8).
- Concretization of surface ground.
- Poor management of springs (source, collection tanks and pipelines), (fig. 7 & 8).
- Forest degradation.

Fig. 7- Broken pipeline carrying spring water from the

Fig. 8- Pictures showing spring degradation

4) Status of Recharge Areas-

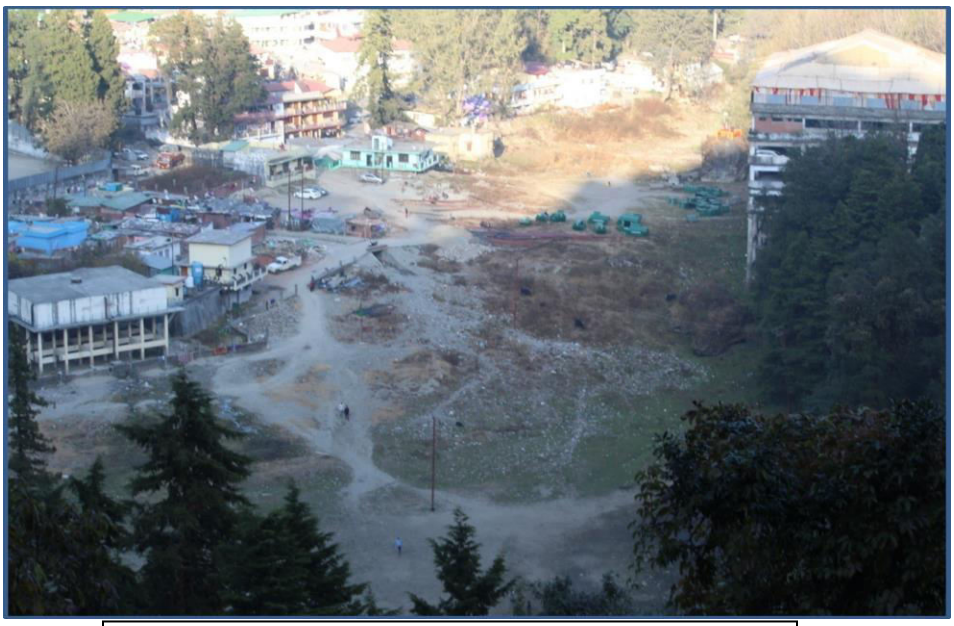


Fig. 9- Sukhatal recharge area. Source: CEDAR

5 out of 14 recharge areas are under severe anthropogenic pressure. The most affected of them is **Sukhatal** (Fig. 9). Sukhatal Lake sits approximately 1km northwest of Nainital Lake. It has an elevation of 6701 ft above sea level compared to 6385 ft for Nainital (Google Earth, 2014). Sukhatal accounts for 43% of the groundwater inflow into the Nainital Lake, or 19.5% of the total inflow into the lake (O'Hanlon, 2014). The approximate area of Sukhatal is 21,467 m^2 (calculated from Google Earth). Out of 15 identified recharge areas, it is the largest.

Approximately 30% of the surface area of the lake has been lost due to the presence of construction. The high water volume of Sukhatal Lake is approximately 154,780 m^3. The depth and the area of the lake have both been significantly affected by the presence of dumped material. In the centre of the lake, the dumped material is visibly 2---3m deep, and along the perimeter, there are piles of dumped material as high as 7---8m. Construction has gradually encroached onto the lake, and approximately 25% of the surface area of the lake has been taken over by construction. The Sukhatal Lake is rapidly disappearing (O'Hanlon, 2014).

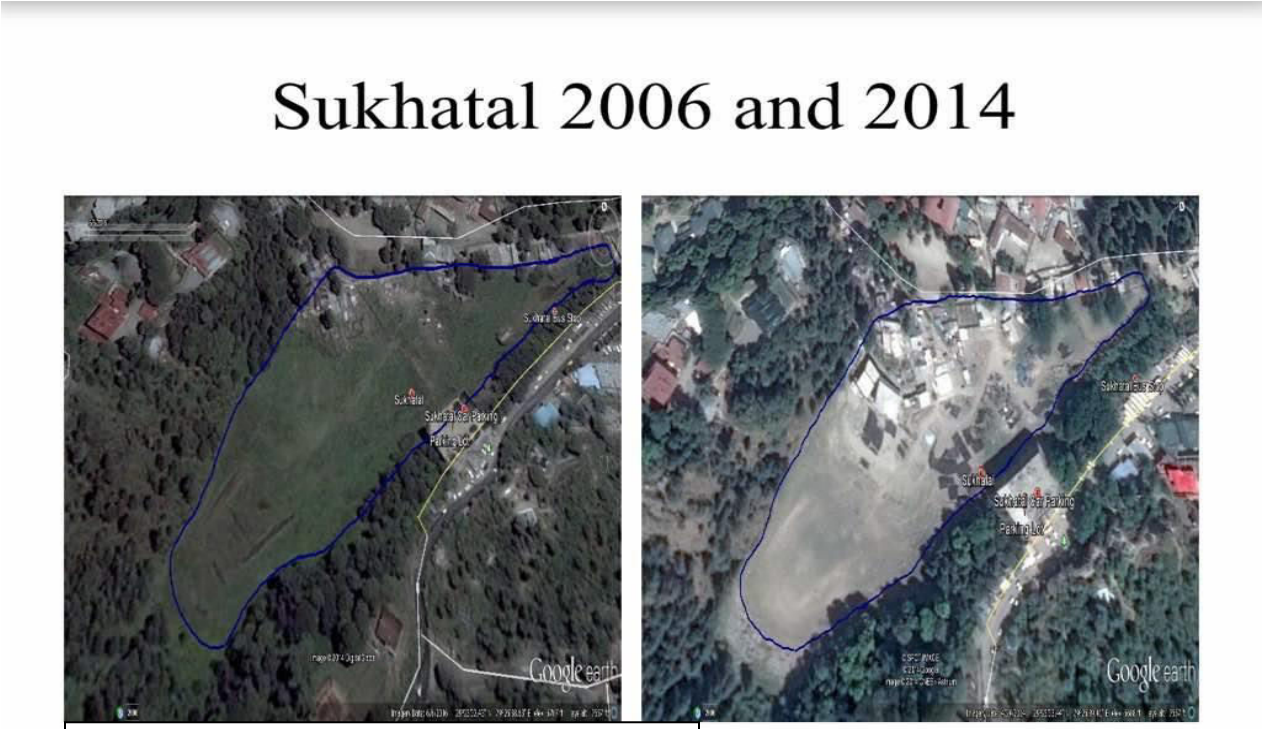


Fig. 10- Sukhatal in 2006(left) and 2014(right)

Source: CEDAR

Source: Google

Fig. 11 – A range of construction materials and municipal solid waste have been dumped on the lakebed

According to the report, "Mitigating the Anthropological Impacts on the Sukhatal Lake" (O'Hanlon, 2014)**:**

The rapid construction on the Sukhatal lakebed has resulted in a significant reduction in the maximum volume capacity of the lake. The following three key effects have been identified:

(1) Compaction of the lakebed due to property presence. Whilst the majority of the properties constructed are only one storey high, the top layer of the lakebed is made up of particularly soft soil. The presence of the properties compacts the upper layer altering the void ratio and increasing the unit weight of the soil (Sujatha, E.R. 2013).

(2) Decreased permeability of soil due to the dumping of non---‑ porous building materials such as cement and loose sands. When cement becomes wet, it coagulates and forms an impervious layer. A coring sample of the centre of the lakebed revealed that 1/2 a meter below the lakebed surface, cement made up the majority of the sample material.

(3) The catchment area of Sukhatal now has been heavily built upon; meaning that permeable soil has been replaced by an impervious concrete layer. This has resulted in an increased volume of surface runoff that leads directly into Sukhatal Lake. Surface runoff will be highest during monsoon season, which is precisely when Sukhatal Lake is at maximum

capacity. The issue is exacerbated by an inadequate surface drainage network to which surface runoff is be directed.

(4) Maximum lake volume has been significantly reduced because of the presence of construction. During monsoon season, the lake is prevented from reaching its maximum water level as overground pumping is initiated to prevent flooding of the properties that have been constructed on the lakebed.

The results of this study show that the most significant impact on the lakebed has been caused by twenty years of dumping construction materials. The lake basin has effectively been 'filled in' by construction debris. A lack of awareness of the hydrological importance of Sukhatal Lake, poor enforcement of dumping regulations and a failure to assign an appropriate location for municipal solid waste have all led to the rapid degradation of the lakebed.

The other 4 recharge areas- The Fair Light Hotel parking, Metropole Hotel parking, Sherwood school parking and Flats are also facing anthropogenic pressure of- dumping of construction debris, extreme vehicular pressure due to increasing number of tourists and dumping of municipal waste.

5) **Water Infrastructure of the Town-** There are about 18 overhead water tanks with a toatal capacity of **7384 kl** (approx.), installed by ADB (Asian Development Bank) and Jal Sansthan.

6) **Analysis of Water Consumption Pattern of the Academic Institutions-** 16 academic institutions were surveyed which included 14 schools, Government Polytechnic College and 1 government hostel. It was found that out of total 9,920 stakeholders, 2,384 were residential and 7,536 were non-residential.
The total water storage capacity of the institutions was found to be **18,92,578 litre.** There are total 66 R.O.s (water filtration system), both domestic and commercial. There are total 647 toilets in which 135 are of western style and 512 are of Indian style (fig. 12). Out of 16 institutions, 9 said that their overall water demand is easily met, while 7 said that there is a little shortage during summer (fig. 13).

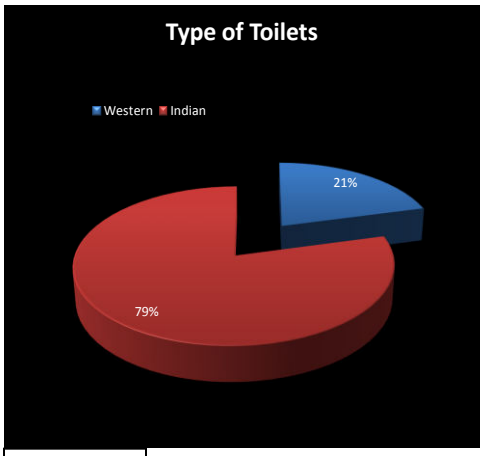


Fig. 12

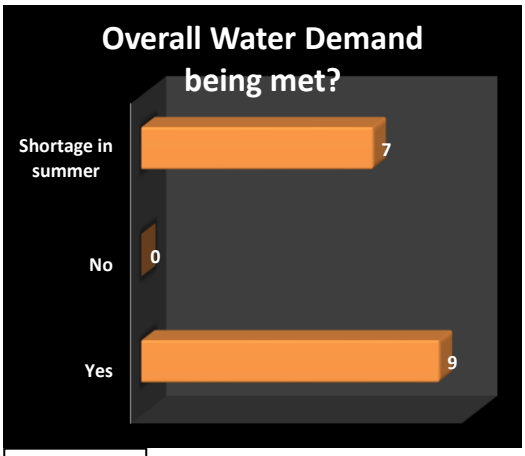


Fig. 13

#Note- the above values are in approximation

7) **Water Collection in the Town by Tube-wells-** The water collection continuously increased from minimum 141 MLD IN 2006 to maximum **198 MLD in 2015**. Then it came down to 176.50 MLD in 2016 (fig. 14 & 15)

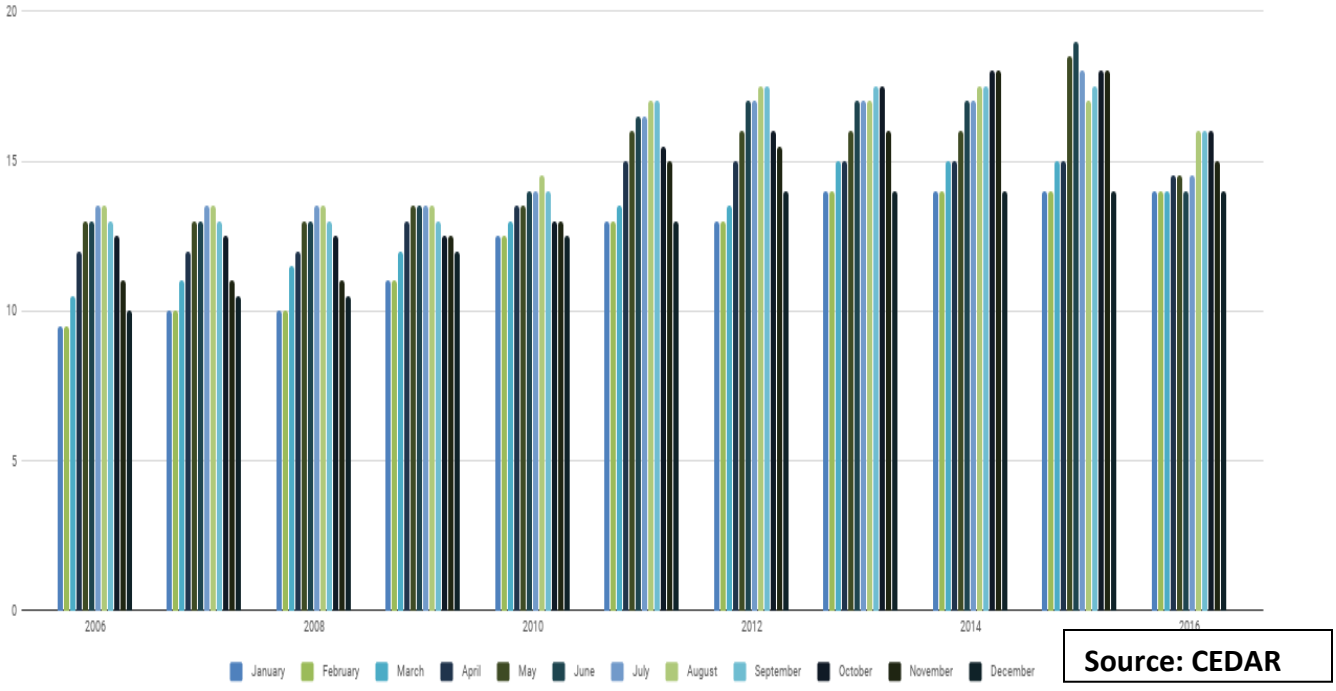
Uttarakhand Jal Sansthan Nainital

Water Collection in Nainital Town by Tubewell(Unit in MLD)

Month	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
January	9.50	10.00	10.00	11.00	12.50	13.00	13.00	14.00	14.00	14.00	14.00	14.00
February	9.50	10.00	10.00	11.00	12.50	13.00	13.00	14.00	14.00	14.00	14.00	14.00
March	10.50	11.00	11.50	12.00	13.00	13.50	13.50	15.00	15.00	15.00	14.00	14.00
April	12.00	12.00	12.00	13.00	13.50	15.00	15.00	15.00	15.00	15.00	14.50	
May	13.00	13.00	13.00	13.50	13.50	16.00	16.00	16.00	16.00	18.50	14.50	
June	13.00	13.00	13.00	13.50	14.00	16.50	17.00	17.00	17.00	19.00	14.00	
July	13.50	13.50	13.50	13.50	14.00	16.50	17.00	17.00	17.00	18.00	14.50	
August	13.50	13.50	13.50	13.50	14.50	17.00	17.50	17.00	17.50	17.00	16.00	
September	13.00	13.00	13.00	13.00	14.00	17.00	17.50	17.50	17.50	17.50	16.00	
October	12.50	12.50	12.50	12.50	13.00	15.50	16.00	17.50	18.00	18.00	16.00	
November	11.00	11.00	11.00	12.50	13.00	15.00	15.50	16.00	18.00	18.00	15.00	
December	10.00	10.50	10.50	12.00	12.50	13.00	14.00	14.00	14.00	14.00	14.00	
Total:-	141.00	143.00	143.50	151.00	160.00	181.00	185.00	190.00	193.00	198.00	176.50	42.00

Executive Engineer

Fig. 14- Table showing water collection in Nainital town by tube-wells
Source: Jal Sansthan, Nainital



Source: CEDAR

Fig. 15- Graph showing water collection trend in Nainital town by tube-well 2006-2016

8) Annual Average Winter Precipitation-

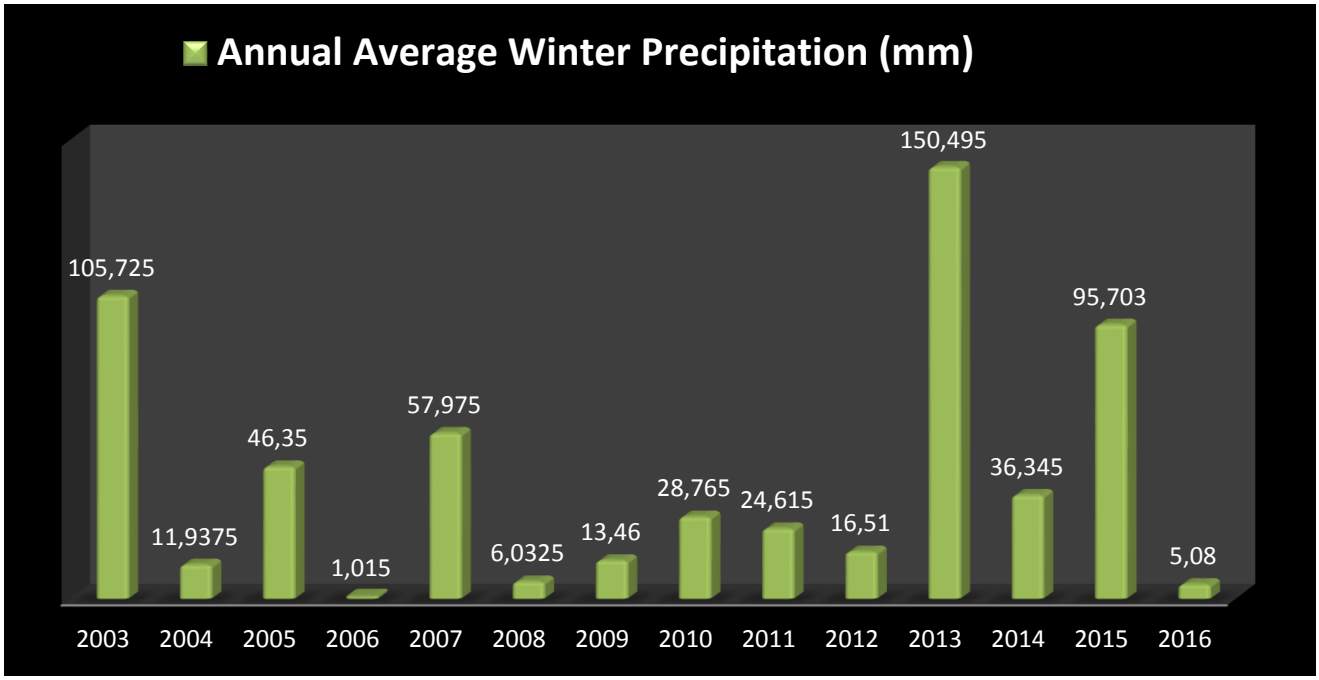
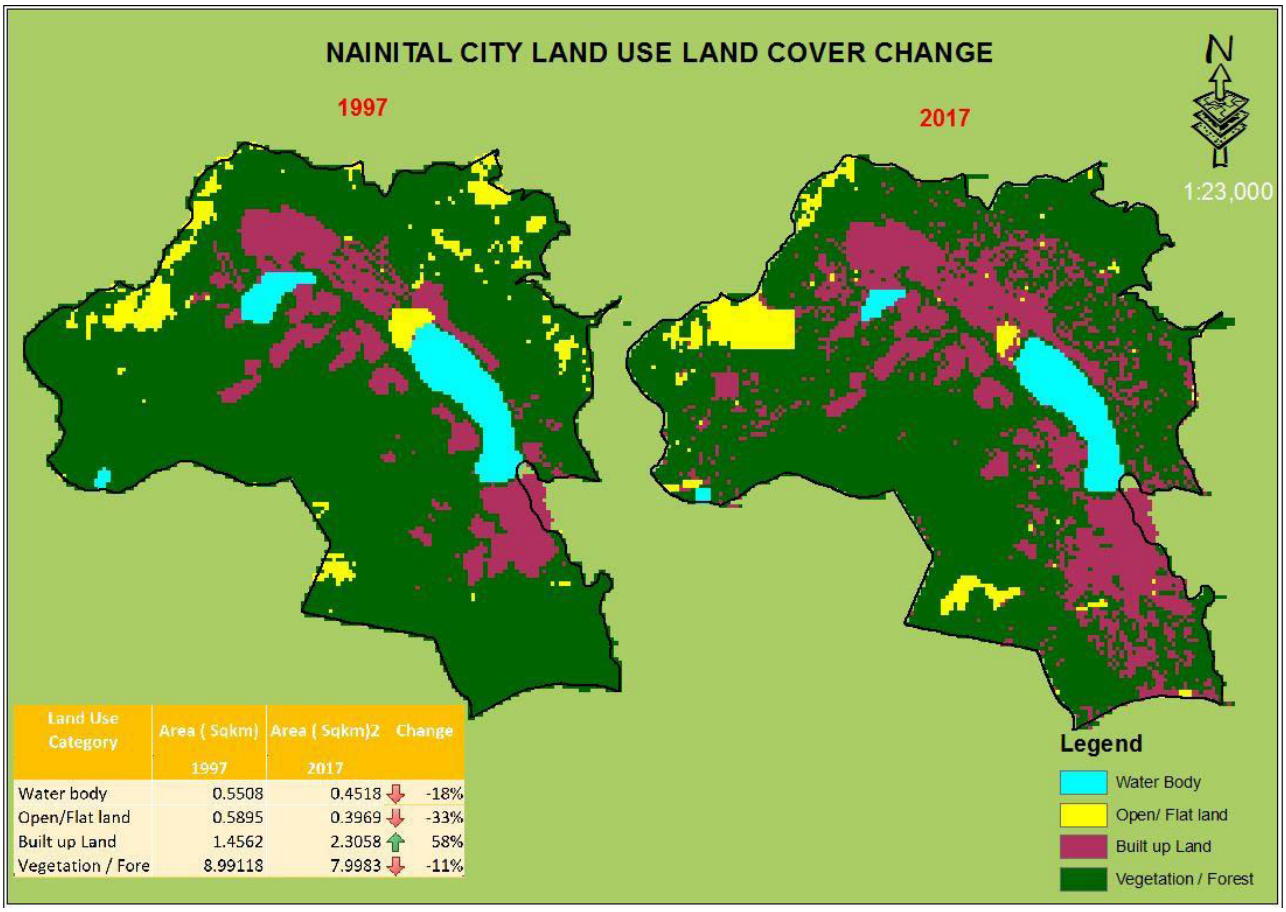


Fig. 16- Graph showing annual average winter precipitation (mm). Data Source: Jal Sansthan, Nainital

9) **Land Use Land Cover Change-** Fig.17 shows that the built up area has increased by 58%, water bodies have decreased by 18%, vegetation/forest cover has decreased by 11% and open/flat land has decreased by 33%



Land Use Category	Area (Sqkm) 1997	Area (Sqkm)2 2017	Change
Water body	0.5508	0.4518	-18%
Open/Flat land	0.5895	0.3969	-33%
Built up Land	1.4562	2.3058	58%
Vegetation / Fore	8.99118	7.9983	-11%

Fig. 17- LULC maps of Nainital town for years 1997 & 2017. Source: CEDAR

Land use/ Land cover map of the area around Nainital for 2005 (left) & 2010 (right)

Source: Disaster Mitigation and Management Centre (2011)

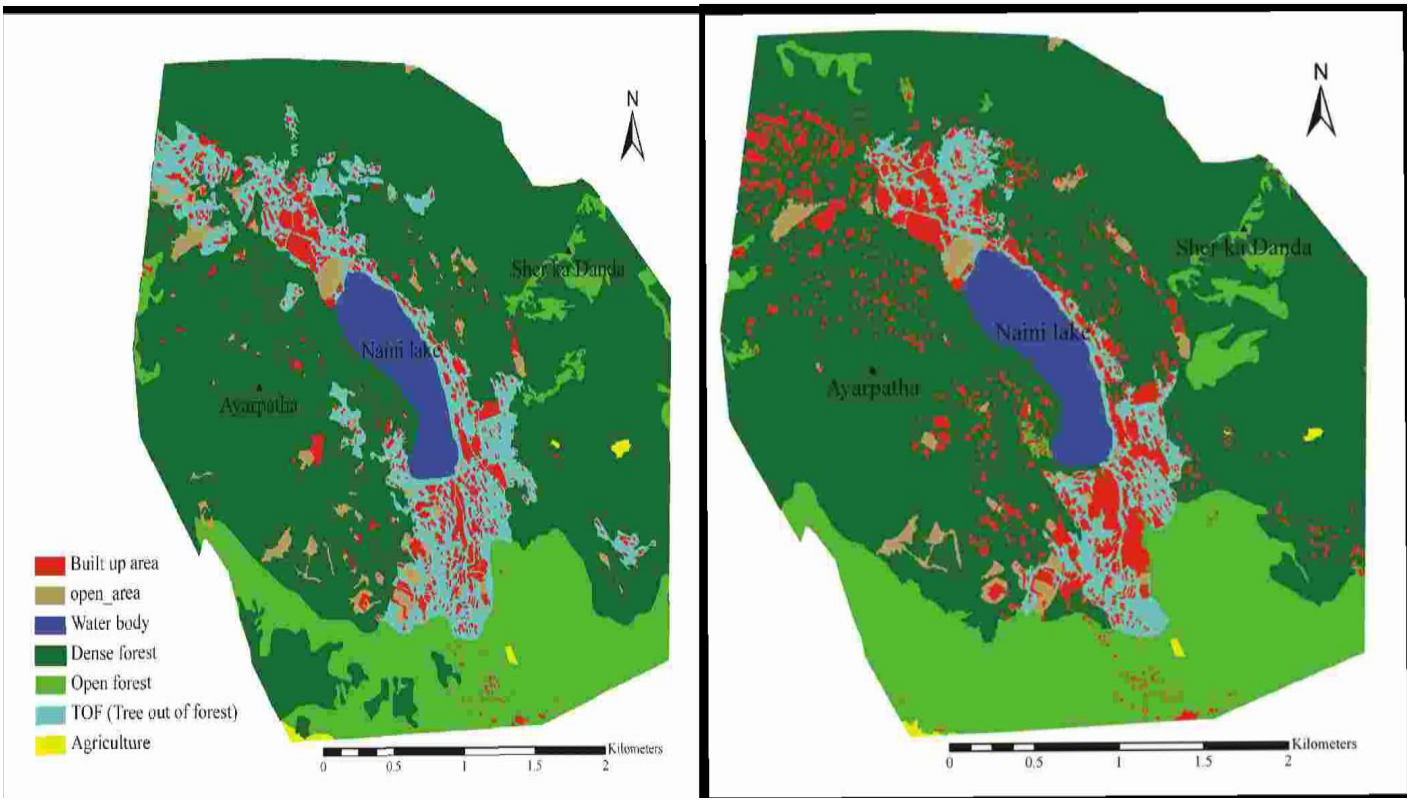


Fig. 18- - LULC maps of Nainital town for years 2005 & 2010

Fig. 18 clearly shows a huge increase in the built up area and decrease in the trees out of forest from 2005 to 2010.

Chapter 5 CONCLUSION

Nainital town is under extreme anthropogenic pressure. The springs are gradually vanishing, recharge zones are shrinking. There is acute population pressure on the carrying capacity of the town. Water is over extracted from the lake/aquifers for the water supply of the town. There is no proper limited water supply and also the water supply management and monitoring is poor. Winter precipitation has remarkably declined from past 10-12 years. The drains are extremely degraded. The town's solid waste management is also poor. The management of the water tanks and pipelines is unsatisfactory. Still one can see illegal debri dumping and uncontrolled construction activities in the town, the reason probably could be- lenient laws.

The lake water as such is not potable as it contains unacceptable levels of organic matterin terms of COD (44 mg/L approx), coliforms (15.6×10^4 MPN/100 ml) and nutrients (Dash et al, 2008).

Due to human activities in the last several years the lake has become eutrophic. The values of BOD, nitrate-nitrogen, ammonium-nitrogen and phosphate-phosphorus were high (Gupta et al, 2008).

During the few decades increasing local population 6903 (1901) to 38559 (2001) and the logarithmic increase in tourist influx into the watershed has affected the water resources and biodiversity of the area. A significant number of water resources have dried up in the past two to three decades. Certain herb and shrub species that were abundant in the oak forests (*Q. leucotrichophora* and *Q. floribunda*) have now disappeared. In Nainital catchment area in un-disturbed sites the tree richness is 11, shrub richness is 19 and herb richness is 51, whereas in disturbed forest the richness is declining and is 7 for tree species, 19 for shrubs and 31 for herb species (Shah et al, 2009).

Chapter 6 RECOMMENDATIONS

- Rejuvenation of recharge areas –particularly Sukhatal through natural process
- Rejuvenation of springs
- Identification of recharge areas of springs
- Proper management of present springs and recharge zones
- Limited water extraction and supply- presently oversupplied
- Checking tank/pipeline damages and/or leakages
- Metering system – incentivised mechanism
- Regulation of tourist and vehicular inflow in the town
- Implementation of water conservation techniques by academic institutions, hotels, etc.
- Strict implementation of laws regarding construction and waste management activities
- Rain water harvesting wherever possible

REFERENCES

- **Francesca O'Hanlon. 2014.** Mitigating the anthropological impacts on the Sukhatal lake: a study into the degradation of Sukhatal lakebed, Nainital, Uttarakhand.
- **Piyoosh Rautela, Sushil Khanduri, Manoj Pande, K.N. Pande, Bhupendra Bhaisora, Suman Ghildiyal, Chanderkala, Peeyush Gupta, Ashish Rawat and Sunil Badoni. 2011.** Slope instability and geo-enironmental issues of the area around Nainital. DMMC 2011.
- **P.K. Gupta, Surendra S. Nadgali, Priyanka Tewari, Nirmal Singh and Ragini Gupta. 2008.** Water chemistry of a national lake of India: lake Nainital, Uttarakhand. Proceedings of Taal2007: the 12th world lake conference, 209-216.
- **Ragini Gupta, P. Bhagat, M. Joshi, S. Inaotombi and P.K. Gupta. 2010.** Heavy meatl pollution status of lake Nainital, Uttarakhand. Indian J.Sci.Res., 1(1): 15-19.
- **RM. P. Nachiappan, Bhishm Kumar and RM. Manickavasagam. 2002.** Estimation of subsurface components in the water balance of lake Nainital (Kumaun Himalaya, India) using environmental isotopes. Hydrological Sciences-Journal-des Sciences Hydrologiques, 47(S).
- **R.R. Dash, I. Mehrotra, P. Kumar and T. Grischek. 2008**. Lake bank filtration at Nainital, India: water quality evaluation. Hydrogeology Journal., 16: 1089-1099.
- **Shruti Shah, Ashish Tewari and Bhawna Tewari. 2009.** Impact of Human Disturbance on Forest Vegetation and Water Resources of Nainital Catchment. Nature and Science., 7(10): 74-78.
- **S.P. Singh, Brij Gopal, Vinish K. Kathuria, Shirish K. Singh, Malavika Chauhan, Manisha Upadhyay & Mohan Bharti. 2002.** Integrated Management of Water Resources ofLake Nainital and its Watershed:An Environmental Economics Approach. EERC Working Paper Series: WB-8.