Water and Land Environment Carrying Capacity of Baddi – Barotiwala – Nalagarh Region of District Solan, Himachal Pradesh

A Thesis

Submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF TECHNOLOGY

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CIVIL ENGINEERING

With specialization in

ENVIRONMENTAL ENGINEERING

By

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MAY, 2018

CERTIFICATE

This is to certify that the work which is being presented in the project title **"Water and Land Environment Carrying Capacity of Baddi – Barotiwala – Nalagarh Region of District Solan Himachal Pradesh"** in partial fulfillment of the requirements for the award of the degree of Master of Technology with specialization in Environmental Engineering and submitted in Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Hitesh Bans** during a period from August 2017 to May 2018 under the supervision of **Dr. Veeresh S Gali,** Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of my knowledge.

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DECLARATION

I hereby declare that the work reported in the M-Tech thesis entitled **"Water and Land Environment Carrying Capacity of Baddi – Barotiwala – Nalagarh Region of District Solan Himachal Pradesh"** submitted at **Jaypee University of Information Technology, Waknaghat, India,** is an authentic record of my work carried out under the supervision of **Dr. Veeresh S Gali.**

I have not submitted this work elsewhere for any other degree or diploma.

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ABSTRACT

The present study evaluates the carrying capacity of two environmental settings: 1) Water Environment Carrying Capacity (WECC) and 2) Land Environment Carrying Capacity (LECC). WECC is based on two main factors: i) Water quantity and ii) Water quality. The Water Quantity Carrying Capacity (WQCC) involves population carrying capacity and water resource carrying capacity. The Water Quality Carrying Capacity (WQTCC) constitutes pollutant carrying capacity and carrying capacity based on water quality variables. The LECC constitutes Land Resource Carrying Capacity (LRCC) and carrying capacity based on Land Balance (LBCC).

Based on the WQCC, the population carrying capacity per thousand is 736.60 and water resource carrying capacity is 2.33 i.e., conditionally save. Pollutant carrying capacity is measured in terms of COD and NH_4-N at three different locations: i) Sirsa river upstream of Sitomajri Nallah with 13217 tonnes per annum in terms of COD load and 1599 tonnes per annum of NH_4-N ii) Sirsa river downstream Nalagarh bridge with 14714 tonnes per annum in terms of COD load and 1778 tonnes per annum of NH_4-N and iii) Sirsa river downstream of Nalagarh town with 14404 tonnes per annum of COD load and 1894 tonnes per annum of NH_4-N. In order to evaluate WQTCC, 3 locations in Sirsa river and 2 open wells in each region (i.e., Baddi, Barotiwala and Nalagarh region) were considered. Among the two wells in each region, one well corresponding to industrial region and another well corresponding to non-industrial region were identified. WQTCC based on water quality variables was estimated by Indicator Evaluation (IE) method as suggested by Peng Kang and Linyu Xu. The LECC in both Land resource and Land balance carrying capacity were found to overshoot.

Keywords: Carrying capacity, Water and Land Environment, Indicator Evaluation Method, Land Balance.

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NOTATIONS AND ABBREVATIONS

WECC	Water Environment Carrying Capacity
LECC	Land Environment Carrying Capacity
WQCC	Water Quantity Carrying Capacity
WQTCC	Water Quality Carrying Capacity
LRCC	Land Resource Carrying Capacity
LBCC	Land Balance Carrying Capacity
BBN	Baddi – Barotiwala – Nalagarh
Sq. Km	Square Kilometers
BBNDA	Baddi Barotiwala Nalagarh Development Authority
BBNIA	Baddi Barotiwala Nalagarh Industrial Association
AHP	Analytic Hierarchy Process
WRCC	Water resource carrying capacity
Kg/d	Kilogram per day
WRDCC	Water Resource Design Carrying Capacity
IDR	Indonesian Rupiah
NFMC	Non-Fully Mixed Coefficient
COD	Chemical Oxygen Demand
g/s	grams per second
t/a	tonnes per annum
IPH	Irrigation and Public Health

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CHAPTER – 1

INTRODUCTION

1.1 GENERAL

Baddi - Barotiwala - Nalagarh (BBN) region of district Solan is mainly recognized as the industrial hub of Himachal Pradesh (HP) because of the existence of large number of industries. BBN is the most important industrial belt of the State. This area is fast developing as an industrial hub and is most popular because of several factors attributable to its geographical edge over other areas of the State; an account of nearness to Chandigarh (the city beautiful), nearness to broad gauge Rail at Kalka, developable land, accessibility and availability of basic infrastructure.

Industrialization is an important factor because it drives economic development. Rapid Industrialization results in serious environmental and water degradation problems. Carrying capacity is an indicator of regional sustainability and it depends strongly on environmental water resources. In order to increase the level of life and human well being, the development of an area is a major effort. Environment carrying capacity covers all the factors such as life of humans, animals and other living beings with their requirements in accordance with the availability of needs. The WECC covers aspects of water quality and the water quantity. The quality perspective is identified with the help of the characteristics of the water bodies which covers almost all characteristics such as pH, DO, BOD, COD, Ammoniacal Nitrogen etc. Within the study area, the only main surface water resource is River Sirsa which carries all the requirements of the area. As BBN region is an industrial area, there is large amount of water requirement for the industries as well as for public services. But the water requirements depend on various factors such as industrial use, public use, wastewater etc. Therefore, the measure of WECC is useful for the calculation of availability of water, the amount of polluted water and the remedial measures required for the betterment of water usage. The LECC is a measure of the study of land use plan of a particular area to identify how much area is actually required by the community and how much area is available. The LECC depends on Agriculture, Infrastructure, Forest Land, Land for Public Services etc. In the BBN area the amount of land available at present is very low as all the area is used for the industrialization as well as for public sectors. Therefore a suitable land carrying capacity measure is required in order to clear some of the land area for the betterment purposes of the area. For the sustainability of an area, carrying capacity is must as it depends strongly on the resources of the environment.

1.2 STUDY AREA

1.2.1 GENERAL

BBN area is located in the lap of Shiwalik foothills of Solan District of HP. The BBN area has 229 local villages and 2 urban local bodies namely Barotiwala and Nalagarh with total population of 42,362. The total area of BBN is 318.74 Sq. Km or 31874 Hectares according to Himachal Pradesh town and country planning (HPTCP). The area is constituted under section 66 of the HPTCP, 1977. An authority was formed for comprehensive and regulated development of BBN area under the name and style of Baddi – Barotiwala - Nalagarh Development Authority (BBNDA) and for industries, Baddi – Barotiwala – Nalagarh Industrial Association (BBNIA).

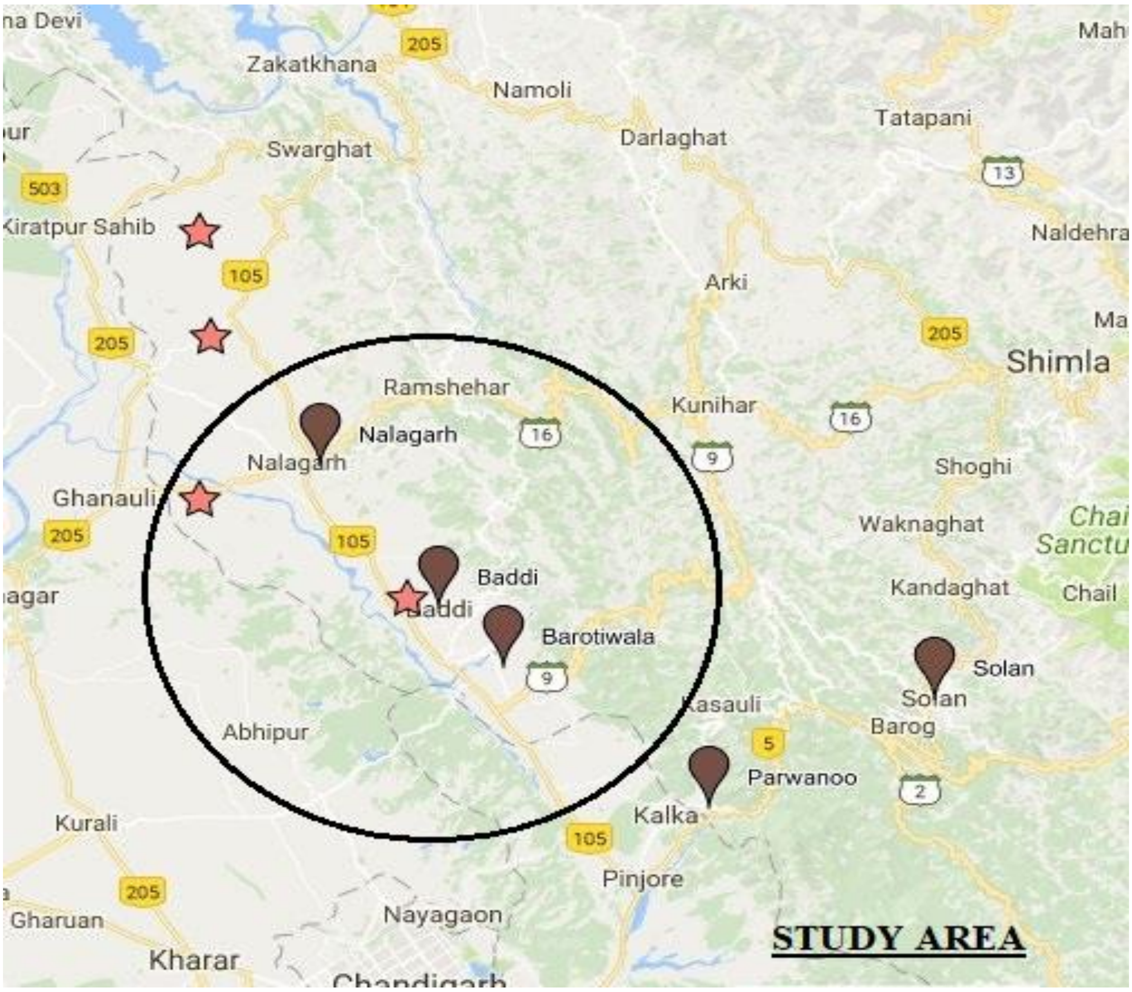

Figure-1: Map of study area [Source: www.mapsofindia.com]

1.2.2 CLIMATE

The average annual temperature of BBN region is 23.4 Degree Celsius. The annual precipitation is 1186 mm. The climate in this region is generally cold from November to February and hot from March to October. The rapid industrialization in this region leads to change in the climatic factors.

1.2.3 DEMOGRAPHICS

As per the provisional data for the year 2013, the BBN region of District Solan, HP had a population of 42,362.

1.3 NEED OF THE STUDY

This study is carried out in order to assess the water availability, water demand, land availability and land demand in the BBN region. By the means of Water and Land Environment Carrying Capacity, we can easily frame the supply and demand of water and land. The LECC describes the availability of the land and the demand of the land in the study area by the estimation from the land use plan. By the study of Water and Land Environment Carrying Capacity we can easily calculate the supply and demand of water and land and can find suitable remedial measures for their proper use so that they cannot be exploited early.

1.4 SCOPE OF THE STUDY

Water and Land Environment Carrying Capacity is a study that indicates the life of resources and we can find remedial measures to save the natural resources such as consumptive use of the water, effective water usage and the use of water saving techniques and also to impart knowledge to the people regarding the importance of water and land resources. The water and land environment carrying capacity depends upon various factors related to the water and the land environment such as the supply and demand of land and water and the physical and chemical characteristics of the water body which are beneficial for constructing the carrying capacity model. This study also contributes for the land demand of an area with proper data analysis of land which will be beneficial for the public sectors for easy classification of the land.

CHAPTER – 2

LITERATURE REVIEW

2.1 STUDIES ON ENVIRONMENTAL CARRYING CAPACITY

2.1.1 Evaluation planning of spatial and regional in West Sumatra's Solok Regency based on environmental carrying capacity

Alvan Pahuluan et al. (2017) evaluates the land supply and land demand the land carrying capacity. The LECC is based strongly on the land availability and the land demand. The land availability and land demand are calculated form the land use plan of the area. There was a need of increasing the housing settlement areas for the betterment of the land balance in accordance with the available land. The results show that the land carrying capacity of Solok regency in 2014 is 1.47 that means it is conditionally sustain. The constraint in the study is the limitation of data that belongs to calculate the land production value. The land supply and land demand are calculated with respect to the rice equivalent agriculture of the area and the production values of the commodities. All the factors that are required in this are production values of the commodities and the rice unit price and the rice productivity per hectare of the total area. The total production values of the commodities are 5344.51 in Billion IDR. The prediction of land carrying capacity in 2031 is calculated which is 2.12 and lies in sustain limits. The land supply in 2014 is very low approximately 40% less as compared to the land supply in 2031.

2.1.2 Research on water resource design carrying capacity

Guanghua Qin et al. (2016), The Water resources carrying capacity is a recently proposed concept, which aims at sustainable socio-economic development in a region. The calculation of future water resource carrying capacity (WRCC) is not considered well in most studies, because water resources and socio-economic development part for one region in the future are quite uncertain. This literature focused on the limits of traditional methods of WECC and proposed a new concept namely water resources design carrying capacity (WRDCC). In WRDCC, the population size based on the local water resources is calculated based on the balance of water supply and water consumption under the design water supply mode. The WRDCC of Chengdu city in China is measured. Results show that the WRDCC of Chengdu city in 2020 and 2030 has a bigger gap, which means there will be more pressure on the society for economic sustainable development. The results show that the WRDCC with respect to the population size that is [WRDCC (population size)] of Chengdu city under design water supply in development mode I, II and III will be $997*10^4$ ($770*10^4$, $504*10^4$) in 2020, and $934*10^4$ ($759*10^4$, $462*10^4$) in 2030.

2.1.3 Water environmental carrying capacity evaluation method construction for Erhai river basin

Liu WeiHong et al. (2015), With the increase in urbanization and increasing energy consumption in China, the pollution emission rate and the pollution load is increasing day by day. In many rivers, the pollutant load is more than the environment capacity of the water which results in the destruction of the structure and the function of the river basin. This literature puts forward the methodology of WECC and constructs the basic model of calculating WECC. The Erhai River is an example for calculating the WECC. The main problem in Erhai is the land use zoning of the river basin. This literature carries out the Erhai River Basin and pollution prevention and control planning objectives of the river Erhai and its drainage basin for land use zoning based on the principle. The following principles shall be followed: Prevention of pollution and planning of functional zoning, and the principle of distribution of sources of pollution, and relevant provisions of the river Erhai protection. The Erhai river basin is divided into four tracts. The West of the river Erhai, the scope of the National Road 214 and the mountain conservation forest are some of the comprehensive development zones of the river basin.

2.1.4 Water environmental carrying capacity fluctuations in a huge river connected lake

Hua Wang et al. (2015), In this literature a new method, with the non-fully mixed coefficient (NFMC) was put forward for the calculations of WECC for a huge river-connected lake in which the hydrological conditions vary widely during a year. Poyang Lake is the most typical river-connected lake and it is the largest freshwater lake in China which was selected as the research area. Based on field surveys and numerical calculations the monthly pollutant degradation coefficients and the non-fully mixed coefficients of different regions of lake were determined to explore the WECC of COD, Total nitrogen and Total phosphorus of Poyang Lake in a water year. The results show that the WECC's of COD, Total nitrogen and Total phosphorus in the lake are $181.9*10^4$ t, $33.3*10^4$ t and $1.86*10^4$ t. Due to the change in the lake water volume and self-purification ability, a fluctuation of WECC in the Lake basin was observed. The dry seasons were characterized by lower WECC's owing to the lower water level and degradation. The variation coefficients of COD and Total nitrogen water environmental carrying capacities were close to each other, of which the average was about 58.5%, a little higher than that of Total phosphorus. August is characterized by the peak month for the WECC, whereas in January and December it drops down to its lowest level. The COD, Total nitrogen and Total phosphorus WECC's fluctuated similarly in the year but their amplitudes were different. The WECC of Total phosphorus was observed to show a relatively lower variation range than those of COD and Total nitrogen. The results of this literature will play important role in pollution control and environmental water protection for the study.

2.1.5 Evaluation of Water Environmental Carrying Capacity of a city in Huaihe River Basin based on the AHP method

Yan Lu et al. (2015), In Huaihe River Basin there is abundant rainfall as a land flowing with milk and honey and it is the area that is prone to flood disaster. Huaian was selected for the study on WECC from 2005 to 2014 using a method of Analytic Hierarchy Process (AHP). The literature combined water environmental condition with the characteristics of socio-economy and environment in Huaihe River Basin. The results show that WECC appeared an upward tendency. In three layers, social factors have a significant impact on the WECC and their changes were consistent. So, we can further increase the carrying capacity of water resources in Huaian City from the following aspects. Firstly, we must raise the level of sewage treatment and water use efficiency. We have to strengthen the construction of rural sewage treatment facilities and development of efficient water-saving agriculture. Industrial wastewater such as the cooling water and the process water must be recycling and regenerating used for minimizing waste water emissions and hence resulting in controlled pollution.

2.1.6 Analysis of environmental carrying capacity of Yogyakarta urban area for the development of sustainable settlement

Widodo B et al. (2014) analyzed the water and land environment carrying capacity of Yogyakarta urban area. The growth of urbanization in the area leads to environmental degradation. The indication about this degradation of the environment is made possible with the water and land environment carrying capacity. The research was aimed to analyze the land resource and water resource carrying capacities of the Yogyakarta urban area. The analysis shows that settlement LRCC is 2.89 that is in conditionally-save condition and water carrying capacity is in save condition. This area is fast growing area that covers all areas of Yogyakarta city out of which some are located in Bantul regency. The concept of green open space also helps in strengthening the land and the WRCC. The land conversion rates contamination symphysis the effective strategies for the WRCC.

2.1.7 Water environment carrying capacity of Gucheng lake basin analysis based on water quantity and quality

Yang Zhe et al. (2013) analyzed that the WECC is an important factor for socio-economic development. By the means of water quantity and quality the WECC of Gucheng lake basin was analyzed. In this literature COD and NH_4-N are considered as the major pollution factors for the calculation of the pollutant carrying capacity. By estimating the total amount of water in the basin the carrying capacity based on water quantity perspective is measured. The results show that carrying capacity based on water quantity > carrying capacity based on COD > carrying capacity based on NH_4-N. The pollutant carrying capacities of Gucheng lake basin is 8483.97 tonnes per annum for COD and 622.47 tonnes per annum for NH_4-N. By raising the management efficiencies and implementing relevant control measures is useful for discovering the keys to WECC.

2.1.8 Environmental carrying capacity and progress of resources

Tian et al. (2013), China is a very fast developing country with a very large population growth rate. The peoples living conditions are directly linked with the development of china. Environmental carrying capacity and resources as the basis of sustainable development has been paid more and more attention. This literature discusses the major concepts of environment carrying capacity and resources to identify the major problems in the area. The results pointed out the development rate of the area that requires attention.

The characterization of results for the carrying capacity is the major factor of concern that how can we characterize the factors related to the carrying capacity. In conclusion the study of environment carrying capacity and resources is a human consideration towards the nature and it depends on how humans can work for the foundation of carrying capacity to make it sustainable. The understanding of humans towards nature and the resources leads to the proper use of resources and environment without any depletion to the environmental resources.

2.1.9 Assessment of an industrial park for water environment carrying capacity

Peng Kang et al. (2012) analyzed that industrial parks are the areas that undergoes high strength resource consumption and very high economic activities. For sustainable regional development the WECC is most important factor. In this literature Zhuhai city's Fushan industrial park was selected for case study, and an Indicator Evaluation (IE) method was established to carry out the WECC. The selection of various indicators for the calculations of WECC depends strongly on water characteristics. This study calculates the comprehensive values of WECC from year 2007 to year 2030. The results show that the WECC follows a decreasing trend per year from 2007 to 2030. The WECC follows a declining rate due to the increase in the industrialization. The value of the carrying capacity remains in between 0.4 and 0.7. This literature applies the dynamic system combined with index assessment to calculate the WECC of the industrial park.

2.2 OBJECTIVES

The objectives of the study are:

1. To assess the sustainability of water resources in BBN special area for its quantity and quality.
2. To study land use planning for BBN special area for its carrying capacity.
3. To suggest appropriate techniques for efficient water and land management.

CHAPTER – 3

MATERIALS AND METHODS

The calculations of the water and the land environment carrying capacity requires brief data collection of the concerning stream for water carrying capacity and the land use plan for the land carrying capacity. After the collection of data with the help of numerical formulations and calculations we can easily calculate the water and the land environment carrying capacity of the BBN area. The methodology is shown below:

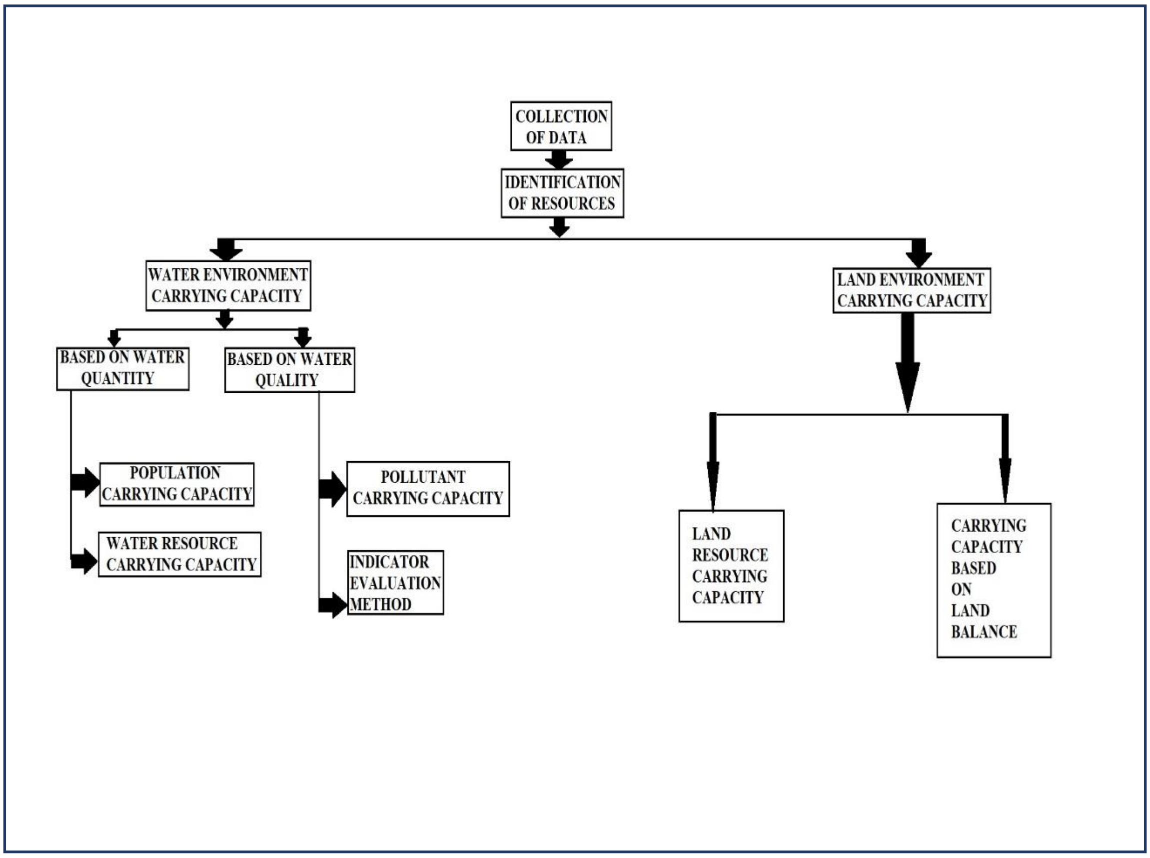

Figure-2: Methodology

After the collection of the data the resources are identified viz. water resources and the land resources. The only stream in the BBN area is River Sirsa which is the main surface water source of the area. Also, there are many open wells and tube wells that also contribute to the water resources. After the adopted methodology we can separately analyze the WECC and LECC.

CHAPTER – 4

WATER ENVIRONMENT CARRYING CAPACITY

The WECC is defined as the usable amount of water per unit demand. As in the study area, the only source of water is river Sirsa; therefore, this river is selected as a baseline for the analysis of the WECC.

4.1 WATER ENVIRONMENT CARRYING BASED ON WATER QUANTITY

WECC based on water quantity can be analyzed in two different ways:

4.1.1 POPULATION CARRYING CAPACITY

With respect to the status of economy and water resources in BBN area a model is used to calculate the Population carrying capacity and the economic carrying capacity of water resources of BBN area according to the data of year 2013.

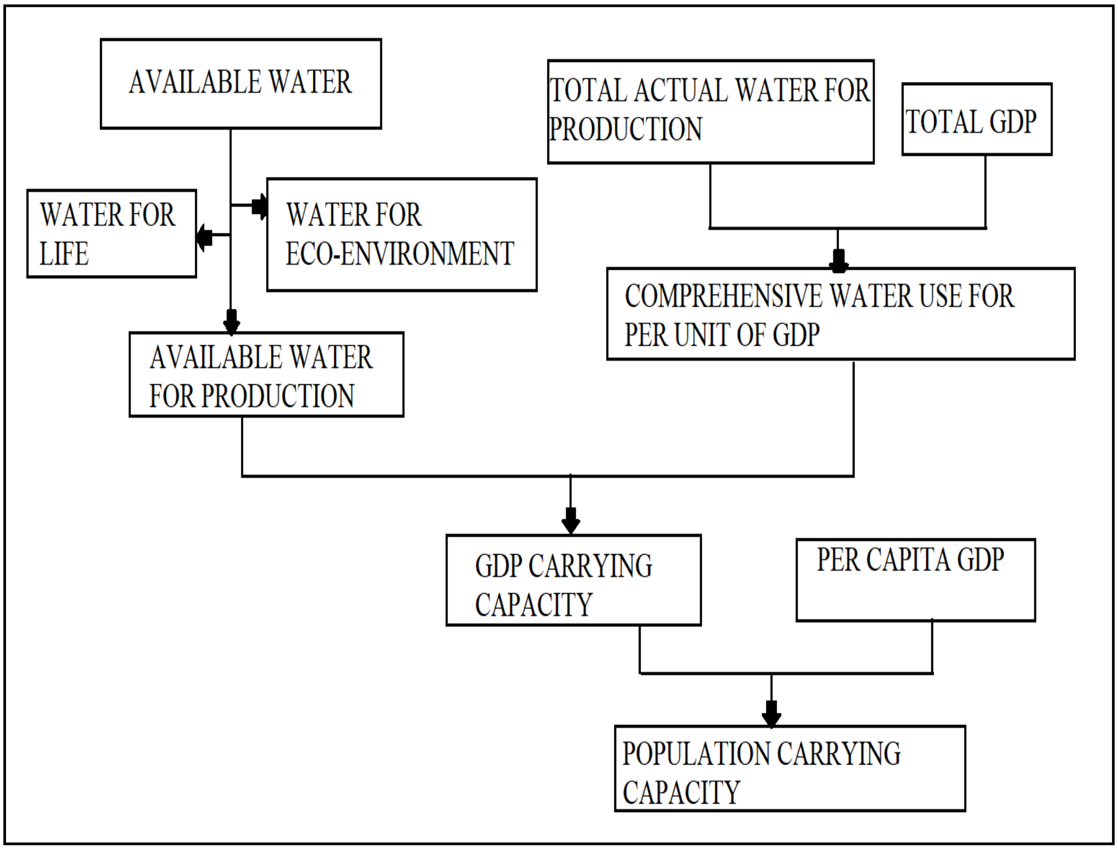

Figure-3: Population Carrying Capacity model

Formulations of Population carrying Capacity:

This formulation is suggested by Yang and Li School of Environment and Natural Resources, Renmin University, China.

$W_{AR} = W_{AS} + W_{AG} + W_T + W_{RW} – W_{RC}$

$W_{ARP} = W_{AR} – W_L - W_E$

Here;

W_{AR} = Available Water

W_{AS} = Available Surface Water

W_{AG} = Available ground Water

W_T = Transfer Water

W_{RW} = Reused waste water

W_{RC} = Repedetally calculated water

W_{ARP} = Available water for Production

W_L= Water for Life

W_E= Water for Eco environment

For BBN area these values as per IPH Department Nalagarh are:

W_{AS} = 2049999 m^3

W_{AG} = 120000 m^3

W_T = 0

W_{RW} = 51000 m^3

W_{RC} = 210000 m^3

Substituting values in $W_{AR} = W_{AS} + W_{AG} + W_T + W_{RW} – W_{RC}$

Therefore W_{AR} = 2049999 + 120000 + 0 + 51000 – 210000

= 2010999 m^3

Now $W_{ARP} = W_{AR} – W_L – W_E$

$W_L = 53000\ m^3$ and $W_E = 9320\ m^3$

Therefore $W_{ARP} = 2010999 – 53000 – 9320$

$= 1948679\ m^3$

$W_{ARP} = 1948679\ m^3$

GDP of BBN area is assumed to be 95 billion that is $1/12^{th}$ of GDP of HP

Comprehensive Water Use Per Unit of GDP = U_C

And $U_C = C_U/GDP$

$C_U = (C_A+C_I+C_S) = 1140000 + 21400 + 13900 = 1175300m^3$

C_A= water for agriculture = $1140000\ m^3$

C_I= water for industry = $21400\ m^3$

C_S= water for public services = $13900\ m^3$

These values as per IPH Department Nalagarh and Shreya Environmental Consultancy Baddi.

Now U_C = 1175300/95 = 12371.57 m^3 per billion

U_C = 12371.57 m^3 per billion

GDP CARRYING CAPACITY = C_E

And $C_E = W_{ARP}/C_U$

= 1948679/1175300 = 1.65 Per Billion

Population carrying capacity = C_E / per capita GDP

= 1.65 per billion / .00224 = 736.60

Table-1: Population carrying capacity

GDP	Per capita GDP	GDP Carrying Capacity	Population Carrying Capacity per thousand
95 Billion	.00224	1.65 / Billion	736.60

4.1.2 WATER RESOURCE CARRYING CAPACITY

It is a mathematical calculation method that helps us to evaluate the availability of water resources per unit demand according to the data available of year 2013.

FORMULATIONS:

This formulation is suggested by Widodo and Lupyanto, Department of Environmental Engineering, universities Islam Indonesia (UII).

Water Resource Carrying Capacity (WRCC) = DDA
(DDA) = Water availability(SA) / Water demand(DA)

Water Availability (SA) = 10*C*R*A

Where $C = \sum(C_i \times A_i) / \sum A_i$

$R = \sum R_i / m$

A = Total Area and A_i = Land Use Area

C = Coefficient of Weighted Runoff and C_i = Coefficient of Land Use Runoff i

R = Annual Rainfall and R_i = Annual rainfall on i station

m = No. of Rainfall observation stations

A = Total Area

10 = Conversion Factor

<u>Values of coefficient of land use runoff C_i</u>

Table 1. Coefficient of Land Use Runoff

No	Land Cover	Ci
1.	City, asphalted road, roof tile	0.7 – 0.9
2.	Industrial area	0.5 – 0.9
3.	Multi-unit settlement area, shopping centre	0.6 – 0.7
4.	Housing complex	0.4 – 0.6
5.	Villa	0.3 – 0.5
6.	Park, cemetery	0.1 – 0.3
7.	Yard of heavy land:	
	a. > 7 %	0.25 – 0.35
	b. 2 – 7 %	0.18 – 0.22
	c. < 2 %	0.13 – 0.17
8.	Yard of lightweight land:	
	a. > 7 %	0.15 – 0.2
	b. 2 – 7 %	0.10 – 0.15
	c. < 2 %	0.05 – 0.10
9.	Heavy land	0.40
10.	Meadow	0.35
11.	Land for agricultural cultivation	0.30
12.	Production forest	0.18

Source: Regulation of Environmental State Minister No. 17/ 2009

Figure-4: Coefficient of land use runoff

The BBN land use plan 2013 according to BBNDA is shown below which will help in calculating the water availability and water demand of the area.

Table-2: Land use for water resource carrying capacity

COMPONENT	AREA IN HECTARES
Industrial	6115.34
Commercial	266
Residential	9944.69
Traffic and transportation	1913.07
Parks and open space	546.56

Therefore

C = [(0.6*6115.34*10000) + (0.4*9944.69*10000) + (0.1*546.96*10000) + (266*10000*0.6) + (1913.07*0.7*10000)]/3187400 = 91935250/3187400 = 28.85

R = 1186 mm/yr = 1.186 m/yr

A = 3187400 m^2

SA = 10*28.85*1.186*3187400 = 1090603971 m^3/yr.

SA = 1090603971 m^3/yr.

Water demand (DA) =Demand for domestic water (DAD) + Demand for Non-Domestic Waste water (DAND)

The water demand is calculated with the demand of the water with help of the figure mentioned below:

Demand for Domestic water *[DAD]*
-Village (rural): 80litres/day/capita
-City (urban): Small city: 1000litres/day/capita, and average city: 10000 litres/day/capita
Demand for Non-domestic waste water *[DAND]*
-Industries based on number of units
-More than 500 units - 30000 litres/day/capita
-Metween 500 - 1000 units - 50000 litres/day/capita
-More than 1000 units - 70000 litres/day/capita

Figure-5: Demand of domestic and non domestic waste water

Now the water demand = 70,000 liters per day per capita according to Figure 5 from the calculation because there are 2150 number of units in Baddi, Barotiwala and Nalagarh.

Water demand DA = 70,000 l/d/capita = 1082349100 m^3/yr

Calculated Value of SA = 1090603971 m^3/yr

Calculated Value of DA = 1082349100 m^3/yr

WATER RESOURCE CARRYING CAPACITY (DDA) = SA / DA

SA / DA = 1090603971 / 1082349100

SA / DA = 1.0076

DDA = 1.0076

<u>OUTPUT ANALYSIS</u>

DDA < 1 = WRCC Is Overshoot

DDA 1 – 3 = WRCC Is Conditionally-save

DDA > 3 = WRCC Is Save

Here DDA That Is Water Resource Carrying Capacity Is <u>1.0076</u> which lies between 1 and 3 and hence according to the output analysis it in in <u>Conditionally-save</u> region.

This approach is not systematic but is true up to some extent because it depends directly on the standards and the rainfall values which may also be taken by the assumption of the particular area.

4.2 WATER ENVIRONMENT CARRYING CAPACITY BASED ON WATER QUALITY

By the name water quality, it is clear that the characteristics study of water is taken into account. Based on the water quality there are two factors of concern which are discussed below:

4.2.1 POLLUTANT CARRYING CAPACITY

Pollutant carrying capacity is a measure of calculating the amount of pollutants (considered) carrying in the river. Since there is the discharge of many industries of BBN area in the Sirsa river its pollutant carrying capacity is determined with the help of data available from IPH Department Nalagarh and Shreya Environmental Consultancy Baddi of year 2013. Here two pollutant factors are considered namely COD and NH_4-N.

FORMULATION:

This formulation is suggested by Yang and Li School of Environment and Natural Resources, Renmin University, China.

$$W_R = [C_S - C_O * \exp(- KL / u)] * \exp(KL / 2u) * Q$$

Here

W_R = River pollutant carrying capacity

C_S = water quality target concentration at downstream cross-section of the river (mg/l)

C_O = actual water quality concentration at the upstream cross-section of the river (mg/l)

K = Pollutant Degradation Coefficient (d^{-1}) = 1/d (Assumed)

L = Length of The River (m)

u = Average Flow Velocity at River's Cross-section (m/s)

Q = Designed Flow at The Rivers Cross-section (m^3/s)

The existing values as per Shreya Environmental Consultancy Baddi are shown in the table:

Table-3: Existing values for pollutant carrying capacity

LOCATION	C_o(mg/l)		C_s(mg/l)		Length (Km)	Q (m^3/s)	u (m/s)
	COD	NH_4-N	COD	NH_4-N			
SIRSA RIVER U/S SITOMAJRI NALLAH	13.2	0.36	50	5.0	11.9	9.96	0.83
SIRSA RIVER D/S NALAGARH BRIDGE	12.3	0.25	50	5.0	11.9	10.79	0.78
SIRSA RIVER D/S NALAGARH TOWN	18.96	0.64	50	5.0	11.9	12.45	0.84

The pollutant carrying capacity is calculated at three different sites from the formulation of pollutant carrying capacity the results of which are shown below in the table:

Table-4: Pollutant carrying capacity

LOCATION	POLLUTANT CARRYING CAPACITY	
	COD	NH_4-N
SIRSA RIVER U/S SITOMAJRI NALLAH	419.07 g/s or 13217 t/a	50.72 g/s or 1599 t/a
SIRSA RIVER D/S NALAGARH BRIDGE	466.52 g/s or 14714.04 t/a	56.38 g/s or 1778.45 t/a
SIRSA RIVER D/S NALAGARH TOWN	456.69 g/s or 14404.25 t/a	60.05 g/s or 1894.17 t/a

The pollutant carrying capacity is expressed in terms of pollutant load i.e., grams per second or kilograms per day or ton per annum which is maximum at Sirsa river downstream Nalagarh bridge in terms of COD and maximum at Sirsa river downstream Nalagarh town in terms of NH_4-N. The pollutant carrying capacity is also calculated for seasonal variations for two seasons i.e. summer and the winter season. And also, the pollutant carrying capacity is calculated at various distance between the stations of the river.

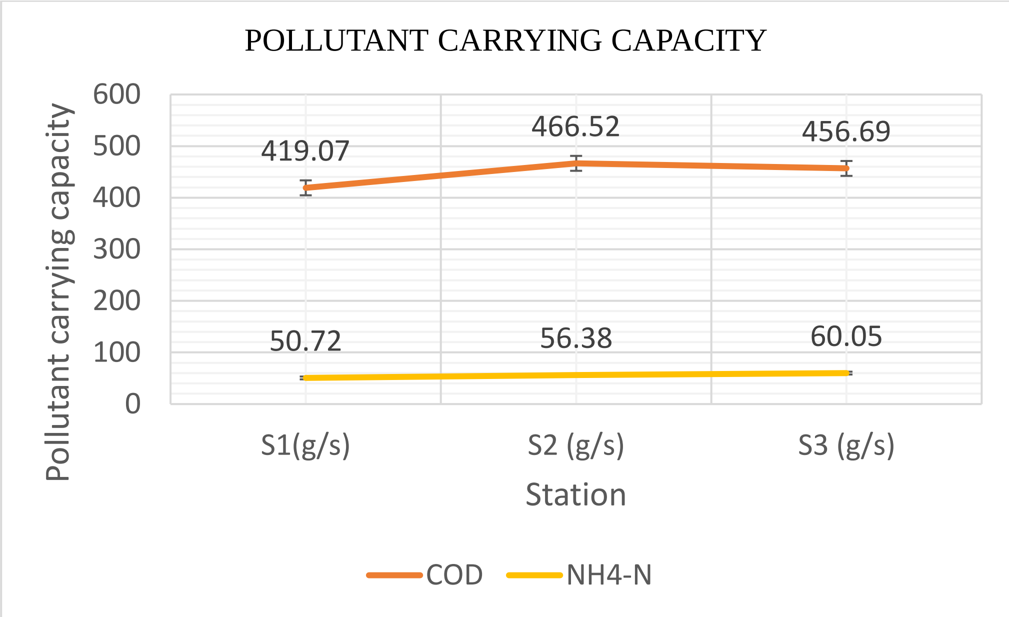

Figure-6: Pollutant carrying capacity of Sirsa river

4.2.1.1 CONSIDERATION WITH SEASONAL VARIATION

The rise and fall in the river water flow and discharge depends on the seasonal variations. Likewise, in the summer i.e., from March to August the discharge and the velocity of flow is very low and, in the winter, i.e., from September to February the discharge and flow velocity is high as compared to summer. So, these factors affect the pollution carrying capacity and hence we have to calculate the pollutant carrying capacity during summer and also in winter.

4.2.1.1.1 SUMMER SEASON

During summer, the discharge and the velocity of flow is low which will affect the pollutant carrying capacity. The data of river Sirsa during summer is collected from Shreya Environmental consultancy Baddi and Irrigation and Public Health Department Nalagarh.

Stations: S1: Sirsa river upstream Sitomajri Nallah

S2: Sirsa river downstream Nalagarh Bridge

S3: Sirsa river downstream Nalagarh town

Table-5: Existing Values for pollutant carrying capacity during summer

Station	C_O (mg / l)		C_S (mg / l)		L (Km)	Q (m^3 / s)	U (m / s)
	COD	NH_4-N	COD	NH_4-N			
S1	13.2	0.36	50	5.0	11.9	5.43	0.41
S2	12.3	0.25	50	5.0	11.9	6.79	0.38
S3	18.96	0.64	50	5.0	11.9	8.54	0.43

After that by the same formulation of pollutant carrying capacity given below we can calculate separately the pollutant carrying capacity during summer and winter.

$$W_R = [C_S - C_O * \exp(- KL / u)] * \exp(KL / 2u) * Q$$

From the average of pollutant carrying capacity is calculated above the values of Discharge and Flow velocity varies and all the parameters remains the same.

<u>Pollutant carrying capacity in terms of COD is calculated as:</u>

For S1

$= [50-13.2\exp(-1d^{-1}*11.9Km/0.41ms^{-1})]*\exp(1d^{-1}*11.9Km/2*0.41ms^{-1})*5.43m^3/s$

= 257.99g/s or 22290.3Kg/d or 8968.37t/a

For S2

$= [50-12.3\exp(-1d^{-1}*11.9Km/0.38ms^{-1})]*\exp(1d^{-1}*11.9Km/2*0.38ms^{-1})*6.79m^3/s$

= 334.67g/s or 28915.4Kg/d or 11633.96t/a

For S3

$= [50-18.96\exp(-1d^{-1}*11.9Km/0.43ms^{-1})]*\exp(1d^{-1}*11.9Km/2*0.43ms^{-1})*8.54m^3/s$

= 362.10g/s or 31285.4Kg/d or 12587.49t/a

<u>Pollutant carrying capacity in terms of NH_4-Nis calculated as:</u>

For S1

$= [5-0.36\exp(-1d^{-1}*11.9Km/0.41ms^{-1})]*\exp(1d^{-1}*11.9Km/2*0.41ms^{-1})*5.43m^3/s$

= 30.17g/s or 2606.6Kg/d or 1048.78t/a

For S2

= [5-0.25exp(-1d^{-1}*11.9Km/0.38ms^{-1})]*exp(1d^{-1}*11.9Km/2*0.38ms^{-1})*6.79m^3/s

=39.02g/s or 3371.3Kg/d or 1356.43t/a

For S3

= [5-0.64exp(-1d^{-1}*11.9Km/0.43ms^{-1})]*exp(1d^{-1}*11.9Km/2*0.43ms^{-1})*8.54m^3/s

= 45.36g/s or 3919.1Kg/d or 1576.82t/a

Table-6: Pollutant Carrying Capacity during Summer

STATION	POLLUTANT CARRYING CAPACITY DURING SUMMER			
	COD		NH_4-N	
	grams/second	tonnes/annum	grams/second	tonnes/annum
S1	257.99	8968.37	30.17	1048.78
S2	334.67	11633.96	39.02	1356.43
S3	362.10	12587.49	45.36	1576.82

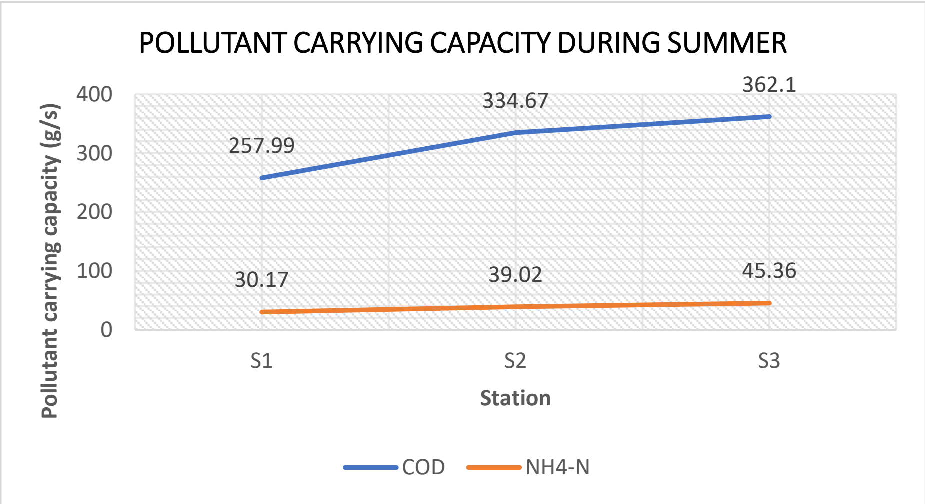

Figure-7: Pollutant carrying capacity of Sirsa river during Summer

4.2.1.1.2 WINTER SEASON

During winter, the discharge and the velocity of flow is high which will affect the pollutant carrying capacity. The data during winter of river Sirsa is collected from Shreya Environmental consultancy Baddi and IPH Department Nalagarh.

Stations: S1: Sirsa river upstream Sitomajri Nallah

S2: Sirsa river downstream Nalagarh Bridge

S3: Sirsa river downstream Nalagarh town

Table-7: Existing Values for pollutant carrying capacity during winter

Station	C_O (mg / l)		C_S (mg / l)		L (Km)	Q (m^3 / s)	U (m / s)
	COD	NH4-N	COD	NH4-N			
S1	13.2	0.36	50	5.0	11.9	14.49	1.25
S2	12.3	0.25	50	5.0	11.9	14.79	1.18
S3	18.96	0.64	50	5.0	11.9	16.36	1.27

After that by the same formulation of pollutant carrying capacity given below we can calculate separately the pollutant carrying capacity during summer and winter.

$$W_R = [C_S - C_O * \exp(- KL / u)] * \exp(KL / 2u) * Q$$

From the average of pollutant carrying capacity is calculated above the values of Discharge and Flow velocity varies and all the parameters remains the same.

<u>Pollutant carrying capacity in terms of COD is calculated as:</u>

For S1

$= [50-13.2\exp(-1d^{-1}*11.9Km/1.25ms^{-1})]*\exp(1d^{-1}*11.9Km/2*1.25ms^{-1})*14.49m^3/s$

= 581.19g/s or 50214.8Kg/d or 20203.6t/a

For S2

$= [50-12.3\exp(-1d^{-1}*11.9Km/1.18ms^{-1})]*\exp(1d^{-1}*11.9Km/2*1.18ms^{-1})*14.79m^3/s$

= 605.49g/s or 52314.3Kg/d or 21048.3t/a

For S3

$= [50-18.96\exp(-1d^{-1}*11.9Km/1.27ms^{-1})]*\exp(1d^{-1}*11.9Km/2*1.27ms^{-1})*16.36m^3/s$

= 564.29g/s or 48754.6Kg/d or 19616.1t/a

<u>Pollutant carrying capacity in terms of NH_4-Nis calculated as:</u>

For S1

= [5-0.36exp(-1d^{-1}*11.9Km/1.25ms^{-1})]*exp(1d^{-1}*11.9Km/2*1.25ms^{-1})*14.49m^3/s

= 71.20g/s or 6151.6Kg/d or 2475.1t/a

For S2

= [5-0.25exp(-1d^{-1}*11.9Km/1.18ms^{-1})]*exp(1d^{-1}*11.9Km/2*1.18ms^{-1})*14.79m^3/s

= 74.23g/s or 6413.4Kg/d or 2580.4t/a

For S3

= [5-0.64exp(-1d^{-1}*11.9Km/1.27ms^{-1})]*exp(1d^{-1}*11.9Km/2*1.27ms^{-1})*16.36m^3/s

= 76.09g/s or 6574.1Kg/d or 2645.1t/a

Table-8: Pollutant Carrying Capacity during Winter

STATION	POLLUTANT CARRYING CAPACITY DURING WINTER			
	COD		NH_4-N	
	grams/second	tonnes/annum	grams/second	tonnes/annum
S1	581.19	20203.6	71.20	2475.1
S2	605.49	21048.3	74.23	2580.4
S3	564.29	19616.1	76.09	2645.1

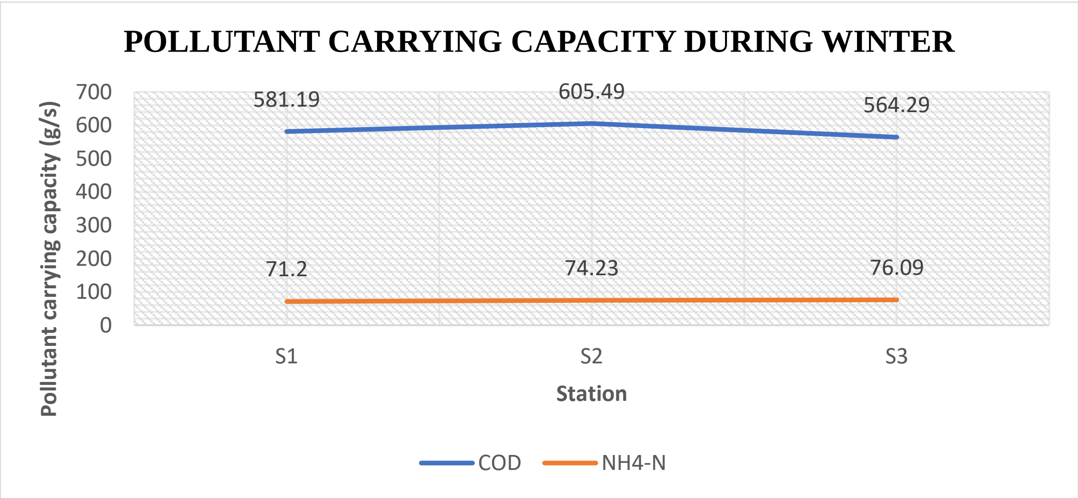

Figure-8: Pollutant carrying capacity of Sirsa river during Winter

4.2.1.1.2 COMPARISON OF POLLUTANT CARRYING CAPACIY DURING SUMMER AND WINTER

The results show that the pollutant carrying capacity during winter is higher as compared during summer in both cases that is with respect to COD and with respect to NH_4-N. The pollutant carrying capacity is higher due to large discharge and flow velocity during winter as compared to summer. The graphical representation of the comparison of pollutant carrying capacity during summer and winter is shown below:

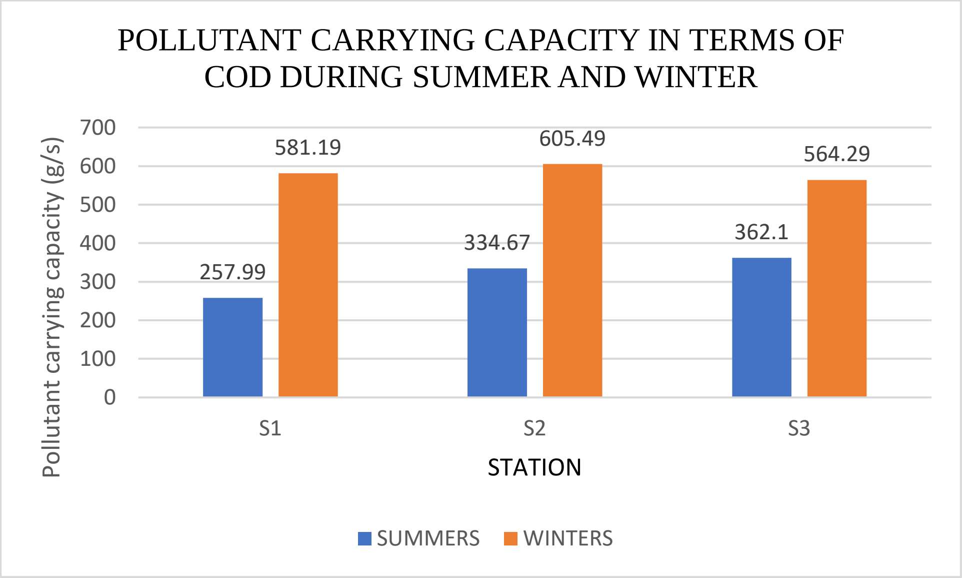

Figure-9: Pollutant carrying capacity in terms of COD during summer and winter

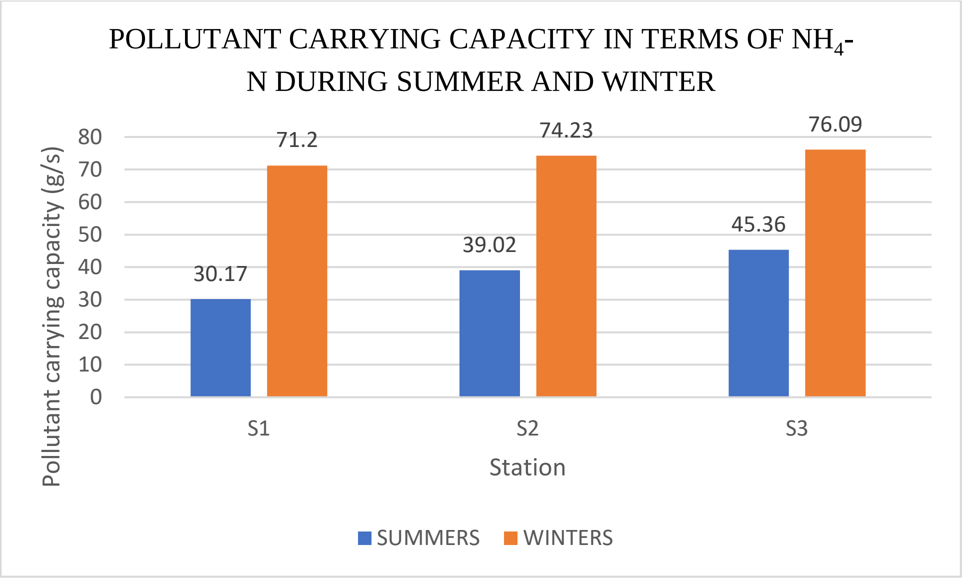

Figure-10: Pollutant carrying capacity in terms of NH_4-N during summer and winter

4.2.1.2 POLLUTANT CARRYING CAPACIY BETWEEN STATIONS

The study includes three stations namely:

S1: Sirsa river upstream Sitomajri Nallah

S2: Sirsa river downstream Nalagarh Bridge

S3: Sirsa river downstream Nalagarh town

The Sitomajri Nallah is the first station when Sirsa river enters the BBN area, the next station is Nalagarh Bridge and the last station after which the Sirsa river exits the BBN area is Nalagarh town. Now the pollutant carrying capacity is calculated in between these stations and before station S1 and after the station S3. All the Sirsa river length in the BBN area is totally 11.9 kilometers. Now we calculate the pollutant carrying capacity at different spans of this 11.9 kilometers length.

The illustration of these stations is shown below:

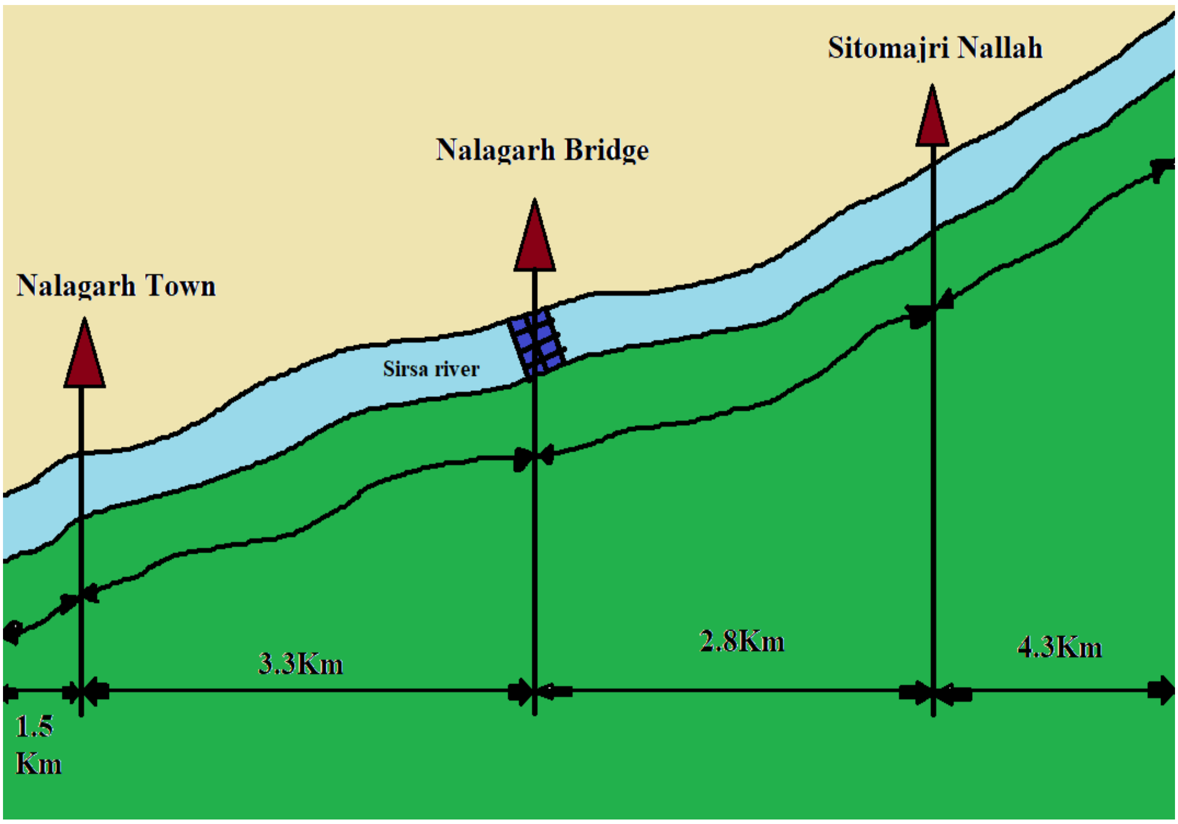

Figure-11: Illustration of Stations

The existing values in between these stations as per IPH Department and Shreya Environmental Consultancy are as follows:

Table-9: Existing Values for pollutant carrying capacity at different Distances

STATION	C_O (mg/l)		C_S (mg/l)		L (Km)	Q (m^3/s)	U (m/s)
	COD	NH_4-N	COD	NH_4-N			
Before Sitomajri Nallah	13.9	0.38	50	5.0	4.3	9.81	0.82
Sitomajri Nallah to Nalagarh Bridge	13.4	0.31	50	5.0	2.8	9.96	0.79
Nalagarh Bridge to Nalagarh Town	15.9	0.45	50	5.0	3.3	10.60	0.81
Sitomajri Nallah to Nalagarh town	14.7	0.38	50	5.0	1.5	10.85	0.85
After Nalagarh town	18.9	0.65	50	5.0	6.1	12.45	0.87

There are five different spans of the Sirsa river for the calculation of pollutant carrying capacity namely:

T1: Before Sitomajri Nallah

T2: Sitomajri Nallah to Nalagarh Bridge

T3: Nalagarh Bridge to Nalagarh Town

T4: Sitomajri Nallah to Nalagarh Town

T5: After Nalagarh town

After that by the same formulation of Pollutant carrying capacity given below we can calculate separately the pollutant carrying capacity at different spans of Sirsa River.

$$W_R = [C_S - C_O * \exp(- KL / u)] * \exp(KL / 2u) * Q$$

The total length of the river Sirsa is divided into five different spans named above as T1, T2, T3, T4 and T5 and the pollutant carrying capacity is measured by the above formulation at these five stations.

Pollutant carrying capacity in terms of COD is calculated as:

For T1

$= [50-13.9\exp(-1d^{-1}*4.3Km/0.82ms^{-1})]*\exp(1d^{-1}*4.3Km/2*0.82ms^{-1})*9.81m^3/s$

= 372.94g/s or 32222.1Kg/d or 12964.32t/a

For T2

$= [50-13.4\exp(-1d^{-1}*2.8Km/0.79ms^{-1})]*\exp(1d^{-1}*2.8Km/2*0.79ms^{-1})*9.96m^3/s$

= 377.21g/s or 32590.9Kg/d or 13112.75t/a

For T3

$= [50-15.9\exp(-1d^{-1}*3.3Km/0.81ms^{-1})]*\exp(1d^{-1}*3.3Km/2*0.81ms^{-1})*10.60m^3/s$

= 375.5g/s or 32443.2Kg/d or 13053.3t/a

For T4

$= [50-14.7\exp(-1d^{-1}*1.5Km/0.85ms^{-1})]*\exp(1d^{-1}*1.5Km/2*0.85ms^{-1})*10.85m^3/s$

= 390.12g/s or 33706.3Kg/d or 13561.5t/a

For T5

$= [50-18.9\exp(-1d^{-1}*6.1Km/0.87ms^{-1})]*\exp(1d^{-1}*6.1Km/2*0.87ms^{-1})*12.45m^3/s$

= 421.58g/s or 36424.5Kg/d or 14655.17t/a

Pollutant carrying capacity in terms of NH_4-N is calculated as:

For T1

$= [5.0-0.38\exp(-1d^{-1}*4.3Km/0.82ms^{-1})]*\exp(1d^{-1}*4.3Km/2*0.82ms^{-1})*9.81m^3/s$

= 46.88g/s or 4050.4Kg/d or 1629.67t/a

For T2

$= [5.0-0.31\exp(-1d^{-1}*2.8Km/0.79ms^{-1})]*\exp(1d^{-1}*2.8Km/2*0.79ms^{-1})*9.96m^3/s$

= 47.74g/s or 4124.7Kg/d or 1659.56t/a

For T3

= [5.0-0.45exp(-1d^{-1}*3.3Km/0.81ms^{-1})]*exp(1d^{-1}*3.3Km/2*0.81ms^{-1})*10.60m^3/s

= 49.30g/s or 4259.5Kg/d or 1713.79t/a

For T4

= [5.0-0.38exp(-1d^{-1}*1.5Km/0.85ms^{-1})]*exp(1d^{-1}*1.5Km/2*0.85ms^{-1})*10.85m^3/s

= 50.62g/s or 4373.5Kg/d or 1759.6t/a

For T5

= [5.0-0.65exp(-1d^{-1}*6.1Km/0.87ms^{-1})]*exp(1d^{-1}*6.1Km/2*0.87ms^{-1})*12.45m^3/s

= 56.84g/s or 4910.9Kg/d or 1975.89t/a

Table-10: Pollutant Carrying Capacity at Different Spans of Sirsa River

STATION	POLLUTANT CARRYING CAPACITY			
	COD		NH_4-N	
	grams/second	tonnes/annum	grams/second	tonnes/annum
T1	372.94	12964.32	46.88	1629.67
T2	377.21	13112.75	47.74	1659.56
T3	375.5	13053.3	49.30	1713.79
T4	390.12	13561.5	50.62	1759.6
T5	421.58	14655.17	56.84	1975.89

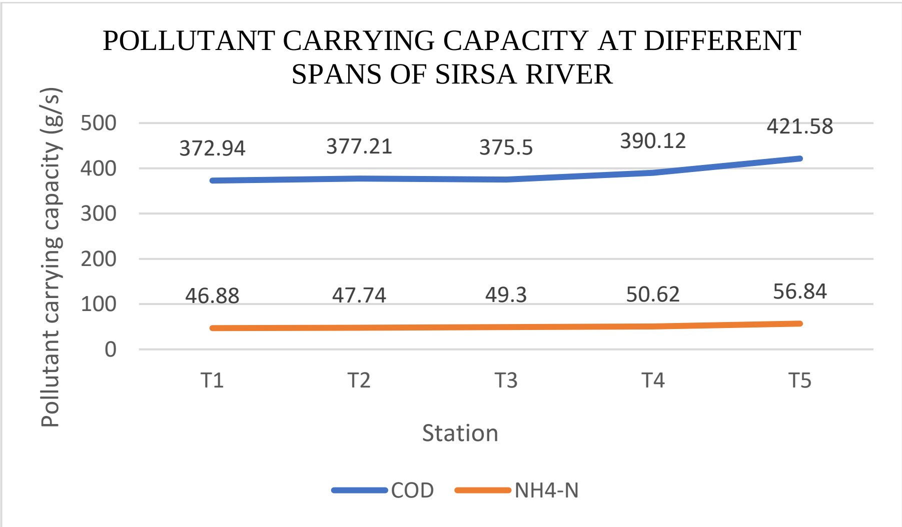

Figure-12: Pollutant carrying capacity at different spans of Sirsa River

4.2.1.3 COMPARISON OF POLLUTANT CARRYING CAPACITY OF SIRSA RIVER WITH BEAS RIVER IN MANDI PLAIN

Comparison of pollutant carrying capacity of Sirsa river was made with river Beas which is in Mandi plain of HP, India. The existing data of river Beas is taken from IPH Mandi, HP, India. The COD values for river Beas taken at six different stations are shown in Table 11.

COD values are taken at 6 different stations of Beas river

Table-11: COD values of Beas river

Beas Kund	0
Shamshi	4.7
Pandoh Dam	1.3
Dharampur	9.4
Nadaun	3.9
Pong dam	1.9

Average value from these six values of COD = 3.54mg/l

Total length of Beas River in Himachal Pradesh = 256 Km

Average Length in Mandi Plain = 27 Km

Discharge = $48 m^3/s$

Average flow velocity = 1.8 m/s

Than from the formulation $W_R = [C_S - C_O*exp(-KL/u)] *exp(KL/2u) *Q$

Therefore, W_R = [50 – 3.54 * exp(-1*27/1.8)]*exp(1*27/2*1.8)*48 = 2460 g/s

The pollutant carrying capacity = 2460 g/s or 212544Kg/d which is greater than Sirsa river i.e. 456.69 g/s or 39458.1Kg/d

Table-12: Comparison results of Sirsa river with Beas River

FACTOR	SIRSA RIVER	BEAS RIVER	RESULT
COD [mg/l]	18.96	3.54	COD of Sirsa river is higher than Beas river
LENGTH [Km]	11.9	27	Length of Beas river at selected span is more
DISCHARGE [m^3/s]	12.45	48	Discharge of Beas river is more
FLOW VELOCITY [m/s]	0.84	1.8	Flow velocity of Beas river is more
POLLUTANT CARRYING CAPACITY [g/s]	456.69	2460	Pollutant carrying capacity of Beas river is more

The results show that:

1) COD of Sirsa river is higher than Beas river.
2) Length of Beas river is greater that Sirsa river when considering area wise.
3) Discharge of Beas river is higher than Sirsa river.
4) Flow velocity of Beas river is higher than Sirsa river.
5) Pollutant carrying capacity of Beas river is higher than Sirsa river which shows that river Beas has more capability to carry pollutants because of its higher flow velocity and discharge.

4.2.2 CARRYING CAPACITY BASED ON WATER QUALITY VARIABLES

The WECC indicators play an important role in evaluation of the water carrying capacity. Due to complex regional environmental systems, it is difficult to assess all activities to evaluate the WECC. The Indicator Evaluation (IE) method consists of selecting particular number of indicators with their values at specified time and evaluating the comprehensive values of WECC by Mathematical methods. The method is suggested by Peng and Linyu, State key Laboratory of Water Environment Simulation, School of Environment, Beijing, China. The method includes a matrix method for the calculation of comprehensive values of WECC's at different sites. The selection of indicators is based on quality of water body or it may be socio- economic factors. The characteristics based on the four water quality variables are considered depending upon the quality of the water body. The carrying capacity by indicator evaluation method consists of three steps which are mentioned below.

It Includes the Following Steps:

- ➢ Selection of Indicators
- ➢ Calculating Weight of Each Indicator
- ➢ Evaluation of Water Environment Carrying Capacity

For the calculation of carrying capacity by indicator evaluation method the selected indicators are pH, DO, BOD and COD. The selected sites for the calculations of WECC by indicator evaluation method are:

1. Sirsa River Upstream Sitomajri Nallah
2. Sirsa River Downstream Nalagarh Bridge
3. Sirsa River Downstream Nalagarh Town
4. Well at Baddi, Barotiwala And Nalagarh
5. Well at industrial area Baddi, Barotiwala And Nalagarh

Formulation of INDICATOR EVALUATION METHOD

The comprehensive value of water environmental carrying capacity is Si which is:

$$\mathbf{Si = \sum W^{(C1\text{-}C4)} * Y_K}$$

Here $W^{(C1-C4)}$ is the Total of Average values of the indicators i.e. C1+C2+C3+C4

And Y_K = [Sa-Min(R)]/[Max(R)-Min(R)]

Sa = (C1+C2+C3+C4) / n

n = number of selected indicators

Min(R) and Max(R) are the minimum and maximum values of particular time.

4.2.2.1 CARRYING CAPACITY OF SIRSA RIVER UPSTREAM SITOMAJRI NALLAH BY INDICATOR EVALUATION METHOD

The selected indicators with their values are shown below:

Table-13: Existing values of indicators of Sirsa river upstream Sitomajri Nallah

Date	pH (C1)	DO (C2)	BOD (C3)	COD (C4)
Apr-15	7.31	7.7	2.2	20
May-15	7.08	8.1	1.8	24
Jun-15	8.75	5.2	2.2	32
Jul-15	6.74	5.5	7.5	30
Aug-15	7.96	5	10	40
Sept-15	7.32	5.6	18	40
Oct-15	7.74	8.1	1	8
Nov-15	7.39	7.1	0.8	20
Dec-15	6.97	5.8	1.6	20
Jan-16	6.95	6.9	0.8	12
Feb-16	8.25	8.7	1.2	16
Mar-16	8.37	9.2	0.8	8
Apr-16	8.09	6.1	0.8	16

Table-14: Average values of indicators of Sirsa river upstream Sitomajri Nallah

INDICATOR	C1	C2	C3	C4
AVERAGE VALUE	7.6	6.84	3.74	22

Now $W^{(C1-C4)}$ = 7.6 + 6.84 + 3.74 + 22 = 40.18

Sa = (C1+C2+C3+C4) / n = (7.6+6.84+3.74+22)/4 = 10.04

Now, Y_K = [Sa-Min(R)]/[Max(R)-Min(R)]

The value of Y_K and S_i is calculated shown below in the table:

Table-15: Water environmental carrying capacity (WECC) of Sirsa river upstream Sitomajri Nallah

Date	pH (C1)	DO (C2)	BOD (C3)	COD (C4)	Min (R)	Max (R)	Y_K	S_i
Apr-15	7.31	7.7	2.2	20	2.2	20	0.44	17.7
May-15	7.08	8.1	1.8	24	1.8	24	0.37	14.9
Jun-15	8.75	5.2	2.2	32	2.2	32	0.26	10.5
Jul-15	6.74	5.5	7.5	30	5.5	30	0.18	7.4
Aug-15	7.96	5	10	40	5	40	0.14	5.7
Sept-15	7.32	5.6	18	40	5.6	40	0.12	5.1
Oct-15	7.74	8.1	1	8	1	8.1	1.27	51.1
Nov-15	7.39	7.1	0.8	20	0.8	20	0.48	19.3
Dec-15	6.97	5.8	1.6	20	1.6	20	0.45	18.4
Jan-16	6.95	6.9	0.8	12	0.8	12	0.82	33.1
Feb-16	8.25	8.7	1.2	16	1.2	16	0.59	24
Mar-16	8.37	9.2	0.8	8	0.8	9.2	1.1	44.2
Apr-16	8.09	6.1	0.8	16	0.8	16	0.60	24.4

Figure-13: Water environmental carrying capacity of Sirsa river upstream sitomajri nallah

4.2.2.2 CARRYING CAPACITY OF SIRSA RIVER DOWNSTREAM NALAGARH BRIDGE BY INDICATOR EVALUATION METHOD

The selected indicators with their values are shown below:

Table-16: Existing Values of Indicators of Sirsa river downstream Nalagarh Bridge

Date	pH (C1)	DO (C2)	BOD (C3)	COD (C4)
Apr-15	7.37	8.2	2	36
May-15	7.34	4.7	2.2	32
Jun-15	7.93	4.7	2.8	36
Jul-15	6.73	5	4.5	18
Aug-15	7.95	4.9	10	32
Sept-15	7.93	4.5	10	32
Oct-15	7.98	6.4	2	12
Nov-15	7.68	5.9	1.4	32
Dec-15	7.99	4.7	1.2	36
Jan-16	7.6	5.2	0.3	32
Feb-16	8.82	4.8	4	44
Mar-16	7.62	8.3	1.2	32
Apr-16	8.18	5.3	3.2	48

Table-17: Average values of indicators of Sirsa river downstream Nalagarh Bridge

INDICATOR	C1	C2	C3	C4
AVERAGE VALUE	7.77	5.58	3.44	32.46

Now $W^{(C1\text{-}C4)}$ = 7.77 + 5.58 + 3.44 + 32.46 = 49.25

Sa = (C1+C2+C3+C4) / n = (7.77+5.58+3.44+32.46)/4 = 12.31

Now, Y_K = [Sa-Min(R)]/[Max(R)-Min(R)]

The value of Y_K and S_i is calculated shown below in the table:

Table-18: Water environmental carrying capacity of Sirsa river downstream Nalagarh Bridge

Date	pH (C1)	DO (C2)	BOD (C3)	COD (C4)	Min (R)	Max (R)	Y_K	S_i
Apr-15	7.37	8.2	2	36	2	36	0.3	14.9
May-15	7.34	4.7	2.2	32	2.2	32	0.33	16.7
Jun-15	7.93	4.7	2.8	36	2.8	36	0.28	14.1
Jul-15	6.73	5	4.5	18	4.5	18	0.57	28.49
Aug-15	7.95	4.9	10	32	4.9	32	0.27	13.46
Sept-15	7.93	4.5	10	32	4.5	32	0.28	13.98
Oct-15	7.98	6.4	2	12	2	12	1	50.77
Nov-15	7.68	5.9	1.4	32	1.4	32	0.35	17.55
Dec-15	7.99	4.7	1.2	36	1.2	36	0.31	15.72
Jan-16	7.6	5.2	0.3	32	0.3	32	0.37	18.65
Feb-16	8.82	4.8	4	44	4	44	0.2	10.23
Mar-16	7.62	8.3	1.2	32	1.2	32	0.36	17.76
Apr-16	8.18	5.3	3.2	48	3.2	48	0.2	10

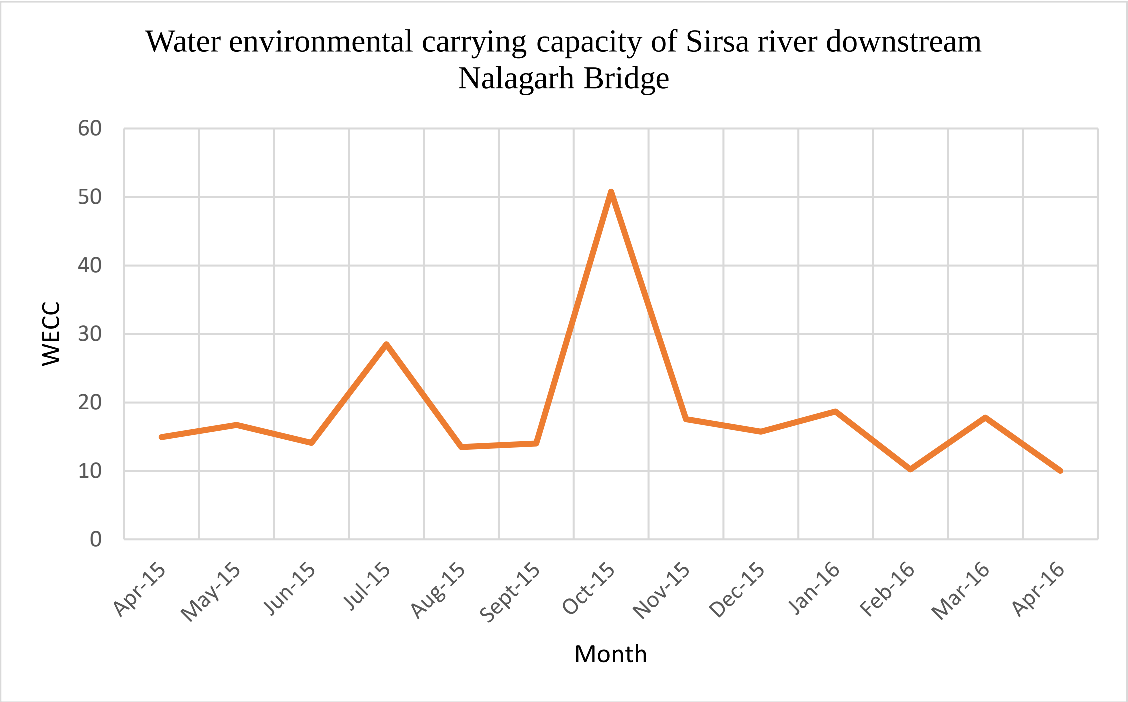

Figure-14: Water environmental carrying capacity of Sirsa river downstream Nalagarh Bridge

4.2.2.3 CARRYING CAPACITY OF SIRSA RIVER DOWNSTREAM NALAGARH TOWN BY INDICATOR EVALUATION METHOD

The selected indicators with their values are shown below:

Table-19: Existing Values of Indicators of Sirsa river downstream Nalagarh Town

Date	pH(C1)	DO (C2)	BOD (C3)	COD (C4)
Apr-15	7.2	8.8	2.4	40
May-15	6.9	5.3	1.8	36
Jun-15	8.57	5.1	1.8	32
Jul-15	6.09	5.2	10	40
Aug-15	7.92	5.2	12	28
Sept-15	7.82	5.1	12	30
Oct-15	8.3	6.1	1	6
Nov-15	7.56	6.5	1	28
Dec-15	7.16	5.2	1	32
Jan-16	7.77	4.9	0.6	36
Feb-16	8.55	5	6	52
Mar-16	7.89	8.7	2	44
Apr-16	8.51	5.3	3	52

Table-20: Average values of indicators of Sirsa river downstream Nalagarh Town

INDICATOR	C1	C2	C3	C4
AVERAGE VALUE	7.71	5.87	4.2	35.07

Now $W^{(C1-C4)}$ = 7.71 + 5.57 + 4.2 + 35.07 = 52.55

Sa = (C1+C2+C3+C4) / n = (7.71+5.57+4.2+35.07)/4 = 13.13

Now, Y_K = [Sa-Min(R)]/[Max(R)-Min(R)]

The value of Y_K and S_i is calculated shown below in the table:

Table-21: Water environmental carrying capacity of Sirsa river downstream Nalagarh Town

Date	pH (C1)	DO (C2)	BOD (C3)	COD (C4)	Min (R)	Max (R)	Y_K	S_i
Apr-15	7.2	8.8	2.4	40	2.4	40	0.28	14.99
May-15	6.9	5.3	1.8	36	1.8	36	0.33	17.4
Jun-15	8.57	5.1	1.8	32	1.8	32	0.37	19.71
Jul-15	6.09	5.2	10	40	5.2	40	0.22	11.97
Aug-15	7.92	5.2	12	28	5.2	28	0.34	18.27
Sept-15	7.82	5.1	12	30	5.1	30	0.32	16.94
Oct-15	8.3	6.1	1	6	1	8.3	1.66	87.31
Nov-15	7.56	6.5	1	28	1	28	0.44	23.6
Dec-15	7.16	5.2	1	32	1	32	0.39	20.56
Jan-16	7.77	4.9	0.6	36	0.6	36	0.35	18.6
Feb-16	8.55	5	6	52	5	52	0.17	9
Mar-16	7.89	8.7	2	44	2	44	0.26	13.92
Apr-16	8.51	5.3	3	52	3	52	0.2	10.8

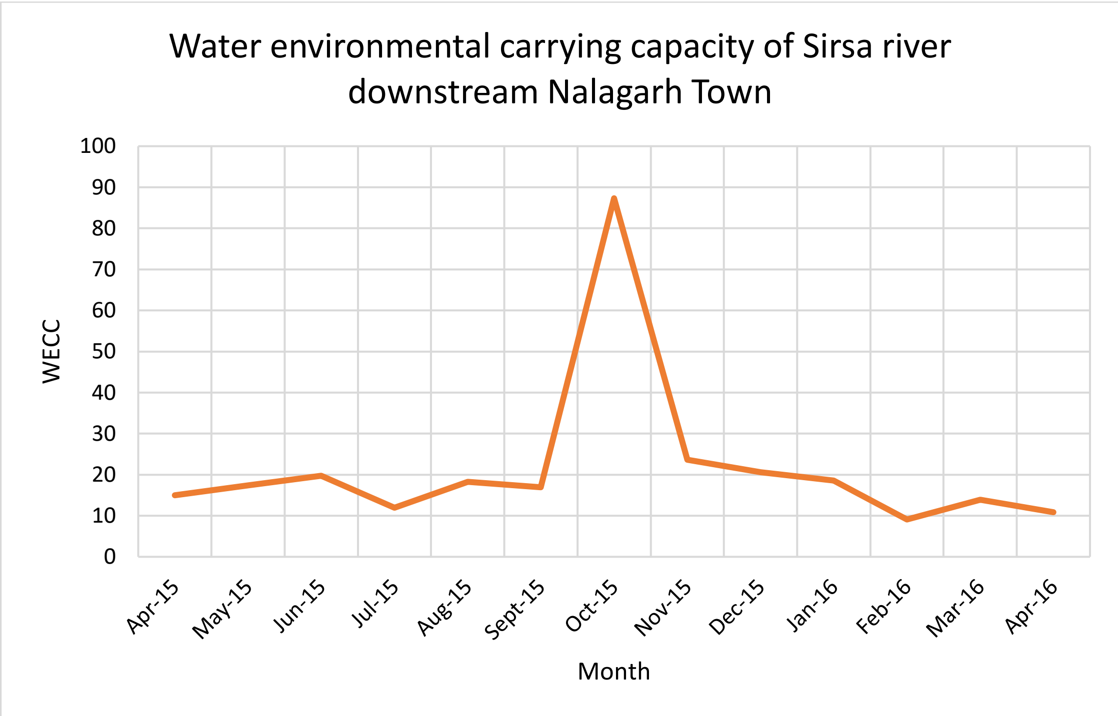

Figure-15: Water environmental carrying capacity of Sirsa river downstream Nalagarh Town

4.2.2.4 WELL AT BADDI, BAROTILWALA AND NALAGARH

Well at BADDI

The selected indicators with their values are shown below:

Table-22: Existing Values of Indicators well at Baddi

Date	pH (C1)	DO (C2)	BOD (C3)	COD (C4)
Apr-15	7.7	5	0.1	0.8
Oct-15	7.86	9.9	0.4	2
Apr-16	8.55	5.1	0.1	1.2
Oct-16	7.96	9.6	0.1	0.4

Table-23: Average values of indicators of well at Baddi

INDICATOR	C1	C2	C3	C4
AVERAGE VALUE	8.01	7.4	0.17	1.1

Now $W^{(C1\text{-}C4)} = 8.01 + 7.4 + 0.17 + 1.1 = 16.68$

Sa = (C1+C2+C3+C4) / n = (8.01+7.4+0.17+1.1)/4 = 4.17

Now, Y_K = [Sa-Min(R)]/[Max(R)-Min(R)]

The value of Y_K and S_i is calculated shown below in the table:

Table-24: Water environmental carrying capacity of well at Baddi

Date	pH (C1)	DO (C2)	BOD (C3)	COD (C4)	Min (R)	Max (R)	Y_K	S_i
Apr-15	7.7	5	0.1	0.8	0.1	7.7	0.53	8.93
Oct-15	7.86	9.9	0.4	2	0.4	9.9	0.39	6.61
Apr-16	8.55	5.1	0.1	1.2	0.1	8.55	0.48	8.03
Oct-16	7.96	9.6	0.1	0.4	0.1	9.6	0.42	7.14

Well at BAROTIWALA

The selected indicators with their values are shown below:

Table-25: Existing Values of Indicators well at Barotiwala

Date	pH (C1)	DO (C2)	BOD (C3)	COD (C4)
Apr-15	7.58	6	0.1	0.8
Oct-15	7.85	10.2	0.5	2.5
Apr-16	8.57	6.2	0.1	1.2
Oct-16	7.99	9.4	0.1	0.8

Table-26: Average values of indicators of well at Barotiwala

INDICATOR	C1	C2	C3	C4
AVERAGE VALUE	7.99	7.95	0.2	1.32

Now $W^{(C1\text{-}C4)}$ = 7.99 + 7.95 + 0.2 + 1.32 = 17.46

Sa = (C1+C2+C3+C4) / n = (7.99+7.95+0.2+1.32)/4 = 4.36

Now, Y_K = [Sa-Min(R)]/[Max(R)-Min(R)]

The value of Y_K and S_i is calculated shown below in the table:

Table-27: Water environmental carrying capacity of well at Barotiwala

Date	pH (C1)	DO (C2)	BOD (C3)	COD (C4)	Min (R)	Max (R)	Y_K	S_i
Apr-15	7.58	6	0.1	0.8	0.1	7.58	0.56	9.94
Oct-15	7.85	10.2	0.5	2.5	0.5	10.2	0.39	6.94
Apr-16	8.57	6.2	0.1	1.2	0.1	8.57	0.5	8.78
Oct-16	7.99	9.4	0.1	0.8	0.1	9.4	0.45	7.99

Well at NALAGARH

The selected indicators with their values are shown below:

Table-28: Existing Values of Indicators well at Nalagarh

Date	pH (C1)	DO (C2)	BOD (C3)	COD (C4)
Apr-15	7.17	5	0.1	0.8
Oct-15	8.36	11.4	0.4	1.6
Apr-16	7.92	5.6	0.6	1.6
Oct-16	8.85	11.4	0.45	1.8

Table-29: Average values of indicators of well at Nalagarh

INDICATOR	C1	C2	C3	C4
AVERAGE VALUE	8	8.35	0.38	1.45

Now $W^{(C1-C4)}$ = 8 + 8.35 + 0.38 + 1.45 = 18.18

Sa = (C1+C2+C3+C4) / n = (8+8.35+0.38+1.45)/4 = 4.54

Now, Y_K = [Sa-Min(R)]/[Max(R)-Min(R)]

The value of Y_K and S_i is calculated shown below in the table:

Table-30: Water environmental carrying capacity of well at Nalagarh

Date	pH (C1)	DO (C2)	BOD (C3)	COD (C4)	Min (R)	Max (R)	Y_K	S_i
Apr-15	7.17	5	0.1	0.8	0.1	7.17	0.62	11.4
Oct-15	8.36	11.4	0.4	1.6	0.4	11.4	0.37	6.84
Apr-16	7.92	5.6	0.6	1.6	0.6	7.92	0.53	9.78
Oct-16	8.85	11.4	0.45	1.8	0.45	11.4	0.37	6.79

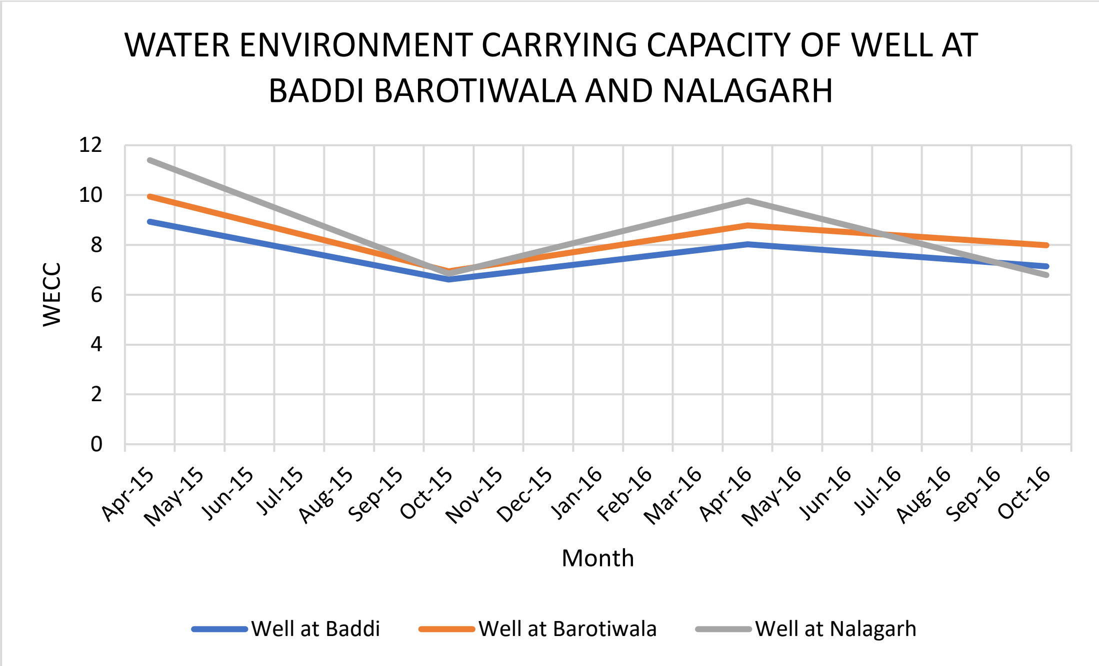

Figure-16: Water environmental carrying capacity of well at Baddi, Barotiwala and Nalagarh

4.2.2.5 WELL AT INDUSTRIAL AREA BADDI, BAROTILWALA AND NALAGARH

Well at industrial area BADDI

The selected indicators with their values are shown below:

Table-31: Existing Values of Indicators well at industrial area Baddi

Date	pH (C1)	DO (C2)	BOD (C3)	COD (C4)
Apr-15	7.78	4.5	0.1	0.4
Oct-15	7.94	8.9	0.5	2
Apr-16	8.04	4.9	0.6	12
Oct-16	7.48	8.2	0.1	0.4

Table-32: Average values of indicators of well at industrial area Baddi

INDICATOR	C1	C2	C3	C4
AVERAGE VALUE	7.81	6.62	0.32	3.7

Now $W^{(C1-C4)}$ = 7.81 + 6.62 + 0.32 + 3.7 = 18.45

Sa = (C1+C2+C3+C4) / n = (7.81+6.62+0.32+3.7)/4 = 4.61

Now, Y_K = [Sa-Min(R)]/[Max(R)-Min(R)]

The value of Y_K and S_i is calculated shown below in the table:

Table-33: Water environmental carrying capacity of well at industrial area Baddi

Date	pH (C1)	DO (C2)	BOD (C3)	COD (C4)	Min (R)	Max (R)	Y_K	S_i
Apr-15	7.78	4.5	0.1	0.4	0.1	7.78	0.58	10.83
Oct-15	7.94	8.9	0.5	2	0.5	8.9	0.48	9.02
Apr-16	8.04	4.9	0.6	12	0.6	12	0.35	6.48
Oct-16	7.48	8.2	0.1	0.4	0.1	8.2	0.55	10.27

Well at industrial area BAROTIWALA

The selected indicators with their values are shown below:

Table-34: Existing Values of Indicators well at industrial area Barotiwala

Date	pH (C1)	DO (C2)	BOD (C3)	COD (C4)
Apr-15	7.33	6.2	0.1	0.4
Oct-15	7.68	7.8	0.1	0.4
Apr-16	8.07	6.3	0.2	8
Oct-16	7.41	9.2	0.1	1.2

Table-35: Average values of indicators of well at industrial area Barotiwala

INDICATOR	C1	C2	C3	C4
AVERAGE VALUE	7.62	7.37	0.12	2.5

Now $W^{(C1-C4)}$ = 7.62 + 7.37 + 0.12 + 2.5 = 17.61

Sa = (C1+C2+C3+C4) / n = (7.62+7.37+0.12+2.5)/4 = 4.40

Now, Y_K = [Sa-Min(R)]/[Max(R)-Min(R)]

The value of Y_K and S_i is calculated shown below in the table:

Table-36: Water environmental carrying capacity of well at industrial area Barotiwala

Date	pH (C1)	DO (C2)	BOD (C3)	COD (C4)	Min (R)	Max (R)	Y_K	S_i
Apr-15	7.33	6.2	0.1	0.4	0.1	7.33	0.59	10.47
Oct-15	7.68	7.8	0.1	0.4	0.1	7.8	0.55	9.83
Apr-16	8.07	6.3	0.2	8	0.2	8.07	0.53	9.39
Oct-16	7.41	9.2	0.1	1.2	0.1	9.2	0.47	8.32

Well at industrial area Nalagarh

The selected indicators with their values are shown below:

Table-37: Existing Values of Indicators well at industrial area Nalagarh

Date	pH (C1)	DO (C2)	BOD (C3)	COD (C4)
Apr-15	7.16	9.5	0.1	0.4
Oct-15	7.78	10.9	0.8	2
Apr-16	6.78	9.7	0.1	0.4
Oct-16	7.81	7.1	0.2	3.2

Table-38: Average values of indicators of well at industrial area Nalagarh

INDICATOR	C1	C2	C3	C4
AVERAGE VALUE	7.38	9.3	0.3	1.5

Now $W^{(C1\text{-}C4)}$ = 7.38 + 9.3 + 0.3 + 1.5 = 18.48

Sa = (C1+C2+C3+C4) / n = (7.38+9.3+0.3+1.5)/4 = 4.62

Now, Y_K = [Sa-Min(R)]/[Max(R)-Min(R)]

The value of Y_K and S_i is calculated shown below in the table:

Table-39: Water environmental carrying capacity of well at industrial area Nalagarh

Date	pH (C1)	DO (C2)	BOD (C3)	COD (C4)	Min (R)	Max (R)	Y_K	S_i
Apr-15	7.16	9.5	0.1	0.4	0.1	9.5	0.48	8.88
Oct-15	7.78	10.9	0.8	2	0.8	10.9	0.37	6.98
Apr-16	6.78	9.7	0.1	0.4	0.1	9.7	0.47	8.70
Oct-16	7.81	7.1	0.2	3.2	0.2	7.81	0.58	10.73

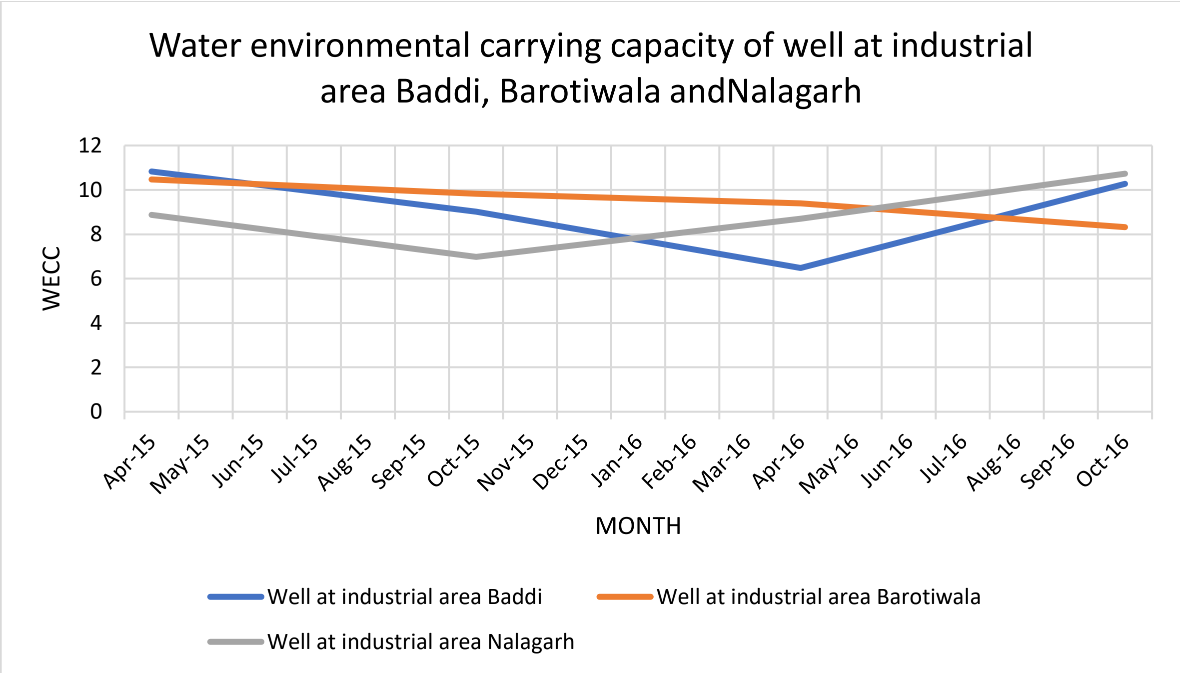

Figure-17: Water environmental carrying capacity of well at industrial area Baddi, Barotiwala and Nalagarh

CHAPTER – 5

LAND ENVIRONMENT CARRYING CAPACITY

5.1 LAND RESOURCE CARRYING CAPACITY

The LRCC is based on the availability of land which varies from village to village or from city to city or from village to city. The quantitative method was used to analyze the LRCC which includes mathematical formulations. The LRCC is based on the availaibility of land of that area and out of that available land area how much area is used for which type of purpose. The LRCC is based on the Land Use Plan of the area which provides us brief detail about the land use composition of the area.

<u>Formulation</u>

This formulation is suggested by Widodo B and R Lupyanto, Department of Environmental Engineering, universities Islam Indonesia (UII).

$$DDLB = (\alpha * Lw) / LTb$$

Here

DDLB: Land resource carrying capacity

LW: Extent of Land (Hectares)

α : Coefficient of maximum extent of built-land

And LTb = LB + LTp

The value of α is 70% for cities and 50% for villages

Table-40: Classification based on Population Size

Classification	Population
City	100,000 +
Town	10,000 to 100,000
Village	< 10,000
Hamlet	< 100

LTb: Extent of Built-Land (Hectares)

LB: Extent of Buildings (Hectares)

LTp: Extent of land for infrastructures such as roads rivers drainages etc.

It is taken as 10% of building extent

The Land Use Plan for the BBN area is shown below in the table in accordance with the BBNDA.

Table-41: Land Use Plan of Baddi, Barotiwala and Nalagarh

Sr No.	Component	Area in Hectares
1	Water bodies	3120
2	Rivers and flood plains	510.02
3	River buffer	3051
4	Slope1:5	1462.88
5	Industrial	6115.34
6	Commercial	266
7	Public and semi public	896.61
8	Residential	9944.69
9	Transportation	1913.07
10	Vacant	4047.83
11	Park and open space	546.56
12	Total	31874

The land use plan of BBN area includes all the area used in water bodies, River buffer, Industrial, Commercial, Slope 1:5, Rivers and flood plains, Public and Semi Public, Residential, Transportation, Vacant and Parks and Open Spaces.

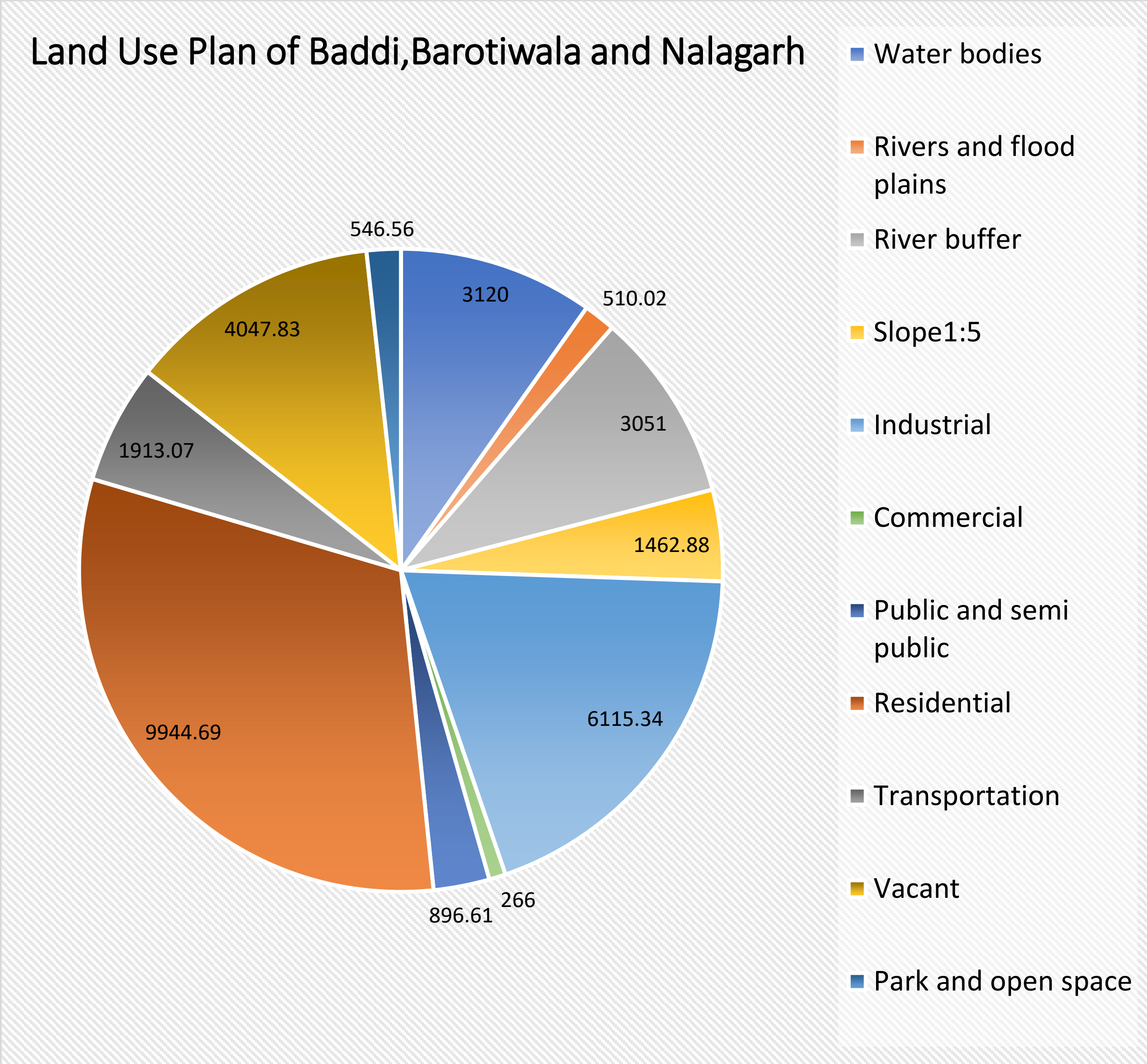

Figure-18: Land Use Plan of BBN

Now, LB = Extent of building that is area covered by something

Therefore LB = 3120 + 510.02 + 3051 + 6115.34 + 266 + 896.61 + 9944.69 + 1913.07 + 546.56

= 26363.29 Hectares

Now, LTp = 10% of LB

= 10% of 26363.29 = 10/100 * 26363.29 = 2636.329 Hectares

LTb = LB + LTp

= 26363.29 + 2636.329 = 28999.619 Hectares

Now

Land Resource Carrying Capacity (LRCC)

$$DDLB = (\alpha * Lw) / LTb$$

Here we take α = 70% that is for city

Lw is 31874 Hectares

And LTb is calculated as 28999.619 Hectares

Therefore DDLB = (70/100*31874) / 28999.619 = 0.76

<u>Output analysis</u>

DDLB < 1 i.e. Overshoot

DDLB 1-3 i.e. conditionally-save

DDLB > 3 i.e. save

Here DDLB = 0.76 i.e. < 1 which means OVERSHOOT

Now the DDLB value calculated at different values of α

If α = 30%

Then, DDLB = (30/100*31874) / 28999.619 = 0.32

If α = 40%

Then, DDLB = (40/100*31874) / 28999.619 = 0.43

If α = 50%

Then, DDLB = (50/100*31874) / 28999.619 = 0.54

If α = 60%

Then, DDLB = (60/100*31874) / 28999.619 = 0.65

If α = 80%

Then, DDLB = (80/100*31874) / 28999.619 = 0.87

If α = 90%

Then, DDLB = (90/100*31874) / 28999.619 = 0.98

If α = 95%

Then, DDLB = (95/100*31874) / 28999.619 = 1.04

If α = 99%

Then, DDLB = (99/100*31874) / 28999.619 = 1.08

Only at α = 95% and 99% the Land Resource Carrying Capacity is Conditionally-Save.

Table-42: DDLB with change in values of α

α in %	DDLB
30	0.32
40	0.43
50	0.54
60	0.65
70	0.76
80	0.87
90	0.98
95	1.04
99	1.08

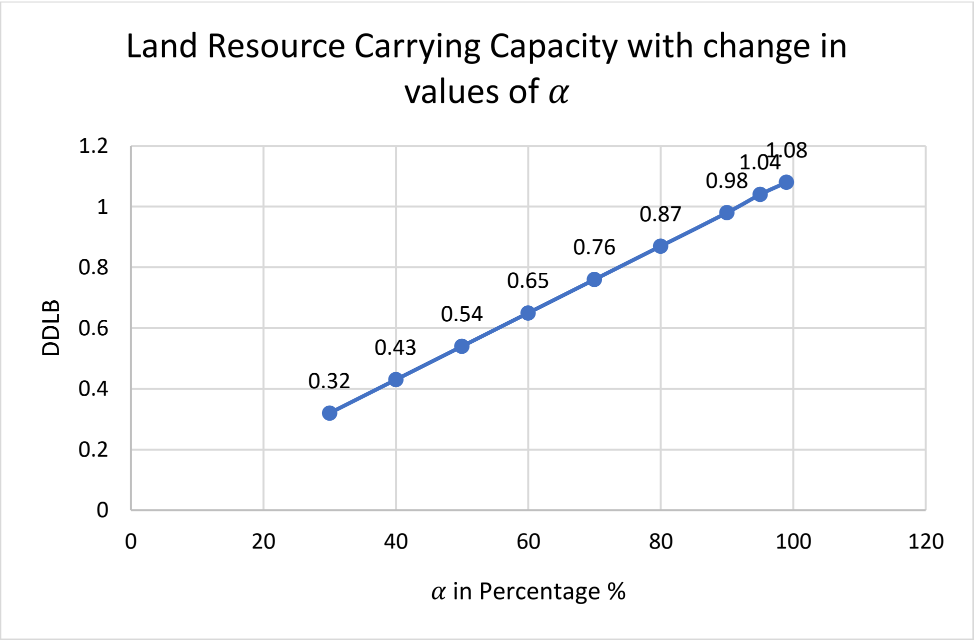

Figure-19: DDLB with change in values of α

5.2 Carrying Capacity Based on Land Balance

The Carrying Capacity based on Land Balance (LBCC) is dependent on the Land Supply and the Land Demand in relation with the production values of the commodities. Therefore the land supply and land demand are calculated separately in order to evaluate the Carrying Capacity based on Land Balance.

Formulation

The formulation is suggested by Alvan Pahuluan and Tri Retnaningsih Soeprobowati.

The Carrying Capacity based on land balance = SL / DL

Now SL is land supply calculated as:

$$SL = \sum(P_i * H_i)/(H_b * P_{tvb})$$

Here,

SL = Land supply in Hectares

P_i = Actual production of commodity and H_i = Unit price of commodity

$P_i * H_i$ = Production value of the commodities

H_b = Rice unit Price and P_{tvb} = Rice productivity

And,

DL is the land demand calculated as

$$DL = (N * KHL_L)$$

DL = Land demand

N = Total population

KHL_L = land area needed for decent living needs per population

Now,

Carrying Capacity based on land balance = SL/DL

Now, the production values of commodities:

Table-43: Production values of commodities

COMMODITIES	PRODUCTION VALUE (INR) Crores
Minerals	2.11
Fruits and vegetables	5.7
Agriculture	10.22
Animal husbandry and Fishing	5.46
Industry and Manufacturing	20.48
Construction	12.2
Transport	8.23
Community and personnel services	7.42
Total	**71.82**

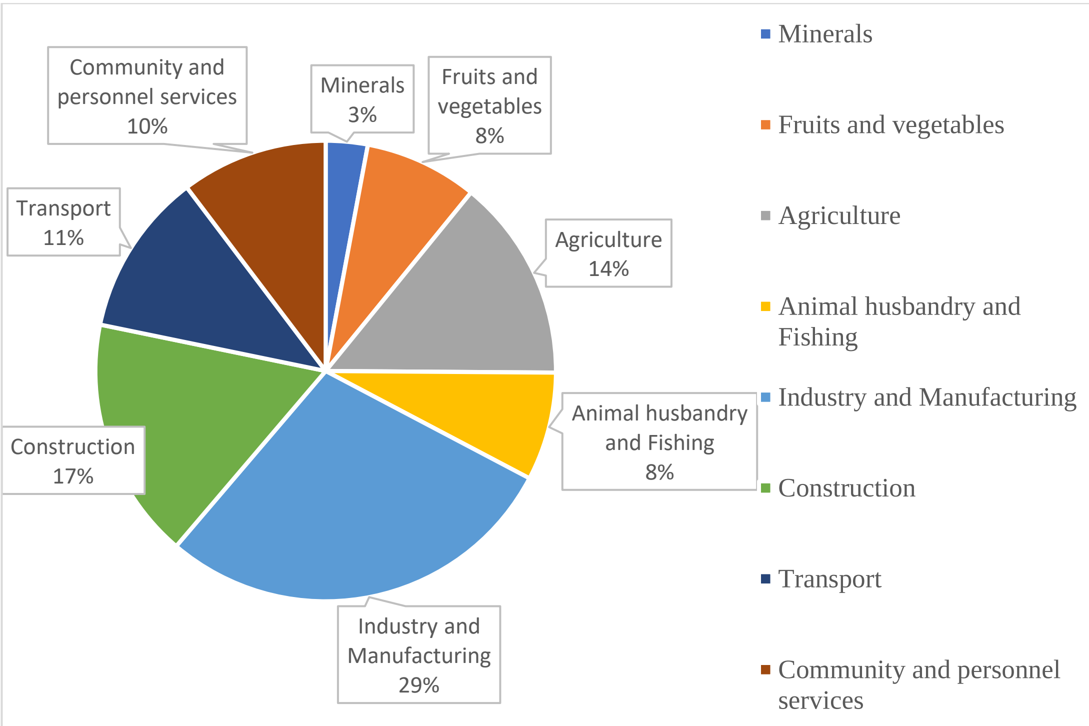

Figure-20: Production values of commodities

Now, SL the LAND SUPPLY calculated by the formula:

$$\mathbf{SL = \sum(P_i*H_i) / (H_b*P_{tvb})}$$

Here

Rice unit price = Hb = 35 INR/Kg

Local Rice productivity of Solan District = 1861 Kg/Ha

The BBN Area constitutes 35% area of Solan District

Rice productivity in BBN area = Ptvb = 35% of 1861 Kg/Ha = 651.35 Kg/Ha

Here $\sum(P_i*H_i)$ is the total production values of the commodities which is the sum of all production values of the commodities:

= 2.11 + 5.7 + 10.22 + 5.46 + 20.48 + 12.2 + 8.23 + 7.42 = 71.82 crores (INR)

Now, the LAND SUPPLY:

SL = (71.82 * 10000000) / (35 * 651.35) = 31503.79 Hectares

Therefore, the LAND SUPPLY is 31503.79 Hectares.

Table-44: The Land Supply

THE LAND SUPPLY			
Factor	Formula	Value	Unit
Production value of commodity	∑(Pi*Hi)	71.82	Crore INR
Rice unit price	Hb	35	INR/Kg
Local rice Productivity	Ptvb	651.35	Kg/Ha
The land supply	SL = ∑(Pi*Hi)/(Hb*Ptvb)	31503.79	Ha

Now, DL the LAND DEMAND calculated by the formula:

$$\mathbf{DL = (N * KHL_L)}$$

N = Total Population = 42362

KHL_L = land area needed for decent living needs per population = 1Ton/Ptvb

1 Ton = 907.185 Kg and Ptvb = 651.35 Kg/Ha

Therefore, KHL_L = 907.185 / 651.35 = 1.399 = 1.4 Hectare / person

Therefore, the Land Demand DL = 42362 * 1.4 = 59306.8

Table-45: The Land Demand

THE LAND DEMAND			
Factor	Formula	Value	Unit
Total Population	N	42362	Person
The land area needed for decent living	KHL_L = 1Ton/Ptvb	1.4	Ha/Person
The land demand	DL = N * KHL_L	59306	Ha

After the calculations of the land supply and the land demand we have to calculate the carrying capacity based on land balance that is the ratio of the land supply and the land demand termed as SL/DL

The carrying capacity based on land balance = SL/DL = 31503.79 / 59306 = 0.53

<u>Output analysis</u>

Carrying capacity = SL/DL

SL/DL > 2 i.e. Sustain

SL/DL 1-2 i.e. Conditionally Sustain

SL/DL < 1 i.e. Overshoot

Here SL/DL = 0.53 that is < 1 therefore OVERSHOOT

Table-46: Status of the land carrying capacity

STATUS OF THE LAND CARRYING CAPACITY			
Factor	Formula	Value	Unit
The Land Supply	SL	31503.79	Ha
The Land Demand	DL	59306	Ha
Ratio	SL/DL	0.53	
Status		**OVERSHOOT**	

CHAPTER - 6

RESULTS AND DISCUSSION

Table-47: Results and discussion

FACTOR	RESULT	DISCUSSION
WATER ENVIRONMENT CARRYING CAPACITY		
Population Carrying Capacity	736.60 per Thousand	It is decreasing with the growth rate of population and increased use of water
Water Resource Carrying Capacity	8.39	It is in save condition which is moving towards conditionally-save condition with the use of water resources day by day
Pollutant Carrying Capacity	Results are calculated at three different locations of same river with an average of 453 g/s	The amount of pollutant carrying capacity is reasonably high which will come into limits by suitable treatment measures before discharge of industrial pollutants to the river.
Carrying Capacity by INDICATOR EVALUATION METHOD	Estimated at five different sites	It follows a decreasing trend which is made in limits by consumptive use of water and the techniques of water saving technologies.
LAND ENVIRONMENT CARRYING CAPACITY		
Land Environmental Carrying Capacity	0.76	Overshoot that will get exploited after some time
Carrying Capacity based on Land Balance	0.53	Overshoot that will get exploited after some time

The pollutant carrying capacity is estimated at three different sites of the Sirsa river with seasonal variations and at different spans of the river. All the analysis shows that there must be proper treatment measures before discharging the industrial wastes of the area to the Sirsa river to reduce the pollutant carrying capacity.

The Indicator Evaluation (IE) method shows that there is a increase in the carrying capacity in the month of October every year due to the monsoon season of HP. The river water rises after rains which results in increased carrying capacity.

CHAPTER – 7

CONCLUSION

Carrying capacity whether it is water environment or land environment must be in suitable limits for the social and the economic benefits of the society. In the BBN area the WECC is in conditionally-save area up to some extent but the LECC is overshoot. In order to reduce the pollutant carrying capacity of Sirsa river, following measures are suggested:

1. There must be proper waste treatment measures in every industry which is beneficial for discharging industrial output with treatment.

2. Consumptive use of water and establishment of water saving technologies to enhance the water environmental carrying capacity.

3. Construction of temporary DAMS and storage reservoirs in between the river area to make appropriate use of water to increase the water environmental carrying capacity.

The LECC is overshoot and the land resources will get exploited after some time. There is no measure for the improvement of the LECC.

CHAPTER – 8

FUTURE SCOPE

By the methods of evaluating WECC a brief result is made indicating the life of resources and we can find remedial measures to save the natural water and land resources such as consumptive use of water and the use of water saving techniques and effective land management. Further a complete carrying capacity model was constructed which includes water and land environment carrying capacity which will be beneficial for the commodity as well as for the industrial associations for the betterment of their facilities in order to enhance the carrying capacity and to make suitable use of resources. Estimation of the area with suitable land use planning is beneficial to estimate that how much area is left and what amount of area is made in use by suitable land management.

REFERENCES

Kang P et al., “Water environmental carrying capacity assessment of an Industrial park”. Procedia environmental sciences 13, 2012, PP 879-890.

Ling Xu et al., “Study on Evaluation of Water Ecological Carrying Capacity”. International Conference on Biology, Environment and Chemistry, 2011, PP 458-462.

Lu Y et al., “Evaluation of water environmental carrying capacity of city in Huaihe River Basin based on the AHP method: A case in Huai'an City”. Water resource and industry, 2018, PP 71-77.

Pahuluan A et al., “Environmental carrying capacity based on land balance for evaluation planning of spatial and regional in Solok regency, west Sumatra”. Journal of Ecological Engineering, volume 18, May 2017, PP 22-30.

Qin G et al., “Reseach on water resources design carrying capacity”. Water MDPI, April 2016.

Tian Y.N et al., “Progress of resources and environmental carrying capacity”. Journal of clean energy technologies, Vol 1 April 2013, PP 132-135.

Wang H et al., “Fluctuation of the Water Environmental Carrying Capacity in a Huge River-Connected Lake”. International Journal of Environmental research and public health. March 2015. PP 3564-3578.

Wei-Hong L et al., “Construction of water environment carrying capacity evaluation model in Erhai river basin”. International conference on economics, Social science, Arts, Education and Management Engineering (ESSAEME), 2015, PP 247-250.

Widodo B et al., “analysis of environmental carrying capacity for the development of sustainable settlement in Yogyakarta urban area”. Procedia environmental sciences, 2015, PP 519-527.

Zhe Y et al., “Analysis of water environment carrying capacity based on water quality and quantity, a case study of Gucheng Lake Basin”. School of Environment and Natural Resources, Renmin University of China, Beijing 100872, China.