Source Water Vulnerability Assessment for The Coca Cola Company

Major Project Report

Submitted by

Vijay Kumar

Pritha Bhattacharya

In the partial fulfillment of the

Degree of Master of Science in

Water Resources Management

Submitted to

Department of Natural Resources

TERI University

10, Institutional Area, New Delhi-70

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DECLARATION

This is to certify that the work that forms the basis of this project "*Source Water Vulnerability Assessment for The Coca Cola Company*" is an original work carried out by us and has not been submitted anywhere else for the award of any degree.

We certify that all sources of information and data are fully acknowledged in the project report.

Vijay Kumar

Pritha Bhattacharya

Date:

CERTIFICATE

This is to certify that **Vijay Kumar** and **Pritha Bhattacharya** has carried out their major project in fulfillment of the requirement for the degree of Master of Science in Water Resources Management at TERI University, New Delhi, India on the topic “Source Water Vulnerability Assessment for The Coca Cola Company” for the duration spanning a single academic semester from January 2011 to May 2011. The project was carried out at Asian Consulting Engineers Private Limited, New Delhi.

The report embodies the original work of the candidates to the best of our knowledge.

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Vijay Kumar

Pritha Bhattacharya

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ABSTRACT

Water resources are naturally limited. It is then, essential to understand and appreciate the value of water as it forms the integral constituent in our lives, communities and environment. Water resource sustainability is directly related to our system's sustainability and it is critical that we maintain a reliable source of high quality water to meet our present water demand without compromising the ability of future generation to meet their water demand too. Water is a shared resource and that is under growing stress quantitatively and qualitatively. Demographic trends, climate change and economic growth are certain factors contributing to this. Water is the largest component of TCCC's supply chain. To access sufficient quantity of water for current operations and for future growth along with no water quality risks are two critical parameters to be maintained for their sustainable business growth and brand equity. Risks of source water vulnerability are real and multidimensional. In India, the risks associated with source water quantity and quality is location specific. Source water availability, chronic droughts, watershed extent, community concern, local water supply capacity, water treatment system are some important points to be consideration while assessing risks. Subsequently a mitigation plan or protection plan of water related risks for a particular plant are important to ensure the sustainability and supply reliability of water resources used for manufacturing, to meet current and future water needs and to avoid plant closure, water supply reduction and production loss. And more important is the community participation and promotion of corporate social responsibility through different initiates to increase awareness and to enhance reputation of brand.

Keywords: Water resource sustainability, water resource vulnerability, source water availability, watershed extent and protection plan.

LIST OF ABBREVIATIONS

DEM	Digital Elevation Model
EC	Electrical Conductivity
GEAS	Global Environmental Alert Service
IPCC	Intergovernmental Panel on Climate Change
ISDR	International Strategy for Disaster Reduction
LULC	Land Use Land Cover
MCM	Million Cubic Meter
NDPL	Narmada Drinks Private Limited
SDWA	Safe Drinking Water Act
SVA	Source Vulnerability Assessment
SWAP	Source Water Assessment Programs
SWPP	Source Water Protection Plan
TCCC	The Coca Cola Company
UNEP	United Nations Environment Program
WRMT	Water Resource Management Team

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1. INTRODUCTION

1.1. Background

Sustainable availability of water resources in today's globally changing environment is a major concern for all the countries. So vulnerability assessment of water resources has become an important measure to keep a check on the quality and quantity of source water to meet future water demand. United States, in the year 1996, under its program called Source Water Assessment Programs (SWAP) implemented this approach i.e. Source Vulnerability Assessment (SVA) under the Safe Drinking Water Act (SDWA) (Washington State Department of Health, 2005). Under this, State has to ensure following requirements to meet safe drinking water system.

- For source water, delineate source water protection area.
- List the possible potential contaminating sources to the source water.
- Conduct the susceptibility assessments for the source water and to find the vulnerabilities.

The Coca Cola Company (TCCC) which is a U.S. based company has initiated this global project to meet its water resource sustainability requirements for all of its company owned and franchisee owned bottling plants all over the world. To meet its water resource sustainability requirements it should must include meeting its water quantity and quality demand sustainably so that it can help in ensuring its worldwide brand image in a more accepted way.

The goals of this initiative are to:

- Ensure the source water managed at the level that, it should protect product quality;
- Ensure the supply continuity of water for TCCC to meet its present and future demand;
- Ensure the indentified potent risk and its mitigation measures related to source water;
- Ensure the water right of people and community welfare involving stakeholders at all levels.

In India and its neighbouring nations including Srilanka, Nepal, Bhutan, Maldives, there are around 53 bottling units of The Coca Cola Company whose sustainability and risks for the source water needs to be identified and judged because of expanding water demand and due to increasing population, changing climate and changes in land use pattern.

Based on the risks identified a Source Water Protection Plan (SWPP) is developed, which includes the mitigation and monitoring plan that summarizes the source water vulnerabilities and assigned mitigation actions.

1.2. About the Project

TCCC's global project that includes SVA study and SWPP development has to follow water resource sustainability guidance document that outlines various tasks necessary to identify its water resource sustainability requirements. The guidance document includes various components and requirements to follow step by step procedure for completing SVA and developing SWPP. It also includes composition of Water Resources Management Team (WRMT) that must involve individuals that are responsible for the plant's source water protection, stakeholders and water experts etc.

The various components necessary to be included in SVA study are:

- Regional water resource description
- Groundwater and Hydrogeology
- Watershed extent
- Conceptual hydrologic model
- Water quality
- Water agencies and regulations
- Local community water availability
- Treatment and distribution system effectiveness
- Summarization of risks

The various components necessary to be included in developing SWPP are:

- Comprehensive vulnerability review
- Monitoring and mitigation plan
- Stakeholder engagement plan

1.3. Objectives

The aim of the study is to assess the vulnerabilities and to prepare a source water protection plan to mitigate the risks (associating the vulnerabilities), so that the present and future water demand of TCCC can be met.

The objectives of the study area are:

i. To calculate water budget for the watershed
ii. To estimate the current and future water demand of the block and compare it with available groundwater
iii. To assess vulnerabilities at micro-level through plant survey and social survey of the nearby villages
iv. To propose Mitigation measures

2. STUDY AREA

2.1. Brief description of the study area

The plant named M/S Narmada Drinks Private Limited, which is a franchisee, owned bottling plant of TCCC lies in the Sirgitti industrial area of the Bilha block in the Bilaspur district of Chhattisgarh state. The plant is located at 22°02’29.67’’N latitude and 82°08’42.98’’E longitude. Figure 2.1 shows the location of plant.

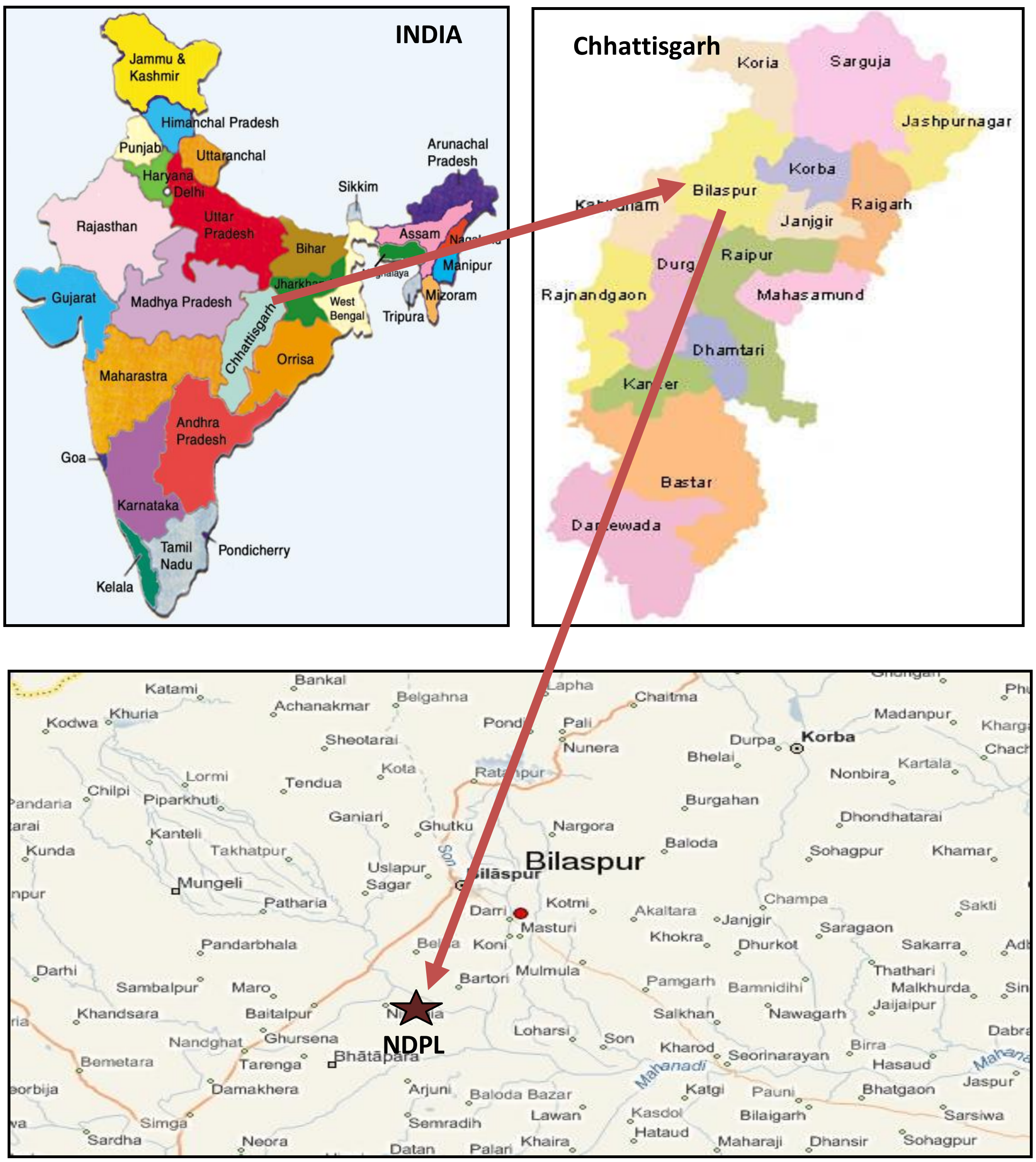

Figure 2.1 Location of NDPL

Source: http//:www.mapsofindia.com

2.1.1. Topography

The district is divided into two types of land features:

a) The hilly terrain in the northern part of the district.
b) The plain area in the central and southern part of the district.

2.1.2. Climate

The rainfall in the region is restricted in four months starting from end of April to August-September. The average annual rainfall of the Bilaspur district is 1100 mm. The temperature in the region is tropical type with a moderate to high summer and winter season.

2.1.3. Soil

There are four types of soil in the watershed (as per US soil taxonomy):

a) The Vertisols are mostly found in the south and southeastern part of the district. They are almost impermeable when saturated.
b) The Ultisol types of soil are found in east and northern part of the district.
c) Inceptisols mainly occupy the hill slopes and are found along the western boundaries of the district.
d) Alfisols are the fertile soils and form a thick humus layer. The soil in the region is slightly alkaline and the pH is around 7.7. The water holding capacity is 44.67% and the EC is 0.19 siemens. The organic content by weight is 0.278 %.

2.1.4. Hydrogeology

The Bilaspur district has three types of formations (Sahoo, 2010):

a) Achaean rocks consisting of granites, gneisses, schists, phyllites and quartzites.

b) Proterozoic sediments mainly consisting of limestone, shale and dolomites. The permeability of this formation is very poor. The groundwater in this formation mainly occurs in the weathered fractured zone of rocks. The Pandarian formation of this group consists of alternate bed of shale and limestone. The Maniari formation of this group consists of shales which are fine grained, soft and compact in nature having gypsum lamina. The other formation in this group is Tarenga, where the plant is located. The predominant rock in Hirri formation of this group is limestone.

c) Semi consolidated and unconsolidated sediments mainly comprising of sandstone and alluvium deposits. The alluvium formed along the course of River Arpa, which is one of the tributary of River Mahanadi and drain about 90% of the area of Bilaspur.

2.1.5. Aquifer characteristics

There are two aquifer systems in the district:

a) The top unconfined aquifer is formed by weathered zone, the thickness of which varies from less than five meters to more than 40 meters.

b) The deeper layer below to it is confined aquifer which is discontinuous.

2.2. Watershed details

The study area includes the watershed of Gokena nala which flows upstream to plant in southwest direction. Figure 2.2 shows the watershed extent of Gokena nala in which plant lies. The northern part is almost hilly with highly undulating topography where the agriculture is restricted to few patches only. The highest location is at 300 m altitude near Mohanbhatta village and the lowest point is at an altitude of 250 m at the confluence point. The watershed has an average slope of 0.75° in direction from northwest to southeast. The plant is at an elevation of 270 m.

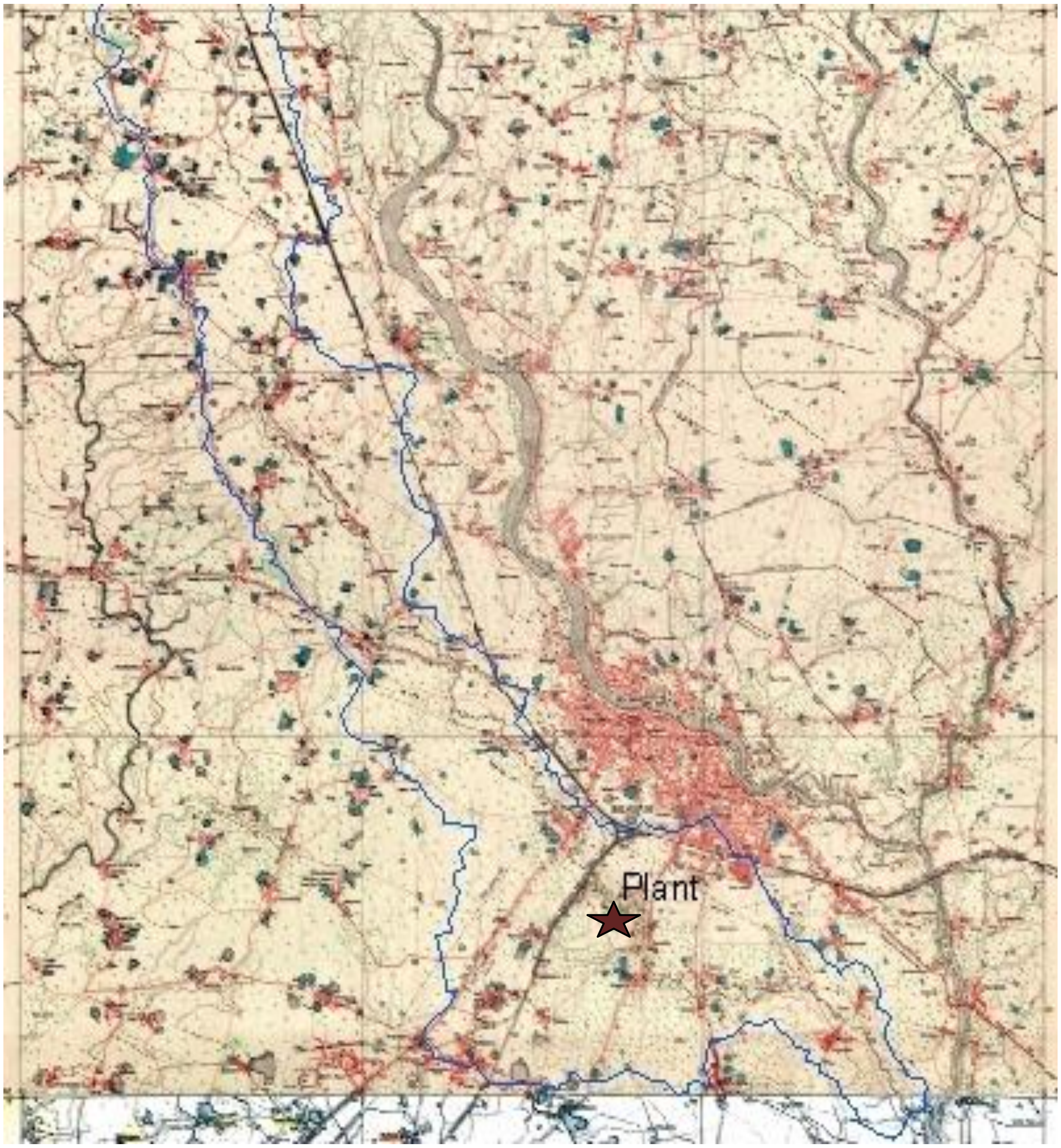

Figure 2.2 Location of plant and watershed extent on SOI Toposheet.

The plant lies in the southern part of the watershed which is plain land with gentle slope. This area is called the Chhattisgarh plains (covers about 48% of the total geographical area in the district). The watershed is 148.55 km^2 in area having approximately 36 km in length and 8 km of width. There are 31 villages in the watershed having a total population of 92,295 (census 2001). In addition to this, a part of Bilaspur city and Sirgitti industrial area having about 324 industries are located in the watershed.

This area receives rainfall from the south-west monsoon that starts in 3rd - 4th week of June continue till August-September with heaviest shower in the month of July-August. The natural drain in the watershed i.e. Gokena nala are flooded during the monsoon season and for rest of the year i.e. in pre-monsoon season it is almost dry.

The wastewater of plant after treatment is drained into the Gokena nala flowing in southwest direction and upstream to the plant. The plant is not reusing the treated water inside the plant premises. The drained water of Gokena nala finally joins the River Arpa to the downstream of plant. Figure 2.3 shows the location of plant and the flow of Gokena nala and River Arpa.

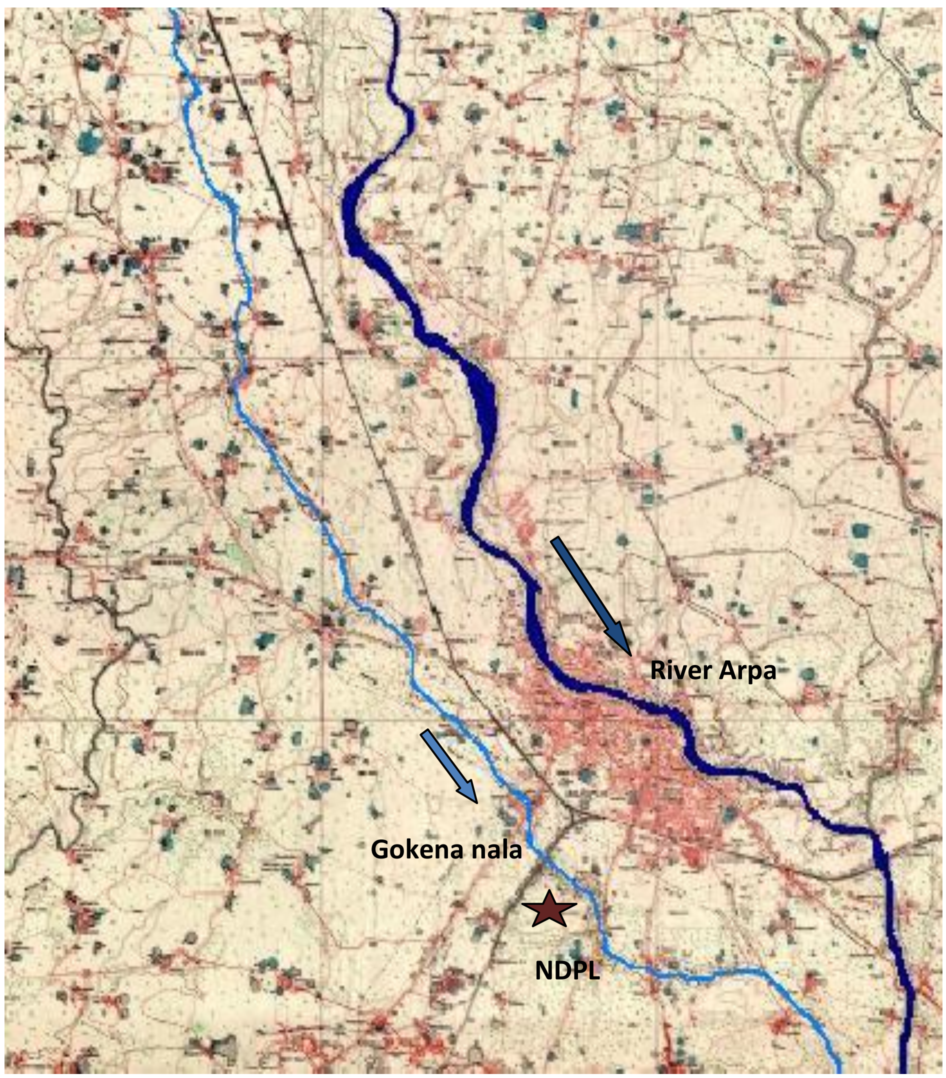

Fig 2.3 Location of NDPL, River Arpa and Gokena nala

Gokena nala is a seasonal stream flowing at a distance of 175m north of the plant which becomes almost dry in summer season. In the upstream region, it is used as source of water to animals for drinking and bathing as its quality is good in the upstream to the plant. To the downstream of plant the quality deteriorates as nearby industries drains their wastewater into the nala. The Gokena nala takes a semi-circle flow pattern finally meets the River Arpa at a distance of 9.25 km downstream to the plant.

The Land Use-Land Cover (LULC) of the watershed is prepared by obtaining LISS III imagery from National Remote Sensing Agency (NRSA). The imagery is of 17th March, 2010 and has 23 meter resolution. Figure 2.4 shows the LULC of the Bilaspur district.

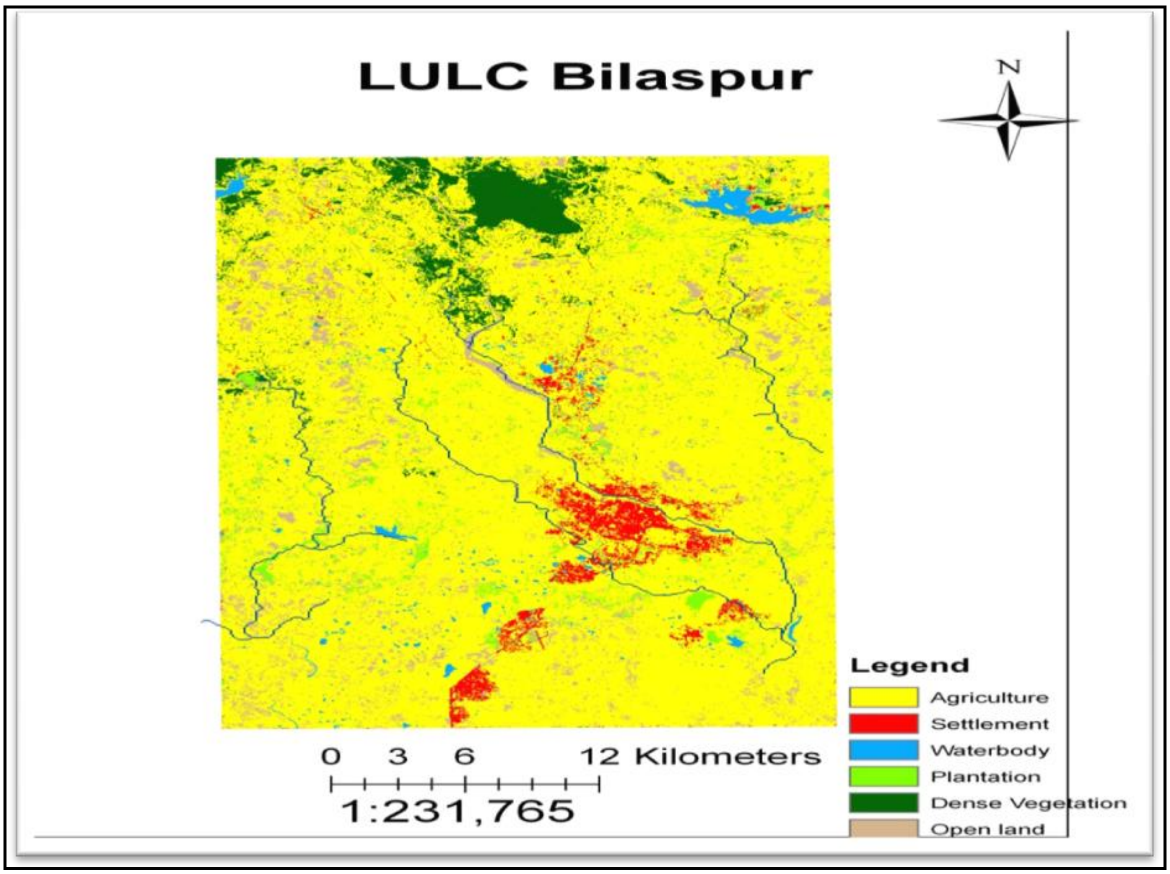

Figure 2.4 LULC of Bilaspur district

Agriculture forms the major portion of the land use and the main crops of the area are rice and wheat. The percentage of land under different classes has been shown in Table 2.1 and Figure 2.5.

Table 2.1 Land Use Pattern of Bilaspur

Class	Percentage
Agriculture	83.69
Settlement	5.14
Water body	1.05
Plantation	4.97
Dense Vegetation	0.51
Bare land	4.64

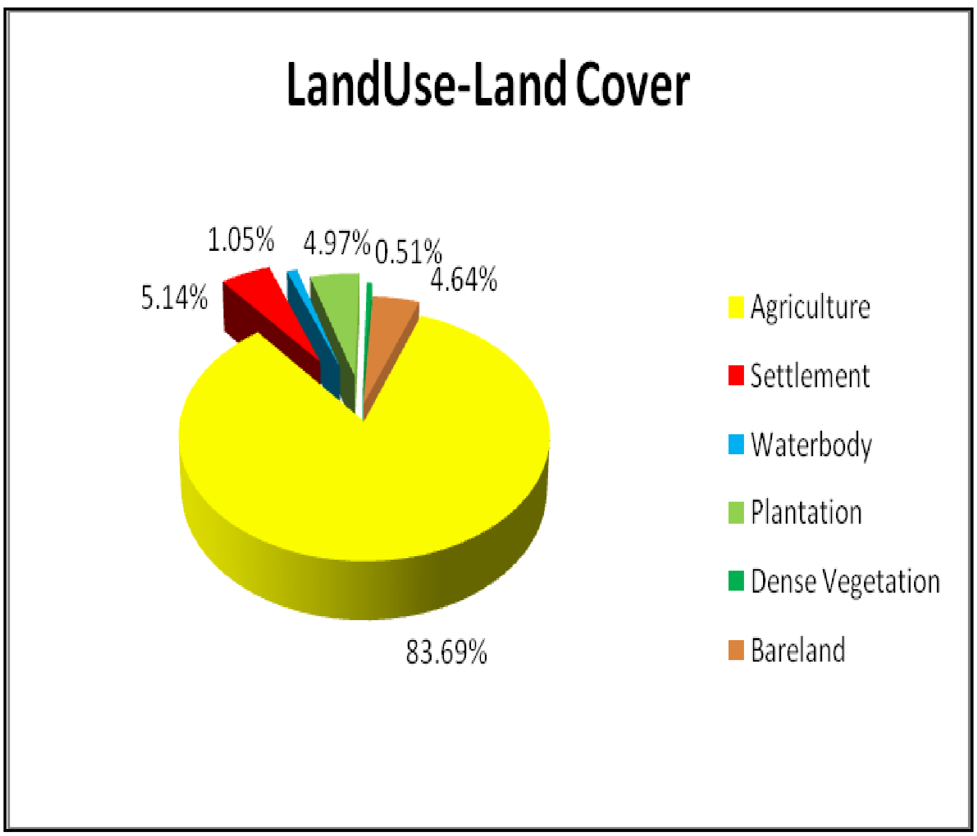

Figure 2.5 LULC Classes of Bilaspur

3. LITERATURE REVIEW

3.1. General

Vulnerability is a dynamic concept. Scientists from various academic fields have tried to explain the term, but getting a wholesome definition has not been possible. Vulnerability can only be described according to the type of threat posed. The threat describes the vulnerability, that is, greater the threat to any system, the system is more vulnerable to that threat. So researchers have described vulnerabilities according to the threat they tried to solve. International Panel for Climate Change (IPCC) has described vulnerability in the context of climate change and according to them “Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity” (IPCC, 2007).In terms of disaster management, International Strategy for Disaster Reduction (ISDR) has defined vulnerability as conditions determined by physical, social, economic factors or processes which increases the susceptibility of a community to the impact of hazard (UN/ISDR, 2004). So to understand the concept of vulnerability it is important to understand the threat considered.

Today due to rapid industrialization and destruction of natural resources, environmental threats have increased. The types of environmental threat have enlarged from natural to anthropogenic. UNEP Global Environmental Alert Service (GEAS) has classified environmental risk in terms of their occurrence which has been described in Table 3.1 given below.

Table 3.1 Types of Environmental Threats

1.Ongoing and Rapid Onset threats	Oil spills, nuclear plant failures, and chemical plant accidents, geological hazards and hydro-meteorological hazards-except droughts.
2.Slow onset (creeping) threats	Air/soil pollution, acid rain, climate change, droughts, ecosystems change, nitrogen overloading, radioactive waste, coastal erosion, etc.
2.1 Location specific Environmental threats	Ecosystems changes, urban growth, trans-boundary pollutants, loss of wetlands etc.
2.2 New emerging science	Associated with bio-fuels, nanotechnology, carbon cycle, climate change, etc
2.3 Contemporary Environmental threats	E-waste, bottled water, etc

The slow onset or the creeping threats are devastating as pollution of air, water and soil cannot be easily detected, cannot be controlled and their effects on human being are continuous. These threats have been aggravated by rapid industrialization, urbanization and misuse of natural resource by man. Pollution of these resources not only degrades their quality but also minimizes their quantity fit for human use. Today groundwater pollution has become a major threat in many parts of world.

Groundwater is globally an important natural resource. It is the most essential source of freshwater contributing a major portion of the world's drinkable water. Found universally, groundwater can easily be drawn on demand and used directly as it is considered to be risk free from contamination. In rural area groundwater is mainly for irrigational purposes and is the only source of drinking water during drought. In urban areas ground water is the source of domestic water supply. Also, all the industries are dependent on ground water, thus it has an important role in the economic development of a country.

Groundwater pollution has been defined as the artificially degradation of natural groundwater quality (Todd, 1959). Due to excessive pumping of groundwater and uncontrolled wastewater discharge by man into ground water, pollution of aquifer has become a common problem. Seepage of agricultural runoff is also affecting the ground water quality as pesticides used in the fields are contaminating the aquifer. Thus ground water pollution has become a major threat. Not only human life is at risk but agricultural products are getting affected as plants directly take up ground water. The pollution of ground water is difficult to detect, can persists from years to centuries and is difficult to control (Todd, 1959). It has been seen that the characteristic of the aquifer also determine how much prone the aquifer is to pollution .Thus ground water or aquifer vulnerability is affected by the aquifer properties and also by human activities.

3.2. Groundwater vulnerability assessment techniques

Ground water vulnerability assessment has been described as identification of areas where the ground water is likely to get contaminated by human activities (Evans and Maidment 1995). Masetti *et al*. (2008) has described various approaches for assessing ground water vulnerability. According to them there are three main categories: (i). Overlay and Index methods (ii). Process based method (iii). Statistical methods.

i. Overlay and index methods are the simplest methods. In this method specific physical attributes which influence the groundwater quality are given weights according to expert's opinion. Then they are manually or in a GIS program system are overlaid on each other to develop a vulnerability map. According to Hamerlinck and Ameson (1998), overlay method essentially integrate ratings and attributes of important factors controlling pollutant transfer from ground surface to the aquifer. These methods have evolved considerably as development of parameter weighting schemes and utilization of GIS technologies has made the process easier.

But this method has certain flaws:

- Weights given to the parameters are entirely based on expert opinion
- This method goes not capture the uncertainty of ground water system
- Validation of a method with respect to another method becomes difficult as the parameters of one model is fixed and is different than that of other model

ii. Numerical approach method is also known as process based method, is a new technique. This model can forecast the fate and transport of contaminants from known sources with accuracy in a localized area by applying fundamental physical principals to predict the flow of water in porous media and the behavior of chemical constituents carried by that water. Various assumptions have to be taken into consideration for this type of study related to the ground water flow condition, transit time of percolation. According to Brouyere *et al*. (2001), three parameters were used to define vulnerability in a numerical approach. The parameters are mean transit time of the contaminant from the source to the target, variance of the contaminant's breakthrough curve at the target, and the ratio between the maximum concentrations at the target to the released concentration at the contamination source. Vulnerability is expressed in a "cube" where all three parameters are integrated in the approach. These methods involve a lot of mathematical equations thus becoming very complicated. Comprehensive climatic data is needed to carry out the simulations which are sometimes very difficult to obtain. But it gives a quantitative vulnerability assessment. Spatial and temporal distribution of solutes in the ground water can be mapped.

iii. Statistical methods are based on the concept of uncertainty. The variables which influence the water quality are linked to see their effect on water quality parameters. According to Burkart *et. al* (1999a), statistical methods help in identifying variables that can be used to describe ground water vulnerability. Logistic regression and Bayesian methods are commonly used for analysis. This method are the least used as they involve complex calculations.

Scientists have used methods according to their convenience. Below some case study has been discussed describing above three types of approaches.

i. Overlay Method

a. Ground water risk assessment has been done by Dimitriou *et al.* (2008) for heavily industrialized catchment in which COP methodology has been used. In this paper ground water vulnerability and risk mapping method is used to assess the natural protection of aquifers from the pollution caused by human activities. First concentration flow map was prepared of the study area by assigning weight to the slope, vegetative cover, karstic feature of the study area. Then O map was prepared which describes the soil type, thickness as well as litho logy of the layers .After that precipitation factor was taken into account by preparing P map in which intensity, quantity and spatial distribution of precipitation was prepared. These maps were overlaid on top of each other to construct the vulnerability map. The map was verified by using other method to assess the vulnerability. In this method the protection provided by the soil layers is taken into account to assess the impact of pollution in the aquifer.

b. Coastal areas are more prone to ground water contamination due to salt water intrusion. In this study ground water vulnerability mapping has been done of coastal area. RISKE model was used in which, maps of aquifer rock, infiltration condition, soil, degree of karstification was prepared for the study area. After that weighted sum overlay was done of the maps, weights were given to the maps according to the pollution potential of the layers. Overlaying of the maps helped in creation of vulnerability index of the area. This model helped in preparation of a general vulnerability index of the area which can be used by planners. However, more parameters like land use pattern should be included in the model to obtain a comprehensive vulnerability index.

ii. Numerical Method

Numerical method was adopted by Neukam and Azzam (2009) for estimating ground water vulnerability. In this method first the soil layer thickness and distribution was simulated. Then a double porosity model was used to generate unsaturated water flow and solute transport for each layer. The model used one dimensional finite element approach for the simulation. Daily climate data were used to calculate ground water recharge from precipitation. Solute injection method was also used to validate the results .Results was obtained in form of temporal distribution of the solute dilution in the aquifer. Spatial variability of solute at different region of the aquifer was also mapped.

iii. Statistical Method

Nitrate concentration was used to detect ground water vulnerability by Evans and Maidment (1995). Nitrate concentrations from different wells of the study area were obtained. Different threshold values for nitrate concentration were selected and exceedance probabilities of nitrate concentration from the samples were calculated. Maps of the showing the variation of the exceedance probabilities for the selected threshold values were constructed. Four physical parameters which affect the nitrate concentration in the ground water like annual average precipitation, average soil thickness, average soil organic matter and average annual nitrogen were chosen. Then with the use of stepwise multiple regression, the exceedance probability of nitrate concentration with respect to each indicator was plotted. Thus a correlation was figured out between the parameters and the nitrate concentration in ground water. Vulnerability was assessed in terms of which exceedance probability is likely to affect the aquifer more and which parameter is more likely to influence the exceedance probability.

In India overlay method are mostly used for estimating ground water vulnerability. Some of the case studies are presented below:

a) Assessment of aquifer vulnerability in parts of Indo Gangetic plain, India done by Khan *et al.* (2010). In this research work the Indo Gangetic plain was divided into different vulnerable zone by using DRASTIC method.

DRASTIC stands forare: (i)depth to water table (D), (ii) net recharge (R), (iii) aquifer media (A),(iv) soil media (S), (v) topography (T), (vi) impact of vadose zone (I) and vii) hydraulic conductivity (C) Land use Land cover factor was taken into account as heavy industrialization has taken in the belt. The model helped in providing a numerical basis for estimating vulnerability indices and the map prepared from the indices helped in classifying the plains into low, medium and high vulnerable zones.

b) Rahman *et al.* (2008) used DRASTIC model to assess ground water vulnerability of shallow aquifer. In this study the result of DRASTIC model where verified using Map removal sensitivity analysis, Single Parameter sensitivity analysis and Ground water contamination analysis. In map removal sensitivity analysis, layers from the DRASTIC model are removed one by one to see which combination of factors of the model affects the maximum. Thus we can know the significance of the seven parameters of the model. Where as in, Single Parameter Analysis the weight given by the model is compared with the theoretical weight that should be given to parameter. Through this analysis contribution of each parameter can be found out. Ground water contamination analysis was done by testing ground water from different wells of the study area. The results very verified with the results of the DRASTIC model and the areas showing high TDS concentration corresponded to high vulnerable zone as shown by the DRASTIC model.

All the above procedures give either qualitative or quantitative vulnerabilities of an area. The above procedures involve lot of costly softwares. Availability of software is a hindrance and also comprehensive data is required for running of the softwares which are unavailable. Also no protection plan is suggested to lower the risk of the vulnerabilities. Thus in our work we have tried to study both the quality and quantity aspect of ground water. Vulnerabilities have been described with respect to quality and quantity by using simple methods in our work. Also we have developed a Source Water Protection Plan enlisting all the vulnerabilities and required mitigation action to lower the risk.

4. MATERIALS AND METHODOLOGY

4.1. Materials

The following data were used for the source vulnerability assessment:

a) Primary data

- Bore well details of the plant
- Raw Water Quality test report
- Social survey report

b) Secondary data

- Census data (2001)
- Rainfall data (2004-2008)
- Temperature data (1980-2002)
- CGWB report (2010)

c) Software

- ArcGIS 9.3

4.2. Methodology

The methodologies to meet different objectives have been described below following the same order:

i. Water Budget calculation for the watershed

Daily rainfall data of the area for the last five years was procured from IMD. Average rainfall for a year was calculated. To calculate runoff average of the Khosla's formula and Weighted Runoff Method was taken. According to Khosla's formula runoff was calculated by the following formula: $R_m = (P_m - L_m)$,

$$L_m = 0.48\, T_m \quad \text{for } T_m > 4.5^{\circ}c$$

$$\text{Annual runoff} = \sum R_m$$

Where, R_m = Monthly runoff in cm and $R_m > 0$

P_m = Monthly rainfall in cm

In weighted coefficient method, area of different land use classes which was obtained from the LULC map of the watershed. Then the area was multiplied with the runoff coefficient of the respective classes and then divided by the total watershed area to get the weighted runoff. Then weighted runoff was multiplied with monthly average rainfall for each month. Total runoff was obtained by adding runoff from each month.

After that average of both the methods were taken was taken to find the runoff from the watershed. Total runoff volume was calculated by multiplying it with area of the watershed.

Actual ground water recharge was estimated by the formula:

Ground water Recharge = Area $\times$ Water level fluctuation $\times$ Specific yield

Specific yield of the formations underlying the watershed was obtained from the ground water brochure of the district.

ii. Present and Future Water Demand Estimation

Water demand estimation of the block in which the watershed was located was done. As the Groundwater brochure of the district gave the groundwater availability, agricultural water draft, industrial water draft and domestic water draft block wise so future water demand estimation was done for the block. 2001 census of the block was noted from the Census of India cd rom. Then future population of the district was estimated till 2030 by the method as given in the Manual on Water Supply & Treatment (CPHEEO).

According to the manual, Arithmetical increase method, Incremental increase method, Geometrical increase method and Geometric ratio then average of the above methods was calculated to estimate the future population of the district upto 2030. It was assumed that the population increase rate would be same for both the district and block. So ratio of the 2001 population of the block and district was calculated and the ratio was multiplied with the future district population to get the future block population.

Future domestic water demand was also calculated by taking 40 liters per capita per day as the consumption of rural population. Then water scarcity evaluation for done by building scenarios for the block. Three scenarios were built according to the rate of development as specified in the 11th five year state plan of the Chhattisgarh which has been described below in Table 4.1.

Water Quality issues of the watershed were dealt. The geological formation of the watershed, the soil types and its characteristics, aquifer characteristics were taken into consideration for explaining the different factors influencing the water quality issues. The different factors which were taken into account were domestic, agricultural and industrial factors.

Table 4.1 Different Scenarios for Water Demand Calculation

S.No.	Scenarios	Conditions
1	Scenario 1	• Domestic Water Demand Growth Rate- As increase in the rate of population growth (2%) ▪ Agricultural Water Demand Growth Rate - As increase in the rate of population growth. ▪ Industrial Water Demand Growth Rate-10% per year (as given in the state plan) ▪ Plant Water Demand Growth Rate- 11% per year (as given by the plant authorities)
2	Scenario 2	▪ Domestic Water Demand Growth Rate- As increase in the rate of population growth. ▪ Agricultural Water Demand Growth Rate -50% of the rate of increase of agriculture i.e. 8% as specified in the 11th five year plan of the state. ▪ Industrial Water Demand Growth Rate-10% per year (as given in the state plan) ▪ Plant Water Demand Growth Rate- 11% per year (as given by the plant authorities)
3	Scenario 3	▪ Domestic Water Demand Growth Rate- As increase in the rate of population growth. ▪ Agricultural Water Demand Growth Rate -100% of the rate of increase of agriculture i.e. 16% as specified in the 11th five year plan of the state. ▪ Industrial Water Demand Growth Rate-10% per year (as given in the state plan) ▪ Plant Water Demand Growth Rate- 11% per year (as given by the plant authorities)

Thus breakdown year for each scenario was calculated by adding domestic, industrial, agricultural and plant water requirement and subtracting it by net ground water availability (as specified in the ground water district brochure). All the calculations were done in Microsoft Excel.

iii. Micro Level Vulnerability Assessment: Vulnerabilities related to the plant and the community was assessed by doing two level survey:

a) Plant Survey- The water supply and treatment unit of the plant was inspected. It included the review of test reports of raw water quality and effluent water quality of the plant. All the units from extraction of raw water till the discharge of the waste water from the plant was thoroughly checked and noted. The Effluent Treatment Plant (ETP) was also inspected.

b) Social Survey – Survey of 10 villages situated within the watershed was done to understand the water demand and the relationship of the people with the plant. 5 % household population of all villages was surveyed at random. Question were asked to the people about their domestic water demand, problems related to drinking water supply, water quality issues, agricultural and cattle water demand if they had, water scarcity problems in the recent years and reasons for the scarcity ,their relationship with the plant and is the plant working towards watershed management. In this section analysis of the survey was done and various inferences were given to the plant to improve their relationship with the local community and work for watershed management.

iv. Vulnerability Assessment and Proposing Mitigation Measures: A list of vulnerabilities which were identified after survey of the plant and villages was made. Risk associated with each vulnerability was discussed. Then suitable mitigation action for each vulnerability was proposed.

5. RESULTS

Based on the study and assessment done in the study area, the following results have been obtained, and are presented against the respective objectives:

5.1. Water Budget for the Watershed

Present Scenario of Groundwater resources

Central Ground Water Board (CGWB) has categorized Bilha Block (where plant is located) to be in a “semi-critical” zone. This categorization is based on the very high level of groundwater development stage in the block. The water development stage for the block is 70%. At present, there is no permit required by the plant for withdrawal of groundwater. It is likely that in future a permit for withdrawing more groundwater may be required.

Groundwater Recharge

The plant is located down south of the watershed. The surface and groundwater flow follow the similar pattern and flow towards the confluence point of the Gokena nala and Arpa River. The land use in the upper part of the watershed is largely under agriculture.

For quantitative estimation of the groundwater recharge potential the hydrologic model was followed. The input for the aquifer is precipitation in the form of rainfall and inter-flow basin transfer (which is not present for the existing study area) and the output component is taken as evapotraspiration, consumptive use, losses as infiltration, surface runoff and baseflow etc.

Water Balance Equation: Δ Storage in aquifer = Input – Output

The recharge potential for the existing aquifer as been described below in detail:

1. Total average rainfall in a year (using rainfall data from 2004-2008)
   = 122.12 cm

2. Runoff calculation

i) Using Khosla's formula: $R_m = (P_m - L_m)$,

$L_m = 0.48\ T_m$ for $T_m > 4.5^\circ c$

Annual runoff = $\sum R_m$

Where, R_m = Monthly runoff in cm and $R_m > 0$

P_m = Monthly rainfall in cm

Annual runoff generated by using this formula came out to be 45.09 cm and was restricted to only four month i.e. June, July, August and September.

ii) Using weighted coefficient method for different LULC in the watershed the runoff came out to be 51.28 cm (see Annexure 5)

Taking the average of two (i and ii) i.e. 48cm as the runoff generated in the watershed, the groundwater recharge availability is calculated.

i.e., Groundwater recharge availability = (Rainfall –Runoff in m) $\times$ Area of watershed in m^2

$= (1.22 – 0.48) \times 148550000$

$= 110858500\ m^3$

iii) Groundwater Recharge = Area $\times$ Water level fluctuation $\times$ Specific yield

Watershed is underlaid with different formation and as its own specific yield and different fluctuation. Based on that, computed recharge came out to be 8965297 m^3 (see Annexure 6).

This show that about 80% of the available water for groundwater recharge is actually going for recharge and rest is considered as loss in the form of evapo-transpiration, consumptive use etc.

Thus, the water budget for the watershed is shown in Table 5.1.

Table 5.1 Water Budget for the Watershed

Annual Precipitation	181.806 MCM
Annual Runoff	70.948 MCM
Total Groundwater Recharge Potential	110.858 MCM
Actual Groundwater Recharge	8.965 MCM
Total Water Loss	172.841 MCM
Plant Annual Water Consumption	0.106 MCM
Percent Consumption by plant	1.2 %

5.2. Current and Future Water Demand of the Plant

The plant's source water requirement, when put sustainably, has been estimated according to scenarios discussed earlier. The groundwater resource (or availability) of the Bilha block is 97.661 MCM. The water demand of the study area for different years under different scenarios has been given in Table 5.2 to Table 5.4.

Table 5.2 Water Demand according to Scenario 1

S.No.	**Parameters**	**Water Demand (MCM)**			
		2010	**2020**	**2028**	**2030**
1	Domestic water demand	1.769	2.157	2.527	2.629
2	Industrial water demand	3.783	4.179	4.525	4.616
3	Agriculture water demand	63.386	77.268	90.532	94.189
4	NDPL water demand	0.089	0.357	0.661	0.771
5	Total Water Demand (1+2+3+4)	69.029	83.961	98.246	10.220

Table 5.3 Water Demand according to Scenario 2

S. No	Parameters	Water Demand (MCM)		
		2010	2020	2030
1	Domestic water demand	1.769	2.157	2.629
2	Industrial water demand	3.783	4.179	4.616
3	Agriculture water demand	63.388	93.828	138.888
4	NDPL water demand	0.089	0.357	0.771
5	Total Water Demand (1+2+3+4)	69.029	100.342	146.312

Table 5.4 Water Demand according to Scenario 3

S. No	Parameters	Water Demand (MCM)			
		2010	2013	2020	2030
1	Domestic water demand	1.769	1.877	2.157	2.629
2	Industrial water demand	3.783	3.897	4.179	4.616
3	Agriculture water demand	63.386	98.940	286.440	1,233.557
4	NDPL water demand	0.089	0.208	0.357	0.771
5	Total Water Demand (1+2+3+4)	69.029	104.894	293.133	1,240.981

Therefore, after comparing the existing water resource of watershed with the future demand under three different scenarios it is found that in scenario 1, the breakdown year for plant is year 2028. According to scenario 2, the breakdown year for plant is year 2020 and according to scenario 3, the breakdown year for plant is year 2013

This clearly remarks that the water demand for the plant will compete severely with the other sectors like domestic, agricultural and industrial water demand in the coming years. And water demand for all sectors will exceed the available water resource of the study area, if the same condition prevailed.

Moreover, the quality aspect of the source water in the study area is also deteriorating at the faster rate. The industries in the vicinity of 2 km radius of plant and the agricultural activities in the watershed area have potent to alter the groundwater quality from where plant is withdrawing the water. As such no time line boundaries have been defined for declaring its sustainable use to be safe.

5.3. Micro-level Vulnerability Assessment

Plant level assessment

The primary source of process water for NDPL was found to be ground water. No external supply or surface water was being used by the plant. The plant has six borewells of which three were regularly used and remaining three was intermittently used for supply of process water. Table 5.5 gives the details of borewells in the plant. Galvanized pipes were being used for the raw water transport from borewell to water treatment system while for process water transportation stainless steel pipes were used.

Table 5.5 Details of Borewells in the NDPL

S. No.	Borewell	Status	Depth of Borewell, meters	Pump Capacity, HP	Pump Discharge, m^3/hr	Average Duration of Operation, hrs/day
1	No.1	Regularly used	46	5	10	8
2	No.2	Regularly used	65	10	30	10
3	No.3	Regularly used	55	7.5	20	12
4	No.4	Intermittently used	46	5	10	Not specified
5	No.5	Intermittently used	46	7.5	15	Not specified
6	No.6	Intermittently used	55	5	10	Not specified

Treatment system and Distribution Effectiveness

The plant is provided with raw water and wastewater treatment system. The raw water or process water treatment system consists of a series of filters like pressure sand filter, activated carbon filter, micron filter of size 10 µ, 5 µ and 1 µ, along with reverse osmosis and ultra violet treatment system. The raw water quality data show that the parameters meet IS 10500-1991 standards. The existing effluent treatment system in the plant includes screen chamber, equalization tank, aeration tank, primary and secondary clarifier provided with sludge drying beds. The effluents water also meets the standards set by State Pollution Control Board (SPCB). All this quality parameters show that at present, the quality aspect of the plant is being taken as a matter of concern and more importance is given to that.

Regarding the distribution of water in the process of production and transmission, the system is designed in such a way to minimize wastage of water due to leakages. Flow-meters and valves have been provided at critical points to monitor the controlled use of water. Also, the pipelines designs and materials used in the plant is with the concern that it should not affect the water quality. The water quality is a principal factor that decides the extent to which the region is vulnerable to water. The different factors that influence the quality of water are discussed below.

Sewage and Sanitation

The watershed has mainly of rural population that does not have proper sanitation plant in the region. The domestic sewage generated is discharged into the unlined (kuccha) drainage lines which generally joins the Gokena nala or the ponds in the area. It causes the surface water source to get polluted and unfit for drinking and bathing. The wastewater generated and its projected generation has been given in Table 5.6.

Table 5.6 Projected Wastewater generated for the Watershed

	Years			
	2001	**2011**	**2020**	**2030**
Population	92295	110964	130820	161527
Annual Water demand (@40 lpcd), MCM	1.347	1.620	1.909	2.358
Annual Sewage generation (80% of water demand), MCM	1.078	1.296	1.527	1.886
Annual Solid waste Generation (0.2 kg/person/day), kilotons	6.737	8.100	9.549	11.791

The chances of percolating the polluted water from the drains and ponds are likely to pollute the subsurface water bodies. But, the chances of getting polluted for groundwater is low as rock profile do not permit deep percolation and also the deeper aquifer is confined one. The concentration of chlorides and fluorides are within the permissible limits showing that groundwater quality is within safe limits.

Agricultural Runoff

Paddy is the principal crop the area and is a water demanding crop. The application of fertilizers and pesticides are prevalent in the area. The common fertilizers used are Urea, DAP (Di-ammonium Phosphates), whereas the common pesticides used are Cholopyrifos, Along with chemical fertilizers application, organic manures and cowdung ashes are also being used.

The nitrogen requirement for paddy is 70-80 kg but at present 120-150 kg are being applied in field. The high application of nitrogenous-rich fertilizers can cause leaching of nitrate and ammonium ions into the surface water bodies i.e. ponds, nalas and even the infiltration into the soil can cause pollution of unconfined aquifer. The concentration of nitrates has been found relatively higher in confined aquifer than unconfined aquifer but within the permissible limits shows that groundwater is safe to withdraw for the plant production. The chances of occurrence of pesticides have also been found none in the deep water aquifer.

Industrial Effluents

There are around 20 small and medium scale industries in the 2 km vicinity of NDPL. Some of them are water-intensive industries and some of them are highly polluting industries like Shivangi oils, Bhaskar Press, Abis liquor bottling plants, Vandana Vidyut etc. The effluent water generated is drained into the nearby Gokena nala which finally meets the River Arpa. The soil profile and rock structure around the region do not allow deep percolation of effluents but is proable of polluting shallow aquifer.

The concentration of certain metals in the unconfined aquifer has been found higher like Arsenic, Lead. But the deep located confined aquifer fro where plant is withdrawing water is generally safe.

The plant conducts its raw water quality test and results of the test parameters for raw water are within the guided value for the maximum limit. The different testing parameters and testing frequency for the raw water quality test at NDPL has been put under Table 5.7.

Table 5.7 Testing Parameters and Frequency of raw water at NDPL

S. No.	**Testing Parameters**		**Testing Frequency**
1.	Inorganic constituents	Arsenic, Barium, Boron, Cadmium, Chromium, Copper, Cyanide, Fluoride, Lead, Manganese, Mercury, Molybdenum, Nitrate, Nitrite, Uranium, Selenium, Nickel	Once in an year (during monsoon)
2.	Organic constituents	Carbontetrachloride, Dichloromethane, Vinyl chloride, Trichloroethane, Trichloroethene, Benzene, Xylene, Acrylamide, Ethylene Diamine TetraAcetic acid, Formaldehyde, Chloroform, Dichloro Acetic acid	Once in an year (during monsoon)
3.	Pesticides	Alachlor, Aldicarb, Aldrin, Atrazine, Carbofuron, DDT, 2 4-D, MCPA, Metachlor	Once in an year (during monsoon)
4.	Herbicides	2 4-D, 2 4 5-T, Dichloroprop, Fenoprop, Menoprop	Once in an year (during monsoon)
5.	Disinfectants	Chloride, Chlorate, Bromide, Monochloramane, Chlorite	Once in an year (during monsoon)
6.	Radioactive constituents	Gross Beta activity, Gross Alpha activity	Do not tested

Local Community Water Availability and Stakeholders

A social survey in relation to assess the community perception about the water availability and water related issues was conducted in 10 villages of the study area. The 6 villages namely Ghuru Sakari, Uslapur, Tifra, Sirgitti and Nagpura which are located upstream to plant was chosen and 4 villages namely Basiya, Parsada, Chakarbhatta, Silpahri which are located downstream to plant was chosen. The salient findings of the survey have been listed below along with the list of vulnerabilities mentioned under Table 5.8.

1. Drinking water source for all the people is groundwater.
2. House connection and borewells are two most frequent used source of water supply.
3. The average water level in the wells in the surrounding areas is 50 m.
4. Water level is reported to be going down around 5 m each year.
5. Water shortage is a common issue in summer season.
6. Relationship of community with NDPL is neutral
7. There is a common notion among local people that water level is going down due to increasing industrial activity in the area.

Table 5.8 List of Vulnerabilities

Vulnerability Description	Pumping failure
Information Source	Primary source
Details	The plant is using pump for each borewells but there is no standby pumps, in case the pump fails to operate.
Risks	If the pump fails in the peak season then the plant will not be able to meet the production demand and that can decrease faith among the dealers.

Vulnerability Description	Water scenario in Bilha block
Information Source	Central Ground Water Board Report, 2010
Details	Bilha block in which plant lies have been categorized as semi-critical by CGWB due to water development of more than 70%. Although there is no water permit issue but if water use continued to be same, in near future area will be notified as critical. This may cause regulated withdrawal or cut-off of water supply to the plant.
Risks	Water auditing may lead to reduced amount of water availability and may restrict the business from expanding anymore.

Vulnerability Description	Relationship with the local community
Information Source	Primary source
Details	Good relationship with the local community is very important for proper functioning. But the plant is maintaining the neutral relationship with the local community which is not sufficient. The industries in the vicinity are also not doing much for the local community. The workforce in the industry is from far by places and locals are not getting employment.
Risks	There is chance of misguidance to the local community about the perception and functioning of the plant if a proper relationship is not maintained.

Vulnerability Description	Stakeholder demand issue
Information Source	Stakeholder survey
Details	Due to less rainfall and industrial activity the region around plant is experiencing water shortage issue. In summer, there is a huge water demand but the source is falling short of providing adequate water. In some rural areas the municipal water tanker is there to supplement the water supply but is not adequate to fulfill the water demand satisfactorily. There is a common notion among the stakeholders that the situation is due to large number of industries especially the water intensive industries.
Risks	As the industry is utilizing huge quantity of water there is a business risk to it. The protest, if any, may take the shape of revolt and may lead to closure of the plant.

Vulnerability Description	Poor watershed management and development practices
Information Source	Social survey
Details	No watershed management is being practiced. Majority of the villages have water scarcity issues. The surface water bodies are getting dried up and whichever are left are rendered unfit for consumption. There is no prevention for stopping effluent water from industries in mixing with water bodies like Gokena nala. The major landuse in the watershed is under agriculture. High usage of

	fertilizers and pesticides, which is usual practice there, can in turn affect the surface water bodies by mixing with them or along with runoff water.
Risks	Plant is using groundwater however due to surface water pollution will be depending on groundwater and there will be a issue of water shortage thus it will impact plant adversely. In addition, there is no watershed management practice, it will lead to deterioration of watershed resulting in water crisis.

Vulnerability Description	Inadequate regulation
Information Source	Primary source
Details	In Bilha block, main source of drinking water is groundwater owing to its good quality. The other dependency on groundwater is the lack of perennial surface water bodies in the area. Also, the industries are withdrawing groundwater. Since, there is no laws that barrs or prevent anyone from withdrawing groundwater, it is being used as a private resource and to care is taken to use it judiciously. Due to this practice, very soon water resource is going to be a scarce resource.
Risks	Plant will be affected badly if water is being withdrawn at present rate. Down the line there will be less water available and water level will go down, so plant will require to dug more borewells.

Vulnerability Description	Raw water quality assessment
Information Source	Primary source
Details	The various raw water parameters as specified by IS 10500-1991 are being treated together with the same frequency monitoring which needs to be changed. The various parameters should be specifically monitored and it should be as per monitoring frequency prescribed.
Risks	Using specific monitoring measures for each parameter would help the plant to take specific action, if in any case any parameter fails to meet specific standard.

Vulnerability Description	Well head protection zone vulnerability
Information Source	Primary source
Details	Well head protection zone of the plant borewell has been estimated using WhAEM version 3.2.1. The zone is defined in circular area with a radius of 1.5 km. In this area, there are many industries and dump sites of industries that has been shut down. And if there is a polluting source groundwater, it is very hard to be cleaned.
Risks	Water is the major raw material and main source is groundwater. Any impact on groundwater will have a negative consequence to the plant. The treatment cost will increase and if not treated properly the product may be contaminated which will affect the brand.

Vulnerability Description	Industrial pollution
Information Source	Primary source
Details	There are around 23 small and medium scale industries within 2 km radius of plant. Many of them are water polluting industries and produces wastewater with high concentrates of oxides, colours, paints, ammonium, carbon compounds which when disposed to nearby water bodies pollute the and its seepage into the soil may cause pollution of sub-surface water bodies
Risks	The impact like leaching of the toxic chemicals into groundwater will increase the cost of treatment of process water.

Vulnerability Description	Lack of ETP lab
Information Source	Primary source
Details	There is no ETP lab established in the plant premises. Wastewater generated is not monitored at the ETP inlet point. Further, the plant is dependent on the consultant lab for wastewater quality analysis which is also not done regularly.
Risks	If ETP is not running properly then plant may be fined by CECB if the wastewater quality is not meeting the standards.

Vulnerability Description	Sludge disposal system
Information Source	Primary source
Details	The sludge generated during different processes is of different qualities, as they should be separately disposed off. No details of the sludge generated are provided.
Risks	Many wastes are hazardous and if not handled carefully can be a serious threat to nearby natural resources.

5.4. Source Water Protection Plan

The mitigation measures for the identified vulnerabilities have been described in Table 5.9.

Table 5.9 Mitigation measures for different vulnerabilities

Vulnerability	Pumping failure
Mitigation Measures	Back-up pump should be there.
	Back-up source of energy to operate the pump should be there.
Stakeholders involved	NDPL

Vulnerability	Water scenario in Bilha block
Mitigation Measures	Other industries should be encouraged to use water judiciously.
	Water loss during supply should be minimized.
Stakeholders involved	NDPL, CGWB

Vulnerability	Relationship with the local community
Mitigation Measures	CSR (Corporate Social Responsibility) like providing sanitation facilities, drinking water plant in schools, rainwater harvesting structures etc should be promoted.
	Employment to locals should be promoted.
	Community meeting should be done frequently.
Stakeholders involved	NDPL, local residents, NGO's, Press media

Vulnerability	Stakeholder demand issue
Mitigation Measures	Sustainable use of water should be done and water should be made available to the poor and weaker section of the society.
Stakeholders involved	NDPL, local industries, local residents, Bilaspur municipal corporation

Vulnerability	Poor watershed management and development practices
Mitigation Measures	Desilting and rejuvenation of lakes and ponds should be done.
	Water conservation structures should be established.
	Afforestation should be done.
Stakeholders involved	NDPL, NGO's, local community

Vulnerability	Inadequate regulation
Mitigation Measures	The optimization and regulated use of water distribution needs to be followed taking priorities into prime consideration.
Stakeholders involved	NDPL, local industries, CGWB

Vulnerability	Raw water quality assessment
Mitigation Measures	Efficient treatment mechanism for raw water with lab monitoring plant is required.
	Testing of raw and process water quality at different control point is necessary.
	Regular monitoring of water quality for each borewells should be done, and it should be done separately.
Stakeholders involved	NDPL, CECB, CPCB

Vulnerability	Well head protection zone vulnerability
Mitigation Measures	Polluting industries in well head protection zone should be informed about the consequences.
	Remove dumps from well head protection zone.
	Proper management approach should be encouraged.
Stakeholders involved	NDPL, local industries, local residents

Vulnerability	Industrial pollution
Mitigation Measures	For finding aquifer properties the resistivity test should be done to have knowledge of permeability of contaminants.
	Persuade industries to clean the drains/nalas.
Stakeholders involved	NDPL, local industries, CECB, CGWB, Bilaspur municipal corporation

Vulnerability	Lack of ETP lab
Mitigation Measures	To keep a check on wastewater quality ETP lab should be set up and regularly upgraded.
	Proper water quality monitoring system and treatment system should be practiced.
Stakeholders involved	NDPL, CECB, CPCB

Vulnerability	Sludge disposal system
Mitigation Measures	To assess the quality of sludge proper lab should be established with frequent monitoring to treat separate parameters.
Stakeholders involved	NDPL, CPCB

6. CONCLUSION

Vulnerability assessment of an area not only helps in pointing vulnerable areas but also helps in planning out the future in a more safe way. In case of water resource, particularly ground water optimum utilization and proper allocation are vital factors that have to be considered.

Water quality is one of the prominent factors that affect the aquifer vulnerability to pollution. Though care is being taken by the plant to control effluent water quality, but still its drainage into the Gokena nala and thus its infiltration into the ground will have a negative impact in the future. Not only this infiltration from the dumping site will have a negative impact on the quality of the aquifer, but also, drainage of pesticide and insecticide from the agricultural field will influence the quality of the ground water of the study area.

From agricultural, industrial to domestic water requirements, all are met from groundwater in the study area. Thus there is huge dependency on the aquifer. It has been seen that if the population rate remains same and the rate of industrialization also doesn’t increase then water scarcity will be felt in the area by 2028. But the area lies in industrial area so more industries are likely to come in the coming years. This will lead to rapid population increase in the area as employment opportunities will be created. Increase in the population will lead to increase in agricultural production. So in the coming years there would be rise in the demand of water. Not only this, the state government trying to increase the agricultural production of the state so water consumption of the area will amplify. Thus if there is increase in industrial water usage and agricultural water usage then water scarcity will be felt from 2013. Thus residents of the area will dig more borewells into the ground water to support their increasing water needs.

Apart from this the block in which the plant is located has been categorized as semi critical by CGWB as the ground water stage development in the block more than 70%. So from the above scenario it is probable that over excessive water extraction will place the block in critical zone with respect to ground water stage development.

Taking all such factors plant should involve other stakeholders or a approach rendering community benefitted program should be there to have a sustainable way a meeting its water demand quantitatively and qualitatively.

6.1. Recommendations

The key recommendations based on the present study have been listed below:

1. The withdrawal of water by the plant should be in accordance with the optimal with the other sectors like domestic water demand, agricultural water demand and other industries water demand.
2. The production to withdrawal ratio of water should be increased, if possible. At present it is 2.3
3. The more and more reuse of water should be facilitated in the premises, so that the dependence on groundwater for miscellaneous activities should be avoided. At present plant is draining all its treated waste water into the nearby flowing Gokena nala. Or it can be supplied to others for horticulture and floriculture.
4. The rainwater harvesting structures should be promoted within the plant's premises and in nearby surrounding to it, to enhance recharging of groundwater.
5. The quality check of treated waste water should be regularly monitored, to avoid its percolation into soil and influencing the water quality of underlying aquifer.
6. The watershed development activities like development of water storing structures, ponds desiltation, and afforestation should be promoted to have environmental friendly approach to manage and conserve water resources.
7. The more CSR activities should be promoted in the vicinity of plant like providing drinking water plant in schools, health awareness campaign, frequent meeting with local community to help in understanding the activities of plant in a more fair way and to assist in solving some societal problem to help in building the communal support and addition to brand valuation.

This study clearly helps in understanding the importance of a good quality of source water. Water is the primary component for a sustainable society. Quality and quantity of water both these aspects are critical in planning development of an area as from domestic to agricultural and to industrial growth, all are dependent on water. Good quality of raw water not only promises a good health to the people using it but also helps in reducing treatment cost. . In today's world increase of population in a place is inevitable. This will put a load on the water supply of the area. Therefore, sustainable use of water should be promoted here.

6.2. Limitations of the study

The study of such kind which involved support from the plant, external agencies, stakeholders, local communities of the study area has been a more of learning to manage between all these to have the objectives achieved and aim fulfilled.

The limitations encountered during the study have been described below:

1. The data collection from government offices took a long time.
2. Some basic data like water demand and supply, litho-log data of the study area where not available, thus calculations gives a rough estimate rather than being exact.
3. Lack of software prevented us from doing groundwater modeling.
4. Time was short to carry out the study as analysis of data and social survey of the villages took most of the time.

6.3. Scope for future work

The study can be refined by adding the modeling of ground water to understand its flow in the area. A component of well head zone monitoring can be carried to comprehend the flow of pollutants from the dump sites into the aquifer. The result of well head zone protection modeling can help in identifying the pollutants which are more likely to affect the aquifer.

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ANNEXURES

Annexure 1 Population growth of Bilaspur district

Year	Arithmetic Progresion	Geometric Progression	Incremental Increase	Geometric Ratio(Avg.)	Geometric Ratio(Latest)	Geometric Ratio(Max.)	Average	Round off
2001	4509384	4509384	4509384	4509384	4509384	4509384	4509384	4509384
2005	4764834	4861802	4793312	4895016	4832202	4984360	4855254	4855254
2010	5084147	5341305	5171106	5423758	5268413	5649039	5322961	5322961
2011	5148009	5442737	5249716	5536171	5360272	5792254	5421527	5421527
2015	5403459	5868099	5574327	6009612	5744003	6402355	5833642	5833642
2020	5722772	6446849	6002974	6658748	6262524	7256128	6391666	6391666
2025	6042084	7082680	6457049	7378002	6827854	8223754	7001904	7001904
2030	6508859	7781220	6936550	8174947	7444216	9320416	7694368	7891953

Annexure 2 Population Growth of Bilha block

Present Ratio	0.022769					
Year	**Bilaspur**	**Bilha Block**	**Rounding off**	**Water demand (lpcd)**	**Annual**	**m^3**
2001	4509384	102675	102675	4107000	1499055000	1499055
2005	4855254	110550.1847	110550	4422007	1614032696	1614033
2010	5322961	121199.4905	121199	4847980	1769512562	1769513
2011	5421527	123443.7429	123444	4937750	1802278647	1802279
2015	5833642	132827.2858	132827	5313091	1939278373	1939278
2020	6391666	145533.0265	145533	5821321	2124782186	2124782
2025	7001904	159427.642	159428	6377106	2327643573	2327644
2030	7891953	179693.3339	179693	7187733	2623522675	2623523

Annexure 3 Population growth of Watershed

Present Ratio	0.02046732			
	Year	**Population of Bilaspur**	**Population of Watershed**	**Round off**
	2001	4509384	92295	92295
	2004	4769060	97609.87148	97610
	2005	4855254	99374.03745	99374
	2010	5322961	108946.7444	108947
	2011	5421527	110964.1125	110964
	2015	5833642	119399.0197	119399
	2020	6391666	130820.2647	130820
	2025	7001904	143310.1945	143310
	2030	7891953	161527.1123	161527

Annexure 4 Social Survey Perception Form

Social Survey Perception Form, SVA, Bilaspur

I	**General Information**				
1.	**Date of Survey**				
2.	**District**	**Tehsil**	**Block**	**Village**	
3.	**Name of Respondent**	**Age**	**Relationship with the Head of Household**	**Name of Head of Household (HH)**	
II	**Socio- Economic Profile**				
4.	**Religion of the Household**				
	A. Hindu	B. Muslim	C. Sikh	D. Christian	
5.	**Caste of the Household**				
	A. General	B. OBC	C. SC/ST		
6.	**Type of the Family**				
	A. Joint	B. Nuclear	C. Extended		
7.	**How many members in the family ……………**				
8.	**Whether family has a ration card**	A. Yes	B. No		
	If Yes, Colour: A. White	B. Yellow	C. Pink		
9.	**Major Occupation and Annual Income of the family………………………...**				
III	**Water**				
10.	**What is the primary source of Drinking water?**				
	Household Connection	Public Stand Post	Public Handpump	Private Handpump	Borewell
	Dugwell	Ponds/Rivers	Municipal Tanker	Neighbour's House	Others
11.	**Quality of water from these source**	A. Good	B. Bad		

12.	**In the village how many of the following are there**			
	A. Borewell ………		B. Handpump ……….	
	C. Dugwell ………		D. Ponds ……….	
13.	**Any water shortage faced during summer?**	A. Yes	B. No	
14.	**If Yes, Alternate source:**	A. Purchase	B. Specify ………	
15.	**Average amount of water/person/day** ………………….liters			
16.	**Do you have rainwater harvesting system in your house?**	A. Yes	B. No	
17.	**What is the level of water in borewell/dugwell** ………………….. meters			
18.	**What is the depth of borewell** ………………….. meters			
19.	**What is the trend of water level in borewell/dugwell over last?**			
	5 Years …………..m above/below		10 Years ……………. m above/below	
20.	**What is the trend of water availability**	A. Increasing	B. Decreasing	
21.	**What are the causes of change in water availability?**			
	A. Population demand		B. Agricultural demand	
	C. Industrial demand		D. Others	
22.	**Has quality of source changed over time?**	A. Improved	B. Deteriorated	
23.	**If deteriorated what are the reasons**			
	A. Municipal waste		B. Agricultural waste	
	C. Industrial waste		D. Others	
24.	**If industrial waste**			
	Name of the industry ………….. Discharge ……………			
25.	**Are there any health impact on deteriorating water quality?** Yes / No			
26.	**Major quality problem faced**	A. Dirt	B. Smell	C. Others
27.	Any Water-borne disease …………..			
IV	**Agriculture**			
28.	**Available land (consolidated) …………………**			
29.	**Land under**	Kharif …………..	Rabi …………….	Zaid ……………

30.	**Source of water for irrigation**	A.Groundwater	B.Ponds/Rivers	C.Rainwater
31.	**Duration of pump operated per day** ……………….. hrs			
32.	**Days of irrigation**	Kharif …………..	Rabi …………….	Zaid ……………
33.	**If source is Groundwater, what is the capacity of pump** ………ltr/hr			
34.	**What is the** …………….**HP of the pump**			
35.	**What is the trend of irrigation**	Increasing	Decreasing	Same
36.	**Fertilizers used** …………………………………			
37.	**Insecticides used** ………………………………			
38.	**Trend of fertilizer being used**	A. Increasing	B. Decreasing	
39.	**Are you shifting from agriculture to other occupation?**	Yes	No	
40.	**If Yes, cause behind it** …………………………………			
41.	**Any soil conservation practice being followed?**	Yes	No	
42.	**If Yes, then what** ……………………………………..			
43.	**Do you practice rainwater harvesting** ……………………			
V	**Livestock/Poultry**			
44.	**Number and Type of livestock/poultry you have** ………………………………..			
45.	**Drinking water source for animal** ……………………………………….….			
46.	**Amount of water/animal/day** ……………..			
47.	**Trend of livestock/poultry growth**	Increasing	Decreasing	Same
48.	**Was there any event like death due to drinking infected water?**	Yes	No	
49.	**If Yes, what is your opinion** ……………………………………………………			
VI	**Industrial Impact**			
50.	**What do you think about the industries coming up?**			
	A. Good	B. Bad	C. Neutral	
51.	**Reason, if any** ……………………………………			

52.	**Impact of industries on water source**				
	A. Good	B. Bad		C. Neutral	
53.	**Reason, if any** ………………………………………				
54.	**Relationship with the company**				
	A. Good	B. Bad		C. Neutral	
VII	**Perception**				
55.	**How do you rate the activities of industries in your area**				
	Excellent	Good	Bad	Neutral	
56.	**What is your view about change in water availability?**				
57.	**Any beneficiary services received by companies?**				
58.	**Any member of family employed in the company?**			Yes	No
59.	**If Yes, his/her view about company's activity** ……………………………………………………………………………………				
60.	**Any watershed management activities being done?** …………………………………………………………………………………….				

………………………… ……………………….

Signature of Respondant **Signature of Interviewer**

Annexure 5 Calculation of Weighted Runoff Coefficient

LULC	Percentage	Area (km^2) 'a'	Runoff Coefficient 'b'	a×b	Weighted Runoff Coefficient Total (a×b)/Total area
Agriculture	83.09	123.70	0.4	49.48	0.41
Settlement	5.14	7.60	0.6	4.56	0.41
Water body	1.05	1.55	1	1	0.41
Plantation	4.97	7.34	0.25	1.83	0.41
Dense Vegetation	0.51	0.76	0.15	0.11	0.41
Bare Land	4.64	6.86	0.8	5.49	0.41
Total	100.00	147.81		61.47	0.41

Annexure 6 Computation of Groundwater Recharge

Geological formation	Area (km^2)	Area (m^2)	Specific yield (%)	Average water level fluctuation (m)	Recharge (m^3)
Pandaria	43.03164056	43031640.56	0.018	2.5	1936424
Maniari	0.886590808	886590.808	0.015	5.2	69154.08
Hirri	26.22015842	26220158.42	0.020	4.0	2097613
Chandi	2.763483917	2763483.917	0.018	6.5	323327.6
Tarenga	75.64630601	75646306.01	0.020	3.0	4538778
				Total Recharge	8965297