# GIS Based Groundwater Vulnerability Assessment using DRASTIC Model at Mahi River Basin, Rajasthan, India

**Amit Verma, Suraj Kumar Singh, Shruti Kanga**

***Abstract*****:** ***Groundwater is one of the important source to humankind, but there has been an increasing load to this precious resource which has become necessary to study it in detail. In the present study such an attempt has been made to account the groundwater vulnerability using as overlay index method, DRASTIC which is used to prepare a vulnerability map using GIS Technique for Mahi river basin, Rajasthan, India. This method accounts for the aquifer parameters like depth to water, net recharge, aquifer media, soil media, impact of vadose zone and hydraulic conductivity. The DRASTIC Vulnerability index (DVI) is calculated as the sum of product of ratings and weights assigned to each of the parameter on the scale of 1 to 10 and 1 to 5 respectively. The vulnerability index is then classified into five different classes and it was deduced that lies as Very Low (20.6 %), Low (28.23 %), Medium (29.11 %), High (18.82 %), and Very High (3.24 %) Vulnerability zones. Further research is conducted in order to assess the general threat to groundwater growth by the multiple industries, showing that the district will quickly collapse into a Exploited Zone, as the present pattern of growth in the agricultural and Industrial sector remains Continued. The map created for the sustainable use of the aquifer can be used as a managerial assessment in order to track and further Preventive Measures can be taken in advance to control the Growth of various Vulnerability Zones.***

***Index Terms*****:** GIS***, Aquifer, Vulnerability zones, overlay index method***

## I. INTRODUCTION

All aquifers and the groundwater are susceptible to contamination. However, with respect to all aquifers, the capacity of a contaminant introduced on the surface of the ground water is not the same. The identifying of aquifers that are more susceptible to pollution than others, both globally and regionally, is of importance, since it is a cost efficient measure for the detection and implementation of measures to protect soil waters.

In areas of having vast hydro geological setup and characteristics, it provides' information about the ratio of variability with regard to the vulnerability to soil contamination.' The mapping of groundwater vulnerability is mainly based on pollution factors and contaminant distribution. In the groundwater system, contaminant may have constituents that has been absorbed naturally by the host rock or inducted during the infiltration / percolation process of water from the ground surface by anthropological activity. The vulnerability assessment is the basis for initiating protective action to prevent contamination of groundwater resources and is usually the first step in the groundwater pollution assessment. The risk of contaminating groundwater depends on the hydro geological nature of this area.

Many approaches have been developed to assess the vulnerability of aquifer contamination. These include a process-based method, statistical method, and overlay and index methods, which are commonly adopted. Models for simulation are used to estimate contaminant migration in process-based methods, but the data scarcity and computational difficulties limit them. Statistical methods employ statistics to identify interactions between spatial variables and actual incidence in groundwater pollutants. They have inadequate observations of water quality, data accuracy and appropriate selection of spatial variables. The methods of overlays and indexing include factors that monitor pollutant movements from the ground surface into the saturated area, and provide vulnerability indexes at various locations. Although data on factors such as rainfall and depth to soil can be obtained in large areas, this method contributes to assessment at regional scales, the great disadvantage is that numerical values and relative weights are assigned for the various attributes by subjectivity.

### A. Background of Study

DRASTIC is a approach proposed as a standardized system by Linda Aller et al. (1987) for the assessment of the pollution potential of the groundwater in hydro-geological conditions. The Hydro-geological environment includes the main hydrological factors. The factors that constitute DRASTIC and include depth of water, net recharge, aquifer media, soil media, topography, impact of the vadose zone and hydraulic conductivity of the aquifer. A combination of weights and ratings, called DRASTIC INDEX, contributes to priority areas with regard to contamination potential, is used to produce a numerical value that is called as relative ranking system. It is an index model designed by combining several thematic lays to produce vulnerability scores for the various sites. This approach became more applicable in Europe, South America, Australia, New Zealand, Asia, and Africa and the United States of America. Nevertheless, Gaikwad who

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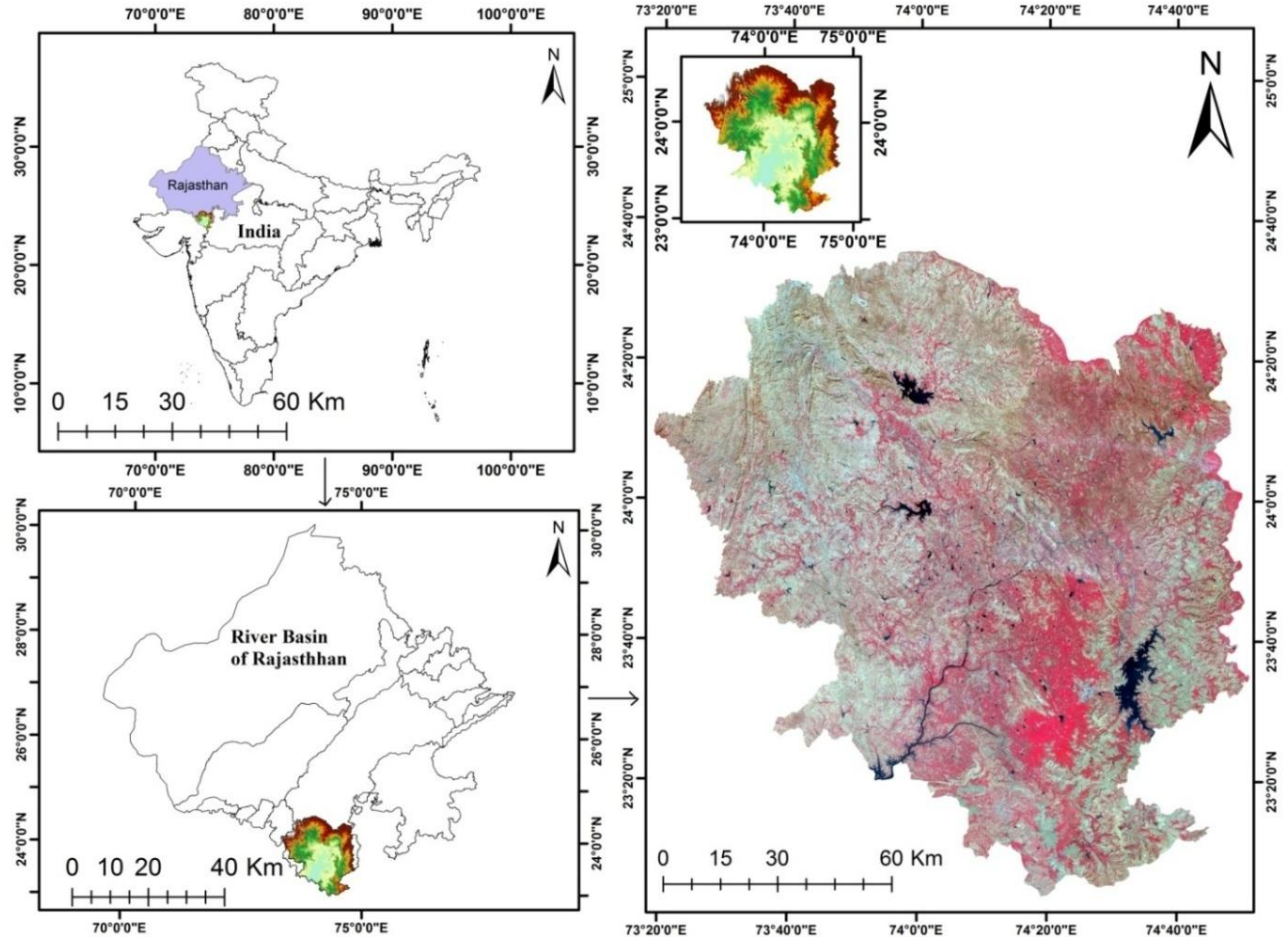


Fig 1: Study area map of mahi river basin

conducted pollution studies at the Bengaluru Vrishabhavati Valley System in Karnataka, had held that the DRASTIC value of an area could not be used to compare a comparative interpretation unless it is compared to the values of its surrounding area or with some other part.

This view from Gaikwad was originally drawn for manual superimposition of semi-quantitative data layers by the DRASTIC methodology. However, the fault indicator showed the feasibility to calculate with GIS as a linear combination of factors. In the contamination vulnerability mapping of the DRASTIC model, the applicability of the remote sensing and geographic information system have now assumed great importance. These techniques have fundamentally changed the thinking and ways in which natural resources and water resources in general are managed. GIS is designed to analyze different spatial data, which are spatially variable phenomenon in the spatial database, through an overlay analysis of data layers. The DRASTIC Model is used in the current research study to evaluate vulnerability in the mahi river basin area of Rajasthan, India.

## II. STUDY AREA

The area of the Mahi river basin covers an average of 34,842 sq km, or almost 1.1 percent of India's total geographical area, But in this Study the mahi river basin of Rajasthan has been considered which extends to an area of 16,453 sq. km. The Mahi area in Rajasthan is between 73 ° 15' E to 75 ° 52' E and 23 ° 04' N to 24 ° 35' N, and is distributed across Gujarat and Madhya Pradesh. The Mahi River comes from Mahi Kanta Hills, in the northern pit of the M.P. Dhar District, at an altitude of+ 500 m. It flows about 120 km towards south in MP before it enters the district of Banswara near Rajasthan, Chandangarh. The Rajasthan is left by Mahi River in the village of Salakari. The Mahi river in Rajasthan makes an "U" shaped river before it goes into the Gulf of Cambay. Mahi River, one of India's largest western river, drains into the Khambhat Gulf. It borders on the north and northeast side of the Aravalli Hills, on the east on Malwa Plateau, on the south on the Vindhyas and on the west on the Khambhat Gulf. There are two Mahi basins: the Mahi subbasin with a total of 41 watersheds, and the Mahi subbasin with a total area (65,11 per cent) with a total area of 41 and the Mahi-low basin with a total area of 34,89 per cent with a total of 22 water sheds. The study will consider only the Upper Mahi Basin in Rajasthan. All the necessary analytical data i.e, maps of soil depth, HSG maps were obtained from the Info system watershed Indian-WRIS website.

The overall Drainage area in the Mahi River Basin is 34,842 sq. km, of which Rajasthan has 16,453 sq. km. It is located in the south of Banas Basin; in Madhya Pradesh it is Mahi Basin on the eastern edge, and Sabarmati Basin is on the western edge. It extends over parts of Rajasthan district of Pratapgarh, Banswara and Udaipur and Dungarpur.

The river is around 100-130 meters broad on average and mainly flows across the rocky soil. It could be steep, but not very high, its banks. The basin is marked with hill terrain from the Aravali chain in orographic terms. In the southern part of hills the soil elevations range approximately from approximately + 465 m to + 1046 m, while on the alluvial level there are approximately + 208 m to + 262 m. Banswara at the south-eastern end of the Basin is the main town. Dungarpur is the second largest city centre. The Mahi River has huge water harvest potential. The two large dam, Mahi Bajaj, was built on Mahi River, on the Rajasthan Sagar Dam, while the Kadana Dam in Gujrat. The total area of the catchment is 6,149 sq km to the Mahi Bajaj sagar. Mahi Bajaj Sagar, Jakham, and Jaisamand are three other major projects in the Mahi Basin in Rajasthan. In Mahi Basin, there are four medium-sized and 220 small irrigation projects. In Panchmahal district of Gujarat, Panama Dam is also one of the major water reserves. Several other small irrigation projects with less than 25 ha were built and managed by Panchyat Samiti and NGOs. The barracks of Mahi Bajaj Sagar are located 16 kilometers northwest of Banswara village, near Borkhera. This dam has a total of 6149 km2 covered by Rajasthan.

The Mahi River has approximately 16,895 sq km of total catchment area. However, in Rajasthan there are a large area of catchment, approximately 15.770 sq km. There are many affluents draining into the main river Mahi. Some are Erau, Pundia, Jakham, Som, Anas, Hirran, Chap, Nori, Moran and Bhadar, and many others. Only the river Anas is the everlasting of these. The rivers Jakham and Gomti are the nests of the Mahi River, which come from both pratapgarh and Udaipur districts. The main tributary is the Som River in Dungarpur district, the last lap on the Mahi River in Rajasthan. Moran, a seasonal river, also passes through the district, is another contributory element. The selective watershed, as shown in the map, is located in Pratapgarh and Banswara, in the Mahi Bajaj Sagar river basin catchment. The average annual precipitation ranges from approximately 900 mm to 1165 mm in the Mahi Basin, about 94% of which are during four months of the monsoon (June -September). The predominant path in the hilly portion varies from 20 to 45% and in the valley portion from level to 10%. The region, especially near the river, is frequent by plate and gully erosion.

**A. Climatic Condition**

Three marked periods of summer (Mar-May), monsoon (June-Sep) and winter (Oct-Feb) take place in the Mahi Basin. From available data, the basin contains two climactic areas, with sub-tropical wet climate (usually the Rajasthan basin area) in the northern part of the basin. The bulk of the basin consists of tropical wet weather, caused mainly by Vindhyas and the West Ghats. The area near the origins of the river experiences a relatively colder and moderate precipitation climate because of its relatively high altitude in wooded areas, which gradually changes to warm and dry weather when the river flows north into and flows through Rajasthan.

*a. Temperature*

May is usually the warmest summer month with an average maximum temperature of 39.77 ° C. The coldest month of January is 11.1 ° C, the minimum mean temperature. The annual minimum average temperature is 19.36 ° C (1969-2004). For that same period, the average maximum annual temperature is 32.82 ° C. The annual average temperature is 26.09 ° C for this period. In the plains (lower reaches) the temperatures are higher than in the hills (higher reaches).

*b. Rainfall*

The mean annual precipitation in the Mahi Basin (1971-2004) is 899,98 mm. The monsoon in the South-West begins in June and retreats in October for the first week. During the monsoon month, approximately 90 percent of the total rainfall is received, 50 percent in July and August. The southwest monsoons are mainly the cause of the rainfall.

The average annual precipitation over the Mahi Basin is 700 mm, of which 94% is during the four months of Monsoon (June-September)..

*c. Wind*

The wind speed in Udaipur is lowest and in kushalgarh the highest. Wind speed is generally the lowest after the monsoon (Oct-Nov) and the highest in June. From the post monsoon until early winter, the direction of wind is uniform i.e Oct –Feb. In March / April, the direction will be changed. In Ratlam, Vadodara & Dahod, the predominant wind direction in the winter is from the north east and east, respectively. In Udaipur, the direction from north to northwest after moonsoon and winter wind changes south-west for the rest of the year.

**B. Drainage**

The river Mahi comes from the Vindhyachal hills on the Mahi Kanta river, in the western part of Madhya Pradesh and enters Rajasthan in the district of Banswara, near Chandangarh. It leaves the country in the village of Salakari. The river is about 100-130 m in width on average and mainly flows through cliffy terrain. Its banks may not be very high, though steep. Anas, Hiran, Eru, and Chap Rivers in Banswara are the main tributaries to the Mahi River. The Anas River alone is everlasting. The Jakam and Gomti Rivers are the next major downstream Mahi River, from the districts of Chittorgarh and Udaipur. The main tributary is the Som River in Dungarpur district, the last lap on Rajasthan's Mahi River. A seasonal river, the Moran, also passes through this district which is a tributary.

**C. Geology**

The Basin is covered mainly by rocks belonging to the Achaean metamorphic complex and The Aravali Super-Group of rocks. Alluvium either does not exist or is present to an insignificant extent. This is true also of the colluvial deposits and even the windblown sands, which are very thinly spread in The Mahi River basin.

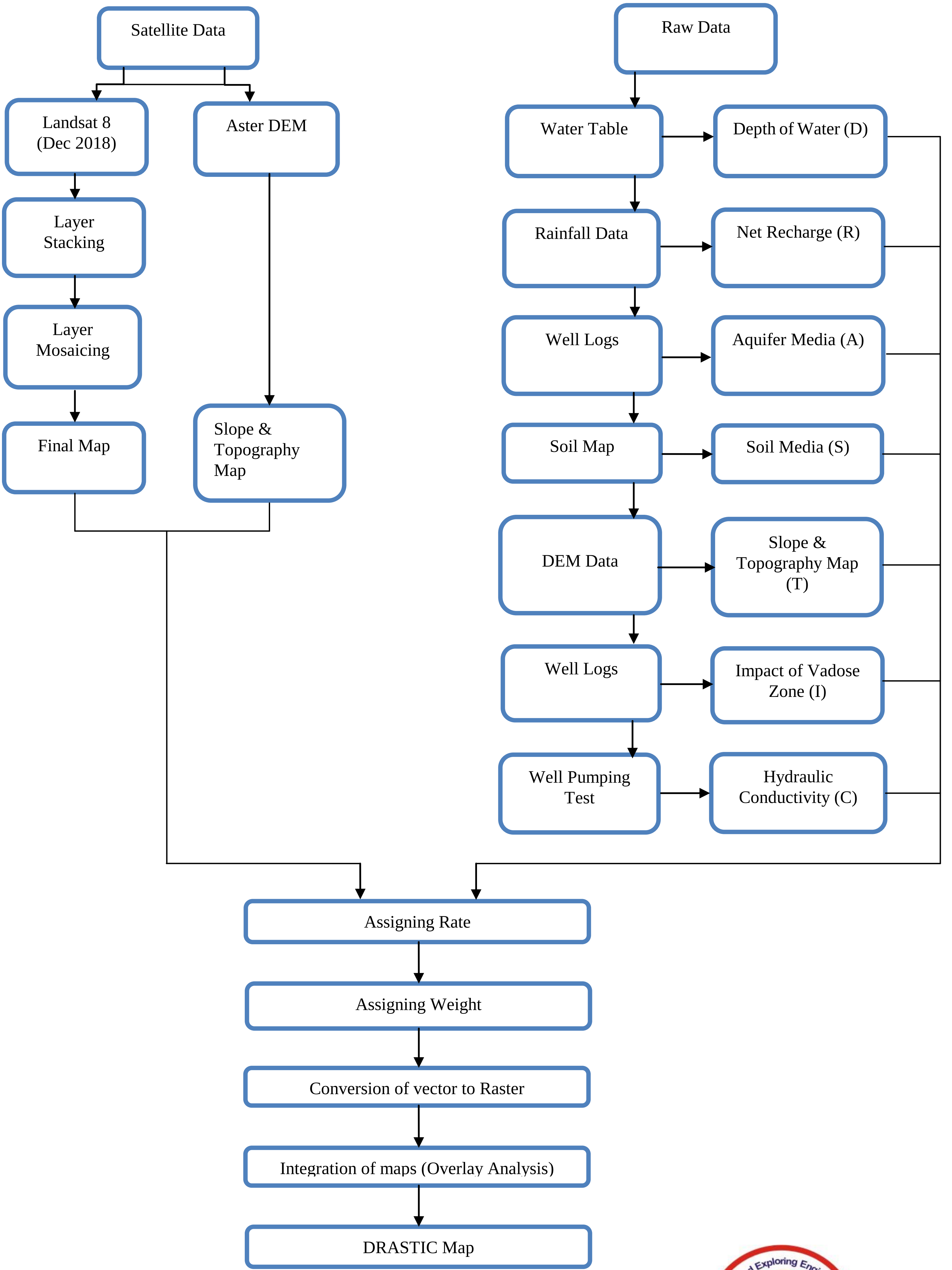


Fig 2: Methodology of DRASTIC Model

## III. DATA USED AND METHODOLOGY

The mapping of a zone's vulnerability is comparable to that of the vulnerability to soil water contamination in other similar areas. In areas with different hydrogeological structures and characteristics, it provides' information on the ratio of variability in relation to groundwater contamination vulnerability. The mapping of vulnerability in groundwater is mainly based on pollution and contaminant diffusion factors. Groundwater contaminants may have been components naturally absorbed by the host rock or induced by anthropological activities during the infiltration / percolation process of soil water. Vulnerability assessment is the foundation of protection measures to prevent groundwater pollution and is normally the first step in the groundwater pollution assessment stages (Foster et al., 2002 and Pandey and Singh 2015). In general, the vulnerability to groundwater contamination depends on the hydrogeological arrangement of the area.

DRASTIC is a method of evaluating ground water pollution potential using hydrogeological conditions proposed as a standardized system by Linda Aller et al (1987). The hydrogeology includes the main hydrological elements. These factors are the DRASTIC acronym and include water depth, net recharging, aquifers, soil media, topography, vadose area impact and aquifers hydraulic conductivity. A combination of weights and ratings, known as the DRASTIC INDEX, helps to prioritize areas with regard to pollution potential, is used for a relative ranking system. It is an index model that produces vulnerability ratings at various locations through the combination of various themed layers. The method has been given greater applicability in the United States of America (e.g. Rupert 2001, Merchant 1994, Loague and Corwin 1998, Wade et al. 1998, Stark et al., 1999, Fritch et al., 2004, Canada, Stigter, et al., 2006, Vias, and al., 2005), South America, Herlinger and Viero, 2001, Australia (Piscopo), New Zealand, 2001 (McLay et al., 2001), Asia (A, Herlinger and Viero, 2004), Australia (Piscopo 2001). That view from Gaikwad et al was first developed for the manual overlay of semi-quantitative data layers by the DRASTIC methodology. However, the vulnerability index was then used as a linear combination of factors to demonstrate the calculation capabilities Using GIS (Fabbri and Napolitano 1995 and Kanga and Singh. 2017) and the application of remote sensing and geographic information system (GIS). These techniques have changed fundamentally the thinking and manner in which natural and water resources are managed in general (Madan et al. 2006 and Singh and Kanga 2017). For analysis of various spatial data, the GIS is designed to represent spatially variable phenomena in the spatial register, through the data layer super positive analysis (Bonham-Cartern 1996 and Tripathi et al. 2017).

### A. Primary Data

An image used to map the Groundwater Vulnerability using Drastic Model has been downloaded from USGS Earth Explorer (https://earthexplorer.usgs.gov/). There are several number of plates are downloaded from USGS Earth Explorer keeping eye at Landsat 8 Image of 30 m Resolution of date 26/12/2018 and Further by Layer Stacking and Mosaicking final Image has prepared.

Also Aster DEM Data is also Downloaded (https://asterweb.jpl.nasa-.gov/gdem.asp) in order to determine the Slope map and Topography map of the Study Area.

*a. Data Acquisition*

In this Process the various Different steps will be classified as per the order, in which the primary function of this process is to Download the various Satellite imagery available online and further process that imagery in order to yield the desired output.

Following are the steps taken to download the satellite imagery

Step 1: Go to web Browser and Open USGS Earth Explore (https://earthexplorer.usgs.gov/).

Step 2: Click Log in/Sign up, which is required in order to download any data From USGS Earth Explorer Website.

Step 3: Set the area of interest in which satellite data has to be downloaded.

Step 4: Once you set your area of interest then assign the image captured date range, then click on Datasets button.

Step 5: Select the proper type of satellite to get the results from the Landsat Archive or Landsat Legacy.

Step 6: Select the Footprints of the image in order to get the view of the location that is to be downloaded.

Step 7: After getting the area information, click the download button and Select the desired location where data has to be saved.

*b. Layer Stacking*

Once Satellite Images has been downloaded then Layer stacking is further done on ERDAS Imgine 2016 using the layer stack tools and Assigning the R colour code to 3rd layer , B colour code to 4rd layer and G colour code to 5rd layer

*c. Layer Mosaicing*

After Layer Stacking, Layer mosaicking images are then mosaicked by using ERDAS Imagine 2016.

*d. Define Projection*

The final mosaicked image has the Lat- Lon values without the unit. For assigning the units and projection, the new projection and units have given to image i.e. Geographic (Lat/Lon) by using ―Define Projection‖ tool of ArcGIS 10.1. Then the image is reprojected to UTM for the ease of access. Following are the details of projected projections used for project work.

- Projection Type – UTM
- Spheroid Name – WGS 84
- Datum Name – WGS 84
- UTM Zone – 43 N
- Units- Meters

## B. Secondary Data

The non-spatial data considered in the present study like Water Table Data, Rainfall Data, Aquifer Data, Soil Data, Geology Data, etc.

Hence in order to use Non spatial data we will classify the various DRASTIC Parameters used as per Table 1 as follows:

Table 1: Representation of different source of data

| S.No | Data Type | Source | Format | Output |
|---|---|---|---|---|
| 1 | Water level Map | CGWB Report | Map | Depth of Water (D) |
| 2 | Average annual rainfall | IMD Data | Table | Recharge (R) |
| 3 | Geology Map | CGWB Report | Map | Aquifer (A) |
| 4 | Soil Map | CGWB Report | Map | Soil (S) |
| 5 | Topographical Sheet | Satellite data(Aster DEM) | Map | Topography (T) |
| 6 | Geological Profile | CGWB Report | Map | Impact of Vadose Zone (I) |
| 7 | Hydraulic Conductivity | CGWB Report | Table | Hydraulic Conductivity (C ) |

*a. Depth to Water Table (D)*

Depth of water is mainly important, as the depth of the material a contaminant must pass through is determined before it reaches the aquifer and the time for contact with the surrounding media can be determined (Aller et al., 1987). It determines the length of the path to the water table by the contaminants. In other words, a deeper water table provides a longer way to mitigate. The interactions between contaminants and earth layers are simultaneously monitored. Due to longer paths, more interaction leads to more disposals.

The distance between the surface and the water table is as mentioned previously. It is possible to obtain this distance from well logs or hydrogeological reports. Data from the well logs operated by CGWD are collected in this study. Furthermore, irrigation water wells are boiled by agricultural cooperatives and municipalities use pools for drinking water purposes. For the purposes of investigation, DSI wells have been boiled (DSI, 1979). A database showing the list of municipal wells, which unfortunately lacks well coordination, is present in the hydrogeological report of the Mahi River Basin. Therefore, well logs in municipalities could not be used to define water table depth. As much information as possible should be compiled in order to create a realistic model of the area of study. This would allow the data collected to select the media ratings correctly and validly.

Thus depth is obtained from the water table map according to directions given by Aller et al. in 1987 in DRASTIC method. In the preparation of the depth map, using imaginary wells makes the model more similar to real life. In particular, the unreal wells on Mahi River ranked as 10, to show existing depths to water table data. In order to create a water table map in depth, real and imaginative wells are executed together. The core regions of the water table near the surface have a higher DRASTIC index like 9, 10 and are indicated in a red color. It is visible briefly. In conclusion, in the middle of the study area, the depth to the table rating is high and is progressively reduced to limits by which the elevation increases.

*b. Net Recharge (R)*

The quantity of water that enters the groundwater table from the bottom of the floor is charged. The recharge is thus a significant parameter for the penetration and transport into the saturated area of the pollutants. Water refills transfers the pollutants vertically, reaches the water table and moves horizontally through the aquifer. The parameter also checks the amount of water produced in saturated and unsaturated areas for the emission and dilution of pollutants. The greater the charging frequency, the greater the groundwater contamination potential. Various variables influence the frequency of recharge such as soil permeability, rainfall level and pitch.

Net charging parameter can be estimated using precipitation-runoff hydro specific models, field trials or simply by multiplying an infiltration coefficient difference between the spatial distribution of evapotranspiration and average annual precipitation spatial distribution (Elçi 2010 and Nathawat et al. 2010). In addition to precipitation infiltration, sources of refill, such as irrigation, artificial refilling and application of waste water should be taken into account (Aller et al., 1987).

The year of groundwater is defined as the period of the following year from June of the year to May. The period for the Monsoon season between June and November is considered non-monsoon season, taking into account the prevailing precipitation conditions in the study area. The methodology of fluctuation of the water table using the monsoon moon water balance is summarized above.

*c. Aquifer Media (A)*

Is a component of a water table, all of which has water saturated porosity and is capable of storing and transporting water. One of the most significant variables is that the chip size, hardness and cementation influence the quantity of contaminant transport into the table. However, by influencing the hydraulic conductivity, the table fabric improves or reduces pollutant rates. The speed of motion of the groundwater relies on the durability of the parts of the saturated zone that in turn affect the porosity, particle size, hardness level and labyrinth. The course duration of groundwater flow is determined by these variables and is crucial in determining time for procedures that perform a part in reducing pollution.

*d. Soil Media (S)*

Soil is essential and has a major impact on the recharge, as the first layer subjected to pollutants. Soil contamination potential relies on features like texture, permeability, the contents of organic matter and soil density. Sand, silt and clay particles are connected to soil texture. Water travels rapidly in coarse sandy soils. It is therefore less capable of absorbing chemicals by itself. High soil permeability improves pollutant leakage into the table. The soil's capacity to preserve and absorb pollutants is affected by organic matter content. The density of soil also affects the decrease of pollution. The higher the density of the ground, the procedures to decrease pollution have a greater chance of reducing contaminants in the ground. In particular, the possibility of pollution by soil with poor permeability and elevated clay contents can be said to be small.

Geological mapping is used as a basis in preparation for this soil media layer, but it could not be used in accordance with DRASTIC. However, as stated by Aller et al., (1987) the users may wish to assess other information, such as organic matter content or permeability in the selection of soil media, in the event of a difficult decision such as the absence of the soil map. Using the permeability of the basin, the soil media rating map is finally obtained.

*e. Topography (T)*

The topography is the slope of the surface. This pitch influences the flow of emissions and has an effect on water stream and plant growth in the area. In general, 0% to 2% of pistes are most susceptible to contamination and more than 80% of paths possess the smallest capacity.

Topographic conditions are generally planned for use of the land. For people's activities, mild topographical places are preferred. In construction, the grading of a mild slope is cheaper.

The soil services of the countries shall classify the soil slope according to the typical range. DRASTIC method pitch ranges are suitable for soil services to easily process the data. The lower limit accepted is 0 to 2 %. The ranges are classified, as long as the 0-2-per-cent pitch gives a pollutant the best chance to infiltrate, since nobody leaves the area as runoff either by pollutants and much precipitation (Aller et al. 1987). Furthermore, the higher limit is 18 %, which in the DRASTIC index is rated 1. Higher pitch signifies higher water movement speed, resulting in rush of surface.

*f. Impact of Vadose Zone (I)*

This subsoil layer expands to the table of water. As a soil layer, the unsaturated layer impacts their potentials of vulnerability and relies on their environmental features and their permeability. The depth is heavily affected by most chemical and physical procedures. In other words, the longer the depth of these procedures, the greater the time to decrease pollution. The potential therefore decreases with depth. Furthermore, the purification and allocation of pollutants rely substantially on the environmental physical characteristics. This factor is less than other variables, because it is hard and costly to obtain data about this factor. The saturated area shall be estimated with exploratory drilling, observational boreholes, field and laboratory observations and measurements. The techniques of assessment are often linked to an alteration. Since the nature of flow, observation, measurements and their characteristics are affected by these techniques.

*g. Hydraulic Conductivity (C)*

In the saturated surroundings the hydraulic conductivity of a water table shows the ability of groundwater mobility. Consequently, the mobility capacity of groundwater-borne pollutants is roughly equivalent to the table's hydraulic capacity. The pores, fractures, joints and inter-granular porosity depend on hydraulic conductivity. This parameter regulates the motion and allocation of contaminants from the stage of infiltration to the saturation area. Therefore, in areas with elevated hydraulic conductivity, there is greater pollution potential.

**C. Software Used**

The software's used in the present study is listed below with their purposes.

1) ArcGIS 10.5 has been used for digitization, IDW Method, Overlay Analysis, preparation of statistics and for Map Layout.

2) USGS Earth Explorer have been used for download images.

3) ERDAS Imagine 14 has been used for mosaic images.

4) Microsoft excel has been used for storing the attribute data.

**D. Rate Assigning**

To determine the relative significance of each factor, each DRASTIC factor has been measured in relation to the other. A relative weight of 1 to 5 (Table 2) was assigned to each DRASTIC. The major factors have a rate of 5; the smallest is a weight of 1. This was done with a Delphi approach (consensus). This rate is constant and cannot be modified.

**D. Weight Assigning.**

Each range for each DRASTIC factor has been evaluated with respect to the others to determine the relative significance of each range with respect to pollution potential. The range for each DRASTIC factor has been assigned a weight which varies between 1-10.

The DRASTIC model is based on seven parameters, corresponding to seven layers to be used as input parameters for modelling. The sources of data for each parameter are given in Weight Assigning to the various 7 Parameters of DRASTIC model are as below:

Below is the Table of different Parameters of DRASTIC Model having the Rating and Weight schema along with the Final index Rating and the Area of the different parameters in (square Km) and Percentage of the area of distinct Parameters.

| Parameter | Range | Rating | Weight | Index | Area (km sq) | Area (%) |
|---|---|---|---|---|---|---|
| Depth To water Table (m) | 0 - 3 | 5 | 10 | 50 | 28750 | 43.45 |
| | 3 - 6 | | 9 | 45 | 28240 | 42.68 |
| | 6 - 9 | | 8 | 40 | 6796 | 10.27 |
| | 9 - 12 | | 7 | 35 | 1836 | 2.77 |
| | 12 - 15 | | 6 | 30 | 376.1 | 0.57 |
| | 15 - 18 | | 5 | 25 | 142.6 | 0.22 |
| | 18 - 21 | | 4 | 20 | 13.05 | 0.02 |
| | 21 - 24 | | 3 | 15 | 11.24 | 0.02 |
| | 24 - 27 | | 2 | 10 | 5.186768 | 0.01 |
| Net Recharge (mm) | 500 - 600 | 4 | 1 | 4 | 1566.27 | 9.42 |
| | 600 - 700 | | 2 | 8 | 8179.41 | 49.19 |
| | 700 - 800 | | 4 | 16 | 3499.22 | 21.04 |
| | 800 - 900 | | 7 | 28 | 1921.38 | 11.55 |
| | 900 - 1000 | | 8 | 32 | 1250.81 | 7.52 |
| | >1000 | | 10 | 40 | 212.38 | 1.28 |
| Aquifer Media | BGC | 3 | 2 | 6 | 3364 | 20.23 |
| | Basalt | | 2 | 6 | 2084 | 12.53 |
| | Hills | | 3 | 9 | 4123 | 24.79 |
| | Limestone | | 4 | 12 | 144.5 | 0.87 |
| | Phylite | | 7 | 21 | 6133 | 36.88 |
| | Quartzite | | 3 | 9 | 0.72885 | 0.00 |
| | Reserve Forest | | 8 | 24 | 90.62 | 0.54 |
| | Schist | | 4 | 12 | 396.2 | 2.38 |
| | Shale | | 10 | 30 | 190.5 | 1.15 |
| | Ultra Basic | | 4 | 12 | 103.3 | 0.62 |
| Soil Media | Fine Sandy | 2 | 2 | 4 | 4744 | 28.52 |
| | Loamy | | 3 | 6 | 3870.1 | 23.28 |
| | Clayey | | 5 | 10 | 8015.2 | 48.20 |
| Topography (%Slope) | 0-10 | 1 | 10 | 10 | 7859.07 | 47.26 |
| | 10 - 20 | | 9 | 9 | 3743.28 | 22.51 |
| | 20 - 30 | | 8 | 8 | 1400.19 | 8.42 |
| | 30 - 40 | | 7 | 7 | 1037.67 | 6.24 |
| | 40 - 50 | | 5 | 5 | 575.37 | 3.46 |
| | >50 | | 4 | 4 | 2013.82 | 12.11 |
| Impact of Vadose Zone | Aravali Supergroup | 5 | 5 | 25 | 8477.61 | 50.98 |
| | Bhilwara Supergroup | | 6 | 30 | 3742.26 | 22.51 |
| | Delhi Supergroup | | 7 | 35 | 278.2 | 1.67 |
| | Extrusive Supergroup | | 6 | 30 | 3611.56 | 21.72 |
| | Vindhyan Super Group | | 8 | 40 | 441.29 | 2.65 |
| | Waterbody | | 10 | 50 | 78.53 | 0.47 |
| Hydraulic Conductivity (m/day) | 0.002 - 0.2 | 4 | 1 | 4 | 4744 | 28.53 |
| | 0.5 - 2 | | 1 | 4 | 3870.1 | 23.27 |
| | 1 - 3 | | 2 | 8 | 8015.2 | 48.20 |

Table 2: Rating and Weight Schema of DRASTIC Model.

**E. Drastic Vulnerability Index (DVI)**

The name DRASTIC is taken from the initial letters of the seven parameters used to evaluate the intrinsic vulnerability of aquifer systems. The fallowing symbols are used in the computation of DRASTIC vulnerability index.

Dr = ratings to the depth to water table,
Dw = weights assigned to the depth to water table,
Rr = ratings for ranges of aquifer recharge,
Rw = weights for aquifer recharge,
Ar = ratings assigned to aquifer media,
Aw = weights assigned to aquifer media,
Sr = ratings for the soil media,
Sw = weights for the soil media,
Tr = ratings for topography (slope),
Tw = weights assigned to topography,
Ir = ratings assigned to vadose zone,
Iw = weights assigned to vadose zone,
Cr = ratings for rates of hydraulic conductivity, and
Cw = weights given to hydraulic conductivity.

The DRASTIC Index is then computed applying a linear combination of all factors according to the following equation:

$$\text{DRASTIC Index} = D_R D_W + R_R R_W + A_R A_W + S_R S_W + T_R T_W + I_R I_W + C_R C_W$$

Where D, R, A, S, T, I, and C are the seven parameters and the subscripts R and W are corresponding ratings and weights, respectively. The DRASTIC parameters are weighted from 1 to 5 as seen in Table 2.2 according to their relative importance in contributing to the contamination potential.

Determination of the DRASTIC index number is done by multiplying each parameter rating by its weight and adding together. Each parameter is rated on a scale from 1 to 10, a rating of 10 indicating a high pollution potential of the parameter.

**F. Overlay Analysis**

Overlaying analysis is an ancient process in which new information is derived from two or more data layers covering the same area. For example, with a soil utilization layer and a soil fertility layer, the percentage of agricultural land developed in fertile soil can be derived from both layers.

A land usage map with a soil map on the light table would traditionally be placed over each other and we would visually inspect the composite to find areas in which fertile terrain overlaps. This manual process is tedious and can make it extremely difficult to see through the human eyes when many layers are involved. In a GIS, digital superposition is performed; many of these restrictions are not applicable.

Composite forming of two data layers is only a first step in the analysis of overlays. Only those areas of interest would normally be selected for us after we have created new areas from overlapping regions. In areas where agricultural land develops over fertile soil, for example, we may have an interest. In a further analysis, we could only be interested in areas of poor soil cultivation of agricultural land.

A map layer has various characteristics. For an overlay analysis, we usually find it convenient to group features into two classes: those that meet certain requirements and those that do not meet the same requirements.

We are interested in agricultural lands in the land use layer of our example. We therefore group all other types of land into non-farmland. Likewise, in the soil fertility layer, we identify fertile and non-fertile soils.

We can perform intersection, union, subtraction and other logical operations after each layer are reduced into two classifications. The results of some of these operations are presented below. The crossroads show agriculture over fertile soils, the combination of farmland and fertile soil, and the subtraction shows agricultural soils over unfertile soils.

It is not just areas that are involved in overlaying. Sometimes we overlay areas along lines, for example, to see how many river-flowing countries. In addition, we could overlay areas on points. For instance, the number of trees in a park would be determined. In theory, it is possible to overlay points with points, points with lines with lines. They are less common and are not supported by many GISs.

## IV. RESULT AND DISCUSSION

To map the study area's groundwater vulnerability, the DRASTIC values were calculated by studying the GIS environment and executing the DRASTIC INDEX equation. Several types of information are used to construct thematic layers for the 7 model parameters: maps for all the seven factors of the DRASTIC model that has to be generated in order to map the vulnerability and the quality zone of the study area. Details on this subject are discussed briefly here:

**A. Depth to water (D)**

The depth of the contaminant to reach the water table will be determined by this parameter. Within this document, the depth of water in an unconfined aquifer, which is otherwise often referred to as the water table, is considered as depth to the water surface. The depth of the material to be transported by the contaminant before it reaches the aquifer may be measured and determined by the amount of time it takes to maintain contact with the surrounding media (Linda Aller et al, 1987). Normally, the contaminant attenuation capacity increases more due to the long duration of the journey with increasing contaminant load in the water table. In confined conditions, depth to water is used to distinguish depth to the top of the contained aquifer, and no consideration shall be given to saturated areas above the top of the confined aquifer. The level of the water in confined aquifers refers to the piezometric level, otherwise known as the piezometric surface. Depth is the term for unconfined aquifer. The presence of low-permeability soil layers restricts pollutant movements towards the aquifer. The Depth of water is determined by the water table report published by CGWB and Ground points are located with the help of these reports. Further with the help of IDW interpolated tool in ArcGIS, the Depth of water table map is then generated and is classified into various required classes where low value determines the less depth and high value determines the higher depth in water level. Thus the Obtained Depth to water level map is shown in fig 3

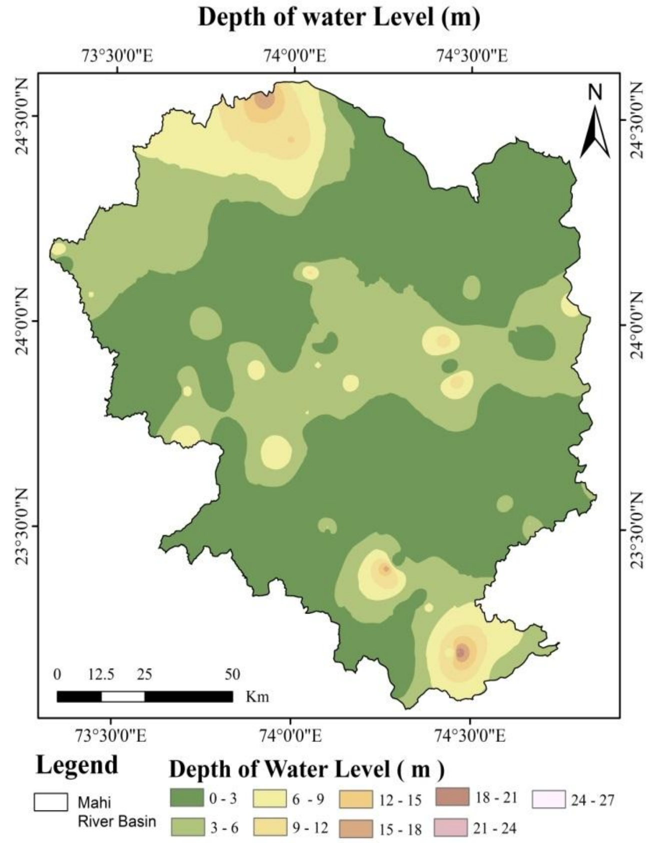


Fig 3: Depth of Groundwater (D)

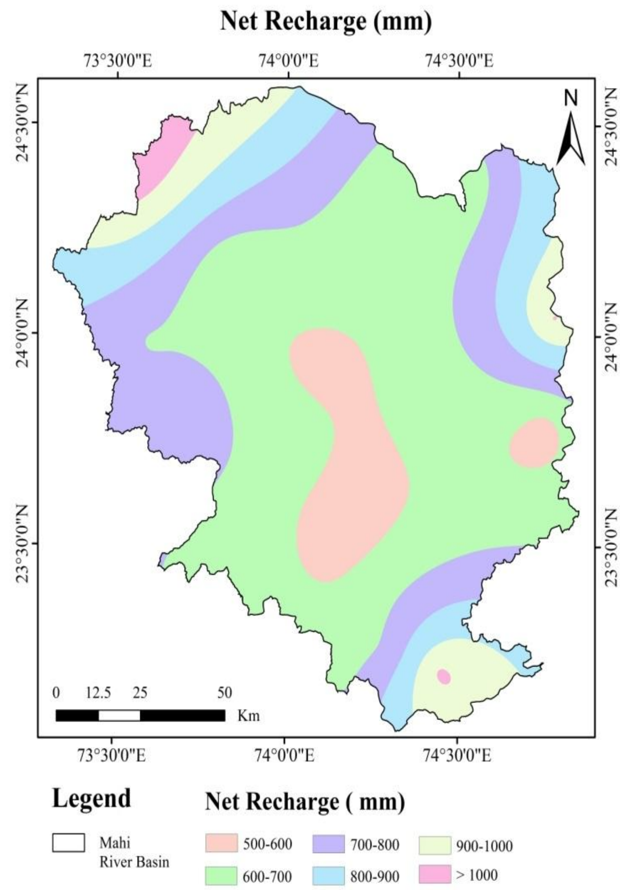


Fig 4: Net Rechage (mm) (R)

**B. Net Recharge (R)**

Net recharge is the water which infiltrates from and reaches the water table from the ground surface. Under unconfined conditions, the groundwater body is usually recharged with vertical infiltration through the aeration area from the ground surface. This means that pollutants are vertically transferred from the water until they reach the water table and distributed further into the saturated section of the aquifer. This parameter therefore reflects the volume of water diffusing the pollutant in the saturated areas and reducing it. Pollution potential is greater in unconfined conditions than in confined areas. The refueling area is far away for confined aquifers.

Net recharge involves the actual annual infiltration quantity and does not take into consideration the allocation and frequency of refilling activities. A major way to carry contaminants from vadose areas to saturated areas is recharging water. For the preparation of the net charge, two maps are required. The first is the rainfall network; the second is the ground permeability chart of the research region, which is generated by multiplying the two maps. Since the annual median precipitation is around 750 mm in the region. The total recharge ability of the region is depicted by one category according to the DRASTIC ranking model.

Here the Net recharge map is generated from the Rainfall data that is generated from CGWB, and then rain gauge points of different blocks is further spatially interpolated using the IDW Technique in order to obtain the Net Recharge Map.

Thus the Obtained Net Recharge map is shown in fig 4

**C. Aquifer media (A)**

Due the lithological characteristics and the environmental aspects of the aquifer, the course of the groundwater flow system. The flaw, cracks; porosity, permeability, transmissibility and storage coefficient values of the aquifer depends on the course of the water movements. The processes of attenuation such as absorption, chemical reactions, dispersion, etc. depend on the time and duration of the water. The environment within the aquifer zone also affects certain effects on pollutant-contact material.

Aquifer media is perhaps the unconsolidated portion of rocks in which water is contained within the pores and fractures. Consequently, aquifer media impact the water flow in the aquifer. This stream regulates the contaminant level within the water tank (Aller et al. 1987).

Because of certain field constraints, soil profiles and soil depths cannot be mapped. The preparation of the soil map and also the variation rates of the saturated and unsaturated aquifer circumstances were collected in log information from exploratory bore wells placed in the research region. For the research region, the information on the product sort in the aquifer setting was identified using the log data and geopsy charts. In order to prepare the Aquifer media map, in the Arc Map environment, the location of exploratory wells, aquifer types and materials, and their respective values, based on the assessment table were used.

The aquifer media layer was designed based on 140 well log information accessible in the research region. Firstly, each well received the aquifer press ranking. In addition, the aquifer media layer was developed and lastly transformed to grid coverage with the classification value and well location places. Aquifer media layer stated that most compact shallow areas have a score of 2 and metamorphic / igneous rocks are 3.

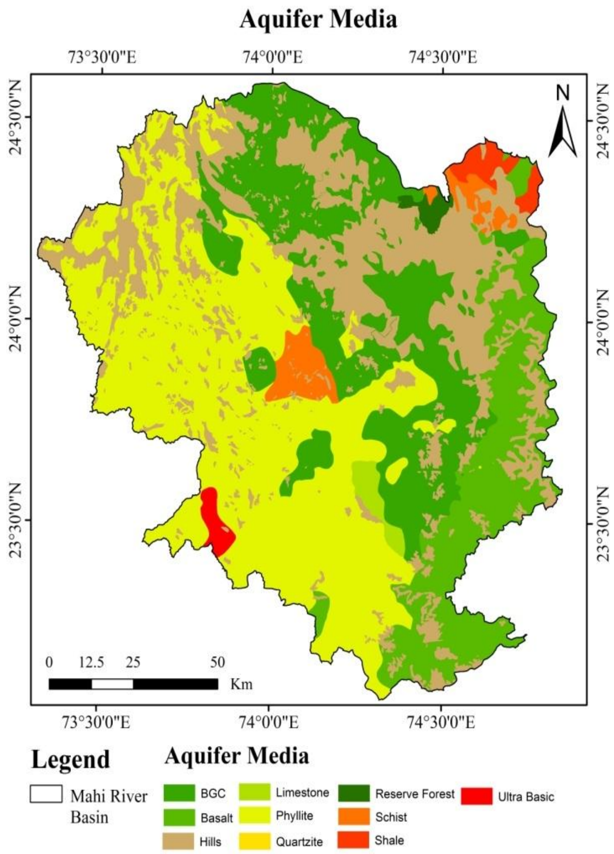


**Fig 5: Aquifer Media (A)**

### D. Soil Media (S)

Soil media that is used for evaluating groundwater pollution is one of the main factors. It is the highest portion, represented by considerable bio-activity, of the unsaturated layer. The quantity of rechargeable water that may interfere in the aquifer unit can have a significant effect.

The soil and the environment influence the water which infiltrates into the water table with pollutants. The presence of materials such as clay and sludge reduces the permeability of the soil, restricts water transportation and movement. The presence of organic materials and plant roots in the high level microbial activities increases the soil layer's pollutant attenuation capacity as compared with the lower parts of the unsaturated zone. In addition, the processes such as attenuation of pollutants, infiltration, absorption, gas leakage etc. will become more important when the thickness is higher. Its textured ranking is the soil environment and the potential for pollution is assessed.

The sort of earth and related equipment for a depth of 2 meters have been determined using drilling log information. In the setting of the Arc Map software was used to map the soil environment by placing the working pools, soil type and equipment and their corresponding values. This map was created and categorized as a raster map of 100 meters.

Geological parts and drilling models were used to develop the region soil media chart. Silky, good sandy and loamy is the soil in this region,

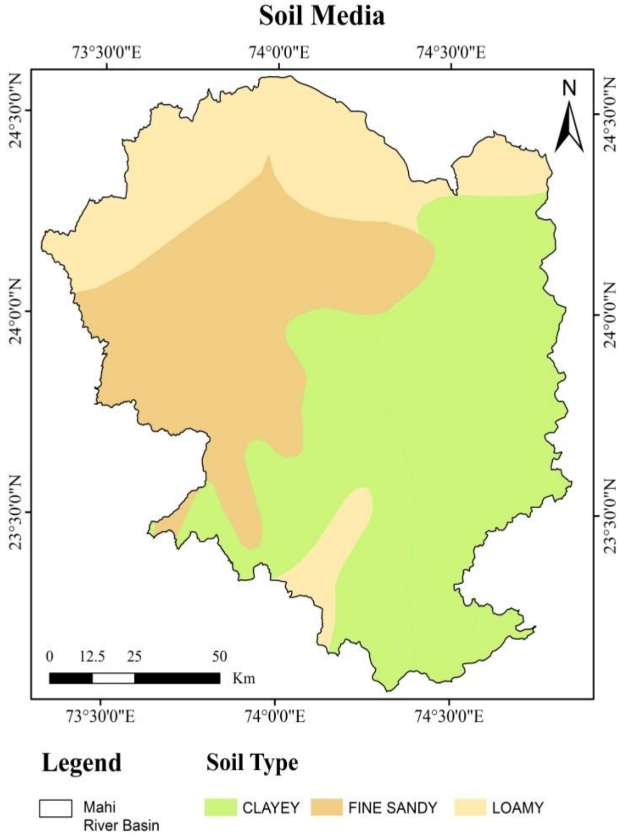


**Fig 6: Soil Media (S)**

### E. Topography

Topography is a geomorphological feature in which the gradient and its variability on the earth's surface have an important impact on the movement and retention of pollution. The potential for infiltration of pollutant-carrying water is increased if the gradient is smaller or moderate. In agricultural land in particular low gradients lead to reduced ruin and increased infiltration into the aquifer, thus increasing the transfer of pollution into soil waters. The topography also influences soil expansion and thus the ability to reduce pollution. In the digital elevation models DEMs) the percentage of the gradient is calculated.

The topography of any of the surfaces depicts the steepness or slope and its surface fluctuations. The lower-slope areas can maintain long-term water retention and permit more water to drain into the floor. These regions are therefore highly contaminated (Sinha et al., 2016). However, fields which are less prone to contamination by soil water, marked by steep hills with surplus runoff and less infiltration (Sinhaet al. 2016). ASTER DEM Satellite Data is used for preparing percentage pitch (Figure 7). The research region is 30 m spatial resolution. Slope map can vary from 0% to 50% and has been categorized into 6 classifications, i.e. 0–10, 10–20, 20–30, 30-40, 40-50, and > 50,. Most areas in the research have 0-10 pitches. The peak, of 10, is due to paths that vary from almost to very mild, while the reduced value is linked with very steep paths (Shekhar et al., 2014).

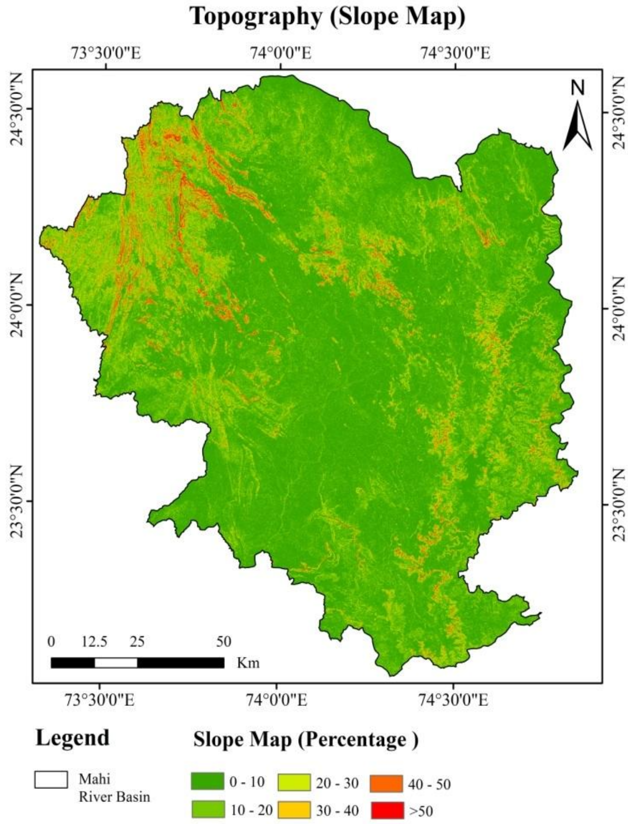


**Fig 7:Topography ( Slope Map) (T)**

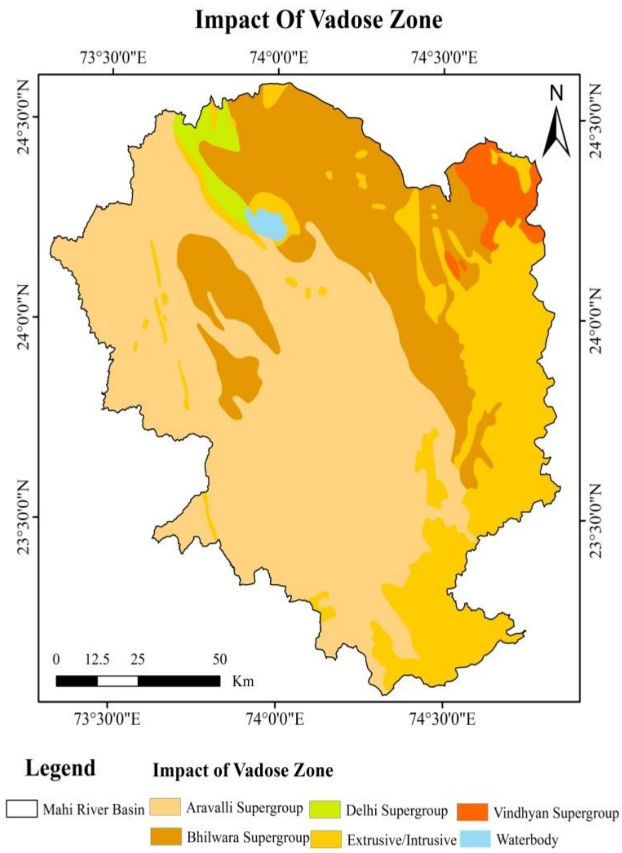


**Fig 8: Impact of Vadose Zone (I)**

### F. Impact of Vadose Zone (I)

The unsaturated zone is a zone not saturated with water above the water table. The saturation level is variable in the case of unconfined water conditions due to fluctuations in the table of water between seasons and / or due to the extraction of water for different human purposes. Among key factors determining aquifer vulnerability and the primary natural factors controlling the charging rate and duration are its thickness and hydraulic properties in the geo-formation of the unsaturated zone. In protects groundwater from pollution by retention, absorption and elimination of pathogens and bacteria, by absorption of numerous chemical, organic and synthetic material, by absorption and responsive absorption, the unsaturated area plays an important role in reducing the amount of heavy metals and any other non-organic chemicals. The depth and the permeability of the soil in the groundwater table are the factors generally affecting the unsaturated zone.

Unsaturated region above that of the water table is known as the vadose zone from which infiltrated water gets filtered to the aquifer. It enables to contain infected material and penetrate it into the saturated area. If the density of the vadosic area is greater, it is less susceptible and less susceptible. The IDW technique spatially interpolates points of research region information referred to vadosic region density to acquire the raster map of vadosic region.

### G. Hydraulic conductivity (C)

The rock's permeability is the ability to transmit water under differential pressure and measured according to the rate of transmission of water per unit distance by unit cross section (Karanth, 1987). Permeability as coefficient was defined in Meinzer by a hydraulic gradient of one foot as the flow rate of water in gallons per day, through a sectional cross-section of one square foot. The term hydraulic conductivity is currently commonly used in favor of the permeability coefficient. The rock's hydraulic conductivity depends on intergranular porosity, cracks, and layered surfaces.

The capacity of an aquifer to transport liquid to surface pores has been determined by hydraulic conductivity. The flow rate of soil water is controlled by a specified hydraulic gradient. For water conductivity maps of the region, the soil chart of the research area is used. After Smedema and Rycroft (1983) were allocated range and scores of C for the specific land cover form and shown in Fig 6.7. The conductivity ranges in the research region between 0.002 and 3 m / day. High water conductivity areas are more likely to be polluted (Aller et al. 1987).

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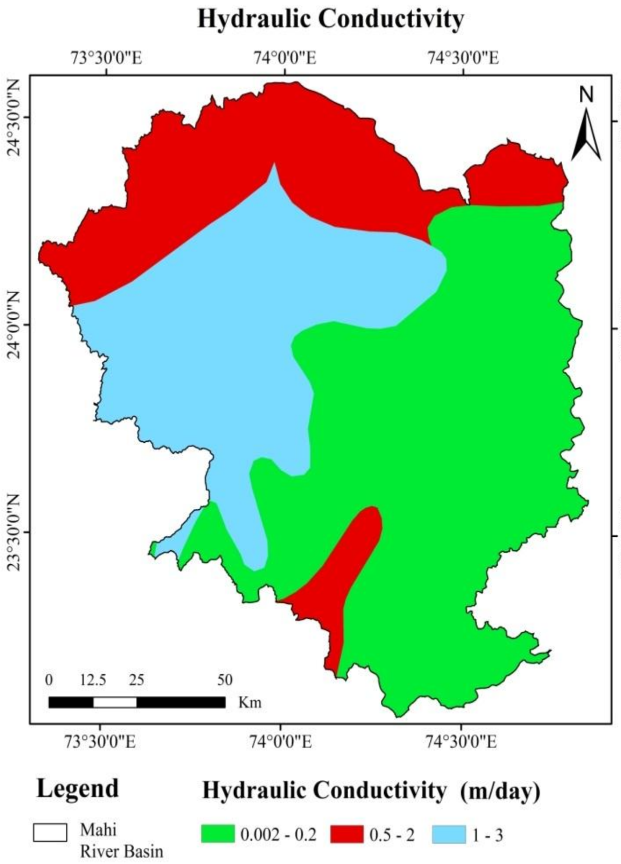


Fig 9: Hydraulic Conductivity (C)

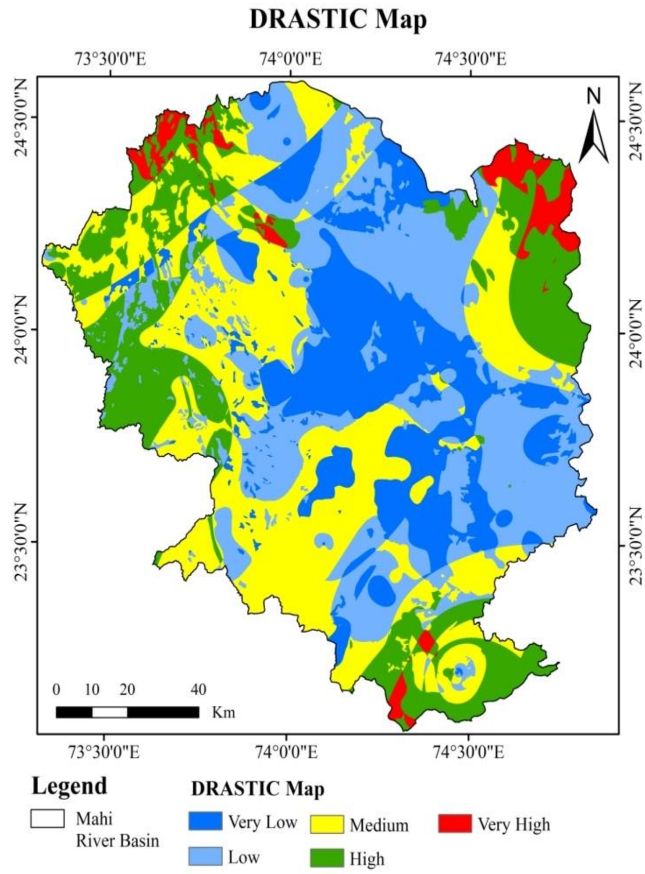


Fig 10: Final DRASTIC Map

**H. Final DRASTIC Map.**

The results map and weights for each factor in DRASTIC were used to prepare the vulnerability map for the Mahi river basin, and it is further categorized into five areas known as Very Low, Low, Medium, High and Very High Vulnerability Zones. The areas show the water table's sensitivity to pollution. Higher areas of vulnerability show greater sensitivity to pollution in the water table. The distribution of figures does not follow a certain standard and is based on the soil type and value range, and is split equally. For instance, if the range of values is small the amount of values would be lower and if the range was bigger it would be possible to divide the same range into more classes.

In this Map the very low and low vulnerability zone defines the Lower areas of vulnerability with lower sensitivity to pollution and Very high and High Vulnerability zones defines the higher areas of vulnerability with greater sensitivity to pollution.

The DRASTIC map exhibits that about 3.24% and 18.82% of the area lie between very high and high vulnerable zone about 29.11 % of area is under Medium Vulnerability Zone and the remaining 20.60% and 28.23% area fall in the Very Low and Low risk vulnerable zone (Table 3).

The highly vulnerable zones are present in the South, North East and North Western parts of the catchment covering an area of 3668.48 km sq.

## V. Conclusion

The DRASTIC technique was employed in this research to evaluate the Mahi River Basin, Rajasthan groundwater vulnerability. Basin-water vulnerability evaluations for the entire basin have been discovered to be realistic and appropriate for plains of that region. But the DRASTIC technique has some disadvantages in spite of its achievement in certain case studies. Regional influences (geology, hydrology, hydrogeology, land use, etc.) are not taken into account, so rating values are used everywhere hence same weighs have applied. If the hydraulic details such as type of aquifer, thickness of aquifer, groundwater level and groundwater flow direction etc. are recognized, this technique will yield more dependable outcomes. Researchers envisaged various changes to the initial DRASTIC model in order to tackle local problems for better representing local hydrogeological environments. The changes included extra parameters, removal of some parameters, and the use of distinct parameter scores and weights.

The DRASTIC approach was studied in this research using DRASTIC model seven parameters to detect vulnerability to soil water. For the validity of this technique the precision of the weights and values of the DRASTIC parameters is essential. In the assignment of scores and weight to model parameters, the DRASTIC procedure is stiff. In that research, the margin of mistake was reduced through thorough hydrogeological field research. Depending upon the field and regional characteristics of the study region the rating values of the parameters were determined and then using the IDW Spatial interpolation methods the maps of different parameters were designed and further the final Drasic map was prepared using the Raster Calculator Tool to design the final DRASTIC Map having five different classes which is Very Low, Low, Medium, High and Very High Vulnerability zone areas.

Table 3: Final DRASTIC Model Statistics

| Parameter | Range | Area (km Sq) | Area (%) |
|---|---|---|---|
| Final Drastic | Very Low | 3426.47 | 20.60 |
| | Low | 4694.72 | 28.23 |
| | Medium | 4839.78 | 29.11 |
| | High | 3129.92 | 18.82 |
| | Very High | 538.56 | 3.24 |

Hence this DRASTIC Method have clearly stated that areas which is highlighted in red color in fig. 10 have high contamination potential and is named as very high vulnerability zone according to the vulnerability map that was prepared using the DRASTIC method.

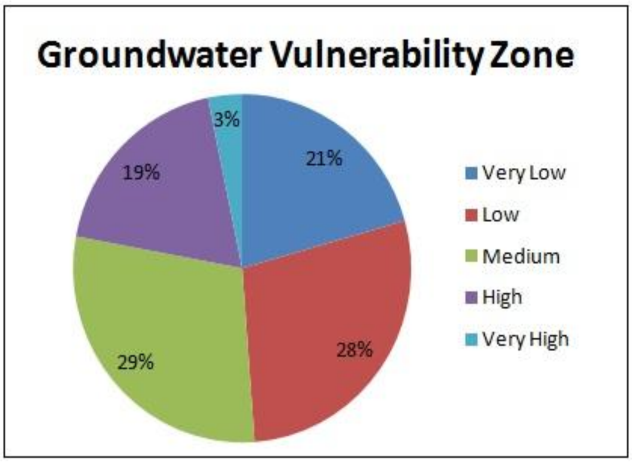


**Fig 11: Pie Chart of Drastic Model Final Statistics**

The DRASTIC map exhibits that about 3.24% and 18.82% of the area lie between very high and high vulnerable zone about 29.11 % of area is under Medium Vulnerability Zone and the remaining 20.60% and 28.23% area fall in the Very Low and Low risk vulnerable zone (Table 3). These variations are mainly due to an arrangement of hydrological parameters in the DRASTIC model. The highly vulnerable zones are present in the South, North East and North Western parts of the catchment covering an area of 3668.48 km sq.

It can be stated that DRASTIC technique has produced more valid and precise outcomes for aquifer sensitivity assessments than other approaches.

Mahi River Basin's maps are an excellent basis for future scheduling research on groundwater vulnerability. In order to monitor evolving concentrations of pollutants, detailed and frequent surveillance of groundwater quality in extremely sensitive regions needs to be carried out. Local managers should also run educational programs and farmers ' awareness activities.

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