Correlation of Various Water Quality Parameters and Water Quality Index of Lonar Tehsil Area, Buldhana, Maharashtra

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Submitted By : Dr. Sandip Kisan Sirsat

[**S**ERB **Q**ualified **U**nique **I**dentification **D**ocument: SQUID-1991-SS-2445]

Submission Date : 10-Aug-2023

PROPOSAL DETAILS

(PDF/2023/003388)

Principal Investigator	Mentor & Host Institution
Dr. Sandip Kisan Sirsat sksirsat@gmail.com Research Scholar(Department of Applied Geology) **Contact No** : +919028584609 **Date of Birth** : 13-Jun-1991 **Name of Father/Spouse :** Kisan Limbaji Sirsat	**Sanjay Narayan Patil** snpatil@nmu.ac.in Professor(School of Environmental and Earth Sciences) **Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon** Kavayitri bahinabai chaudhari north maharashtra university,P. o. box no. 80,Umavi nagar,Jalgaon - 425001 (m.s.) indiauniversity general enquiry telephone number :- +91-0257- 2257250, Jalgaon, Maharashtra-425001 **Contact No.** : +919423937400 **Registrar Email** : registrar@nmu.ac.in **No. of PHD Scholars** : 05 **No. Post-Doctoral Fellow** : 01

Details of Post Doctorate

Ph.D. (Geology)[Degree Awarded on : 02-May-2023]

GEOMORPHOLOGICAL AND HYDROGEOLOGICAL STUDIES OF LOWER PAINGANGA RIVER BASIN AREA, BULDHANA DISTRICT, M.S., INDIA

Research Supervisor/Guide & Institution :

Dr. Mohan A. Sonar

Dr. Babasaheb Ambedkar Marathwada University, Aurangabad

Brief details of Thesis work :

The Ph. D thesis mainly studied by Geomorphological & hydrogeological aspects. In Geomorphological aspects includes morphometric analysis, Hypsometric analysis and hydrogeomorphic unit for the purpose of groundwater circumstances. In hydrogeological studies includes resistivity survey, well inventory and static water level data of 2019 and 2020. Both the aspect for recognazed the groundwater potential zones in the part of Painganga river basin Area (Mehkar & Lonar tehsil).
In morphometric analysis, the drainage characteristics of the Painganga river basin have been studied regarding linear parameters, areal parameters, drainage texture analysis and relief characterization. The linear parameters of morphometry are including stream order, stream number, stream length, mean stream length, stream length ratio, bifurcation ratio, mean bifurcation ratio and Rho coefficient. The areal aspects computed in this study include area, perimeter, basin length, mean basin width, lemniscates and form factor, elongation ratio and compactness coefficient ratio.The drainage texture analysis in the present study area includes drainage pattern, drainage density, drainage texture, stream frequency, circulatory ratio, constant channel maintenance, infiltration number, length of overland flow and constant channel maintenance. The relief characteristics studied in a given basin area include the maximum height of the basin (Z), the height of basin mouth (z), total basin relief (H), absolute relief, relief ratio (Rh), dissection index (Dis), ruggedness number (Rn).
The combination of all types of curves recorded in the study area indicated the presence of a multi-layered homogenous formation. The curves are prominent of H, Q, K and A type indicating the presence of three layers and a combination of curves like KH, HK, AK, HA and KQ indicating the 3–4 layer subsurface layers. The sounding curves are observed in the study area from different locations i. e., H, A, K, KH, HK, AK, HA and KQ types resulting in a 3–4-layer sequence.
The hypsometric integral (HI) indicates that the study of the elevation and quantitative suggestion among the area of a regional horizontal piece, can reflect the watershed development state and it also concludes stages of river development. The HI values of the study area is indicating that all watersheds are in the mature stage of development. The HI curve of the study area is also representing a sigmoidal curve.
Vertical electric sounding data for 40 different locations in the study area, were interpreted using IPI2WIN software to obtain the resistivity values for different subsurface layers, their thickness and depth. The types curve is recognized according in combinations with the basic types, study area also observed KQH, AKH, HHA, KHA, AAK, HKH and HQH type of curves with 5-6 sub-surface layer sequences.
Dar-Zarrouk parameters for different strata resulting from geoelectric parameters have been reported. Dar Zarrouk parameters are longitudinal total conductivity (S), longitudinal resistivity (l), transverse resistance (T), transverse resistivity (t), electrical anisotropy (λ) and groundwater for detecting safety measurements at groundwater potential zones and various VES sites.
VES data obtained from different geoelectric parameters was used to prepare the vulnerability index maps. The data allows us to categorize the area into different vulnerability zones (negligible/poor, weak/low, medium, good/high and extreme/excellent). The protective capacity index rating/vulnerability of the area is determined by comparing three different model's total longitudinal unit conductance, GOD and GLSI from hydrogeological and hydrogeophysical points of view. The study revealed that the protective capacity of the vadose zone ranges from good to moderate.
The well inventory survey method was analysing the open-cut well to know the sub-surface lithology of rock formations within the study area. 35 observations wells are selected in the different geomorphic units. The hydrologic properties of geological formations show a wide range of variations due to their inherent physical properties. Groundwater occurs in the weathered portion of rock formations, weathered vesicular and zeolitic flows, in joints and fractures and contact between two formations.
This groundwater fluctuation is due to the influence of precipitation and drainage pattern and water level fluctuation depend on the local hydrological situation, the static water level fluctuation maps of 2020 show maximum groundwater fluctuation rates are observed in the northwest, northeast and southwest than the central part within the study area. This groundwater variability is because of precipitation and drainage patterns, and water level variability depends on local hydrological conditions. Groundwater table fluctuation in pre-monsoon and post-monsoon water levels with respect to ground level have been observed. This pre-monsoon and post-monsoon static water levels are plotted and compared with the overall fluctuation of weighted mean rainfall. It is also suggested that the precipitation rate of the study area varies every year. The static water level shows that lithological and precipitation control the pre-monsoon and post-monsoon static water levels and seasonal water table fluctuations within the study area.

Technical Details :

Research Area : Earth & Atmospheric Sciences (Earth & Atmospheric Sciences)

Project Summary :

Water is an integral part of human life. Modern civilization mainly depends on water. Although 70% of the earth's surface is covered by water, we can utilize only 1% of it. Out of the total global water, only 3% remains as freshwater in the form of rivers, lakes, and groundwater. Groundwater is the major source of fresh water for rural and urban areas. Due to Industrial development and human population growth, there is ever increasing demand for water day by day. Further, land-use changes have lowered the rate of infiltration in to the soil and the usual rejuvenating aquifers by rainfall. Water samples in the shallow and deeper aquifer of Lonar tehsil show high concentrations of hazardous elements as compared to other tehsil areas. The high content of pH in the study area and high cases of dental fluorosis and skeletal fluorosis are observed in different villages during field investigations. Mottled teeth, stiff joints, and muscular pains are also commonly reported in the villages as isolated patches. In the background of preserving groundwater as a natural asset, water utility management is the key area that managers need to focus upon. Groundwater resources are extremely limited and it is safe for conservation if it is free from pollution. Deterioration of groundwater quality due to the concentration of elements over and above permissible limits in drinking water leads to human health hazards. Buldhana district of Maharashtra is facing adverse effects due to excess intake of elemental concentration through drinking water. In order to understand the probable source of elemental concentration, it is necessary to carry out continuous monitoring of the groundwater quality of Lonar tehsil. Considering all the above aspects and as no systematic study has been made regarding elemental contamination in groundwater, it is necessary to carry out an investigation to assess the existing quality and management of groundwater for drinking and agricultural purposes for future planning and remedial measures, etc. About 60 representative samples from both the types of wells will be collected in each field season visit. For good results continuous monitoring for three years will be required. In the first year, water samples for pre-monsoon and post-monsoon seasons will be collected, same will be repeated for a second and third consecutive years. Samples will then analyze the following parameters: Ca2+, Mg2+, Na+, K+, HCO3-, CO32-, SO42-, Cl-, PO43-, NO3, Total dissolved solids (TDS), Total Hardness, Alkalinity. The field observations, studies in the laboratory, and literature survey will result in research articles, which will be published in reputed journals. Certain results will be presented in symposia/seminars. The results will be useful to geologists, environmentalists, Famers, and Society.

Objectives :

• To carry out the rate of degrading water quality and provide information about the important parameter affecting.
• Dug wells and bore wells water samples will be collected and analyzed to know the depth and nature of aquifer contributing element in drinking waters.
• To demarcate the groundwater polluted zone using GIS techniques.

Keywords :

Drinking Water, Groundwater, Pollution, Water Quality, Water Quality Index (WQI)

Expected Output and Outcome of the proposal :

After completion of this research work definitely benefits for society for use of water to drinking and irrigation purposes. Traditionally water has continuously been accomplished by the rural public and treated water as forestry or ecology subsidy. Water coming from springs and forestry areas is considered good quality by the local community hence very few efforts were made to make the public aware of water quality and issues related to poor water consumption and its treatments. Due to higher water demand, it is useful to reserve water, and the public aware of its useful to reserve water make people aware of its wide use.

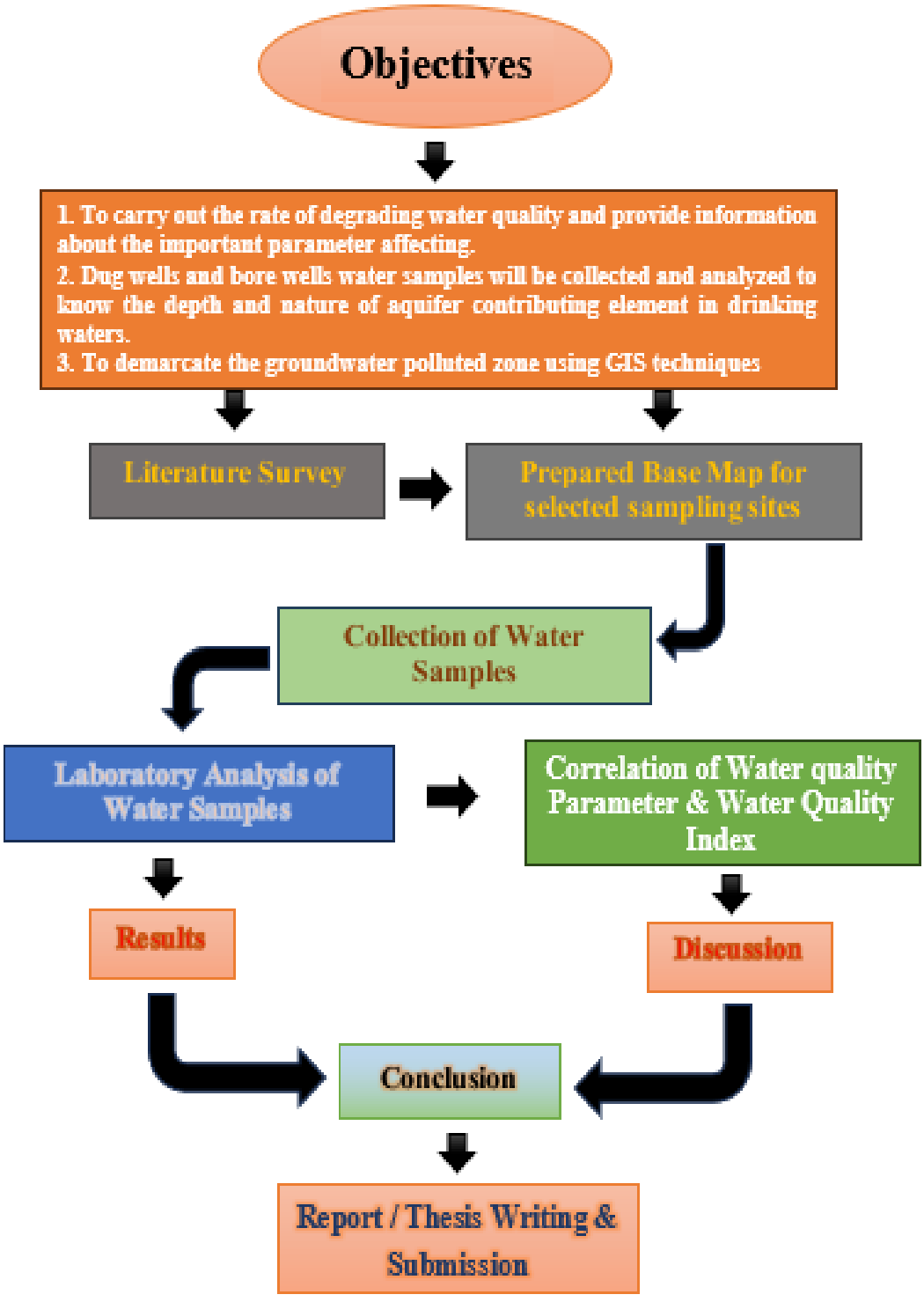
Reference Details :

S.No	Reference Details
1	**Dr M. A. Sonar** **Department of Geology,** **Government Institute of Science,** **Aurangabad, Maharashtra[+9595647374]** drmohansonar398@gmail.com
2	**Dr K. M. Wanjarwadkar** **Department of Geology,** **Government Institute of Science,** **Aurangabad, Maharashtra[+9011775262]** kmwisa2012@gmail.com

Work Plan and Methodology:

Survey of India toposheets on 1: 50 000 scales will be used for generation of base map. Secondary data on hydrogeology and well data will be collected from the Groundwater Survey and Development Agency (GSDA, Buldhana), Central Ground Water Board (CGWB, Nagpur) as well as during the field visits. Geological maps published by Geological Survey of India will be used as reference map. Socio-economic status will be collected during field visits.

Following Flowchart used for Research work



Groundwater Quality Assessments: The present study will start with the collection of water samples from the dug wells and bore wells from various depths. About 60 representative samples from both the types of wells will be collected in each field season visit. For good results continuous monitoring for three years will be required. In first year, water samples for pre-monsoon and post-monsoon season will be collected, same will be repeated for second and third consecutive year. Samples will then analyze following parameters: Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, CO_3^{2-}, SO_4^{2-}, Cl^{-}, PO_4^{3-}, NO_3, Total dissolved solids (TDS), Total Hardness, Alkalinity. Based on the groundwater quality analyses, the elemental contaminated zones/ areas will be identified and mapped.

Table: Details month wise work plan for research works

Month & Year	**Work Plan for Research Work**
First Year	
Jan-2024 To Mar-2024	Literature survey and Preparation of base map related to Research work
Apr-2024 To May-2024	Collection of Water samples Pre monsoon season
Jun-2024 To Aug-2024	Analyze collected water samples in laboratory (Pre monsoon season)
Sep-2024 To Oct-2024	Prepared results Pre monsoon season water sample based on laboratory analysis and correlate to Water quality index or BIS standard
Nov-2024 To Dec-2024	Collection of Water samples Post monsoon season
Second Year	
Jan-2025 To Mar-2025	Analyze collected water samples in laboratory (Post monsoon season)
Apr-2025 To May-2025	Prepared results Post monsoon season water sample based on laboratory analysis and correlate to Water quality index or BIS standard
June-2025 To July-2025	Prepared spatial distribution maps in GIS for Both pre & Post monsoon seasons
Aug-2025 To Sep-2025	Prepared research manuscript & send for publication in SCI/UGC Care/ Peer Reviewed Journal
Oct-2025 To Nov-2025	Report writing/Thesis writing
Dec-2025	Submission of report/thesis

BIO-DATA

1. Name and full correspondence address: **Dr. Sandip Kisan Sirsat**
Department of Applied Geology,
School of Environmental & Earth Sciences,
Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon-425001 (M.S.)

2. Email(s) and contact number(s): **sksirsat@gmail.com; Mob.: +91-9028584609**

3. Institution: **Government Institute of Science, Aurangabad**

4. Date of Birth: **13/06/1991**

5. Gender (M/F/T): **Male**

6. Category Gen/SC/ST/OBC: **OBC**

7. Whether differently abled (Yes/No): **No**

8. Academic Qualification (Undergraduate Onwards)

S. No.	Degree	Year	Subject	University/Institution	% of marks
1.	B. Sc.	2012	Physics, Geology, Computer Science	Dr. Babasaheb Ambedkar Marathwada University, Aurangabad	75.48 %
2.	M. Sc.	2014	Geology	Dr. Babasaheb Ambedkar Marathwada University, Aurangabad	73.50 %
3.	Ph. D.	2023	Geology	Dr. Babasaheb Ambedkar Marathwada University, Aurangabad	-
4.	-	-	-	-	-

9. Ph.D. thesis title: **Geomorphological & Hydrogeological Studies of Lower Painganga River Basin Area, Buldhana district, M.S., India.**
Guide's Name: **Dr. Mohan A. Sonar** (Associate Professor, Govt. Institute of Science, Aurangabad)
Institute/Organization/University: **Dr. Babasaheb Ambedkar Marathwada University, Aurangabad**
Year of Award: **2023**

10. Work experience (in chronological order).

S. No.	Positions held	Name of the Institute	From	To	Pay Scale
1.	Assistant Professor (Fix-Pay)	Deogiri College, Aurangabad	01/07/2014	31/03/2015	Rs. 10000 (Consolidated)
2.	Assistant Professor (Fix-Pay)	Deogiri College, Aurangabad	01/07/2015	31/03/2016	Rs. 10000 (Consolidated)
3.	Assistant Professor (Fix-Pay)	Deogiri College, Aurangabad	01/07/2016	31/03/2017	Rs. 12000 (Consolidated)
4	Assistant Professor (Fix-Pay)	Deogiri College, Aurangabad	01/07/2017	31/03/2018	Rs. 12000 (Consolidated)
5.	Research Scholar	Government Institute of	16/06/2018	02/05/2023	On Stipend

		Science, Aurangabad			

11. Professional Recognition/ Award/ Prize/ Certificate, Fellowship received by the applicant.

S. No	Name of Award	Awarding Agency	Year
-	-	-	-
-	-	-	-

12. Publications *(List of papers published in SCI Journals, in year wise descending order).*

S. No.	Author(s)	Title	Name of Journal	Volume	Page	Year
1.	V. B. Kadam, A. V. Tejankar, M. Venkateshwarlu, R. Maity, **S. K. Sirsat**	Magnetic Properties of Urban Topsoil from Aurangabad (India)-Implications to Industrial Pollution and Road Traffic	Water, Air & Soil Pollutions	233 (7)	Article No-258	2022

13. Detail of patents.

S. No	Patent Title	Name of Applicant(s)	Patent No.	Award Date	Agency/Country	Status
-	-	-	-	-	-	-
-	-	-	-	-	-	-

14. Books/Reports/Chapters/General articles etc.

S. No	Title	Author's Name	Publisher	Year of Publication
1.	Morphometric, Hypsometric and Hydrogeomorphic Investigation in the Region of Painganga River Basin in Buldhana District, Maharashtra, India, Using Remote Sensing & GIS Techniques	M. A. Sonar, **S. K. Sirsat**, V. B. Kadam, R. B. Golekar	Journal of Geomatics	2021
2.	Characterization of Hydrogeological Behaviour of PG-4 Watershed Through Morphometric Analysis of Painganga Basin, Buldhana, Maharashtra	**S. K. Sirsat**, M. A. Sonar, V. B. Kadam	Journal of Indian Water Works Association	2022
3.	Appraisal of Groundwater Quality in parts of Ranjangaon Shenpunji Area of Aurangabad District, Maharashtra	S.M. Deshpande, S.N. Kamble, R.K. Aher, **S.K. Sirsat,** G.D. Gaikwad, K.R. Aher	Bulletin of Pure & Applied Sciences-Geology,	2022
4.	A Case Study on Geoelectrical Resistivity Survey for Groundwater Potential of Nanded Urban & Its Surrounding Area, Maharashtra, India	S.M. Deshpande, K. M. Wanjarwadkar, **S.K. Sirsat,** R.K. Aher, S.N. Kamble P. V. Kathane, K.R. Aher	International Journal of Current Medical & Applied Sciences	2022
5.	The Study of Heavy Metal Contamination in Industrial Soils of Aurangabad	V. B. Kadam, A. V. Tejankar, **S. K. Sirsat,**	Journal of Geomatics	2023
6.	Study of the aquifer vulnerability by longitudinal unit conductance, GOD and GLSI Models in the Painganga river basin, Buldhana (Maharashtra, India)	**S. K. Sirsat,** M. A. Sonar, K. M. Wanjarwadkar, V. B. Kadam	Journal of Indian Geophysical Union	2023
7.	To select the suitable locations for water conservation structures in PG-4 watershed of Painganga river basin	**S. K. Sirsat**, M. A. Sonar, V. B. Kadam	Promoting Sustainability Through Water Management and	2023 Accepted for Publication

	of the Buldhana district, Maharashtra, India.		Climate Change Adaptation, (Advances in Geographical and Environmental Sciences Book Series)	

15. Any other Information (maximum 500 words): During my Ph D research work I has completed research work in parts of Painganga river basin area with geomorphological and Hydrogeological aspects. In this research work I has not carried out groundwater contamination assessment in this research work. The drinking water of this area is contaminated and people are facing problems in many diseases. So, it is need for water quality assessment in Painganga River Basin area and find out the source's contamination of groundwater. When we will complete this study definitely this research work is very beneficial for people.

महाराष्ट्र राज्य माध्यमिक व उच्च माध्यमिक शिक्षण मंडळ, पुणे
Maharashtra State Board Of
Secondary and Higher Secondary Education, Pune

माध्यमिक शालान्त प्रमाणपत्र
SECONDARY SCHOOL CERTIFICATE

असे प्रमाणित करण्यात येते की / This is to certify that

Sirsat Sandip Kisan

आईचे नांव / Mother's Name *Kamal*

विभागीय मंडळ Divisional Board	आसन क्रमांक Seat No.	केन्द्र क्रमांक Centre No.	शाळा क्रमांक School No.	प्रमाणपत्राचा अनुक्रमांक Sr. No. of Certificate
AMRAVATI	H107007	1594	04.06.025	062394

माध्यमिक शालान्त प्रमाणपत्र परीक्षा
has passed the SECONDARY SCHOOL CERTIFICATE EXAMINATION MARCH-2007

श्रेणीमध्ये खाली दर्शविलेले विषय घेऊन उत्तीर्ण झाला/झाली आहे.
in Grade DISTINCTION with subjects shown below.

मुख्य विषय Main Subjects	कमाल गुण Max. Marks	प्राप्त गुण Marks Obtained	श्रेणीचे विषय Subjects of Grade	श्रेणी Grade
MARATHI	100	064	[WORK EXP./TECH.]	
HINDI	100	074	USE MANURES & FERT	A
ENGLISH	100	066	[SCHOOL SUBJECTS]	
MATHEMATICS	150	118	HEALTH PHYSICAL ED	A
			SOCIAL SERVICE	A
SCIENCES	100	088	VALUE EDUCATION	A
			GENERAL KNOWLEDGE	A
SOCIAL SCIENCES	100	085	ENVIRONMENTAL EDUCATION	A
एकूण गुण/ Total Marks	650	495	PERCENTAGE 76.15	
एकूण प्राप्त गुण (अक्षरी)/ Total Marks Obtained (In words)	FOUR HUNDRED AND NINETY FIVE			
जन्म दिनांक / Date of Birth	13/06/1991 THIRTEENTH JUNE NINETEEN NINETY ONE			

G1900144

57006259408

AMRAVATI
26TH JUNE 2007

विभागीय सचिव / Divisional Secretary

12851907092006452930

FORM - 9

[Rule No. 5 (6)]

Form of Caste Certificate for Other Backward Classes person applying for Appointment to post under the Government of India or for the purpose of education under the Government of India.

Documents Verified

1. Rashan Card Second Side
2. Income Certificate for the last 3 years issued by the Tahsildar
3. Photo ID of Applicant
4. Photo of Applicant
5. Copy of Ration Card
6. School Leaving Certificate
7. Photo ID of Beneficiary
8. Copy of Kotwal Book
9. Self Declaration
10. Resident of Beneficiry

CASTE CERTIFICATE

Outward No : 39822121189
Rev Case No :

Application Date : 09/07/2019
MRC : 39822121189

This is to certify that **Mr. Sandip Kisan Sirsat** Son of **Mr. Kisan Limbaji Sirsat** of Village **Pardi Pr.Mehkar,** Tehsil **Lonar,** in District **Buldana** in the State of Maharashtra belongs to the **Kunbi** Caste/Community at Sr No. **70** which is recognized as a backward class under the

i) Government of India Resolution No.12011/68/93-BCC (C), dated the 10th September 1993 published in the Gazette of India, Extraordinary, Part-I, Section-I, No.186, dated the 13th September 1993.

ii) Government of India, Ministry of Welfare, Resolution No.12011/9/94-BCC, dated 19th October 1994 published in Gazette of India, Extraordinary, Part-I, Section-I, No.163 dated 20th October 1994.

iii) Resolution No.12011/7/95-BCC, dated the 24 th May 1995 in the Gazette of India, Extraordinary, Part-I, Section-I, No.88, dated 25 th May 1995.

iv) Government of India, Ministry of Welfare Resolution No.12011/96/94-BCC dated 9th March,1996 published in the Gazette of India Extraordinary Part-1, Section-1, No.60 dated 11th March,1996

v) Government of India, Ministry of Welfare Resolution No.12011/44/96-BCC dated 6th December,1996 published in the Gazette of India Extraordinary Part-1, Section-1, No.210 dated 11th December,1996

vi) Government of India, Ministry of Welfare Resolution No.12011/99/94-BCC dated 11th December,1997 published in the Gazette of India Extraordinary Part-1, Section-1, No.236 dated 12th December,1997

vii) Government of India, Ministry of Welfare Resolution No.12011/13/97-BCC dated 3rd December,1997 published in the Gazette of India Extraordinary Part-1, Section-1, No.239 dated 17th December,1997

viii) Government of India, Ministry of Social Justice and Empowerment Resolution No.12011/68/98-BCC dated the 27th October, 1999 published in the Gazette of India Extraordinary Part-1, Section-1, No.241 dated the 27th October, 1999.

ix) Government of India, Ministry of Social Justice and Empowerment Resolution No.12011/88/98-BCC dated 6th December, 1999 published in the Gazette of India Extraordinary Part-1, Section-1, No.270 dated the 6th December, 1999.

x) Government of India, Ministry of Social Justice and Empowerment Resolution No.12011/36/99-BCC dated 4th April, 2000 published in the Gazette of India Extraordinary Part-1, Section-1, No.71 dated 4th April, 2000.

xi) Government of India, Ministry of Social Justice and Empowerment Resolution No.12011/44/99-BCC dated 21th September, 2000 published in the Gazette of India Extraordinary Part-1, Section-1, No.210 dated 21th September, 2000.

xii) Government of India, Ministry of Social Justice and Empowerment Resolution No.12015/9/2000-BCC dated 6th September, 2000 published in the Gazette of India Extraordinary Part-1, Section-1, No.246 dated 6th September, 2000.

xiii) Government of India, Ministry of Social Justice and Empowerment Resolution No.12011/1/2001-BCC dated 19th June, 2003 published in the Gazette of India Extraordinary Part-1, Section-1, No.151 dated 20th June,2003.

xiv) Government of India, Ministry of Social Justice and Empowerment Resolution No.12011/4/2002-BCC dated 13th January, 2004 published in the Gazette of India Extraordinary Part-1, Section-1, No.9 dated 13th January, 2004.

xv) Government of India, Ministry of Social Justice and Empowerment Resolution No.12011/14/2004-BCC dated 12th March, 2007 published in the Gazette of India Extraordinary Part-1, Section-1, No.67 dated 12th March,2007.

xvi) Government of India, Ministry of Social Justice and Empowerment Resolution No.12015/2/2007-BCC dated 18th August, 2010 published in the Gazette of India Extraordinary Part-1, Section-1, No.67 dated 18th August, 2010.

xvii) Government of India, Ministry of Social Justice and Empowerment Resolution No.12015/2/2007-BCC dated 11th October, 2010 published in the Gazette of India Extraordinary Part-1, Section-1, No.274 dated 12th October, 2010

xviii) Government of India, Ministry of Social Justice and Empowerment Resolution No.12015/15/2008-BCC dated 16th June,2011 published in the Gazette of India Extraordinary Part-1, Section-1, No.123 dated 16th June, 2011.

xix) Government of India, Ministry of Social Justice and Empowerment Resolution No.12015/13/2010-BC-II dated 8th December, 2011 published in the Gazette of India Extraordinary Part-1, Section-1, No.257 dated 8th December, 2011.

xx) Government of India, Ministry of Social Justice and Empowerment Resolution No.12015/05/2010-BC-II dated 17th February, 2014 published in the Gazette of India Extraordinary Part-1, Section-1, No.41 dated 17th February,2014.

xx) Government of India, Ministry of Social Justice and Empowerment Resolution No.20012/129/2009-BC-II dated 4th March, 2014 published in the Gazette of India Extraordinary Part-1, Section-1, No.63 dated 4th March,2014.

Mr. Sandip Kisan Sirsat and/ or his family ordinarily reside(s) in Village **Pardi Pr.Mehkar,** Tehsil **Lonar,** in District **Buldana** of the Maharashtra State.

This is also to certify that he does not belong to the persons/sections* (Creamy Layer) mentioned in column 3 of the Schedule to the Government of India, Department of Personnel & Training O.M. No. 36012/22/93-Estt (SCT) dated 8-9-1993 O.M. 36033/3/2004-Estt.(Res.) dated 9th March, 2004 and O.M.No.36033/3/2004-Estt.(Res.) dated 14th October, 2008 and O.M. No. 36033/1/2013-Estt.(Res.) dated 27th May, 2013.

Signature valid
Digitally Signed by
Jayant Madhukar Deshpande
Date: 2019 12:51:34 PM

Place : **Mehkar**
Date : **25/07/2019**

(With the seal of Office)

al Officer
Mehkar

Printed By -**OMTID** : **VLE Name** :Santosh Ashru Nandewar, **Date**:25/07/2019 11:17AM

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CURRICULAM VITAE

A	Full name	**Dr. SANJAY NARAYAN PATIL**
B	Date of Birth	01/06/1966
C	Name of the Organization	Kvayitri Bahinabai Chuadhari North Maharashtra University, Jalgaon, Maharashtra, India
	Present Post	Head, Department of Applied Geology
	Designation	Professor
	Faculty	Science
	Subject	Geology
	Date of Appointment	10/09/1990 (Since 20/09/2007 in KBCNMU, Jalgaon)
D	Address for communication	Department of Applied Geology, School of Environmental and Earth Sciences, Kavayitri Bahinabai Chaudhari North Maharashtra University, P. O. Box No. 80, Umavi Nagar, Jalgaon - 425001 (M.S.) India
	Residence	24, Deoram Nagar, Gat No. 81/B1, Nimkhedi Shiwar, Old Mumbai Dhule Highway, Jalgaon, Maharashtra-425001, India
E	E-mail ID	snpatil@nmu.ac.in drsnpatil9@gmail.com
F	Office Telephone number	0257- 2257429
	Mobile	9423937400
G	The Indian languages that are able to speak fluently and read	Hindi, Marathi, English

Educational Qualifications

Examination / Degree	Board / University	Institute	Subjects / Specialization	Year of Passing	Division / CGPA	Marks in %
Secondary	Pune Board	Jai Hind School, Dhule	-	1982	First	66.43
Higher Secondary	Pune Board	Jai Hind Junior College, Dhule	-	1985	Second	50.83
Graduation	Pune University, Pune	Z. B. Patil Senior College, Dhule	Geology	1988	First class with distinction	70.16
Post Graduation	Pune University, Pune	Pune University, Pune	Geology	1990	First	62.25
Ph.D.	North Maharashtra University, Jalgaon	-	Geology	Awarded Oct. 2006	-	-
MS-CIT	Maharashtra State Board of Technical Education, Mumbai	-	-	2005	Distinction	80

Professional Experience

University / Institution*	Post	From	To	Total (in years and months)
JTM College of Engineering, Faizpur Dist. Jalgaon	Lecturer	10/09/1990	30/11/2002	12 Years and 03 months
JTM College of Engineering, Faizpur Dist. Jalgaon	Selection grade lecturer	01/12/2002	19/09/2007	04 Years and 09 months
School of Environmental &	Reader in Geology	20/09/2007	19/09/2010	03 Years

Earth Sciences, NMU, Jalgaon				
School of Environmental & Earth Sciences, NMU, Jalgaon	Associate professor in Geology	20/09/2010	19/9/2013	03 Years
School of Environmental & Earth Sciences, KBCNMU, Jalgaon	HOD (Applied Geography)	17/08/2011	23/06/2015	04 years and 01 month
		29/07/2019	30/10/2019	
School of Environmental & Earth Sciences, KBCNMU, Jalgaon	HOD (Applied Geology)	17/08/2011	Till date	09 years and 10 months
School of Environmental & Earth Sciences, KBCNMU, Jalgaon	Professor in Geology	20/09/2013	Till date	07 years and 09 months
Total Experience: 30 Years and 09 months				

Details Of Administrative Experience In The Of Higher Education Not Below The Rank Of Professor And Head Of The Department In A University / Principal (In Professor's Grade) Of A Senior College / Head Of National / International Institutions Of Advanced Learning

Sr. No.	Post	Period From – to – (dates and duration)	Name of the University / Colleges / Institution & Location
1	Professor	20/09/2013 to till date	Department of Applied Geology, School of Environmental and Earth Sciences, Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon-425001

2	Head of the Department in a University (Applied Geology)	17/08/2011 to till date		Department of Applied Geology, School of Environmental and Earth Sciences, Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon-425001
3	Head of the Department in a University (Applied Geography)	17/08/2011	23/06/2015	Department of Applied Geography, School of Environmental and Earth Sciences, Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon-425001
		29/07/2019	30/10/2019	

Awards, Recognitions and honors

- Received **Best Teacher Award** on the eve of Foundation Day by Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon in 2016 as a token of appreciation for contribution in teaching and research field.
- Nominated as a **Fellow** of Geological Society of India (GSI) in year 2016 for contribution in field of Geology & Earth Sciences.
- Served as an **Expert Member** of Jalgaon District Sheep Grazing Committee constituted by Forest Department of Maharashtra State Government during the year 2017-2018
- Served as an **Expert Member** of Balbharti Geoscience Textbook Committee constituted by Department of Higher Education of Maharashtra State Government during the year 2018-2019
- Nominated & serving as a **Member of Academic Council** of Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon since year 2018
- Nominated & serving as a **Chairman of Ad-hoc Board of Geosciences** constituted by Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon since year 2018
- Served as an **Expert Member** in State Expert Appraisal Committee (SEAC-1) constituted by Ministry of Environment & Forest, Government of India for Environment Department, Govt. of Maharashtra State from March 2017 to March 2021
- In year 2021, Elected as a **Member** of The National Academy of Sciences India (NASI), which is recognized as the professional body of the DST and ISRO of the DSIR, Ministry of Science & Technology, Govt. of India

Research Publications

Total no. of research articles published in reputed National/International journals: 81

No	Authors	Title of the paper	Journal name, page Nos. with ISBN/ISSN No	Peer-Reviewed or UGC listed Journals	Impact Factor, if any (to be determined as per Thomson Reuters list)	Year	DOI
1	**S.N. Patil,** N.R.Kachate, S.T. Ingle,	Estimation of Dar-Zarrouk parameters for groundwater exploration in parts of Chopda Taluka, Jalgaon district, Maharashtra (India)	Journal of Indian Geophysical Union, ISSN:0971-9709; (July 2018),v.22, no.4, pp: 425-435	**UGC CARE &Web of Science listed Journal**	--	2018	https://www.academia.edu/38195065/IGU_NRK_pdf

2	S.T.Ingle, **S.N.Patil,** P.M.Kolhe, N.P.Marathe, N.R.kachate,	Evaluation of agricultural soil quality in Khandesh region of Maharashtra, India	Nature Environment and Pollution Technology, An International Quarterly Scientific Journal; ISSN: 0972-6268; Vol.17, Issue.4, pp.1147-1160, 2018	**UGC CARE & Scopus listed Journal**	0.16	2018	http://www.neptjournal.com/upload-images/NL-66-13-(11)B-3506.pdf
3	ST Ingle, **SN Patil,** NK Mahale, YJ Mahajan,	Analyzing rainfall seasonality and trends in the North Maharashtra region,	Environmental earth sciences, **Springer Berlin Heidelberg** ISSN : 1866-6299; Vol. 77 (18), 651;2018,	**UGC CARE & Scopus listed Journal**	1.871	2018	https://doi.org/10.1007/s12665-018-7837-0
4	Kadam, Ajaykumar, Vasant Wagh, James Jacobs, **Sanjay Patil,** Namdev Pawar, Bhavana Umrikar, Rabindranath Sankhua, and Suyash Kumar	A comprehensive assessment of groundwater for seasonal variation in hydro-geochemistry, quality, contamination and human health risk from Deccan Basaltic region, Western India	Environmental sciences and Pollution research, **Springer Berlin Heidelberg**; ISSN: 0944-1344	**UGC CARE & Scopus listed Journal**	2.180	2021	DOI: https://doi.org/10.21203/rs.3.rs-177448/v1
5	K.S. Kumbhar, M.V. Baride, **S.N. Patil** & R.B. Golekar	Characterization of Aquifer parameters through pump test in selected Watersheds of Kolhapur District, Maharashtra	Journal of Geosciences Research, ISSN: 2455-1953; Vol.4, No.1, (2019), pp: 57-60	**UGC CARE &Web of Science listed Journal**	--	2019	https://www.researchgate.net/publication/347949574_Characterisation_of_Aquifer_Parameters_through_Pump

							_Test_in_Selected_Watersheds_of_Kolhapur_District_Maharashtra
6	D.V. Patil and B.D. Patil **S.N. Patil,** S.T. Ingle, D.R. Yeole	Correlation between Magnetic Susceptibility and Heavy Metal contamination in Agricultural Soil of Jalgaon Peri Urban Area, Maharashtra, India	Journal of Geosciences Research, ISSN: 2455-1953; Vol.5, No.2, (2020), pp: 177-122	**UGC CARE & Web of Science listed journal**	--	2020	https://www.gondwanags.org.in/wp-content/uploads/2021/11/4-Abstracts-Vol-5-2-Patil-et-al.pdf
7	Ajaykumar Kadam, Vasant Wagh, **Sanjay Patil,** Bhavana Umrikar, Rabindranath Sankhua	Seasonal assessment of groundwater contamination, health risk and chemo metric investigation for a hard rock terrain of western India,	Environmental sciences and Pollution research, **Springer Berlin Heidelberg** (2021), Vol 80, Issue 05, pp. 1-22,	**UGC CARE & Scopus listed Journal**	2.180	2021	https://link.springer.com/article/10.1007/s12665-021-09414-y
8	Milind Mujumdar, Mangesh Goswami, Ross Morrison, Jonathan Gevans, Naresh Ganeshi, S. S.Sabade, R. Krishnan, **S. N. Patil,**	A study of field-scale soil moisture variability using the COsmic-ray Soil Moisture Observing System (COSMOS) at IITM Pune site	Journal of Hydrology, **Elsevier,** ISSN: 0022-1694; Vol. 597; Year (2021)	**UGC CARE & Scopus listed Journal**	6.4	2021	https://doi.org/10.1016/j.jhydrol.2021.126102

9	Ajaykumar Kadam, Vasant Wagh, **Sanjay Patil,** Bhavana Umrikar, Rabindranath Sankhua, James Jacobs	Seasonal variation in groundwater quality and beneficial use for drinking, irrigation, and industrial purposes from Deccan Basaltic Region, Western India	Environmental Science and Pollution Research, **Springer Berlin Heidelberg;** ISSN: 0944-1344; 28 (20), pp. 26082–26104 (2021)	**UGC CARE & Scopus listed Journal**	5.4	2021	https://link.springer.com/article/10.1007/s11356-020-12115-x
10	Ajaykumar Kadam, Vasant Wagh, James Jacobs**,** **Sanjay Patil,** Namdev Pawar, Bhavana Umrikar, Rabindranath Sankhua, Suyash Kumar	Integrated approach for the evaluation of groundwater quality through hydro geochemistry and human health risk from Shivganga river basin, Pune, Maharashtra, India	Environmental Science and Pollution Research, **Springer Berlin Heidelberg;** ISSN: 0944-1344; 29, 4311–4333 (2022)	**UGC CARE & Scopus listed Journal**	5.4	2022	https://doi.org/10.1007/s11356-021-15554-2
11	Patil Nilesh, Patil Vilas; **Patil Sanjaykumar**, Patil Bhavesh, Suryawanshi Arvind and Jadhav Kavita	Analysis of Urban Growth and Its Impact on Agriculture Land around the Chalisgaon City in Jalgaon District of Maharashtra, India: A Remote Sensing and GIS Based Approach	Journal of Geomatics; ISSN:0976–1330; Vol. 16, No. 2, October 2022; pp.213-222	**UGC CARE &Web of Science listed & Peer-Reviewed**	--	2022	https://doi.org/10.58825/jog.2022.16.2.51

12	Uday Sahu, Vasant Wagh, Shrikant Mukate, Ajaykumar Kadam, **Sanjay Patil**	Applications of geospatial analysis and analytical hierarchy process to identify the groundwater recharge potential zones and suitable recharge structuresin the Ajani-Jhiri watershed of north Maharashtra, India	Groundwater for Sustainable Development, **Elsevier;** ISSN: 2352-801X; Vol.17; May 2022; (100733)	**UGC CARE & Scopus listed Journal**	6.27	2022	https://doi.org/10.1016/j.gsd.2022.100733
13	Ajaykumar Krushna Kadam, **SN Patil**, SK Gaikwad, VM Wagh, Bhavesh D Patil, Nilesh S Patil	Demarcation of subsurface water storage potential zone and identification of artificial recharge site in Vel River watershed of western India: integrated geospatial and hydrogeological modeling approach	Modeling Earth Systems and Environment- **Springer International Publishing**; ISSN: 2363-6203; 2023; pp. 1-16	**UGC CARE & Scopus listed Journal**	3.2	2023	DOI: https://doi.org/10.1007/s40808-022-01656-4
14	Golekar R.B., **Patil S.N.,** Joshi Mrunali , Vaidya Aakanksha, Kamble Pooja and Rohini Ranjit Ambure,	Chemico-mineralogical and petrographical study of natural zeolites and apophyllite in basalts from deccan trap, northern maharashtra (india),	Bulletin of Pure & Applied Sciences-Geology, ISSN: 0970-4639; Volume-37f, Issue-1, Pages 01-17	Peer-Reviewed	5.195	2018	http://dx.doi.org/10.5958/2320-3234.2018.00001.X
15	**S.N.Patil,** N.P.Marathe, S.T.Ingle	Geochemical Investigation for Groundwater	International Journal of Current Engineering and Scientific	Peer-Reviewed	6.263	2018	http://www.neptjournal.com/upload-images/N

		Quality and its Suitability for Drinking and Agricultural use of Shirpur Taluka in Dhule District, Maharashtra State, India,	Research; ISSN: 2393-8374, Volume.5, Issue-4, pp. 1147-1160; 2018				L-66-13-(11)B-3506.pdf
16	Y.J.Mahajan, B.D. Patil, **S. N. Patil,**	A Geographical Analysis of Organic Fertilizers Application in Shirpur Tehsil of Maharashtra (MS), India,	International Journal of Engineering, Science and Mathematics, ISSN: 2320-0294; Vol. 7 Issue 5, pp.33-43; May 2018	Peer-Reviewed	6.765	2018	http://ijesm.co.in/uploads/68/5472_pdf.pdf
17	HrushikeshMendole, Prashant Jolhe, **Sanjaykumar Patil,** Nilesh Wagh, Sopan Ingle, Girish Pangavhane,	Molasses based Spentwash Decolorization by Coagulation by Coagulation & Flocculation,	International Research Journal of Engineering and Technology; ISSN: 2395-0072; 6 (5), pp.721-730; 2019	Peer-Reviewed	7.211	2019	https://www.irjet.net/archives/V6/i5/IRJET-V6I5148.pdf
18	Pratik M. Kolhe, **Sanjay N. Patil,** Seema P. Bhole, Nilesh D. Wagh	Multi-way Degradation and process optimization of Phenol from Simulated Wastewater System	Journal of Geography, Environment and Science International; ISSN: 2454-7352; (2019) Vol No.23 Issue No. 02, PP. 1-10	Peer-Reviewed	--	2019	10.9734/jgeesi/2019/v23i230167
19	Yogesh Mahajan, Bharat Patil., **Patil S.N.,**	Change Detection of Land-use and Land-cover of Shirpur Tehsil: A Spatio-Temporal Analysis,	American International Journal of Research in Science, Technology, Engineering & Mathematics, ISSN: 2328-	Peer-Reviewed	5.01	2020	https://www.researchgate.net/publication/334317776_Change_Detection_of_Land-

			3491, Vol. 26(01), pp.28-32				use_and_Land-cover_of_Shirpur_Tehsil_A_Spatio-Temporal_Analysis
20	K Suvarna, MS Pendke, **SN Patil,** BDPatil	An Integrated Remote Sensing & GIS Techniques Based Approach to Study Spatial Distribution of Parameters Controlling Groundwater Contamination in Parbhani Tehsil of Maharashtra State, India	Bulletin of Pure and Applied Sciences ISSN:0970-4639; July-Dec 2022, Vol.41F, No. 02, pp. 212-227	Peer-Reviewed	5.195	2022	http://dx.doi.org/10.5958/2320-3234.2022.00018.X
21	**S.N. Patil,** B.D. Patil, Dipak Chavhan, S.B.Bhavsar, NK Kachate	Applications Of Vertical Electrical Sounding Techniques For Groundwater Investigation In Gul River Watershed Of Chopda Taluka Of Jalgaon District, Maharashtra	Bulletin of Pure and Applied Sciences; ISSN: 0970-4639; Jan-June 2022, Vol.41F, No. 01, pp. 156-163	Peer-Reviewed	5.195	2022	http://dx.doi.org/10.5958/2320-3234.2022.00014.2

Total no. of Book Chapters published by National/International publication houses: 04

Sr. No.	Title of the book / book chapters	Name of the publisher	Type
1	**Hydrogeological Sciences** Chapter 22 (pp271-294): Advances in Geosciences	World scientific Publishing Company, Year: 2010 ISBN/ISSN No.10981-4355-32-1	Reference Book
2	**Hydrogeological Sciences** Chapter 24(305-322): Advances in Geosciences	World scientific Publishing Company, Year: 2010 ISBN/ISSN No.10981-4355-32-1	Reference Book

3	**VICHAKSHAN Masik** Chapter 02 (pp02-04): Earthquake Management	Vichakshan publication company, shirpur, Year: 2015 ISBN/ISSN No.:2394-8027	Reference Magazine
4	**Geo-information Technology in Earth Resources Monitoring and Management**; Chapter 20 (pp. 369-382): Geospatial Distribution of Dar Zarrouk Parameter Resulting fromvertical electrical sounding in Dharangaon and Erandol Block ofJalgaon District, India	NOVA Science Publishers, New York, Year: 2021, ISBN:978-1-536-19-669-6	ReferenceBook

Details Of Major Research Projects Executed

Sr. No.	Title of the project	Project Value (Rs. In lakh)	Granting agency	Date of start	Date of Completion
1	Impact of climate change on river basin and water resources management in Khandesh Region of Maharashtra **(Dy. Coordinator)**	49.00 Lakh	DST-FIST	10/09/2009	20/03/2012
2	SAP Project on Monitoring, Mapping and Risk assessment of Air and Noise pollution in North Maharashtra region. **(Dy. Coordinator)**	37 Lakhs	UGC, Delhi	01/04/2009	31/03/2012
3	Geomedical Health Hazards due to Quality of water, Soil and Agricultural Practices A Case Study **(Co-PI)**	15.98 Lakhs	DST, Delhi	10/09/2010	10/11/2013
4	Applications of Geochemical and GIS techniques in Impact Assessment of Municipal Waste on soil and water Quality of Jalgaon area. **(Principal Investigator)**	10.41Lakhs	UGC, Delhi	01/04/2012	31/03/2015

5	SAP Project on Effect of Micro climatic Variation on Water Availability and Agricultural Pattern region. **(Dy. Coordinator)**	72.50 Lakhs	UGC, Delhi	31/03/2015	31/03/2020
6	Water quality and Geomedical health hazard management in tribal pockets of Nandurbar district, Maharashtra, India **(Principal Investigator)**	8.32 Lakhs	National Academic of Science India (NASI), Prayagraj	25/09/2018	Ongoing

List of Consultancy Project completed till date

Sr. No.	Consultancy area	Consultancy Provided to	Period	Amount Received
1	Environmental and Social impact assessment of Akkalpada Dam.	Irrigation Department, Govt. of Maharashtra	2010-2011	1.5 Lakhs
2	Social Impact Assessment of Lower Tapi Irrigation Project.	Irrigation Department, Govt. of Maharashtra	2012-2013	17.45 Lakhs
3	Environmental Impact Assessment of Mangrul Medium Water Reservoir Project.	Irrigation Department, Govt. of Maharashtra	2014	8.0 Lakhs
4	Environmental Audit of Garware Polyester Ltd.	Garware Polyester Ltd., Waluj, Aurangabad	2016	1.0 Lakhs
5	Green Environmental Audit	Ajanta pharma Ltd, Aurangabad	2019	2.0 Lakhs
6	Geophysical Prospecting for Ground water	Exe. Engineer, Lift Irrigation, Jalgaon	2018	Rs. 4000/-
7	Geophysical Prospecting for Ground water	RTO, Jalgaon	2018	Rs. 1500/-
8	Green Environmental Audit	J.T. Mahajan Collage of Engineering, Faizpur Tal Raver, Dist. Jalgaon	2018	Rs. 12,300/-

9	Geophysical, Geotechnical surveys, Industries Pollution monitoring	Local Industries, organization and individuals	Till date	3.0 Lakhs

Experience To Guide Ph.D. Students

Sr. No.	Student	Thesis title	Period of Guideship	Ph.D. awarded in /Status
1	Padmane S.T.	Hydrogeological Studies on Suki River Project, Jalgaon District M.S.	DOR: 13/05/2008 Awarded on 20/01/2014	Geology
2	Patil Ujawal	An Integrated Approach for Prediction and Assessment of Sulwade Irrigation Project, Dhule.	DOR: 22/01/2009 Awarded on 02/04/2016	Environmental Sciences
3	Yeole Deepali Ramkrishna	Environmental Impact assessment studies of municipal waste on soil and water regime of jalgaon area,Maharashtra State,India	DOR: 22/02/2011 Awarded on 11 /05/2016	Environmental Sciences
4	Munmun Kundu	Assessment of Hydrogeochemistry of Groundwater Resources of Muktainagar Taluk,District Jalgaon,Maharashtra,India	DOR: 22/02/2011 Awarded on 15/09/2017	Environmental Sciences
5	Deshpande Anil Vasant	Impact of Sugar Factory on soil and Ground Water Quality of Kopargaon area of Ahmadnagar Distruct M.S.India	DOR: 04/08/2011 Awarded on 29/01/2018	Geology
6	Mahajan Yogesh Jagannath	An integrated Approach for Sustainable development in Agricultural practices of Shirpur Tehsil, Dhule, Maharashtra	DOR: 31/08/2015 Awarded on 22/5/2019	Geography
7	Kolhe Pratik Mohan	Bio-chemical degradation of toxic aromatic compounds from wastewater	DOR: 06/05/2013 Awarded on 24/08/2019	Environmental Sciences
8	Kachate Nandkishor Raju	An Integrated Approach for Aquifer Mapping Studies of Tapi East Watershed in Chopda area of Jalgaon District, Maharashtra (India)	DOR: 06/05/2013 Awarded on 31/01/2020	Geology
9	Marathe Nilesh Prakash	Geophysical and Geochemical Investigations	DOR: 20/01/2012	Geology

		for Groudwater in Shirpur taluka of Dhule District,Maharashtra State	Synopsis submitted	
10	Bartakke Vikram Vijaykumar	Seasonal and Temporal Variations in Geochemistry of Krishna-Koyna Rivers, Maharashtra, India	DOR: 25/05/2018 Total 03 Progress report submitted	Geology
11	Pimparkar Abhay Madhukar	Date of Provisional registration 20/11/2020		Environmental Sciences
12	Goswami Mangesh Mohanrao	Date of Provisional registration 20/11/2020		Environmental Sciences
13	Patil Nilesh Suresh	Date of Provisional registration 20/11/2020		Geography
14	Bhavsar Sumit Bhalchandra	Date of Provisional registration 20/11/2020		Geology
15	Patil Bhavesh Dinu	Date of Provisional registration 20/11/2020		Geology

International Exposure Through Participation In Workshops, Seminars Or Conferences Held Outside The Country

Sr. No.	Title of Workshop / Seminar / Conference	Month & Year	Place
1	Oceania Geosciences Society (AOGS), 6 th Annual General Meeting & Geosciences, World Community Exhibition	August 2009	Suntech, Singapore

List Of Online Training, E-Conferences, Webinars, E-Courses & Online Refresher Courses Attended In The Field Of Higher Education

Sr. No.	Title of webinar, online workshops, e-events, lectures	Organized by	Month & Year
01	E- Training on course on alteration zone mapping for mineral exploration with case studies from betul belt and others	Geological Survey of India Training Institute (GSITI), Hyderabad	10/05/2021 to 15/05/2021
02	Geology of North Eastern India	Geological society of India & NEHU, Shillong	29/04/2021

03	National Webinar on Significance and Exploration ofCritical Metals and REEs	Department of Geology M.S.University, Udaipur	12/03/2021
04	Webinar on Innovation And IPR: For Biotech Start-Ups and Business Incubators	Dr. B. Lal Instituteof Biotechnology, Jaipur	28/01/2021
05	National level webinar on Challenges in Utilization of Groundwater and Surface water resources in India	Department of Geology M.S.University, Udaipur	28/10/2020
06	National level virtual workshop on Applications of Drone surveys and GIS techniques in Mining sector	Mining Engineers Association of India	18/10/2020
07	Online Industry Academia Conclave-2020	KBC North Maharashtra University, Jalgaon	30/09/2020
08	National level Webinar on Geo-medical Health Hazards and Environmental Problems in Tribal Areas: Issues, Challengesand Opportunities	Department of Applied Geology, KBC North Maharashtra University, Jalgaon	17/09/2020
09	Virtual Seminar on Earthresources management incurrent scenario	S.G.V. University,Jaipur	05/09/2020
10	Webinar on Sustain-o-Preneurship: A key to self-reliance mission of India	Dr. B. Lal Instituteof Biotechnology, Jaipur	05/06/2020
11	National level E- Entrepreneurship Conclave	KBC North Maharashtra University, Jalgaon	30/05/2020
12	National level webinar on Employment Opportunities inIT Sector after Lockdown Period	L.R.T. College,Akola, Maharashtra	20/05/2020
13	National level webinar on Entrepreneurship - Dream To Reality - The Journey and case studies	Sandip Institute of Engineering & Management, Nashik	19/05/2020
14	Two days National level workshop on Industrial Safety:An overview	Department of Environment Sciences, ShivajiUniversity, Kolhapur	12/05/2020
15	National level workshop on Introduction to Galaxy and Satellite System	Indian Institute of Remote Sensing (IIRS)	10/01/2020

16	National level workshop on RS of the Moon byIndian lunar mission with Emphasis on spectroscopic analysis	Indian Institute of Remote Sensing (IIRS)	23/12/2019
17	E- Training on Applications of Remote Sensing in Geosciences	Geological Survey of India Training Institute (GSITI), Hyderabad	26/11/2020 to 28/11/2020
18	E- Training on Refresher course on landslide studies	Geological Survey of India Training Institute (GSITI), Hyderabad	09/11/2020 to 13/11/2020
19	E- Training on Refresher course on Integrated Thematic Mapping	Geological Survey of India Training Institute (GSITI), Hyderabad	20/10/2020 to 26/10/2020
20	E- Training on fundamentals of mineral exploration for industrial and fertilizer minerals	Geological Survey of India Training Institute (GSITI), Hyderabad	15/10/2020 to 17/10/2020
21	E- Training on fundamentals of exploration for gold	Geological Survey of India Training Institute (GSITI), Hyderabad	12/10/2020 to 14/10/2020
22	E- Training on course on Magneto Telluric Survey and Interpretation	Geological Survey of India Training Institute (GSITI), Hyderabad	23/09/2020 to 30/09/2020
23	One week E- course on Environmental Science	Department of Geology, Khare-Dhere-Bhosale College, Guhagar, Tal - Guhagar, Dist-Ratnagiri, Maharashtra	26/4/2020 to 20/05/2020
24	One week E- course on Basics of Applied Geology	Department of Geology, Nowrosjee Wadia College, Pune, Maharashtra	18/05/2020 to 25/05/2020

Experience Of Organizing Skill Oriented, E-Courses, E-Competitions, Online content In The Field Of Higher Education

1. Initiated & worked as a Co-Ordinator for E- course on Watershed Management conducted by Department of Applied Geology, KBC North Maharashtra University Jalgaon during 12/05/2020 to 18/05/2020.

2. In year 2019, Initiated & worked as a Co-Ordinator of one week skill-oriented course in Remote Sensing and GIS organized by School of Environmental and Earth Sciences, KBC NorthMaharashtra University Jalgaon during 22-29 August, 2019
3. As a head of the Department, played active role in initiated, designed and conducting Online quiz competitions in association with esteem institutes such as GSDA, GEOFORUM on Geosciences, Environmental Sciences, hydrogeology, Covid-19 related health issues to help students in study in lockdown period (March 2020 to July 2021). More than 500 students were participated on pan India level for these online free course and quiz.
4. Delivered an online guest lecture entitled "Ecosystem Restoration" on the special occasion of World Environment Day 2021 organized KBGT College of Engineering, Nashik, Maharashtra
5. Actively participated and delivered online guest lectures in Groundwater literacy campaign (Bhujal Saksarta Abhitan) launched & organized in year 2021 by Groundwater Survey and Development Agency (GSDA) in Jalgaon District region.
6. In year 2020, While working as a head of the Department, specially Initiated, designed & launched the free You-tube channel entitled "Geosciences for Society" to create awareness amongst the students & youngsters related to highlighting the role of Geosciences for sustainable development of Society. This initiative played an important role in helping students in online self-study during lockdown period.

Experience Of Organizing Events Such As Workshops, Seminars, Conferences, E-Webinars At An International/National Level Within The Country In The Field Of Higher Education

Sr. No.	Title of Workshop / Seminar / Conference	Month & Year	Place	Role assigned (to you) in organizing the event
1	National Level Technical Paper Contest "Millennium 2000"	January, 2000	J.T.M. college of Engg. Faizpur, Maharashtra	Organizing Secretary
2	STTP on "Environmental management a future perspective" sponsored by ISTE, New Delhi	December, 2000	J.T.M. college of Engg. Faizpur, Maharashtra	Coordinator

3	STTP on “Induction Training for Technical teachers” sponsored by ISTE, New Delhi	December, 2000	J.T.M. college of Engg. Faizpur, Maharashtra	Coordinator
4	STTP on “Ground water management and development” sponsored by ISTE, New Delhi	December, 2001	J.T.M. college of Engg. Faizpur, Maharashtra	Coordinator
5	State Level ISTE Convention on “Value Based Quality Engineering Education – A call of the Time”	September, 2003	J.T.M. college of Engg. Faizpur, Maharashtra	Organizing Secretary
6	One day National Workshop on “Interlinking of Rivers Problems and Perspectives” on Eve of World Water Day sponsored by Geoforum, Aurangabad, MH	March, 2004	J.T.M. college of Engg. Faizpur, Maharashtra	Co-convener
7	Entrepreneurship Awareness Program for Engg. Students	February, 2004	J.T.M. college of Engg. Faizpur, Maharashtra	Coordinator
8	Four days International Conference organized on “HS08: Impact of Climate Change on Groundwater Resources – Problems and Perspectives”	2010	International Convention Centre, Hyderabad	Convener
9	Two days National Symposium on “Pakshi Mitra”	2010	North Maharashtra University, Jalgaon	Organizing Secretary
10	Two days National Conference organized on NRMSD	2010	North Maharashtra University, Jalgaon	Organizing Secretary

11	Two days national conference organized on "Environmental Innovations for Resource Sustainability"	2011	North Maharashtra University, Jalgaon	Organizing Secretary
12	Two days National Conference organized on ESNRM	2012	North Maharashtra University, Jalgaon	Organizing Secretary
13	Four Days International Conference organized on 5th INGWC in year 2012	2012	Aurangabad	Joint Organizing Secretary
14	Two days National Workshop organized on COEPH	2013	North Maharashtra University, Jalgaon	Convener
15	National Conference on Watershed Management for Sustainable Development	2013	SRTM University, Nanded	Advisory Committee member
16	National Conference "Monitoring and Assessment of Natural Resources for Sustainable Management"	January, 2017	KBC North Maharashtra University, Jalgaon	Organizing Secretary
17	Second National Groundwater Conference (INGWC-2018)	December, 2018	M. J. College, Jalgaon, Maharashtra	Organizing Secretary
18	National conference on "Innovations in Environmental and Earth Sciences for Sustainable future (IEESSF-2019)"	February, 2019	KBC North Maharashtra University, Jalgaon	Convener
19	One day workshop "JALSANWAD-2019"	February, 2019	KBC North Maharashtra	Organizing Secretary

			University, Jalgaon	
20	INGWC-2020 III Indian National Groundwater Conference	February, 2020	CWRDM, Kozhikode	Joint Organizing Secretary
21	National level webinar on Geo-medical Health Hazards & Environmental problems in Tribal areas: Issues, Opportunities and Challenges	September, 2020	KBC North Maharashtra University, Jalgaon	Convener
22	Industry Academic E-Conclave-2020	September, 2020	KBC North Maharashtra University, Jalgaon	Joint Organizing Secretary
23	National level webinar on Role of Geosciences in Drought Management: Issues, Opportunities and Challenges	June, 2021	KBC North Maharashtra University, Jalgaon	Convener

Experience Of Working On The Statutory Authorities / Forums Of A University Such As Board Of Studies, Academic Council, Management Council Or Executive Council Of Board Of Management, Senate, Etc

Sr. No.	Institution	Statutory forums / authority and position	From	To	Total (in years and months)
1	Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Member of Academic Council	24/09/2018	Till date	02 year and 09 months

2	Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Chairman of Ad-hoc Board of Studies in subject of Geo-Science	24/09/2018	Till date	02 year and 09 months
3	Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Member of Board of Examination	30/11/2016	30/11/2017	01 year
4	Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Invited Member of Ad-hoc Board of Studies in subject of Geo-Science	01/06/2007	31/05/2012	05 years
5	Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Member of Ad-hoc Board of Studies in Civil Engineering	24/02/2011	23/02/2013	02 Years
6	Shivaji University, Kolhapur, Maharashtra	Member, Ad-hoc Board of Studies in subject of Geology	08/12/2010	8/12/2015	05 Years
7	Dr. Babasaheb Ambedkar Marathwada University, Maharashtra	Member, Ad-hoc Board of Studies in subject of Geology	06/05/2011	05/05/2013	02 Years
8	Environment Department, Govt. of Maharashtra	Expert Member for State Expert Appraisal Committee (SEAC-1) formed by MOEF, New Delhi	17/03/2017	12/01/2021	04 years
9	Forest Department, Government of Maharashtra State, India	Expert member of Jalgaon District Sheep Grazing committee	01/06/2017	31/05/2018	01 year

10	Government of Maharashtra	Expert member of Balbharti Geosciences textbook Committee	28/08/2018	01/03/2019	05 month
11	Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Member of Central Training and Placement cell	10/10/2012	Till date	08 years and 08 months

Demonstrable Experience Of Handling Quality Issues, Assessment And Accreditation Procedures, Etc

Sr.No.	Area	Institution	Duration (From --to) and total period	Achievements
1	Quality issues	Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Duration: 12/07/2010-23/09/2018 Total period: 08 years	Invited Member of the M. Sc. (Applied Geology/M.A./M.Sc Geography/B.Sc Geoinformatics) Syllabus framing committee
		Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Duration: 10/09/2011-10/09/2013 & 14/09/2014-Till date Total Period: 08 years and 09 months	Co-ordinator of Academic Committee for School of Environmental Earth Sciences
		Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Duration: 01/06/2011-Till date Total period: 10 Years	Member of Examination and Admission Committees under Academic Flexibility to School of Environmental and Earth Sciences.
2	Assessment and accreditation procedures	Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, Maharashtra	Duration: 06/05/2011-05/05/2013 Total Period: 02 years	Member of Research and Recognition Committee in Subject of Geology under the

				Faculty of Science and Technology
		Rashtrasant Tukadoji Maharaj Nagpur University, Maharashtra	Duration: 11/10/2018- Till date Total Period: 02 Years and 08 months	Member of Research and Recognition Committee in Subject of Geology under the Faculty of Science and Technology
		Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Duration: 24/09/2018- Till date Total Period: 02 Year and 09 months	Member, Faculty of Science
		Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Duration: 28/06/2011- 20/06/2013 Total Period: 02 Years	Member of Board of University Teachers Recognition (BUTR) committee
		Shivaji University, Kolhapur, Maharashtra	Duration: 08/12/2010- 08/12/2015 Total Period: 05 Years	Member, Ad-hoc Board of Studies in subject of Geology
		Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Duration: 16/04/2019- Till date Total period: 02 Years and 02 months	Chairman of University Green Audit committee at KBCNMU, Jalgaon
3	Any other issue (Please specify)	SSBT's College of Engineering, Bambhori. District:Jalgaon	Duration: 26/02/2011 Total period: 01 day	Judge for Evaluation of Civil Engineering model at National level event called Techwave-2011
		Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Duration: 30/12/2012- 08/01/2013 Total Period: 10 days	Co-ordinator of Finance and Account Committee for Avishkar-2012
		Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Duration: 30/12/2015- 08/01/2016 Total Period: 10 days	Judge for Evaluation of posters/Models during District Level Avishkar-2015

Experience At The State Or National Or International Level In Handling Youth Development Work Such As Organizing Student-Centric Activities For Their All-Round Development And For Providing Them Rich Campus Life

Sr.No.	Nature of Activity / Event	Institution	Duration (From – to – and total period)	Achievements
1	As Programme officer, National Service Scheme University Campus Unit conducted 3 residence camps in Rural areas	Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Duration: 09/09/2014-09/09/2018 Total Period: 04 Years	Constructed two water harvesting Structures Gabion Type and recharge trench cum Band at Savada village along with Participation of NSS Students and local peoples during NSS Winter camp at Savada village.
2	As a Head of Department Provide Internship opportunities for students in CSIR labs	Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Duration: 20/09/2010-Till date Total Period: 10 Years and 09 months	Students benefited and get expose of research due to collaboration (MOU) with Groundwater Surveys and Development Agency (GSDA), Pune and Indian Institute of Geomagnetism (IIGM), Mumbai and Indian Institute of Tropical Meteorology (IITM), Pune.
3	As Co-ordinator of Center of EDUSAT program of Indian Institute of Remote Sensing, ISRO, Dehradun provided E-learning opportunities to students	Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Duration: 01/06/2015 – Till date Total Period: 06 Years	Students have been benefited and introduced to new concepts, updates and innovations in field of Remote sensing

4	As Co-ordinator of Earth science Olympiad exam centre organized by Geological Society of India	Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Duration: 01/06/2015 – Till date Total Period: 06 Years	It helped to create mass awareness among higher secondary school students regarding scope and fundamentals in field of earth sciences
5	As Co-ordinator Conducted certificate course in Remote sensing and GIS	Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Duration: 22/08/2019-29/08/2019 Total Period: 07 Days	Students were benefited and introduced to new concepts, updates and innovations in field of Remote sensing
6	As a Co-ordinator Conducted Online E-course on Watershed Management for students during lockdown period due to Covid-19	Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon	Duration: 12/05/2020-18/05/2020 Total Period: 07 Days	The online course on watershed management was launched to help students in study in lockdown period. Total 180 students were participated on pan India level for this online free course.

Details Of Experience Of Working With National/International Bodies:

Sr. No.	Name of the National/International body	Nature of experience
01.	Association of Geologist and Hydrogeologists (Geo-Forum), Aurangabad, Maharashtra	Secretary
02.	Bulletin of Pure & Applied Sciences- Section F-Geology, International Journal of BPAS publication house, Delhi	Editor in Chief
03.	Hydrological Science, AOGS, World Scientific Pub. Singapore	Associate Editor
04.	Geological Society of India, Bangalore (GSI)	Fellow (F-3387)
05.	National Academy of Sciences India (NASI)	Member
06.	Association of Hydrologist of India	Member (227/517)

07.	Association of Global Groundwater Society	Member (LMAGGS-055)
08.	Indian Society for Technical Education	Member (LM-14834)
09.	Indian Society for Engineering Geology	Member (LM-1122)
10.	Indian Society for Remote Sensing	Member (LM-2632)
11.	Journal of Waste Management and Environmental Issues	Member of National Editorial Advisory Board
12.	International Journal of Advanced Remote Sensing and Geographic Information System	Member of National Editorial Advisory Board
13.	Arabian Journal of Geosciences	Member of Reviewer Board
14.	Hydro-Research International Open Access Journal	Member of Reviewer Board
15.	Gondwana Geological Magazine	Member of Reviewer Board

Skills And Competencies:

Skills		
Technical Skills -		
1	Openness towards technology and a deep conviction regarding its potential applications in a knowledge – based setting	Conducted Online course on watershed management and organized webinar on petroleum geology during lockdown period. Designed and conducted number of quiz and competitions to help students for study in lockdown.
2	Level of comfort in the use of technology	I am well versed with the use of latest technologies like internet, emails, virtual learning centers, whatsapp and google drives for sharing new and innovative ideas for interaction with the students and the study centers.

Managerial Skills –		
1	Ability to anticipate issues and problems advance strategic plans	During the tenure as a HOD Of Department of Applied Geology, The online course on watershed management, Online quiz on hydrogeology, Covid-19 were launched to help students in study in lockdown period. More than 300 students were participated on pan India level for these online free course and quiz.
2	Ability to generate resources and to allocate the same appropriately	During the tenure as a Reader and Professor generated revenue resource worth of Rs. 25 lakhs through consultancy services. A partial amount of these funds are utilized effectively to develop a consultancy laboratory and for monetary benefit to the PG and research students.
3	Capacity to work effectively under pressure and to manage work within right deadlines	Worked as member of Board of Examiner (BOE) of university as well as Member of Examination, Academic and Admission Committees under Academic Flexibility to School of Environmental and Earth Sciences.
4	Understanding of financial management including revenue generation, planning and fiscal control.	Worked as coordinator of on the Finance and Account committee for the AVISHKAR event 2012. During the tenure as a Reader and Professor generated revenue resource worth of Rs. 25 lakhs through consultancy services. Manage to utilize resources within a deadline of the funding agencies for various developments in the University.
Alignment with corporate objectives and State as well as National level priorities -		
1	Ability to identify the needs of the communities in key sectors	While working in the rural sector of Khandesh area the major needs of the communities are identified in agricultural, health and educational sector.
2	Understanding of the challenges before the Nation and to indicate how Higher Education can respond to developmental needs	Deep understanding of the challenges before the National and how higher education can respond to developmental needs.
3	Understanding of curriculum development issues, especially those relating to wide participation and social inclusion	Demonstrable understanding of curriculum development issues, especially those relating to widening participation & social inclusion.
Leadership skills –		

1	Ability to motivate a diverse groups of stakeholders	Working as a member of Central Training and Placement cell for last 10 years.
2	Desire to further the mission and goals of the organization	While working as Co-Ordinator of Consultancy cell trying to generate new revenues resources for school.
3	Ability to think strategically and innovatively and to maintain a board perspective	A) Working as Co-Ordinator of Earth Science Olympiad for last 05 years to create awareness among masses regarding earth sciences. B) Initiated as worked as Co-Ordinator of one week skill-oriented course in Remote Sensing and GIS organized by School of Environmental and Earth Sciences, KBC NMU, Jalgaon. during 22-29 August, 2019
4	Ability to lead by personal example with openness to new ideas and a consultative approach in implementation of the same.	During the tenure as Programme Officer, NSS University Unit, constructed two water harvesting Structures Gabion Type and recharge trench cum Band at Savada village along with Participation of NSS Students and local peoples during NSS Winter camp at Savada village.
Interpersonal communication and collaborative skills –		
1	Details of experience in developing and executing National and international collaborative arrangements	Active member of collaboration (MOU) with Groundwater Surveys and Development Agency (GSDA), Pune and Indian Institute of Geomagnetism (IIGM), Mumbai and Indian Institute of Tropical Meteorology (IITM), Pune.
2	Ability to interact effectively and persuasively with a strong knowledge-base at senior levels and in large for a as well as on a one-to-one basis	A) Served as an Expert Member for State Expert Appraisal Committee (SEAC-1) formed by MOEF, New Delhi for Forest Department of Government of Maharashtra B) Participated and organized more than 25 National and International conferences, conclaves & webinars. C) Delivered invited talk to various scientific forums likes (Conference, workshop, etc)
3	Evidence of being an active member of professional bodies and associations in relevant fields.	A) Currently serving as an Editor In Chief with Scopus listed Bulletin of Pure & Applied Sciences- Section F-Geology International Journal

		B) Currently serving as a Secretary for Association of Geologist & Hydro-geologist (GEOFORUM), Aurangabad, Maharashtra C) Serving as Member of reviewer board of reputed International Journals D) Evaluated Ph.D. theses from the Universities throughout the nation in Environmental Sciences & Geosciences.

Date: 15th July, 2021
Location: KBCNMU, Jalgaon

Prof. (Dr.) Sanjay Narayan Patil

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Study of the aquifer vulnerability by longitudinal unit conductance, GOD and GLSI Models in the Painganga river basin, Buldhana (Maharashtra, India)

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ABSTRACT

Aquifer vulnerability has been assessed in the Painganga river basin area (Mehkar and Lonar Tehsil) of the Buldhana district, Maharashtra state located in the western part of India. The present paper focuses on the use of longitudinal unit conductance, GOD and GLSI models to measure the penetration and possibility of contamination of an aquifer. A total of thirty-five vertical electrical soundings (VES) were carried out in the study area. Schlumberger array methods were utilized to measure the resistivity, thickness and depth of the subsurface layers. The study reveals that the total longitudinal unit conductance index rating for VES S1, S4 and S18 falls under poor overburden protective capacity, and VES S10, S13, S14, S17 and S33 falls under weak overburden protective capacity, which is attributed to the infiltration of leachate and other surface pollutants. GOD model index rating for vulnerability is negligible to low (0.04 to 0.29), except for VES S1, S7, S10, S14, S18, S19 and S24. GLSI parameter index rating for VES S8, S11, S12, S13, S19, S21, S22 and S23 is higher, however for VES S2, S3, S4, S5, S6, S7, S9, S14, S15, S24, S29, S30, S32, S34 and S35, it is moderate. On the other hand, VES S1, S10, S18, S25, S27, S28 and S33 show extreme values that suggest a lower degree of vulnerability level to contamination. Total longitudinal unit conductance overstates the degree of vulnerability than GOD and GLSI models, as it gives a higher preference to the thickness of the subsurface layer. This study indicates that the total longitudinal unit conductance model is more suitable for vulnerability study than GOD and GLS models.

Keywords: Aquifer, Groundwater, Resistivity, Vulnerability, Painganga River Basin (Buldhana, Maharashtra).

INTRODUCTION

Groundwater is the most valuable resource on the surface of earth for drinking, irrigation, and industrial purposes. It offers around one-third of the world's water usage as well as about 90% of the freshwater available to humans. But groundwater is extremely vulnerable to contamination. Since there is a continued increase in population, the need for a combined assessment of groundwater resources was considered by Syed et. al. (2021) as groundwater is a better source of drinking water, compared to surface water. Despite the vast improvement, it is found that groundwater pollution is uncontrolled due to infiltration of contaminants, leaching from the septic tanks, refused dumps, petroleum tanks, and improper handling of pesticides (Sampat, 2000; Oni et al., 2017). Syed et al. (2021) noticed that the world is facing a prevailing problem of groundwater contamination. Though the groundwater has a self-remediation capacity, it becomes hard to remediate, once it is contaminated. For sustainable groundwater management, focus on pollution inhibition is necessitated before considering plans to prevent future groundwater contamination.

The effect of imposed contaminant load on aquifer can be understood by knowing the vulnerability as it indicates sensitivity (Duijvenbooden and Waegeningh, 1987; Foster and Hirata, 1988; Vrba and Zaporozec, 1994; Oni et al., 2017). The main parameters involved in the natural vulnerability assessment are the confinement degree (confined or unconfined), lithology, the groundwater table depth from the surface and the consolidation level of the strata over the saturated zone. In all the vulnerability estimations, the focus is generally given to the unsaturated zones, hydraulic accessibility and pollutant attenuation capacity (Foster and Hirata, 1988). Omosuyi (2010) noted that the shallow aquifers of the basement complex topographies are vulnerable to surface or near-surface contaminants. The low hydraulic conductivity of overlying layers hinders the percolation, delays the degree of contaminants and protects the groundwater reservoirs (Aweto, 2011). Frid et al. (2017) observed that the surface investigation by the geophysical method is very relevant for groundwater studies. The geophysical method is found non-invasive/non-destructive, less risky and cost-effective (Mogaji et al., 2015; Olayanju et al., 2017). In a number of groundwater modeling studies, the earth's superficial properties assessed by geophysical techniques were utilized (Jha et al., 2010; Adiat et al., 2013).

The vulnerability assessment approaches like total longitudinal unit conductance, GOD (G = groundwater occurrence, O = overlying lithology of layers and D = depth of aquifer), and GLSI (Geoelectric layer susceptibility indexing) are mostly based on hydrogeological and geophysical methods. In some of the methods, the thickness of the layers overlying the aquifer and hydraulic conductivity are considered (Mclay et al., 2001; Herbst et al., 2005),

whereas geoelectric parameters of the overlying layers are considered in other methods (Oni et al., 2017). Some of the vulnerability assessment techniques include confined and unconfined GOD. The intrinsic weakness of insensitivity to the possible resistance of lithology in longitudinal conductance is overcome nowadays by recently recognized techniques known as GLSI; it is also utilized for the over-prioritization of the effect of geologic units in the GOD approach (George, 2021). The nature of this is mostly hydrogeological. In GLSI the importance of overburden zone thickness and lithological units in aquifer protection dynamics is indexed with ratings based on an assessment of the thickness proposed and resistivity magnitudes of the layer (Oni et al., 2017).

The concept like total longitudinal conductance proposed by Albinet and Margat (1970), GOD by Foster (1987) and GLSI by Gogu and Dassargues (2000) is indexing parametric methods, in which each parameter shows a variation of values relating to its property and it is also divided into separate and hierarchized intervals by explicit values, which reflect their vulnerability range to contamination indices (George, 2021).

The vulnerability denotes the physical and hydrogeological characteristics of an area that plays a part in the process of an aquifer getting polluted (Mondal et al., 2018). Several scientists have established various approaches for the assessment of vulnerability. A few of them are total longitudinal unit conductance (Albinet and Margat, 1970; Oladapo et al., 2004; Oni et al., 2017), GOD (Foster, 1987; Gogu and Dassargues, 2000; Khemiri et al., 2013; Oni et al., 2017; Nugraha et al., 2020), GLSI (Gogu and Dassargues, 2000; Oni et al., 2017), DRASTIC (Shirazi et al., 2012; Ghosh and Kanchan, 2016; Tiwari et al., 2016; Mondal et al., 2017), AVI (Neukum et al., 2008; Ducci and Sellerino, 2022), SINTACS (Al Kuisi et al., 2006; Kumar et al., 2013), ISIS (Civita and De Regibus, 1995; Gogu and Dassargues, 2000), EPIK (Doerfliger and Zwahlen, 1998; Doerfliger et al., 1999), PI (Goldscheider et al., 2000; Goldscheider, 2003) and OREADIC (Qian et al., 2011; Li et al., 2020).

Geophysical methods have effectively utilized to demarcate landfill boundaries, thicknesses of subsurface layers polluted through leachate and pollutants migration pathways (Aristodemou and Thomas-Betts, 2000; Dawson et al., 2002; De Iaco et al., 2003; Carpenter et al., 2009; De Carlo et al., 2013; Tsourlos et al., 2014). The electrical resistivity approach has been found to be effective in addressing environmental and geotechnical issues in a number of studies (Mondelli et al., 2010; Ustra et al., 2012). According to many studies (Batayneh, 2005; Martinez-Pagan et al., 2010; Ayolabi et al., 2015; Wang et al., 2015; Akiang et al., 2020), the electrical resistivity method can be used to map the contamination of groundwater and detect soil pollution. Numerous geophysical investigations have been conducted to address the issue of soil and groundwater contamination.

The electrical resistivity technique is most frequently used in environmental studies since the electrical resistivity of earth materials is determined by parameters such as fluids, porosity, permeability, temperature, degree of fracturing, degree of cementation, rock type and the extent of weathering (Idornigie et al., 2006; Mosuro et al., 2016). This is basically a geophysical approach for the interpretation of leachate in groundwater and finds the role of lithology in impeding the movement of leachate in the subsurface. Due to the suitability of the method, it has been noted that this technique is used for hydrogeological risk assessment for groundwater contamination. There is a big lack of research work in the present study area as no work is carried out on groundwater quality, aquifer delineation except morphometric and hypsometric work carried out by Sonar et al. (2021). The present paper deals with the estimation of the aquifer vulnerability to contamination zones with the help of three different models such as total longitudinal unit conductance, GOD and GLSI.

STUDY AREA

The study area lies between Mehkar and Lonar tehsil of Buldhana district in Maharashtra, covering 19^0 59' 11" N to 20^0 20' 06" N and 76^0 15' 38" E to 76^0 48' 52" E (Figure 1). Nearly 94% of the study area is covered by dark grey, fine to medium-grained massive Deccan trap (Deshpande, 2012; CGWB, 2022) belonging to K-T boundary age . This massive Deccan trap formations are comprised of a thick pile of lava flows that are separated by 1-3m thick layers of red bole. The dendritic to sub-dendritic drainage pattern is observed in the study area which indicates a homogenous lithology and nearly flat topography (Sonar et al., 2021; Sirsat et al., 2022).

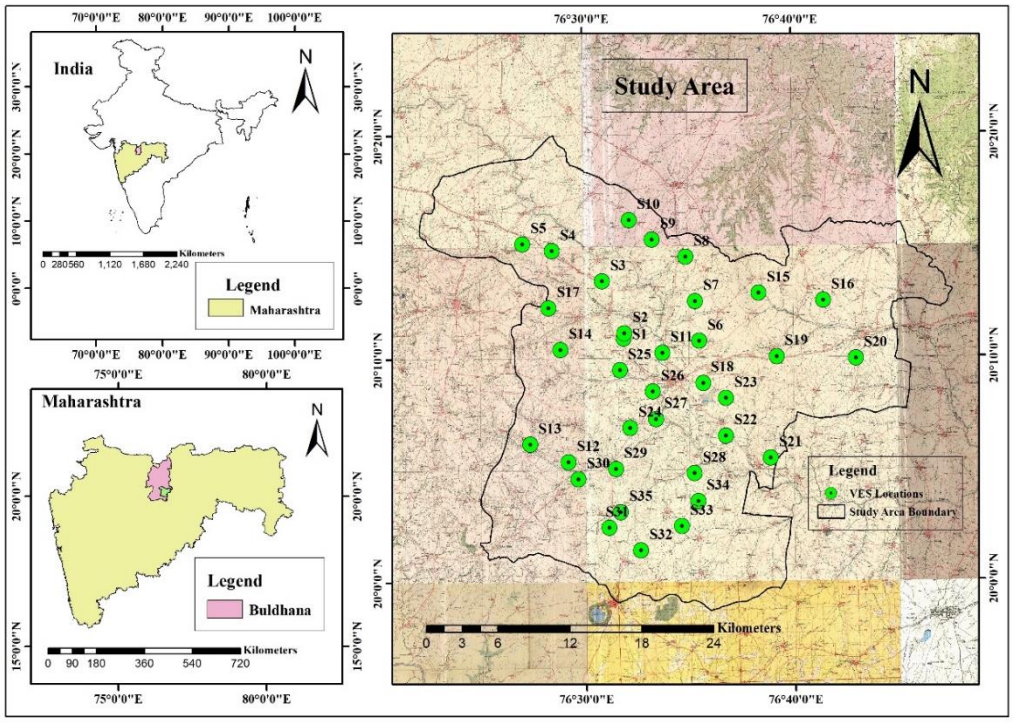

Figure 1. Location map of the study area along with the VES survey points.

METHODOLOGY

This study is carried out to estimate the groundwater vulnerability to contamination in part of the Painganga river basin area using total longitudinal unit conductance, GOD and GLSI models. A Schlumberger method was used to carry out a vertical electric sounding survey at 35 different locations with a resistivity meter (Model: SSR-MP-ATS). The maximum current electrode spacing (AB/2) is up to 100 m and potential electrode spacing (MN/2) is up to 10 m for understanding the subsurface lithology, the thickness and the depth of the layers.

The index rating for the total longitudinal unit conductance model is based on the thickness of the subsurface layer and its resistivity values. The index rating for the GOD model is based on types of aquifers, overlaying lithology of aquifer and depth of aquifer. The index rating for the GLSI model is based on resistivity values and layer thickness. The aquifer characteristics and their classification methods (Table 1) adopted here are modified after Khemiri et al. (2013).

Longitudinal conductance

Longitudinal conductance is calculated by using the following equation

$$S = \frac{h1}{\rho 1} + \frac{h2}{\rho 2} + \frac{h3}{\rho 3} + \cdots + \frac{hn}{\rho n} \quad \text{---------- (1)}$$

Where, S is the longitudinal conductance, h1, h2, h3 and hn are the thicknesses of layers and ρ1, ρ2, ρ3 and ρn are their respective resistivity. The longitudinal conductance protective capacity rating is < 0.1, 0.1 to 0.19, 0.2 to 0.69, 0.7 to 4.9, 5 to 10 and > 10, it respectively corresponds to poor, weak, moderate, good, very good and excellent (Henriet, 1976; Oladapo et al., 2004; Oni et al., 2017).

GOD

The GOD index is measured by the multiplication of the influence of the parameters using the following equation

$$G.O.D.Index = G \times O \times D \quad \text{---------- (2)}$$

Where, G = Type of aquifer, O = Overlying lithology, D = Depth of aquifer.

Attribution notes for GOD model parameters are shown in Table 1 and the vulnerability index ratings for these parameters are 0 to 0.1, 0.1 to 0.3, 0.3 to 0.5, 0.5 to 0.7 and 0.7 to 1, it corresponds to negligible, low, moderate, high and extreme respectively (Foster, 1987; Khemri et al., 2013).

Table 1. Attribution of note for GOD model modified after Khemiri et al. (2013).

Type of aquifer	Note	Resistivity range (Ωm)	Note	Depth of aquifer (m)	Note
Non aquifer	0	0 - 26	0.4	0 - 3	1
Unconfined	0.6 -1	27- 60	0.5	4 - 10	0.6
Semi-confined	0.3 - 0.5	61-100	0.6	11- 20	0.8
Confined	0.2	101- 250	0.7	21- 30	0.7
-	-	> 250	0.8	> 30	0.5
Note: 1. The first layer shows higher resistivity values at some locations due to the presence of the impervious soil nature (Zambre and Thigale, 1980). 2. The aquifer types are identified by the static water level data, depth of the aquifer and their resistivity values.					

Table 2. Geoelectric layer susceptibility index (GLSI) rating for resistivity and lithology.

Resistivity range (Ωm)	Lithology	Susceptibility index rating
0 - 10	Black cotton soil with sand	1
10 - 26	Black cotton soil with murum	1
27 - 60	Highly weathered Basalt	2
61 - 100	Highly fractured Basalt	2
101 - 250	Weakly fractured Basalt	3
> 250	Hard and compact/massive Basalt	4
Note: The first layer has shown higher resistivity values at some locations due to the presence of the impervious soil nature (Zambre and Thigale, 1980).		

GLSI

The GLSI assigns an index to each geoelectric parameter or thickness of the layer and layer resistivity as shown in Table 2. GLSI is determined by the following equation

$$GLSI = \frac{((\rho 1r+h1r)/2+(\rho 2r+h2r)/2+(\rho 3r+h3r)/2+\cdots+(\rho nr+hnr)/2))}{N} \quad ---(3)$$

Where, GLSI denotes geoelectric layer susceptibility indexing, ρ1r, ρ2r, ρ3r and ρnr is the first, second, third and n^{th} layer resistivity index rating respectively, whereas h1r, h2r, h3r and hnr is the first, second, third and n^{th} layer thickness index rating respectively, N is corresponding to geoelectric layers overlying the aquifer.

The GLSI adopts the Multi-Criteria Decision Analysis (MCDA) technique for the index of the rated parameter. This technique uses the capabilities of the GIS environment of geospatial data and the flexibility of the MCDA to combine accurate pieces of information. An MCDA technique used for this model is based on layer resistivity, lithology and thickness of the layer. The low resistivity values are low index ratings and high resistivity values are given high index ratings. The GLSI model index rating for vulnerability is classified as low (1.0-1.99), moderate (2.0-2.99), high (3.0-3.99) and extreme (4.0) (Oni et al., 2017). The allocated parameter indices were then normalized by separating them with the number of geoelectric layers (N) demarcated above the aquifer.

RESULTS

A total of thirty-five vertical electrical soundings were carried out at different locations and the data was interpreted using IPI2WIN software that gives the resistivity values, depth and thickness of the subsurface layers. Besides resistivity and thickness of the layers, the total longitudinal unit conductance, GOD and GLSI models protective overburden index rating capacity were also determined.

Total longitudinal unit conductance

The distribution of the total longitudinal unit conductance of the study area is shown in Figure 2. This map shows closures of longitudinal conductance range < 0.1 in the central part of the VES station S18 and in the northern part of VES station S4. The VES stations S4, S10, S13, S14 and S17 have exhibited values between 0.1 and 0.19.

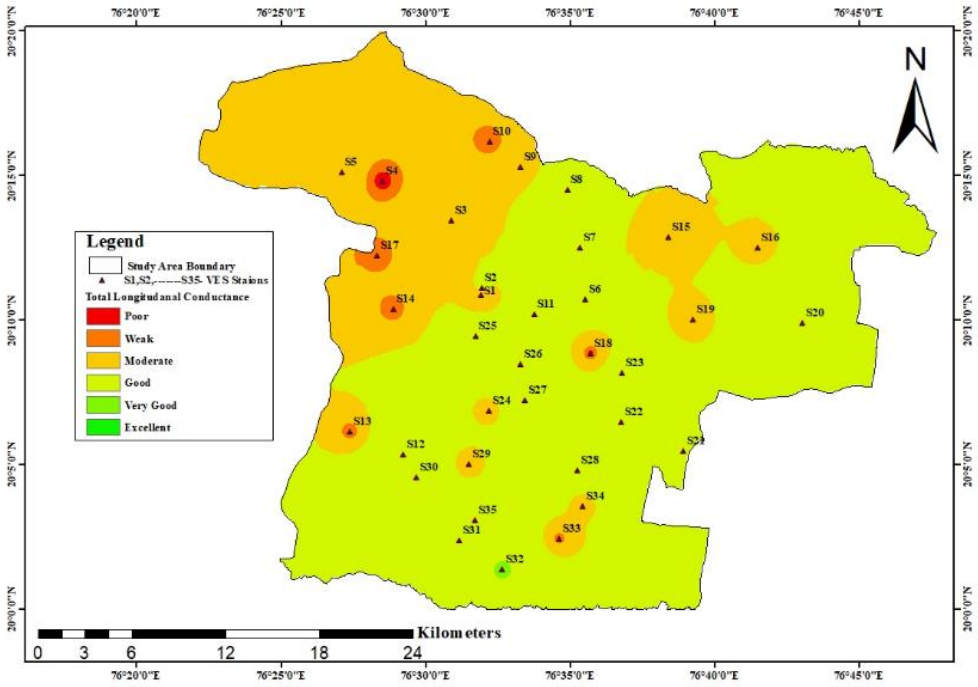

Figure 2. Total longitudinal unit conductance rating map of the study area.

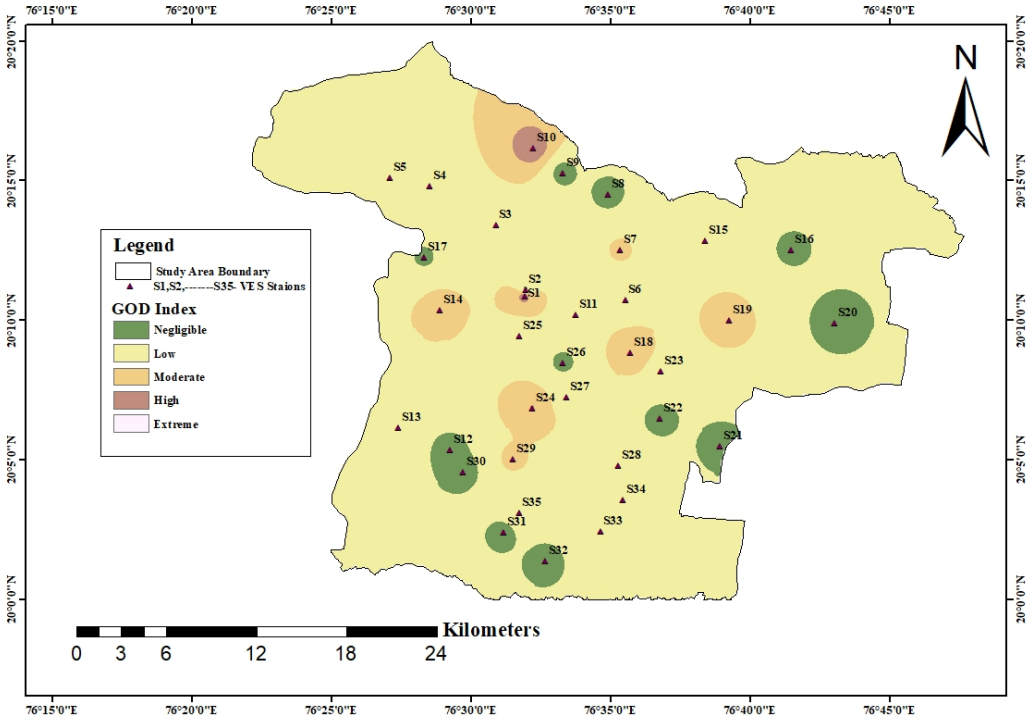

Figure 3. GOD vulnerability index rating map of the study area.

The total longitudinal unit conductance value at VES station 32 is 5.27 and it lies within a very good protective capacity than the other VES stations in the study area. VES stations 2, 6, 8, 11, 12, 20, 21, 22, 23, 25, 26, 27, 28, 30, 31, 37 and 38 fall under the good protective capacity rating where it ranges from 0.78 to 3.17 and the thickness of subsurface layers varies between 7.43 to 100.7 m. The northwest part of the study area shows moderate longitudinal conductance and

other parts show good protective capacity, except the VES station S32 and it shows values from 0.2 to 0.69 and 0.7 to 4.9 respectively. Weak and overburdened protective capacity zones suggest high infiltration rate after precipitation. This area is vulnerable due to infiltration of leachate and other superficial pollutant.

GOD

Figure 3 shows a varying degree of vulnerability designated as negligible and low. VES stations S8, S9, S12, S16, S17, S20, S21, S22, S26, S30, S31 and S32 show a negligible range of vulnerability i.e., 0 to 0.1 and VES station S10 show a higher range of vulnerability such as 0.5 to 0.7 index rating. The S1, S2, S7, S18, S19, S24 and S29 VES stations show a 0.3 to 0.5 range of vulnerability that indicates the area falls under moderate contamination of aquifers. The major part of the study area shows low vulnerability with range between 0.1 and 0.3 (Figure 3).

GLSI

Geoelectric layer susceptibility indexing (GLSI) is an empirical concept introduced to complement other methods of vulnerability assessment. This hydrogeological approach is employed where the electric resistivity contrast between lithological sequence and thickness is indexed (Oni et al., 2017). Lithology, thickness and vadose zone are the main parameters used in the preparation of the overlying index map of GLSI (Figure 4, Table 3).

Most part of the study area exhibits GLSI parameter index rating ranges between 3.0 to 3.99, VES stations S2, S3, S4, S5, S6, S7, S9, S14, S15, S24, S29, S30, S32, S34 and S35 show value ranging from 2 to 2.99 and VES stations S1, S10, S18, S22, S23, S25, S27, S28 and S33 show value range closure to 4.

Table 3. Geoelectric layer susceptibility index rating (GLSI) for layer thickness (Oni et al., 2017).

Vulnerability class	Index rating
< 2	4
2 - 5	3
5 - 20	2
> 20	1

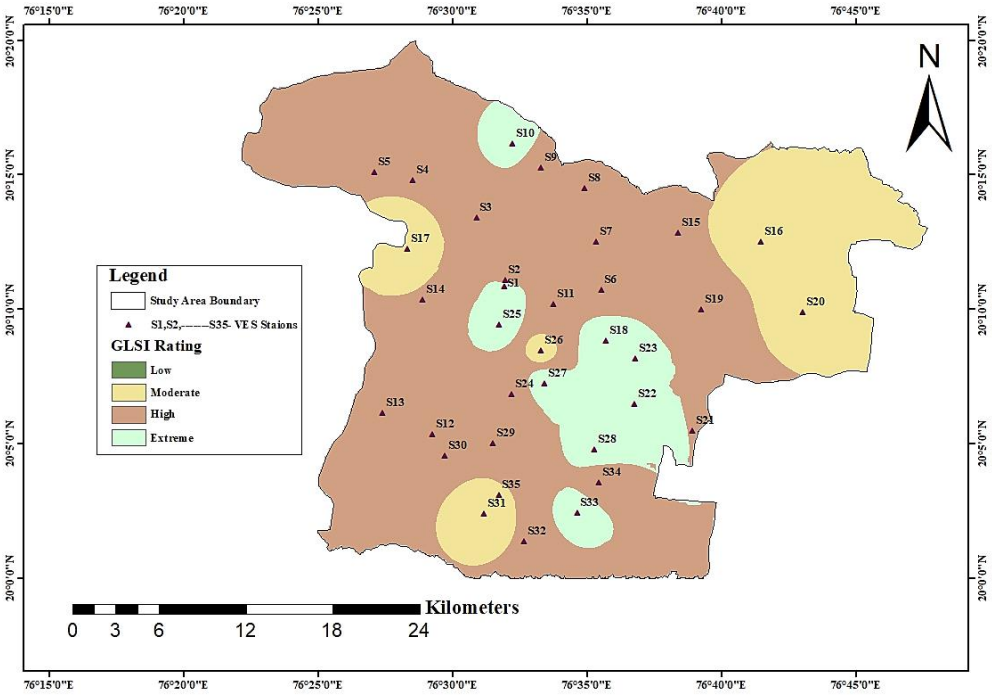

Figure 4. Geoelectric layer susceptibility index (GLSI) rating map of the study area.

DISCUSSION

Resistivity values, depth and thickness of the subsurface layers are measured using the resistivity survey. Resistivity values are important to recognized aquifer and their characteristics. The modeling criteria for the aquifer types are classified by Olorunfemi and Fasuyi (1993), which indicate ranges of resistivity parameter related to the nature of shallow materials that overlies the aquifer's unit of the area. The underlain aquifers were classified into four groups by using the resistivity ranges. Types of aquifers were identified by Khemiri et al. (2013) based on resistivity values but they are for sedimentary terrain, however, in this paper, such classification is based on the resistivity values of Deccan basaltic terrain.

The superficial materials having higher recharge capacity are less resistive i.e., 0 Ωm to 26 Ωm representing non-aquifer zone, 26 Ωm to 60 Ωm represents unconfined aquifer, 61 Ωm to 100 Ωm semi-confined aquifer, 101 Ωm to 250 Ωm represents confined aquifer. The first layer shows higher resistivity values at some locations due to the presence of the impervious soil nature (Zambre and Thigale, 1980). This layer comprises black cotton soil with sand and murum at places that range up to 3 m in depth. The unconfined aquifers correspond to weathered basaltic rocks ranging in depth from 4 m to 10 m. The static water level (SWL) for the corresponding semi-confined aquifer is restricted to the depth ranges from 11 to 20 m for highly fractured/jointed basaltic rocks. A weekly fractured/jointed basalt rock considered as a confined aquifer ranges in depths between 21 m to 30 m. In Basalt, groundwater occurs both in vesicular and massive basalt as well as inter-flow zones in the weathered fractured and jointed zones. In general, groundwater occurs under water table conditions in shallow aquifers and semi-confined to confined conditions in deeper aquifers. The unconfined aquifer is developed due to the weathering and jointing of upper flow in basalt (CGWB, 2022).

In the study area, the resistivity values ranges from 0-10 Ωm. Here the layer is covered by black cotton soil with sand and resistivity values are ranging from 11 to 26 Ωm, it is suggested that the layer covered by black cotton soil with murum. The resistivity value between 27- 60 Ωm, 61-100 Ωm, 101-250 Ωm and > 250 Ωm indicate that the layer is covered by highly weathered basalt, highly fractured basalt, weakly fractured basalt and hard and compact/massive basalt respectively. The first layer (top layer) shows higher resistivity values at some locations due to the presence of the impervious nature of the soil (Zambre and Thigale, 1980).

Henriet (1976) observed that the longitudinal conductance (S) reveals the protection grade of an aquifer that could be directly proportional to the ratio between the thickness and resistivity layers i. e., $S = \frac{h}{\rho}$. Oni et al. (2017) reported the vertical migration containment and protection degree of groundwater. Braga and Francisco (2014) and Oni et al. (2017) however, found high longitudinal conductance (generally >1.0) of the overlying layer providing a high protection level to contamination, these reveals that if the overlying layers are thick, containing more clayey material and less permeable, they show less resistivity. Henriet (1976), Oladapo et al. (2004) and Oni et al. (2017) have classified the level of the protective capacity of the vadose zone as >10 as excellent, 5 to 10 as very good, 0.7 to 4.9 as good, 0.2 to 0.69 as moderate, 0.1 to 0.19 as weak and < 0.1 poor. The closures of poor longitudinal conductance (< 0.1) at the central part and northern part are due to observations made at VES stations S18 and S4 (Figure 2).

The VES stations S10, S13, S14, S17 and S33 demonstrate a weak protective capacity (0.1 to 0.19), which is reasonably higher than the surrounding area; that is categorized as poor protective capacity (Table 4). VES data that includes different geoelectric parameters such as resistivity ranges, the thickness of the layer, the depth of the layer, and the subsurface lithology type of aquifer, helps to measure protective capacity rating (Table 4) for vulnerability models and to prepare the vulnerability index maps.

The northwest part of the study area shows moderate longitudinal conductance and other parts show good protective capacity except the VES station S32 as it shows high longitudinal conductance that is categorized as very good protective capacity. These observations conform with Oni et al. (2017). Good to moderate category could be attributed to the basaltic topsoil (black cotton soil) of the study area since basalt is the predominant rock type.

To assess the vulnerability of the aquifer, GOD index is used and it was measured by multiplying the impact of the three parameters viz., groundwater occurrence (confinement of the aquifer), overlying lithology of the aquifer, depth of the aquifer and the resistivity and thickness of the layers. VES stations S2, S8, S9, S12, S16, S17, S20, S21, S22, S26, S30, S31 and S32 show a negligible range of vulnerability (Figure 3, Table 4). VES stations S1, S10 and S24 show a higher range of vulnerability to contamination and VES stations S3, S4, S5, S6, S11, S13, S15, S23, S25, S27, S28, S33, S34 and S35 show a low degree of vulnerability to contamination, it

indicates a low level of aquifers contamination within the study area. The low to negligible class exhibits a low degree of vulnerability than the longitudinal conductance and GOD approaches; since it gives a higher preference to the characteristic properties of the geo-materials about a degree of compaction and consolidation of subsurface lithology.

Table 4. Aquifer types and parameter index rating of total longitudinal unit conductance, GOD, GLSI models for vulnerability class.

VES stations	Aquifers type	G	O	D	GOD rating/Class	GLSI resistivity range	GLSI rating/class	Total longitudinal unit conductance/ Protective capacity rating
S1	Unconfined	1	0.8	0.8	0.64 (High)	105.27	4 (Extreme)	0.09 (Poor)
S2	Confined	0.2	0.4	0.6	0.048 (Negligible)	38.42	2 (Moderate)	0.95 (Good)
S3	Unconfined	0.5	0.6	0.7	0.21 (Low)	169.66	2 (Moderate)	0.50 (Moderate)
S4	Unconfined	0.4	0.6	0.7	0.168 (Low)	168.18	2 (Moderate)	0.07 (Poor)
S5	Unconfined	0.6	0.7	0.5	0.21(Low)	219.43	2 (Moderate)	0.41 (Moderate)
S6	Unconfined	0.6	0.7	0.5	0.21 (Low)	41.06	2 (Moderate)	1.05 (Good)
S7	Unconfined	0.8	0.8	0.5	0.32 (Moderate)	393.50	2 (Moderate)	0.69 (Moderate)
S8	Semi-confined	0.2	0.4	0.6	0.048 (Negligible)	50.24	3 (High)	1.97 (Good)
S9	Confined	0.2	0.4	0.6	0.048 (Negligible)	41.89	2 (Moderate)	0.42 (Moderate)
S10	Unconfined	1	0.8	0.8	0.64 (High)	109.28	4 (Extreme)	0.10 (Weak)
S11	Unconfined	0.6	0.7	0.5	0.21 (Low)	62.88	3 (High)	0.90 (Good)
S12	Confined	0.2	0.4	0.5	0.04 (Negligible)	74.18	3 (High)	2.08 (Good)
S13	Unconfined	0.6	0.7	0.7	0.294 (Low)	52.66	3 (High)	0.12 (Weak)
S14	Confined	0.8	0.8	0.6	0.384 (Moderate)	178.77	2 (Moderate)	0.13 (Weak)
S15	Confined	0.7	0.7	0.5	0.245 (Low)	205.46	2 (Moderate)	0.29 (Moderate)
S16	Confined	0.2	0.4	1	0.08 (Negligible)	5.25	1 (Low)	0.55 (Moderate)
S17	Confined	0.2	0.4	1	0.08 (Negligible)	11.22	1 (Low)	0.12 (Weak)
S18	Unconfined	0.8	0.8	0.7	0.448 (Moderate)	102.15	4 (Extreme)	0.08 (Poor)
S19	Unconfined	0.8	0.8	0.6	0.384 (Moderate)	62.65	3 (High)	0.51 (Moderate)
S20	Confined	0.2	0.4	0.7	0.056 (Negligible)	4.96	1 (Low)	2.98 (Good)
S21	Confined	0.2	0.4	0.6	0.048 (Negligible)	97.94	3 (High)	0.97 (Good)
S22	Confined	0.2	0.4	0.5	0.04 (Negligible)	62.92	3 (High)	1.81 (Good)
S23	Unconfined	0.7	0.7	0.5	0.245 (Low)	88.11	3 (High)	1.15 (Good)
S24	Unconfined	0.9	0.8	0.7	0.504 (High)	28.5	2 (Moderate)	0.27 (Moderate)
S25	Semi-confined	0.4	0.6	0.7	0.168 (Low)	129.03	4 (Extreme)	1.24 (Good)
S26	Confined	0.2	0.4	0.6	0.048 (Negligible)	17.11	1 (Low)	2.19 (Good)
S27	Semi-confined	0.5	0.6	0.7	0.21 (Low)	134.55	4 (Extreme)	3.17 (Good)
S28	Unconfined	0.6	0.7	0.5	0.21 (Low)	117.38	4 (Extreme)	0.78 (Good)
S29	Unconfined	0.7	0.7	0.7	0.343 (Moderate)	40.09	2 (Moderate)	0.26 (Moderate)
S30	Confined	0.2	0.4	0.5	0.04 (Negligible)	224.79	2 (Moderate)	2.67 (Good)
S31	Confined	0.2	0.4	0.7	0.056 (Negligible)	10.52	1 (Low)	2.58 (Good)
S32	Unconfined	0.2	0.4	0.7	0.056 (Negligible)	25.25	2 (Moderate)	5.27 (Very Good)
S33	Semi-confined	0.5	0.6	0.7	0.21 (Low)	183.38	4 (Extreme)	0.13 (Weak)
S34	Semi-confined	0.5	0.6	0.7	0.21 (Low)	240.25	2 (Moderate)	0.59 (Moderate)
S35	Unconfined	0.6	0.7	0.5	0.21 (Low)	56.08	2 (Moderate)	0.65 (Moderate)

GLSI parameter index rating ranges between 3 to 3.99, that indicates a high vulnerability zone of contamination (Figure 4). The VES stations S8, S11, S12, S13, S19, S21, S22 and S23 show a higher level vulnerability to contamination. The VES stations S2, S3, S4, S5, S6, S7, S9, S14, S15, S24, S29, S30, S32, S34 and S35 of the study area show moderate vulnerability having the value ranging from 2 to 2.99 that indicates moderate contamination of aquifers. The VES stations S1, S10, S18, S25, S27, S28 and S33 exhibit extreme vulnerability index ratings. In the present study, GLSI parameter index rating ranges between 3 to 3.99, that indicate a high vulnerability zone of contamination and the VES stations having value ranging from 2 to 2.99 indicates moderate vulnerability to contamination of aquifers and VES stations having value 4, indicates to extreme vulnerability to contamination of aquifers.

The total longitudinal unit conductance, GOD and GLSI model map was prepared by using calculated geoelectric parameters such as resistivity, the thickness of a subsurface

layer, depth of aquifer and subsurface lithology. These all geoelectric parameters help to identify the protective capacity for vulnerability study. Total longitudinal unit conductance overstates the degree of vulnerability than the GOD and GLSI models as it gives a higher preference to the thickness of the subsurface layer. Due to a higher preference for the thickness of a subsurface layer, the total longitudinal unit conductance model is most suitable for groundwater vulnerability study than the GOD and GLSI models.

CONCLUSION

Vertical electrical sounding (VES) techniques using Schlumberger array were successfully employed in the study of aquifer vulnerability assessment in part of the Painganga river basin area (Mehkar and Lonar Tehsil) of the Buldhana district, Maharashtra, India. Based on VES data, it is observed that different geoelectric parameters viz., resistivity ranges, thickness of layer, depth of layer, subsurface lithology and type of aquifer help in measuring protective capacity rating for vulnerability models and preparing vulnerability index maps. The data allows us to categorize the area into different vulnerability zones (negligible/poor, weak/low, medium, good/high and extreme/excellent). The protective capacity index rating/vulnerability of the area is determined by comparing three different models like longitudinal unit conductance, GOD and GLSI from hydrogeological and hydrogeophysical points of view. The longitudinal conductance exaggerates good to moderate contamination vulnerability in most of the parts of the study area except VES stations S1, S4, S10, S13, S14, S17, S18, and S33. The GOD models overstate the negligible to low degree of vulnerability to contamination in the maximum part of the study area and the GLSI model exaggerates the moderate to high vulnerability, hence it is concluded that the maximum part of the study area is under the influence of low to moderate contamination category. Total longitudinal unit conductance overstates the degree of vulnerability than the GOD and GLSI models as it gives a higher preference to the thickness of the subsurface layer. Due to the higher preference for the thickness of the subsurface layer, it is suggested that the total longitudinal unit conductance model is most suitable for aquifer vulnerability study, than the GOD and GLSI models.

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Compliance with Ethical Standards

The authors declare that they have no conflict of interest and adhere to copy right norms.

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Undertaking by the Principal Investigator

To

The Secretary
SERB, New Delhi

Sir

I, **Dr. Sandip Kisan Sirsat** herby certify that the research proposal ***"Correlation of Various Water Quality Parameters and Water Quality Index of Lonar Tehsil Area, Buldhana, Maharashtra."*** submitted for possible funding by SERB, New Delhi is my original idea and has not been copied/taken verbatim from anyone or from any other sources. I further certify that this proposal has been checked for plagiarism through a plagiarism detection tool i.e. ***https://smallseotools.com/plagiarism-checker*** approved by the Institute and the contents are original and not copied/taken from any one or many other sources. I am aware of the UGCs Regulations on prevention of Plagiarism i.e. University Grant Commission (Promotion of Academic Integrity and Prevention of Plagiarism in Higher Educational Institutions) Regulation, 2018. I also declare that there are no plagiarism charges established or pending against me in the last five years. If the funding agency notices any plagiarism or any other discrepancies in the above proposal of mine, I would abide by whatsoever action taken against me by SERB, as deemed necessary.

10/07/2023

Dr. Sandip Kisan Sirsat

Research Scholar

Endorsement Certificate from the Mentor & Host Institute

This is to certify that:

I. The applicant, **Dr. Sandip Kisan Sirsat,** will assume full responsibility for implementing the project.
II. The fellowship will start from the date on which the fellow joins University/Institute where he/she implements the fellowship. The mentor will send the joining report to the SERB. SERB will release the funds on receipt of the joining report.
III. The applicant, if selected as SERB-N PDF, will be governed by the rules and regulations of the University/ Institute and will be under administrative control of the University/ Institute for the duration of the Fellowship.
IV. The grant-in-aid by the Science & Engineering Research Board (SERB) will be used to meet the expenditure on the project and for the period for which the project has been sanctioned as indicated in the sanction letter/ order.
V. No administrative or other liability will be attached to the Science & Engineering Research Board (SERB) at the end of the Fellowship.
VI. The University/ Institute will provide basic infrastructure and other required facilities to the fellow for undertaking the research objectives.
VII. The University/ Institute will take into its books all assets received under this sanction and its disposal would be at the discretion of Science & Engineering Research Board (SERB).
VIII. University/ Institute assume to undertake the financial and other management responsibilities of the project.
IX. The University/ Institute shall settle the financial accounts to the SERB as per the prescribed guidelines within three months from the date of termination of the Fellowship.

Dated: 10/08/2023

Signature of the Mentor: 

Name & Designation: Dr. Sanjay Narayan Patil (Professor & Head)

Dated: 10/08/2023 

Signature of the Registrar of University/Head of Institute

Seal of the Institution

Professor and Head
Department of Applied Geology Schoc
of Environmental and Earth Sciences
Kavayitri Bahinabai Chaudhari
North Maharashtra University
Jalgaon-425001

Undertaking by the Fellow

I Dr. Sandip Kisan Sirsat, Son of Shri Kisan Limbaji Sirsat, resident of At- Pardi, Post- Wadgaon (Tejan), Tq- Lonar, Dist- Buldana agree to undertake the following, If I am offered the SERB

N-PDF

1. I shall abide by the rules and regulations of SERB during the entire tenure of the fellowship.
2. I shall also abide by the rules, discipline of the institution where I will be implementing my fellowship
3. I shall devote full time to research work during the tenure of the fellowship
4. I shall prepare the progress report at the end of each year and communicate the same to SERB through the mentor
5. I shall send two copies of the consolidated progress report at the end of the fellowship period.
6. I further state that I shall have no claim whatsoever for regular/permanent absorption on expiry of the fellowship.

Date: 10/08/2023

Signature

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Morphometric, Hypsometric and Hydrogeomorphic Investigation in the Region of Painganga River Basin in Buldhana District, Maharashtra, India, Using Remote Sensing & GIS Techniques.

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Abstract: We present a hydro-geomorphological study to demarcate the groundwater potential zones in the water scarcity prone Painganga river basin, which is a sub-basin of Godavari River and located in the Buldhana district of Maharashtra, India. In this, we measured the linear, aerial and relief aspects of this drainage basin along with the slope contribution. Furthermore, a geographic information system (GIS) technique has been utilized to measure the order and length of the streams of the Painganga River. We find that the hydrogeological condition in the studied area is largely controlled by topographic features such as rivers, slopes and hills. The river basin has seven orders with a dendritic and sub dendritic type of drainage pattern without any structural or tectonic control. The drainage pattern is dominated by the first order streams and there is a decreasing trend in stream frequency and order with an increase in the stream order. The basin has an intermediate textural ration (7.549) with a nearly elongated shape. The pervasive nature of the relatively weathering resistant Deccan basalt in the basin pushed the ruggedness number to a minimum level (1.172). Digital elevation model and relief ratio of Painganga River basin suggests a moderate relief. The hypsometric integral value of the basin is in equilibrium stage and river appears to be in a mature phase of development.

Keywords: GIS, Geomorphology, Morphometry, Hypsometry, Painganga River.

1. Introduction

Morphometric analysis includes, the size and mathematical study of the outline of Earth forms, including its landforms (Clarke, 1996; Agarwal, 1998; Obi Reddy et al., 2002; Rai et al., 2017) and it is an important indicator of landform structure and hydrogeologic processes (Horton, 1932; Miller, 1953; Soni, 2017; Gizachew & Berhan, 2018), losses of materials from a watershed, soil physical properties, erosional features and land processes (Khare et al., 2014). It is also important for determining an empirical relation for hydrological activities in arid regions (Tahan et al., 2016). Morphometric study of a basin delivers vital information about the drainage characteristics of a basin (Aparna et al., 2015; Dubey et al., 2015; Strahler, 1964). Morphometric analysis was introduced by Horton (1932, 1945), to study the origin of river networks. Further works were made by Strahler (1952, 1964). Morphometric study was carried out effectively through the measurement of linear aspect, areal aspect and relief aspect of a river basin is computed to derive the general parameter of the basin (Melton, 1958; Miller, 1953; Strahler, 1964; Malik & Shukla, 2018). In drainage basin analysis, the morphometric study plays an important role in order to recognize the hydrogeological behaviour of drainage basin and expresses the prevailing climate, geology, geomorphology and structure etc. The association between the drainage characteristics and aforementioned features are well known by Horton (1945), Strahler (1957), Melton (1958), Pakhmode et. al., (2013) and Gangalakunta et. al. (2004). Various hydrological phenomena can be associated with the physiographic appearances of a drainage basin such as size, shape, slope of the drainage area, drainage density, size and length of the contributories, etc. (Magesh et al. 2012a).
Recently the use of remote sensing and GIS techniques in morphometric study has been increased and delivers an important tool in the assessment of morphometric parameters/characteristics (Asfaw and Workineh, 2019) and also provide effective tool for extraction of river basin and its drainage network (Gebre et al., 2015). Biswajit (2016) noted that remote sensing and GIS help to describe terrain parameters such as nature of bedrock, soil erosion, infiltration and surface runoff. A number of researchers who have conducted morphometric analysis by applying geospatial methods confirmed that, detailed and updated information of drainage basin can be generated in a systematic way (Aparna et al., 2015; Ayele et al. 2017; Farhan et al., 2017; Gizachew & Berhan, 2018; Gutema et al., 2017; Javed et al., 2009; Kulkarni, 2013; Magesh et al. 2012b; Pande & Moharir, 2017; Prakash et al., 2016; Singh et al., 2014; Singh, et al., 2008).

In this study, to evaluate the current situation of the groundwater in the Godavari River basin, we selected the Painganga river basin from Buldhana District of Maharashtra. This study stems with the fact that the Painganga river basin is declared as one of the water scarcities zones of the Maharashtra State due to a continuous declining trend of rainfall and groundwater level since last decade (CGWB report 2019). The river has a seasonal flow with mostly dry during the summer season. In year 2010, Buldhana district received an approximate rainfall 1039.8 mm, whereas in year 2019 it decreased to 842.02 mm. This had a great impact on the groundwater level, which declined drastically. The main objective of this study is to understand the hydrogeological and geomorphological characteristics of the Painganga basin in order to locate the groundwater potential zones that can be utilized by the local peoples.

Hypsometry has been employed to erosion rates of a landscape and resolve spatially variable uplift and whether the landform is characteristic of fluvial or glacial processes

(e.g., Strahler, 1952; Montgomery et al., 2001; Brocklehurst and Whipple, 2004; Walcott and Summerfield, 2008; Pedersen, 2010). In the hypsometric study, which is the association of parallel cross sectional drainage basin area for the elevation, one can identify the physical stage of watershed (natural hydrological entities that cover an area from which rainwater flows to a particular stream/river) and erosion susceptibility of the drainage basin. Here we perform a morphometric and hypsometric analysis of the Painganga river basin using Remote Sensing and Geographical Information System (GIS) techniques in order to understand the local hydrogeological and geomorphological characteristics to demarcate the groundwater potential zones.

1.1 Study area

The study area for this work falls in survey of India Toposheet 55-D3, 55-D7, 55-D8 and 55-D12 and lies between 76°08'10" E to 76°38'30" E and 19°59'40" N to 20°17'00" N. The Painganga River originates at an altitude of ~686 m from above the mean sea level (MSL) in the Buldhana ranges of Maharashtra State, India (Figure 1). It flows through east-south-east direction from Buldhana and Washim districts. Khadakpurna, Dhamana, Koradi, Jamvani Peth rivers are the tributaries that meet Painganga river in Buldhana district. The Buldhana district is bordered by Madhya Pradesh State in the north, on the east by Akola district, on the south by Parbhani district, in the west by Aurangabad and Jalgaon district and in the northeast by Amravati district.

1.2 Geology of study area

Geologically, the most of the area of the Painganga river basin is covered by deccan trap of the upper Cretaceous to lower Eocene age (Deshpande, 2012) show in Figure 2. The Deccan lava succession in this area is grouped under the Sahyadri group. The vesicular and massive basaltic lava flows in the studied area have provided with a multi-layered aquifer system (CGWB Report Buldhana, 2013). The water bearing capacity of vesicular basalts largely depend upon the density and degree of inter connectivity of among the vesicles, whereas water bearing capacity of massive basalt depends on the presence of joints and depth of weathering. In the studied area, road cut section on Chikhli-Mehkar highway near the Barai Phata (Lat: 20° 12'59" and Long: 76° 25' 84") the multiple fractures and jointing patterns can be seen in massive basalt (Figure 3A). Similarly, blocks of joints were observed in Kanchani Mahal hill section (Lat: 20° 07' 76" and Long: 76°35'74") in massive basalt (Figure 3B). Redboles, which are formed by alteration of the basalt, are also commonly observed with a dimension of up to 2m width in different places such as Kanchani Mahal, Sultanpur, Pardi and Shara villages (Figure 3C). The basalts in the basin area also lead to the spheroidal weathering along the top of the lava flow (Figure 3D). There appears to be several lineaments in the study area, which are one of the structural features that control the groundwater movement.

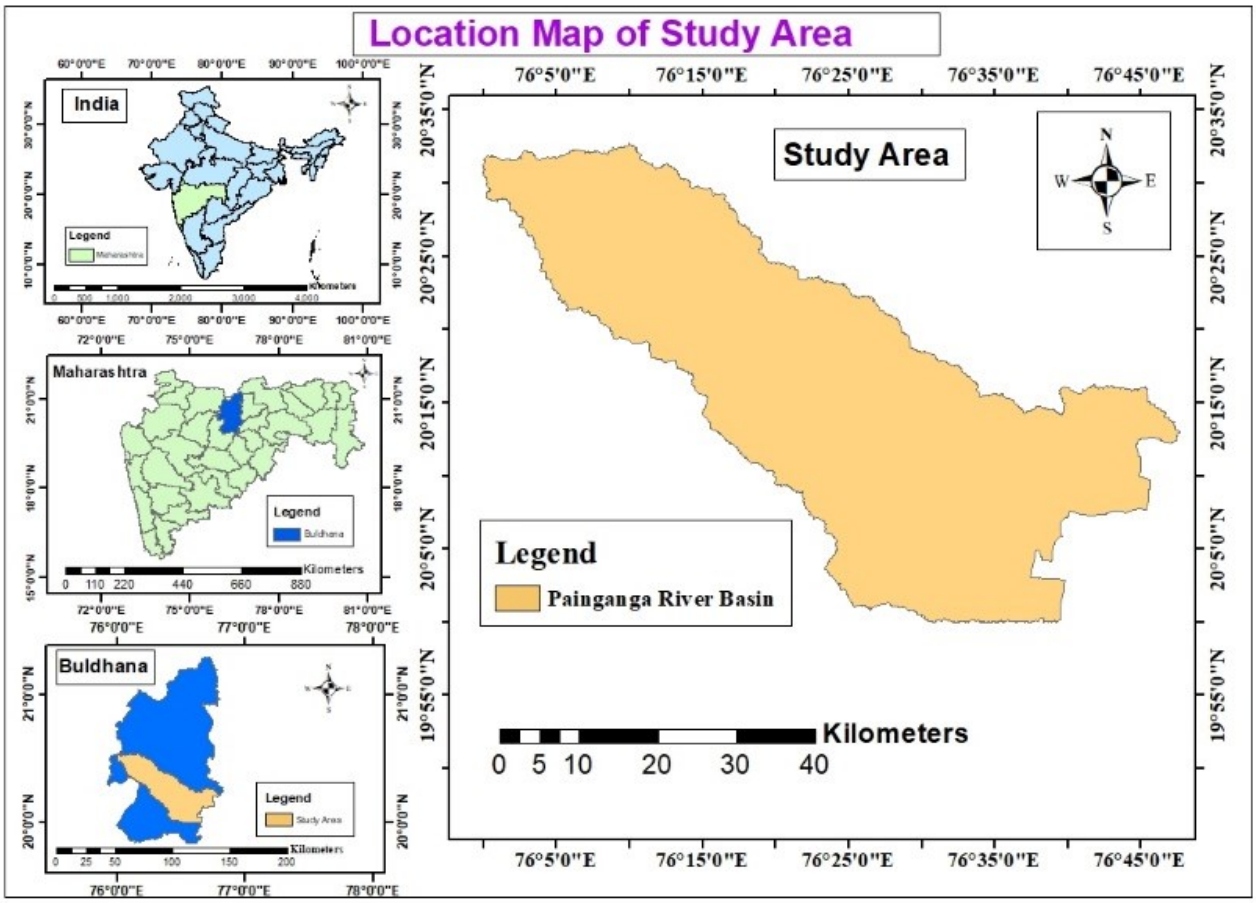

Figure 1. Location map of study area

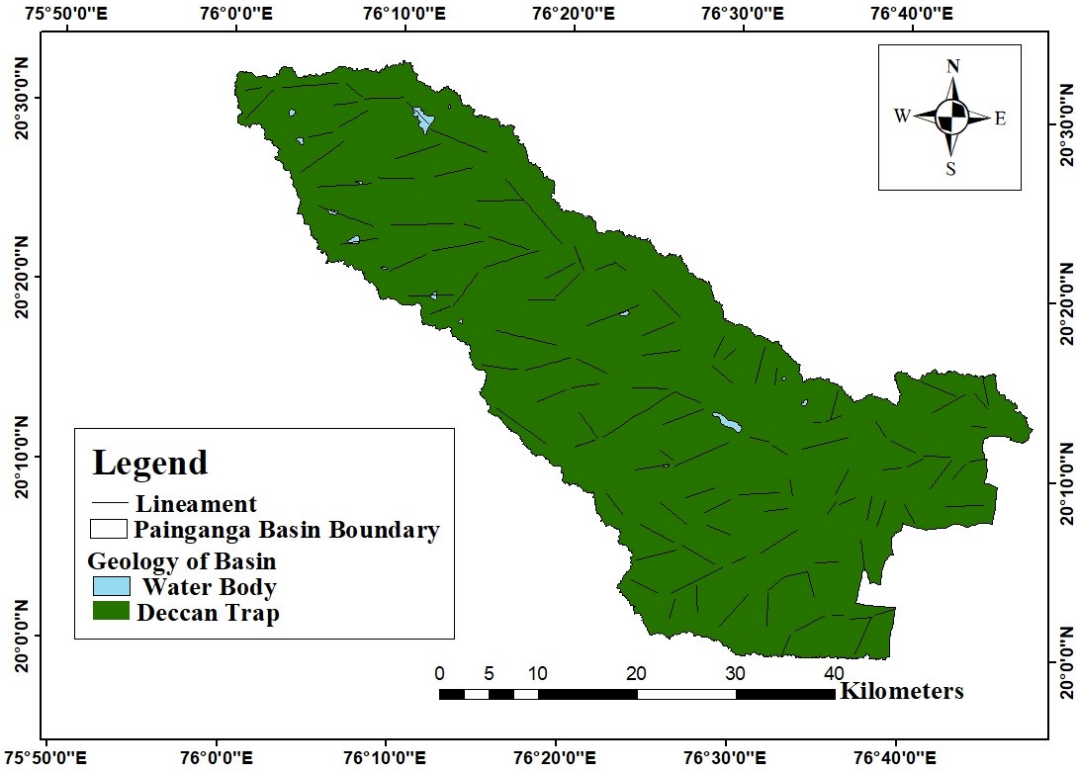

Figure 2. Geological map of Painganga Basin in Buldhana District (Source: G. G. Deshpande, 2012; GSDA Buldhana and Bhukosh, GSI).

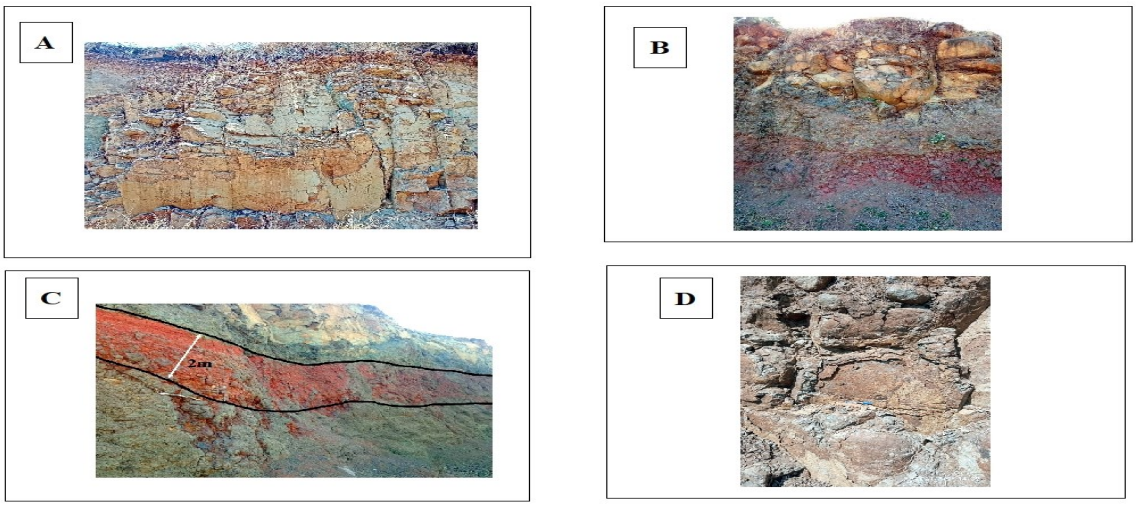

Figure 3. Field photo (A) Jointing pattern in massive basalt of road cutting section (B) Jointing pattern near to kanchani mahal (C) Redbole (D) Spheroidal weathering.

2. Analytical methods

Hydro-geomorphological map of the watershed is prepared using remote sensing and GIS techniques. The survey of India Toposheet number 55-D3, 55-D7, 55-D8 and 55-D12 with the scale of 1:50000 were used for preparation of the base map. The scanned toposheet number 55D/3, 55D/7, 55D/8 and 55D/12 geo-referenced in Arc GIS 10.3 and stream systems were digitized using the Arc digitizing tool and Strahler (1964) stream ordering method. Quantitative morphometric analysis of Painganga river basin is carried out and calculated the various aspect ratios (linear, areal and relief) using standard techniques. Morphometric parameters related to stream including the order, length, length ratio and bifurcation ratio along with the aerial features like drainage density, stream frequency, form factor, circulatory ratio and elongated ratio has been calculated. Percentage hypsometric curve (Strahler, 1952), which involves a ratio of relative height expressed in percentage (cumulative (hx100)/H) is plotted on the relative height and relative area expressed in percentage (cumulative (ax100)/A). In this calculation, 'a' and 'h' respectively denote the area and height between the successive contours, and 'A' and 'H' respectively denote the total area and total height of the basin. The areas between successive contours measured by digital planimeter and their respective heights obtained from the topographic maps are the basic data required for the study of area-height relationship. After plotting these values on a simple arithmetic graph paper and joining all the points,

a smooth line percentage hypsometric curve was prepared. The hypsometric integral (HI) was calculated mathematically from the graph. Longitudinal profile of the Painganga River is drawn from the contour map. Drainage basin analysis was carried out by using SRTM-DEM data with a 90 m resolution map collected from USGS database (https://earthexplorer.usgs.gov). DEM map created by sing software Arc GIS 10.3 (Figure 4). The extractions of stream network were prepared using hydrology tool in Arc GIS 10.3 software and the methodology is shown in flow chart diagram (Figure 5) and other additional processes in Figure 6. Basin boundary was collected from GSDA office, Buldhana, Maharashtra and Geomorphological map data was downloaded from Bhukosh, Geological Survey of India. Groundwater potential zone map was created with the help of groundwater capability of geomorphic unit observed in basin area.

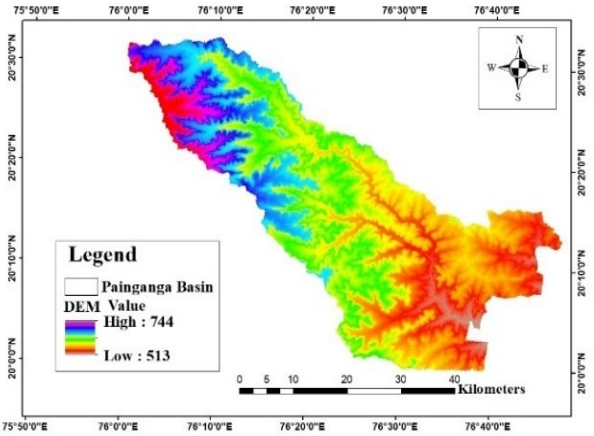

Figure 4. DEM of study area

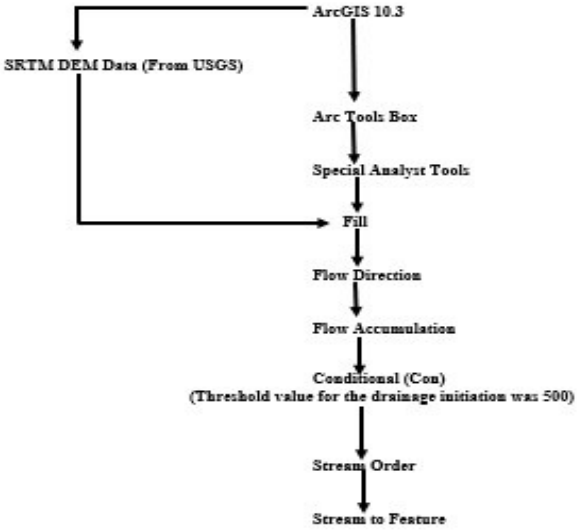

Figure 5. Flowchart for stream order extraction

3. Results

The drainage characteristics of Painganga River basin has been examined with reference to linear, aerial and relief aspects. The digital elevation model (DEM), drainage map, contour map and geomorphological map of the Painganga river basin shown in Figure 4, Figure 7, Figure 8 and Figure 11, respectively. Detailed morphometric data are enclosed in Table 2 and geomorphic unit in Table 3. Where, B-Butte, ES- Escarpment slope, M-Mesa, PLH - plateau highly dissected, PLM- Plateau moderately dissected, PLS-plateau slightly dissected, PLW- plateau weathered and PLWS- plateau weathered shallow.

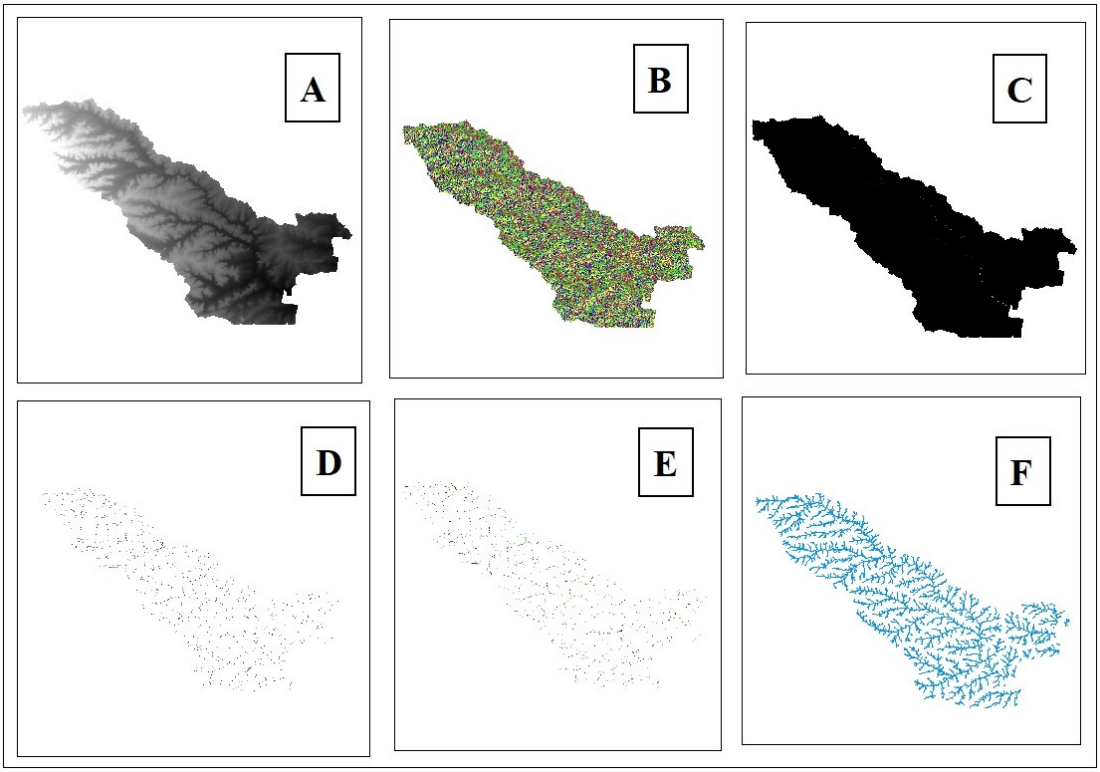

Figure 6. Stream network extraction using DEM data: (A) Fill (B) Flow direction (C) Flow accumulation (D) Conditional (Con) (E) Stream Order (F) Stream to Feature.

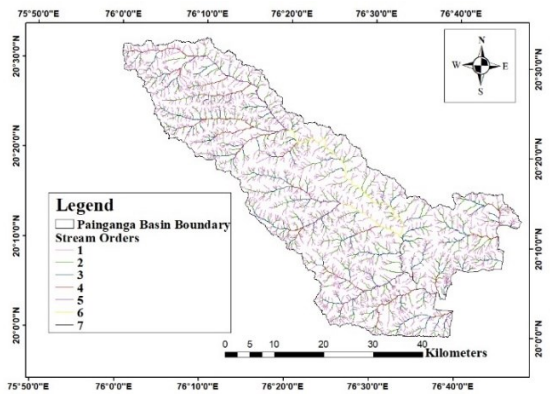

Figure 7. Drainage Map of Painganga River Basin

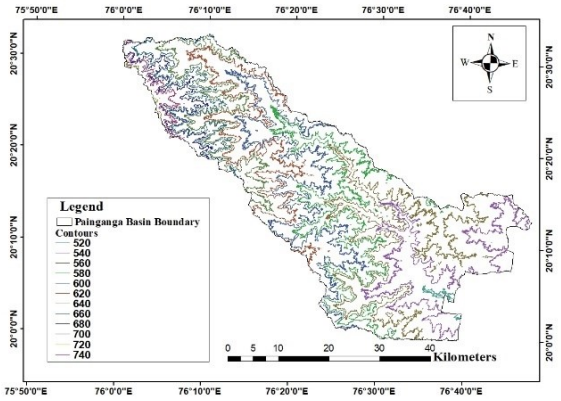

Figure 8. Contour Map of Painganga River Basin

3.1 Linear morphometric aspects

a) Stream order (U): The main step in any drainage basin is investigation of order designation, stream orders and is based on ranking of streams. The results revealed that the first order streams have maximum frequency and there is a decrease in stream frequency as the stream order increases.

b) Stream Number (Nu): The number of streams decrease as the order increases and higher the stream order lower the permeability and infiltration. Stream of each order is counted to get the number of streams of the given order (u). Stream lengths of the different stream orders were calculated. In the study area, the total no of streams is 3208, out of which first order streams have 2438. The second order streams are 598, third order are 133, fourth order are 31, fifth order are 5, sixth order are 02and seventh order are 1 (Table 1).

c) Stream Length (Lu): Stream length is one of the most significant geomorphological parameters of any basin, as it reflects the surface run-off actions. Total length of first order streams are ~1709.94 km, which is highest among all the stream orders. This length decreases as the stream order increases with second order at ~647.39 km, third order at ~310.15 km, fourth order at ~159.73 km, fifth order at ~72.10 km, sixth order at ~59.17 km and seventh order at ~19.71 km.

d) Bifurcation Ratio (Rb): Bifurcation ratio is a ratio of number of streams for a given order to the number of streams of the next higher order (Ziaur et al., 2012). Bifurcation ratio is a factor that affects the discharge rate of a river mainly after the precipitation. According to Strahler (1964), the bifurcation ratio (Rb) larger than 5 is an indication of structural control of the drainage and vice versa for the low bifurcation ratio. Higher bifurcation ratio (Rb) also indicates some sort of geological control, for example mean bifurcation ratio values for a flat and rolling surfaces is up to 2.0 and for mountains and highly dissected basins it is 3 and 4. Within a basin, bifurcation ratio tends to decrease with increasing order. Mean bifurcation ratio of the studied area is ~3.927, which indicates that there is no geological and structure control on the drainage pattern

e) Stream Length Ratio: The ratio of mean stream length of a given order to mean stream length of the next lower order (Horton, 1945). It is the ratio of the total length of streams to the total no of streams and particular ordered stream (Singh et al., 2020). Change in the stream length ratio from one order to another order indicates the development of youth stage of streams. The stream length ratio in the study area varies from 1.218 to 3.002given in Table 1.

f) Rho Coefficient: Horton (1945) defined the Rho coefficient as the ratio between stream length ratio and the bifurcation ratio. Rho coefficient determines the relationship between drainage density and physiographic development of the basin, and allow the evaluation of storage capacity of drainage network (Horton, 1945). Rho coefficient of the study area is 0.556 and this value indicates moderate hydrological storage during the flood. It is influenced by climatic, geological, geomorphological and anthropogenic factors (Prabu and Baskaran, 2013).

Table 1. Stream length Bifurcation Ration of Painganga river basin.

Stream Order	No. of Stream	Minimum Length of Stream in km	Maximum Length of Stream in km	Mean Length of Stream in km	Total Length of Stream in km	Stream Length Ratio	Bifurcation Ratio
I	2438	0.00043	3.602	0.701	1709.94	2.641	-
II	598	0.017	6.089	1.082	647.39	2.087	4.077
III	133	0.021	10.135	2.332	310.15	1.942	4.496
IV	31	0.042	17.508	5.152	159.73	2.215	4.290
V	05	6.532	32.244	14.420	72.10	1.218	6.2
VI	02	15.387	43.787	29.587	59.17	3.002	2.5
VII	01	19.716	19.716	19.716	19.71	-	2.0
Total	3208	-	-	-	2978.19	13.105	23.563
Mean	-	-	-	-	496.365	2.184	3.927

3.2 Basin geometry

a) Basin Perimeter (P): Basin perimeter is an external boundary of the watershed that enclosed its area. It is considered as a divide between the watersheds and may be used as an indicator of watershed size and shape. We have computed the basin perimeter by using ArcGIS-10.3 software, which is ~322.961 km (Table 2).

b) Basin Area (A): Area of the Painganga river basin is one most important parameter, which is similar to the length of the stream drainage to established a stimulating relation between the total basin areas and the total stream lengths, which are supported by the contributing areas (Schumm, 1956). In our study of the Painganga river basin, the basin area is ~1891.144 sq. km (Table 2).

c) Basin Length (Lb): Schumm (1956) defined the basin length as the highest dimension of the basin parallel to the main drainage line. The length of the Painganga river basin in accordance with this definition is ~107.934 km (Table 2).

d) Length Area Relation (Lar): Hack (1957), establish that for a large number of basins, stream length and basin area is related by a simple power function. The length area relation of the Painganga river basin is ~1588.561 (Table 2).

e) Lemniscates (k): Lemniscate's value is used to measure the slope of the basin. Lemniscates (K) value for the Painganga river basin is ~1.540, which shows that the watershed occupies the maximum area in its regions of inception with large number of streams of higher order.

f) Form Factor (Ff): Form factor is the ratio of basin area to the square of basin length (Zaidi, 2011). It correlates between catchment area and catchment length (Fryirs and Brierley 2013). A basin with higher form factor is usually circular and have high peak flows for shorter time period, whereas elongated basin with lower value of form factor has low peak flows for longer time period (Akram et al., 2011). In our study area, the value of form factor is 0.057 (Table 2) indicating that the basin represents elongated shape with lower peak flows for longer time period.

g) Elongation Ratio (Re): Schumm (1956) described elongation ratio as the ratio of diameter of a circle of the same area as the drainage basin and the maximum length of the basin. Re values close to unity correspond to regions of low relief, the Re values in the range 0.6-0.8 are usually associated with high relief and steep ground slope. These values can be divided into three categories namely (a) circular (>0.9), (b) oval (0.8-0.9), (c)less elongated (0.7-0.8) (d) elongated (<0.7). The Re values of the Painganga river basin is 0.455 indicating an elongated shape (Table 2).

h) Texture Ratio (T): Texture ratio (T) is a ratio of total number of streams of any order and perimeter of the area in which it lays. It is an important factor in the drainage morphometric analysis which is depending on the underline lithology, infiltration capacity and relief aspect of the terrain. Texture ratio is depending on a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration ability, relief and stage of development. Based on the values of T it is classified as 0 to 4 Coarse; 4 to 10 Intermediate; 10 to 15 Fine; 15< very fine (bad l and topography). In the present study area texture ratio (7.549) of the basin is categorize as intermediate in the nature (Table 2).

i) Circulatory Ratio (Rc): The circularity ratio (Rc) is the ratio of basin area (Au) to the area of a circle (Ac) having same perimeter as the basin (Strahler, 1964). It is affected by the lithological character of the basin and generally relates with length and frequency of the streams, geological structures, land use/land cover, climate, relief and slope of the basin (Rudraiah et al., 2008). The watershed values are less than 0.5 indicate basin elongation whereas the enduring watersheds have values greater than 0.5, values suggesting that they are more or less circular in shape, characterized by moderate to high relief. In the study area, Rc value is 0.228 and this value indicates basin is elongated (Table 2).

j) Compactness coefficient (Cc): Compactness coefficient is expressed as the ratio of the length of drainage basin boundary and the perimeter of a circle with same area (Prabu and Baskaran, 2013). It is the relationship between the shape of drainage basin and circle. The compactness coefficient of study area is 2.110 (Table 2).

3.3 Drainage texture analysis

a) Stream Frequency (Fs): The stream frequency introduced by Horton (1932 and 1945), it is calculated by the total number of streams of all orders and basin per unit area. It exhibits positive relationship with drainage density in the watershed representing an increase in stream population with respect to increase in drainage density. In the present study, the stream frequency of the watershed is 1.696. This value indicates that the rocks of valley are solid in nature (Table 2).

b) Drainage Density (Dd): Drainage density is the stream length per unit area of watershed is another element of drainage analysis (Horton 1945; Strahler 1952 and Melton 1958). Drainage density indicates the closeness of spacing of channels and provides a numerical measurement of the landscape dissection and surface runoff potential (Horton, 1945). In general, high drainage density value is outcome of impermeable sub-surface material, thin vegetation and mountainous relief whereas area having more resistant rock or more permeable subsoil materials, broad vegetative covers. Low drainage density leads to coarse drainage texture suggesting the area having permeable sub-soil material while high drainage density leads to fine drainage texture thereby implying relatively impermeable rock structure. The drainage density is described as low when < 2 km, moderate when it is between 2 to 5 km and high when it is > 5 km. The drainage density has calculated by ArcGIS-10.3 using Spatial Analyst Tool. The drainage density for this watershed is 1.575 km indicating low drainage density (Table 2).

c) Drainage Texture: Drainage texture (T) is one of the significant concepts of geomorphology, which means relative spacing of drainage lines. It is the total number of streams of all orders per perimeter of basin area (Horton 1945). Smith (1950) have classified drainage texture into five different textures i. e. very coarse (<2), coarse (2 to 4), moderate (4 to 6), fine (6 to 8) and very fine (>8). The low drainage density leads to coarse drainage and high drainage density shows fine drainage texture (Arulbalaji and Padmalal, 2020). The value of drainage texture in study area is 2.671 (Table 2) which indicate that the texture is coarse and coarse drainage texture represent to a presence of massive and resistive rocks (Ziaur et. al. 2012).

d) Drainage Pattern (Dp): Drainage pattern is the universal arrangement of channels in a drainage basin. Two types of drainage patterns namely dendritic to sub-dendritic are recorded in the studied basin. In a drainage basin generally, dendritic pattern is common pattern and composed of fairly non heterogeneous rock without control by the fundamental geological structures. Dendritic pattern is formed when the longer time of formation of a drainage basin.

e) Length of overland flow (Lf): Length of overland flow (Lf) is the length of water over the ground surface before it gets concentrated into definite stream channel (Horton, 1945). Lf is one of the most important independent variables affecting hydrological and physiographic development of drainage basins (Akram et al. 2011). The Lf is nearly equal to the half of the reciprocal of drainage density. The Lf value of study area is 0.787 (Table 2).

f) Constant channel maintenance (C): Schumm (1956) used the termed constant of stream maintenance C inverse of drainage density. This constant, is expressed in units of square feet per foot, has the measurement of length and therefore increase in magnitude as the scale of the landform unit increases. The value C of basin is 0.635 (Table 2). It means that on an average 0.635 surface is needed in basin for creation of one linear foot of the stream channel.

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Table 2. Detailed drainage basin parameters, acronyms, formula and results of Painganga river basin.

Sr. No.	Parameters	Acronym	Formula	Results
Linear Morphometry				
1	Stream order	U	-	1-7
2	Stream Number	Nu	Nu = N1+N2+...Nn	3208
3	Stream Length	Lu	-	2978.19 km
4	Stream Length Ratio	Lur	Lur = Lu / Lu-1	1.218 - 3.002
5	Bifurcation Ratio	Rb	Rb = Nu / N(u+1)	2.0 - 6.2
6	Mean Bifurcation Ratio	-	-	3.927
7	Rho Coefficient	ρ	Lur / Rb	0.556
Basin Geometry				
8	Basin Perimeter	P	-	322.961km
9	Basin Area	A	-	1891.144 km^2
10	Basin Length	Lb	-	107.934 km
11	Length Area Relation	Lar	Lar = 1.4 * A0.6	1588.561
12	Lemniscates	K	$k = Lb^2 / 4* A$	1.540
13	Form Factor	Ff	$Ff = A / Lb^2$	0.162
14	Elongation Ratio	Re	$Re = 2\sqrt{(A /\pi)} / Lb$	0.455
15	Texture Ratio	T	$T = N_1 / P$	7.549
16	Circulatory Ratio	Rc	$Rc = 4\pi A / P^2$	0.228
17	Compactness Coefficient	Cc	$Cc = 0.2841\times P / A^{0.5}$	2.110
Drainage Texture Analysis				
18	Stream Frequency	Fs	Fs = Nu /A	1.696
19	Drainage Density	Dd	Dd = Lu / A	1.575 km
20	Drainage Texture	T	T = Dd × Fs	2.671
21	Drainage Pattern	Dp	-	Dendritic to Sub-dendritic
22	Length of Overland Flow	Lf	Lf = ½ Dd	0.787 km
23	Constant Channel Maintenance	C	C = 1 / Dd	0.635
24	Ruggedness Number	Rn	Rn = Dd × (H/1000)	1.172
25	Maximum Height of Basin	Z	-	744 m
26	Minimum Height of Basin	z	-	513m
27	Total Basin Relief	H	H= Z-z	231 m
28	Relief Ratio	Rh	Rh = H/ Lb	6.893
29	Absolute Relief	Ra	-	744 m
30	Dissection Index	Dis	Dis = Rh / Ra	0.009

g) Ruggedness Number (Rn): Ruggedness Number (Rn) is the product of basin relief and the drainage density which indicates the structural complexity of the terrain (Schumm, 1956). The low ruggedness value of basin implies that region is less flat to soil erosion and have basic structural complexity in relationship with relief and drainage density. The high ruggedness value activates the change of erosion and affects the water potential of the basin. The Rn value of the Painganga river basin is 1.172 (Table 2).

h) Relief Ratio (Rh): The relative relief of basin is a difference in the elevation between the highest point and the lowest point on the basin. The relief ratio is dimensionless number which provides a measured in elevation per unit length of river (Fryirs and Brierley, 2013). The relief ratio of study area is 6.893 (Table 2). This value indicates that study area with moderate relief ratio.

i) Absolute Relief (Ra): The difference in elevation between a given location and sea level. Ra is the maximum height of a known location in a river basin. The absolute relief of the area is 744m (Table 2).

j) Dissection Index (Dis): The ratio between relative reliefs to its absolute relief is called dissection index (Mahala 2020). The value of dissection index ranges between 0 (absence of vertical dissection) to 1 (vertical areas) and dissection value near to 0 indicates maximum denudation stages of evaluation and near to 1 indicate minimum denudation of geomorphic evolution (Mahala, 2020). Dissection index of the basin is 0.009 which indicate that the basin is moderately dissected (Table 2)

3.4 Hypsometric analysis

Hypsometry is the measurement of height of land from sea level. It also represents the association between elevation and area of basin in any watershed or catchment (Strahler 1952 and Golekar et al. 2015). Hypsometric curve (HC) and hypsometric integral (HI) are very important to calculate basin flood response and erosional stage. The Hypsometric curve of Painganga basin suggests that the larger part of the area is moderate to gentle slope (Figure 9). The curve can be characterized as mature/equilibrium stage of landscape development. The curve shows 54 % of area comes under the elevation between 500m -560m and curve shows 36 % of the area between 560m -620m elevation. Whereas curve shows 8 % area between 620m-680m elevation and curve shows 1 % area between 680m-740m elevation. From the present study of contour map, we have calculated two ratios as follows: 1) Area of a given contour inside the basin boundary. 2) Contour height of the over the stream mouth. A graph of relative area verses relative height plotted for Painganga basin.

3.5 Profile analysis

Longitudinal profile is drawn from the topographic map which is an image observation of the real environment of the landscape. The longitudinal section of the valley is called longitudinal profile. The entire distance from source to the mouth of a particular river is considered. The graph drawn reveals the relief impact of the river course (Singh, 1997). The longitudinal profile provides breaks in the longitudinal course of the river flow. These breaks may indicate nick points, and helps in examining the nature and control of landform development (Singh, 1997). Longitudinal profile gives geomorphologists an insight of relief and topographical impact on river flow (Babar, 2005).

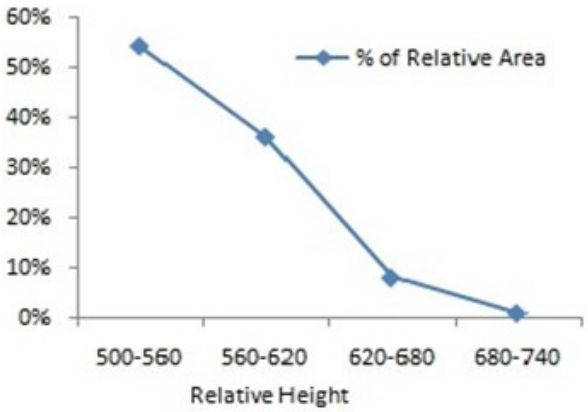

Figure 9. Hypsometric curve of Painganga river basin

3.5.1 Longitudinal profile of the Painganga river basin

The Painganga River originates near village Madh at 681 m and flows almost straight towards east (Figure 10). The slope is gentle with a drop in elevation from 681m to 609m, spreading over 20 km (Figure10). From the south of village Sagwan, Painganga River turns toward south east. After that slope of river Painganga shows moderately gentle with a drop in elevation from 609m to 577m, spreading over 20 km (Figure10). After 40 km of river course, longitudinal profile seen that the river channel is near to the flat with a drop in elevation from 577m to 565m (Figure 10). Once more Painganga river channel showed that moderately gentle slope with a drop in elevation from 609m to 577m, spreading over 20 km (Figure 10). Afterward the 80 km from origin the river channel is near to the flat with a drop in elevation from 533m to 516m (Figure10)

3.5.2 Hypsometric Integral (HI)

Hypsometric investigation can be carried out to conclude stages of river development. The relative area and relative height data are calculated using contour map of 20 m contour interval in ArcGIS-10.3 software. Strahler (1952) classed values of HI and HC into three important classes. Pike and Wilson (1971) proved mathematically that the elevation-relief ratio E which is defined as integration of the hypsometric curve gives the hypsometric integral (I) and given in equation below;

$$E \approx Hsi = \frac{\text{Elev mean} - \text{Elev min}}{\text{Elev max} - \text{Elev min}}$$

Where, E is the elevation-relief ratio equivalent to the hypsometric integral HI; Elevation mean is the weighted mean elevation of the basin estimated from the identifiable contours of the delineated basin; Elevation minimum and Elevation maximum are the minimum and maximum elevations within the basin, the hypsometric integral is expressed in percentage units. If HI values >0.60 is youth stage (Convex Curve), 0.30 to 0.60 for mature stage (Sigmoidal Curve) and HI <0.30 for old stage (Concave Curve).

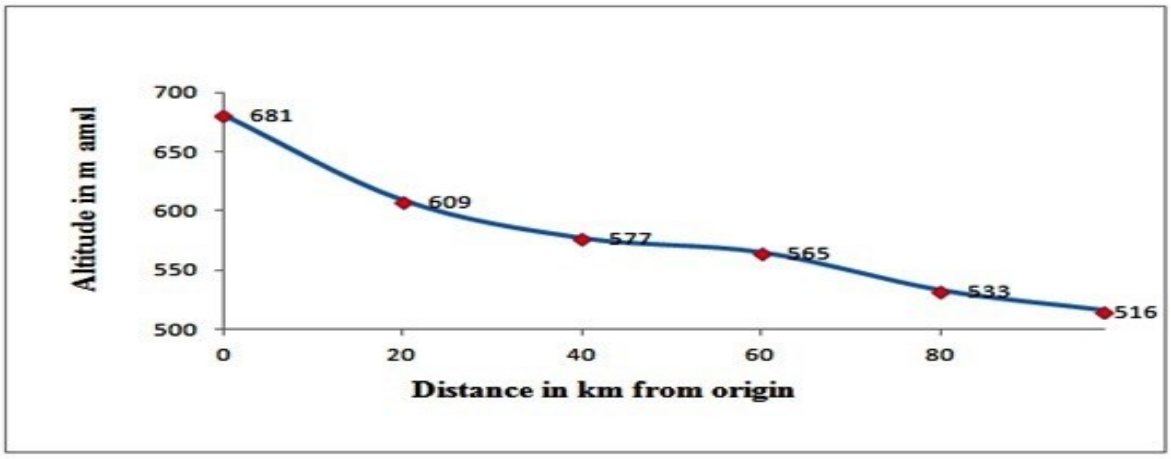

Figure 10. Longitudinal profile of the Painganga river basin.

3.6 Hydrogeomorphology

Geomorphological unit in the studied area were given in map (Figure 11 and Table 3). Hydrogeomorphology is a developing interdisciplinary scientific field, which studies the relationships between geomorphology and hydrology (surface water/groundwater). In a general sense, it links together several fields related with geosciences, hydrology and physical geography, such as geology, hydrogeology, geomorphology, remote sensing, applied geophysics, soil and rock geotechnics, climatology and natural hazards (Babar, 2005). Hydrogeomorphology operates in an interdisciplinary framework focused on the relationship between hydrologic processes with Earth materials and the interaction of geomorphic processes relating surface water/groundwater flow regime (Babar, 2005). Alluvial plain represents the runoff zone while valley belongs to discharge zone, and the denudational hills constitute the infiltration area. It is classified into three zones on the basis of their groundwater potential zone as a) Very favorable zones b) Good to moderate zones and c) Poor zone. The groundwater potential zones are identified with the help of geomorphological units.

3.6.1 Mesa and Buttes: Mesas and buttes are generally found in fairly dry areas. The ground water prospect is very poor in these areas due to fast runoffs over steep slopes so they fall under the category of very poor groundwater potential zone (Figure 11). The area covered by mesa and buttes are 2.64sqkm and 2.20sqkm respectively.

3.6.2 Escarpments: Escarpments are observed in top of the hills and normally seen as step-like surfaces (Singh et al., 2013). It is classified as poor groundwater accumulation zones (Singh et al., 2013) and its cover128.51sqkm area.

3.6. 3 Dissected Plateau (DPT): An extensive flat top and steep slopes formed over horizontally layered Deccan basalts that may be crossed by fractures, joints and lineaments are called as plateaus (Babar, 2005). These units can be expressed regarding the slope of the area, runoff characteristics, drainage density, stream frequency and relief ratio of the area (Babar, 2005). In the present study area, six plateaus were observed, i.e., highly dissected plateau, moderately dissected plateau, slightly dissected plateau, un-dissected plateau, weathered plateau and shallow weathered plateau.

a) Plateau Highly Dissected: This unit geomorphic represents a plateau more often dissected by deep valleys separating individual mesa and buttes and shallow aquifers completely drain away into deep valleys (Sharma and Shukla, 2015). This geomorphic unit is secondary in the studied river basin. The land of this unit is dissected by the streams of the watershed giving rise to a terrain consisting of flat-topped ridges and steep scarps. This unit in the study area covers about 0.04 % of the total area of the basin (0.69 km^2).

b) Plateau moderately dissected: The soils covering in this plateau are moderately thick and well drained. High moisture capacity suggests that the irrigation requirement is moderate in the moderately dissected plateau area. The groundwater potential in these units is moderate to high. In this geomorphic unit shallow aquifer partially drains out into deep valleys (Sharma and Shukla, 2015). Moderately dissected plateau is demarcated as PLM in geomorphological map of the study area which showed in light pink colored (Figure 11). The area covers by this unit is about 1.26 % of the total area of the basin (24.71 km^2).

c) Plateau slightly dissected: This unit covered by 979.81 sqkm area in middle portion of the Painganga river basin. This unit is inferred to recharge and storage zone for groundwater. PLS is good potential zones for groundwater resources or groundwater exploration.

d) Plateau un-dissected: The land of this unit is dissected by the streams of giving rise to un-dissected terrain consisting of flat-topped hills and steep scarps. The groundwater potential in these units is very poor (Babar, 2005). This unit is observed between moderately dissected plateau and eroded lad by stream. The runoff from these areas can be arrested through the construction of check dams and other strategies. Plateau un-dissected is demarcated as PLU in geomorphological map of the study area which showed in sky blue colored (Figure 11). The area covers by this unit is about 6.98 % of the total area of the basin (136.55 km^2).

e) Plateau weathered: Plateau weathered are found in the basin along the major stream in lower reaches. These units have good potential for agriculture. The area covers from

this unit is about 14.89 % of the total area of the basin (291.55 km^2). Plateau weathered is demarcated as PLW in geomorphological map of the study area which showed in light green colored (Figure 11). The Plateau weathered is consisting of weathered product of the surrounding basaltic rocks, mostly comprise moderately thick gravel beds along with sand and silt layers. The groundwater potential ranges from good to moderate.

f) Plateau weathered shallow: Plateau weathered shallow are found in the watershed along the stream in middle reaches. These units have moderate potential for groundwater. The area covers from this unit is about 19.97 % of the total area of the basin (390.93 km^2). Plateau weathered shallow is demarcated as PLWS in geomorphological map of the study area which showed in dark purple colored (Figure 11). The Plateau weathered shallow is consisting of moderately weathered product of the surrounding basaltic rocks, mostly comprise moderately thick gravel beds along with sand and silt layers. This area shows groundwater availability only in the winter season, while during summer season most of the wells in going to dry.

Table 3. Area covers by different Geomorphological units in the Painganga river basin, Buldhana district.

Sr. No.	Name of the Geomorphological Unit	Area (km^2)	Percentage of the area
01	Butte	2.20	0.11 %
02	Escarpment slope	128.51	6.56 %
03	Mesa	2.64	0.13 %
04	PLH - Plateau highly dissected	0.69	0.04 %
05	PLM - Plateau moderately dissected	24.71	1.26 %
06	PLS - Plateau slightly dissected	979.81	50.05 %
07	PLU - Plateau un-dissected	136.55	6.98 %
08	PLW - Plateau weathered	291.55	14.89 %
09	PLWS - Plateau weathered shallow	390.93	19.97 %
Total Area		1957.59	100.00 %

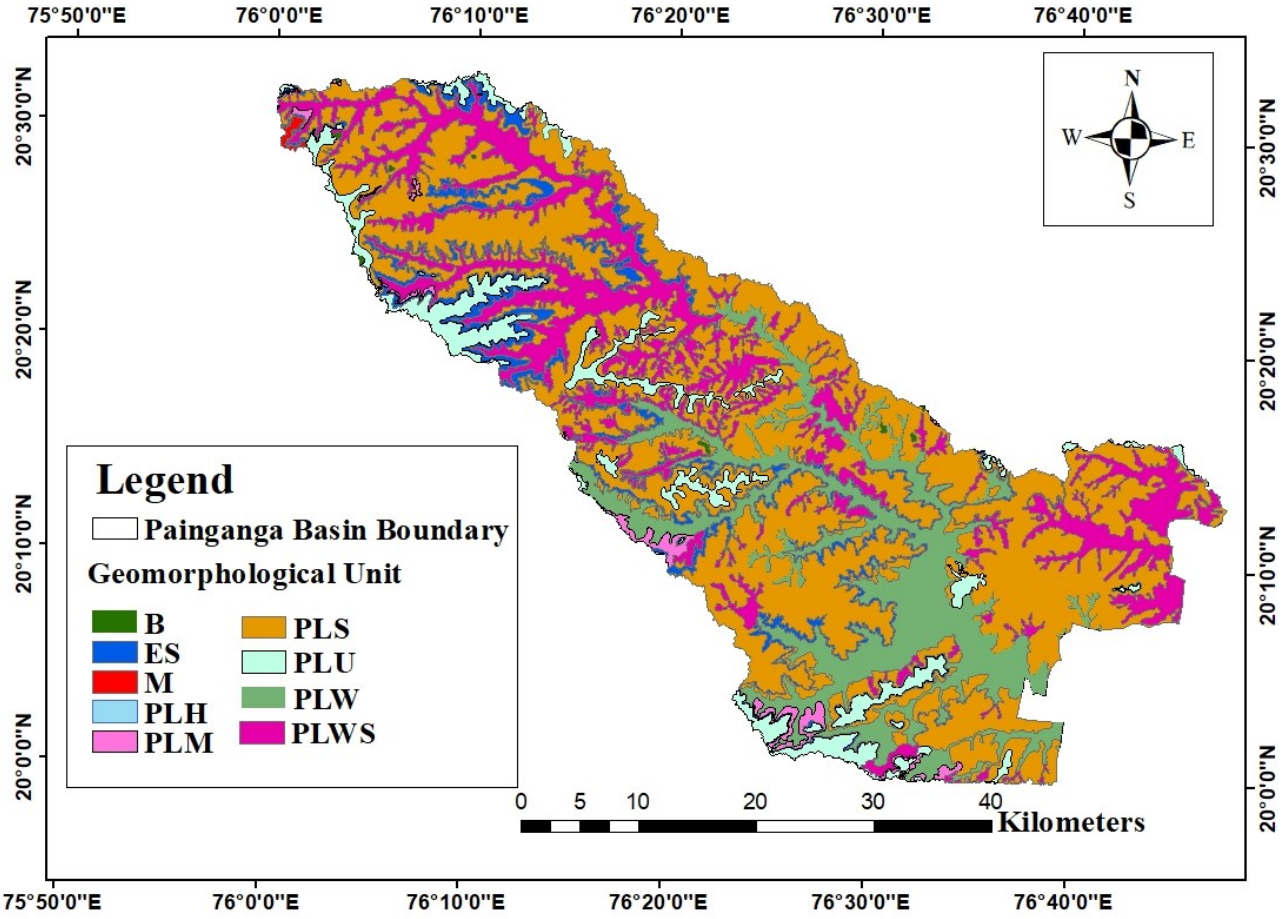

Figure 11. Geomorphological Map of Painganga River Basin (Source: Bhukosh, Geological Survey of India).

4. Discussion

The number of total streams in current study area is 3208 which covers Ist order 76.00%, IInd order 18.64%, IIIrd order 4.14%, IVth order 0.97%, Vth order 0.15%, VIth order 0.06% and VIIth order streams 0.03%. Due to high numbers of the Ist and IInd orders in the high elevated areas, runoff is higher in these parts of the basin. The first order streams present in larger number indicates a uniform lithology and a gentle slope (Kale and Gupta, 2001, Singh and Awasthi, 2011), which suggests that the major portion of precipitation goes to the surface runoff. Morphometry of basin is characterized by a linear and an aerial relief aspect. There is a linear relationship with small deviation of the stream numbers and stream length against stream order. This is an implication of trend line that conform a linear relationship of the stream number and stream length. Stream length ratio is showing variation between streams of different orders, which may be due to the variation in topography. The difference between one order to another order of stream length ratios indicates a mature stage of geomorphic development, further suggesting an important correlation with runoff and erosional status of the basin. The value of bifurcation ratio ranges from 3 to 5 that indicates the basin may have any geological structures but do not distort drainage pattern (Nag, 1998). However, bifurcation ratio value >5 revels that basin is lithological and structurally controlled (Strahler, 1964) and the value of bifurcation ratio <3 it means the basin has any flat region. This bifurcation ratio value (3.927) calculated for the studied area indicates that the geological composition and structure of the area do not control the drainage pattern and flat basin region. Rho coefficient value of the studied basin is 0.556 indicating basin belongs to a moderate hydrological storage during the flood. Elongated nature of the river basin has an implication on both hydrologic and geomorphic processes (Singh et al., 2020). The flow of water of this basin distributed over a longer period of time for distribution, susceptible to erosion and sediment load (Angilliri, 2008). Stream frequency values of the Painganga river basin indicate that the rocks of valley are solid in nature. Ruggedness value of the basin is relatively high, which suggests that there is a chance of high erosion and low water potentiality. This relief ratio values indicates that study area has a moderate relief ratio. From the drainage texture ratio of the studied area, it is observed that the basin can be categorize into an intermediate stage in the nature. Drainage density of the Painganga rivers basin show low values that indicates high infiltration rates (Babar, 2005). This suggest that the study area is most feasible for constructions of new soil and water conservation structure for further development of groundwater. The length of overland flow values of the Painganga basin indicates gentle slopes and longer flow paths. The Re values usually ranges between 0.6 to 1.0 over a wide variety of climate and geologic types. The Re values near to 1.0 are the features of the area of very low relief zone; while, the values in a range of 0.6 to 0.8 generally occur in areas of high relief and steep ground slope (Strahler, 1964). The elongation ratio (Re = 0.455) of given basin shows that the basin is elongated and dendritic drainage pattern which is indicate that less structural control and homogeneous lithology (Shimpi et. al., 2014). Dendritic drainage pattern is relation with areas having homogeneous lithology and very gentle or flat, rolling topographic (Shimpi et. al., 2014). Study area, the streams or rivers, some of which appear fracture-controlled in their flow path give rise to dendritic drainage pattern. Groundwater tables affect the position and shape by the topography and physiography (Shimpi et. al., 2014). The flow of water in elongated basin takes more time for susceptible to erosion and sediment load (Angilliri, 2008). The low circulatory ratio value ratio (Rc= 0.228) of the basin is consistent with the elongated in shaped, low discharge of runoff and highly permeable conditions of subsurface soil. The hypsometric integral (HI) value of the Painganga river basin is 0.50 and this value indicates that the basin is mature stage of river development (Figure 9). In the mature stage, river has more water flow in the stream channel, i.e., the river has a greater discharge than the youthful river channel. This mean the river is capable to carrying more a greater volume of sediments. A study of longitudinal profile reveals the character of Painganga River. The difference in elevation suggests that the river has developed “rapids”. It is formed due to different erosion, relief and presence of lineament and or joints (Golekar et al., 2015). In the present study area plateau highly dissected, plateau moderately dissected, plateau un-dissected, plateau weathered shallow and plateau weathered units were observed as hydro-geomorphological units. Based on hydrogeological characteristics of the hydro-geomorphological units following recharging structure is recommended for the development of groundwater. Plateau Highly Dissected - in this area, recharge shafts like recharging structures are feasible for the further groundwater development. Plateau moderately dissected - in this area, recharge trenches, Nala bunds, contour bunds, percolation tanks and ground water dams recharging structures are recommended for the further groundwater development. Plateau weathered - These areas were developed along the fractures and such places can be exploited for groundwater through deep bore. Hypsometric integral value of Painganga river basin is 0.50, indicated that 50 percent of the original rock masses still exit in Painganga river basin. It was observed from the H_{si} value that the given basin is in mature/equilibrium stage of landscape development and it show Sigmoidal Curve. This revealed that the soil erosion from this basin was derived primarily from the incision of channel beds, down slop movement of top soil and bed rock material, cutting of stream banks and washout of the soil mass. The hydrological response of the basin attaining mature stage will have slow rate of erosion unless there are very high intense storms leading to high runoff peaks (Ritter et al., 2002). The good and very good groundwater potential zones (Figure 12) are confined generally to high rainfall regions which in turn have high infiltration potential. The moderate groundwater potential zones (Figure 12) occur mostly in the valleys and areas of high drainage density. The poor and very poor groundwater potential zones (Figure 12) occur in the steep slope and high drainage density.

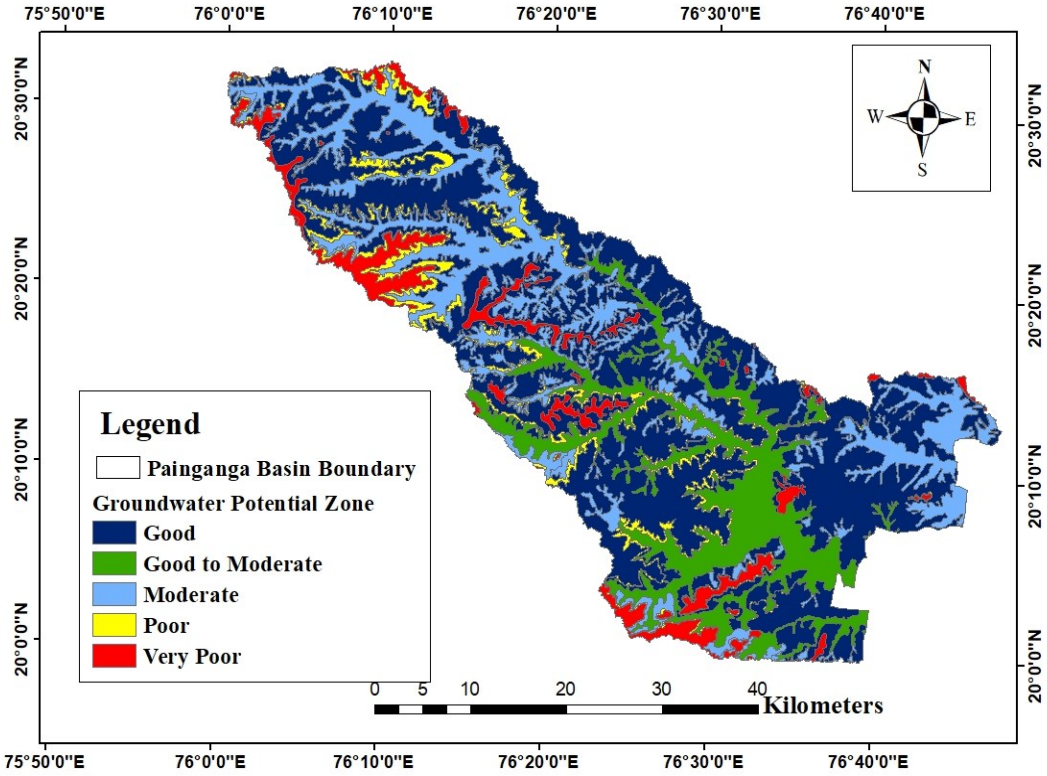

Figure 12. Groundwater potential zones map of Painganga River Basin.

5. Conclusions

The hydrogeological conditions are controlled by topographic features like rivers, slopes, mountains, hills etc. because the geomorphological setup of the area greatly influences the occurrence and movement of groundwater. Considering this fact attempt has been made to undertake detailed morphometric analysis of the Painganga river basin which will be helpful for knowing the relationship of morphometric parameters with groundwater potential and development. GIS techniques have proved that it is correct and a capable tool in drainage description. Three main morphometric features are used i.e., drainage network, basin geometry and drainage texture ratio. The basin under studied is seven orders and its stream order, length ratio and bifurcation ratio indicate that the basin is dendritic and sub dendritic type of drainage pattern. There is no structural or tectonic control. Drainage morphometry data of the present study area indicates that the first order stream present is maximum number of streams. It is also observed that the stream frequency is reduced as the stream order is increases. The total lengths of streams are seen to be decreasing as the stream order increases. Texture ratio of basin is intermediate in nature and elongation ratio and circulatory ratio indicates that shape of basin approximately elongated shape. The ruggedness number of this basin show low value (1.172) due to the occurrence of hard resistant basalts. Digital elevation model and relief ratio of Painganga River basin show moderately relief. The hypsometric integral value the basin is in the equilibrium stage and that the basin is in a mature phase of river development. The hydrogeomorphic units like PLM and PLW have good to moderate for groundwater potential, PLWS have moderately for groundwater potential. The hydro-geomorphic units like PLH, and escarpment (ES) are poor groundwater potential zone and PLU, Mesa and Butte are very poor for groundwater potential zone.

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We,
the Chancellor, Vice-Chancellor
and Members of the Management Council of

Dr. Babasaheb Ambedkar Marathwada University,

Aurangabad (Maharashtra State), India

Certify that the withinsigned

Sandip Kisan Sirsat

who has been found duly qualified for the Degree of

Doctor of Philosophy (Geology)

The Degree of

Doctor of Philosophy

(Geology)

(Under The Faculty of Science & Technology)

has been conferred on him/her at Aurangabad, on the twenty seventh day of the month of June in the year two thousand twenty three.

In Testimony whereof are set the Seal of the said University and the signature of the said Vice-Chancellor.

Date of Notification: **02nd May,2023**
Place : Aurangabad
Date of Issue: **27/06/2023**

Vice-Chancellor