GEOTECHNICAL DATA ANALYSIS USING GIS: A CASE STUDY

[1]Parveen Chander, [2]Dr. Rajiv Chauhan, [3]Dr. Rajesh Kumar

[1]Research Scholar IKG Punjab Technical University Kapurthala, Punjab, India
[2]Department of Civil Engineering, IKG Punjab Technical University Jalandhar, Punjab, India
[3]Department of Civil Engineering, Chandigarh College of Engineering and Technology, Chandigarh, India

Abstract: **The reason for geotechnical site investigation is to prepare a model of the geotechnical frame of reference and interpolations during planning of a project. The model is then used to dissect the undertaking and to settle on venture choices. Geographic Information System (GIS) is extensively used in geotechnical engineering in many different ways. GIS can be utilized as a part of geotechnical site investigation to create a site portrait. In preliminary geotechnical site assessments, GIS can be used for information coordination, information perception and investigation, arranging and condensing site exercises and information introduction. GIS helps in incorporation of previous informational data with project specific information. The coordinated information can be used, to locate the points of data information, hence making the site description. GIS can likewise be utilized to make maps, graphs and figures for further reference to be utilized by project planner. This paper presents the investigation of geotechnical data using GIS. A relevant investigation of Bathinda District of Punjab (India) is discussed in this paper. In this investigation, geotechnical data is analyzed in GIS format. Various maps, graphs and figures are developed based on engineering properties of soil. The paper gives emphasis on different type of soil encountered during soil exploration. Statistical tables and ArcGIS zonation maps based on soil type are presented. Thus, this data is speedily available and can be suggestive and valuable for Engineers and Planners.**

Keywords: **Geotechnical, Data, Soil, ArcGIS, Zonation maps.**

I.   INTRODUCTION

There is a massive challenge in infrastructural development due to insufficient data on physical properties of soil (Shepherd and Walsh, 2007). Soil texture, soil structure and structural form are included in physical properties of soil. An understanding of these properties helps in engineering applications of soil. Soil consistency is vital to the engineer whilst making choice on prudent use of the soil. It provides a method for describing the degree and kind of cohesion and adhesion among the soil particles as associated with the resistance of the soil to deform or rupture consistency (Sowers and George, 1961). The knowledge of soil physical properties is essential in the watershed hydrology management and civil constructions (Buol et al., 1980; Harpstead et al., 1997).

Geotechnical investigation contributes predominantly to the total cost of project. Therefore, sometimes, this aspect is overlooked due to the absence of abundance of sufficient funds available for this important task. Geotechnical data gathered from various governments and private organizations in the midst of project planning, accept a fundamental part in framework of building and foundation works. Geographical Information System (GIS) is an extremely powerful tool for catching, showing and examining topographically referenced information. GIS has demonstrated a vital part in different parts of geotechnical projects for gathering information at out of reach areas.

This paper features a portion of the contextual analyses extending from soil investigation. The outcomes delineate the tremendous capability of GIS towards successfully settling geotechnical project issues under various situations. This work has been done in the field of soil mapping zones, utilizing GIS.

The geotechnical properties have great impact on suitability of soil for construction of a building, development of a project and up gradation of a preexisting construction project. The present techniques for their assurance are costly and tedious. This investigation built up an approach for anticipating soil physical properties utilizing G1S.

An estimation of the soil physical properties was analyzed utilizing the IDW method for spatial analysis of ArcGIS software. The analysis gives a visual and numerical interpretation of the soil physical properties in the Bathinda district of Punjab in India. A guide map of the physical properties of soil was created and is relied upon to give helpful bits of knowledge to development, construction and planning of future projects in the Bathinda district of Punjab in India. This investigation ought to be tried with high determination information sources and other related models, which can enhance the exactness of the information and also forecast of the soil physical properties.

In current years, many airfields, highways, earth dams and bridges have been mounted largely on the premise of soils as an alternate (Lambe 1979; Singh and Chowdhary, 1990). Describing spatial variability enables customers of land resources to make better predictions of soil behavior and performance (Nielsen and Wendroth, 2003) like different engineering materials.

Standard Penetration Test (SPT): This is a common in situ testing method used to decide the geotechnical engineering properties of subsurface soils. Standard Penetration test (SPT), is performed using a standard 50 mm diameter split spoon sampler which is drawn into the ground. The sample tube is driven with the help of dropping weight, 150mm into the soil after which blows required for the tube to penetrate every150mm up to a depth of 450 mm is recorded. The sum of the number of blows required for the second and third150mm of penetration is reported as SPT blow count called N-value. The test is repeated with advancement of borehole till the specified depth is reached. The SPT values are presented in the format of bore log information.

A. The Study Area:

This study covers the area of Bathinda District of Punjab (India) as shown in Fig. 1. District Bathinda is located between two Latitudes 29.840 N and 30.54 N and between two Longitudes 74.70 E and 75.32 E. Bathinda is one of the 22 districts of Punjab state in India. It is the biggest Railway Junction of India. It is also known for the first thermal plant of Punjab. According to population, this is the 10th largest district of Punjab. The total area of Bathinda District is 3,385 km².
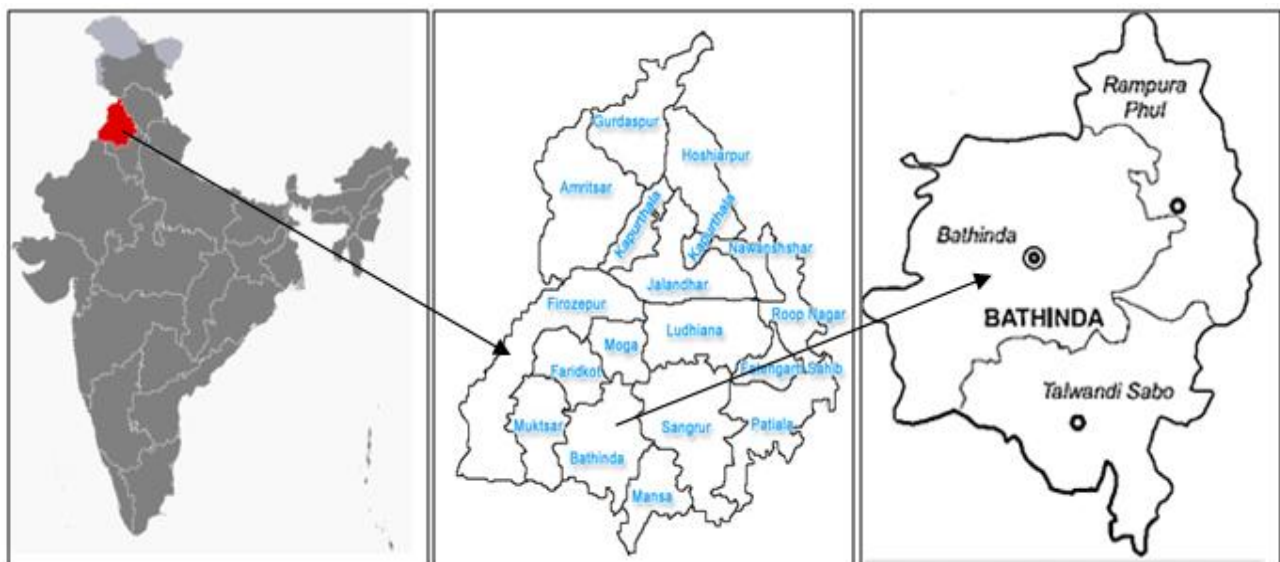

Fig 1: Boundary maps of India, Punjab State and Bathinda District (Study Area)

II. METHODOLOGY

The scope of work in this study included reviewing previous geotechnical studies of the city, conducting additional test pit explorations in areas not previously explored, and presenting the findings. Geotechnical investigation program included studying physical and engineering properties of soil. In the present study, a geotechnical assessment of Bathinda District is carried out as below:

ISSN 2348-1218 (print)

International Journal of Interdisciplinary Research and Innovations   **ISSN 2348-1226 (online)**
Vol. 6, Issue 2, pp: (438-445), Month: April - June 2018, Available at: www.researchpublish.com

A. *Data Collection, Tabulation and Analysis:*

The data collected was in the form of borelogs, which are prepared while performing Standard Penetration Test at the time of soil investigation of a proposed site as shown in Fig. 2.

Depth from NSL (m)	Symbolic Represent ation	IS Classifica tion	Grain Size analysis (%)			Consistency Characterist ics		Bulk Unit Weight	Strength Properties		SPT Value (Observed)		Remarks
			Grave l	Sand	Silt & Clay	LL	PI	Y (t/m³)	C' (t/m²)	Φ⁰	N	Graphical representation	
1.00		ML	0	42	58	NP	NP	1.70	0.00	28.00	8		Silt of low compressibili ty
1.50		ML	0	24	76	NP	NP	1.68	0.00	28.25	80		
2.00		ML	0	6	94	28.7	8.3	1.75	0.12	28.00	130		
3.00		ML	0	6	94	28.7	8.3	1.78	0.12	29.00	15		
4.50		SM	0	56	44	NP	NP	1.79	0.00	31.00	16		Silty Sand
6.00		SM	0	72	28	NP	NP	1.80	0.00	31.00	17		
7.50		SM	0	88	12	NP	NP	1.81	0.00	32.00	24		
9.00		SM	0	90	10	NP	NP	1.82	0.00	32.00	26		
10.50		SM	0	92	8	NP	NP	1.83	0.00	32.25	28		
12.00		SP	0	92	8	NP	NP	1.83	0.00	32.25	29		Poorly Graded Sand
13.50		SP	0	94	8	NP	NP	1.83	0.00	32.50	30		
15.00		SP	0	94	8	NP	NP	1.84	0.00	33.00	32		

Fig 2: A typical Bore log Showing Engineering Properties of soil at a particular location.

Information about the Soil properties was gathered from previous geotechnical studies, the sites were located using coordinates (Latitudes and longitude) for each borehole using GPS equipment. The total numbers of boreholes taken are 99, distributed over the entire area of District Bathinda as shown in Fig. 3.
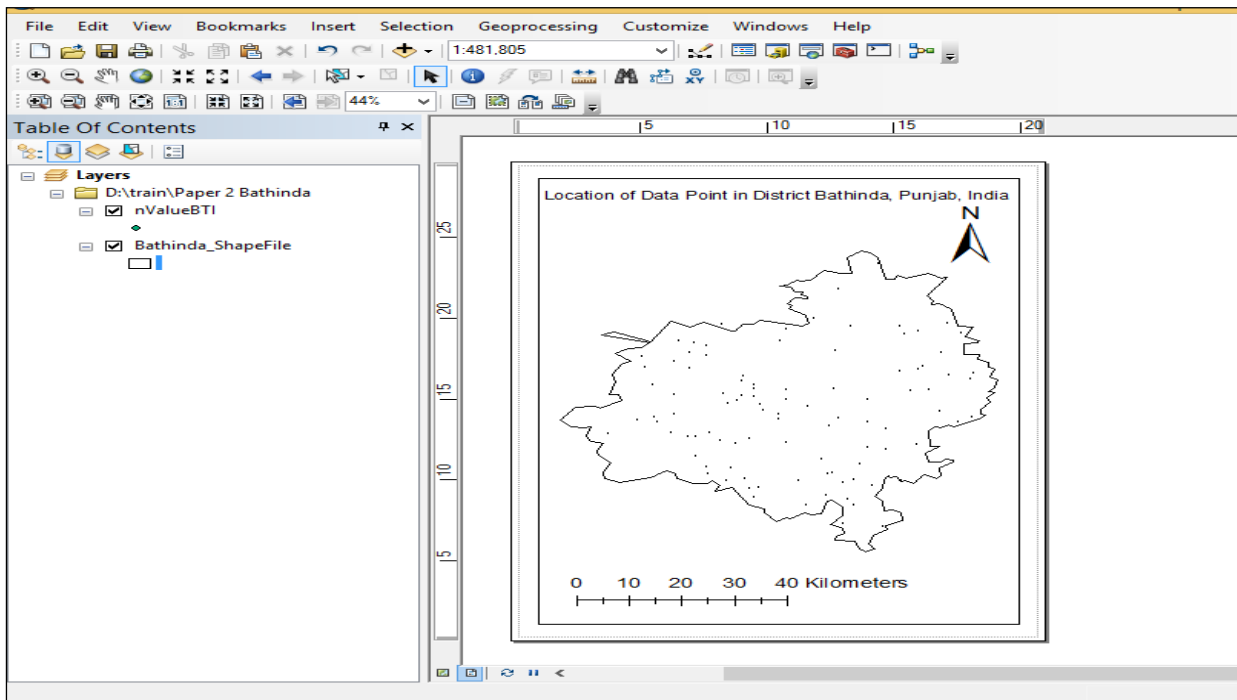

Fig 3: ArcGIS map of Bathinda District showing location of data points.

The Basic engineering characteristics taken under study is soil type, the data is tabulated as per location (Latitude and Longitude) along with its engineering property at a specific depth. The tabulated data have been used as input to the ArcGIS as shown in Fig.4.
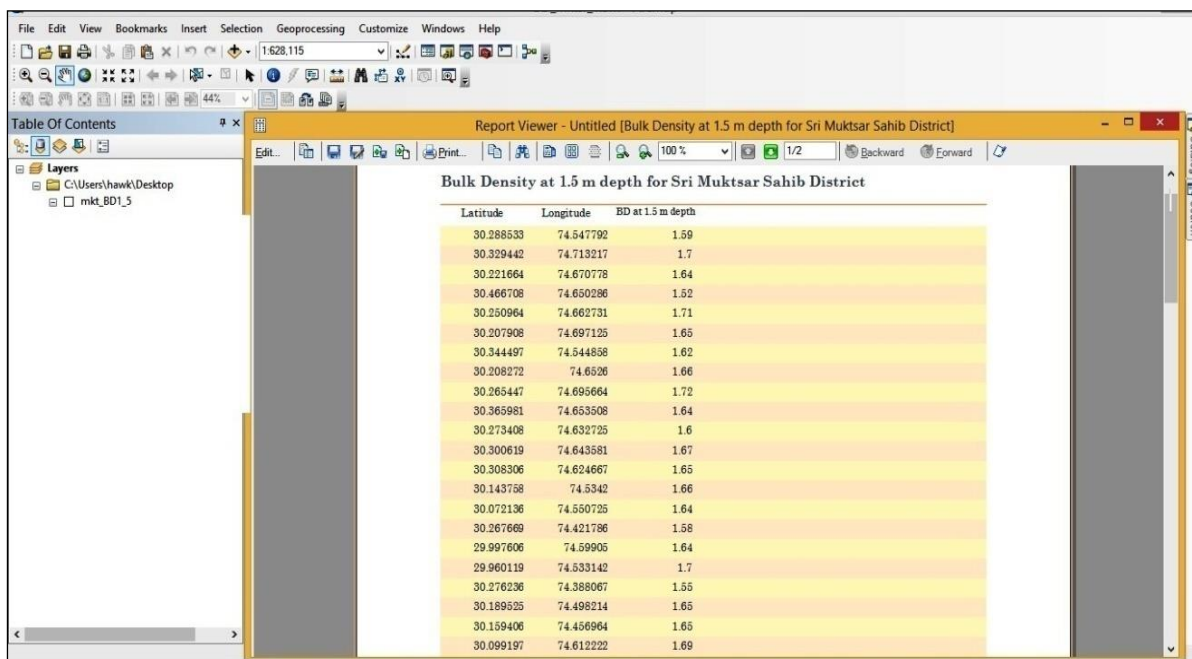
Fig 4: Data input in GIS format.

Geo-statistical spatial analysis, interpolation methodology has been used, which include: Inverse Distance Weighing (IDW) method as shown in Fig. 5.
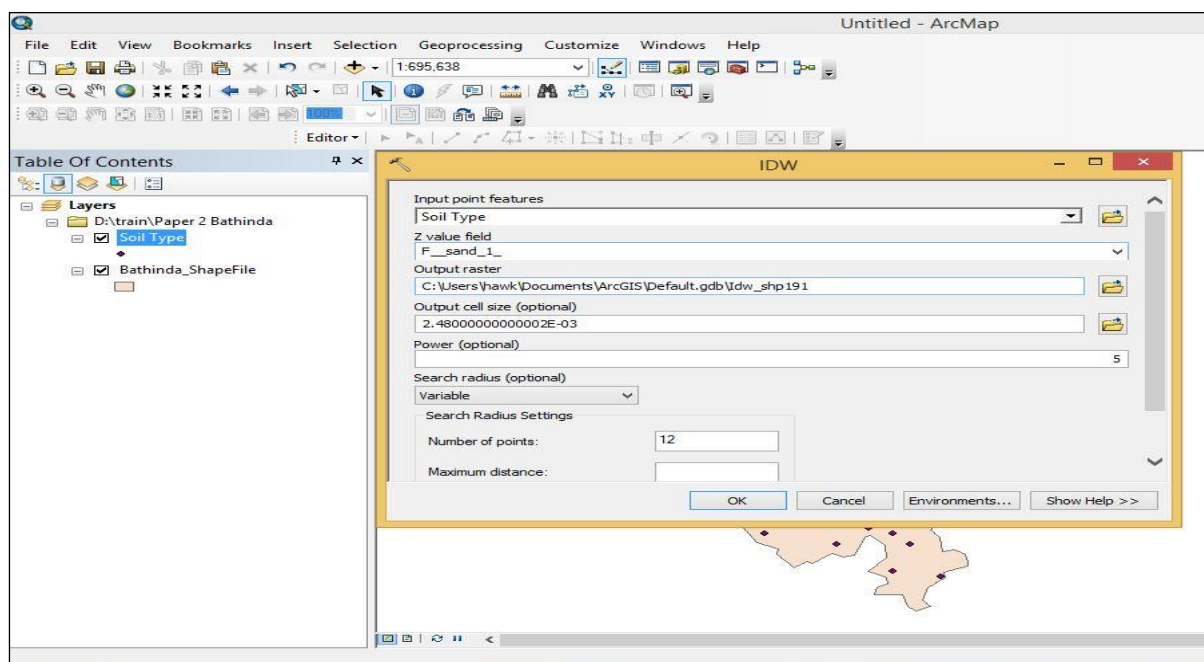

Fig 5: Snap shot while processing the data using IDW method.

Various tables and zonation maps were developed using GIS. Statistical inferences were drawn and data is visualized through tables and zonation maps.

III. RESULTS AND DISCUSSION

In this paper zonation maps have been developed for the area under study. An important measure to predict the spatial variability on the basis of data available are some statistical parameters like; count (frequencies), mean, minimum value, maximum value, range, standard deviation, coefficient of variance and skewness. Variation of above parameters is also depicted through tables.

A. Type of Soil:

Soil type is the most critical issue in geotechnical engineering that is identified with a number of cases. In the study area, the real collection of soil for the most part found is silt, clay, and sand. The conduct of each type of soil is different, in view of its geotechnical engineering characteristics. Consequently, the motive of soil investigation is truly important to understand the soil types prior to start of a project. The suitability of test additionally relies upon the kind of soil. There are two types of results used to present the data, i.e. statistical results and result in the form of zonation maps using ArcGIS

B. Sand Content:

Sandy layer is usually assumed as a good strata for founding a building. So it is important to know the type of soil at a particular depth where foundation is to be laid.

In the present study, the minimum and maximum % of sand varies from 6% to 79% at 1.5 m depth and the maximum sand content goes on increasing as we go deeper into the soil reaching upto 94% at 9.0 m depth. The average sand content varies from 31% at 1.5 m to 71% at 9.0 m. Range of particle size also goes on increasing with depth. Standard deviation at 1.5 m depth is 19.32 but at higher depth it's value varies from 25 to 29. The coefficient of variance ranges between 65% to 35% starting from 1.5 m to 9.0 m, which signifies that variation goes on decreasing with depth. The data is positively skewed with value of 0.468 at 1.5 m. Further from 4.5 m to 9.0 m data (%sand content) is negatively skewed with maximum negative value of -0.782 at 6.0 m as evident from table showing statistical parameters of % age sand content at various depths, as given below in Table I.

Table I: Variation of Statistical Parameters wrt % of sand content with Depth (1.5m to 9.0 m at 1.5 m interval)

Statistical Parameter / Depth	1.5 m	3.0 m	4.5 m	6.0 m	7.5 m	9.0 m
Minimum %age of sand	6	6	6	6	6	6
Maximum %age of sand	79	89	90	92	92	94
Average %age of sand	31.01	41.48	49.60	59.12	66.87	71.25
Range for %age of sand	6.0-79.0	6.0-89.0	6.0-90.0	6.0-92.0	6.0-92.0	6.0-94.0
Standard Deviation for %age of sand	19.32	27.09	29.40	29.30	27.75	25.23
Coefficient of Variance for %age of sand	62.302	65.301	59.280	49.571	41.494	35.403
Skewness for %age of sand	0.468	0.167	-0.290	-0.782	-1.178	-1.432

C. Silt and Clay Content:

Silt and clay content if present in large %age is problematic for foundation of buildings. So, it is neccesory to evaluate its presence.

The range of %age of silt and clay at 1.5 m depth is 21% - 94% and the minimum silt and clay content goes on decreasing as we go deeper into the soil reaching at 6% at 9.0 m depth. The average silt and clay content varies from 69% at 1.5 m to 29% at 9.0 m. Range of particle size also goes on decreasing with depth. Standard deviation at 1.5 m depth is 19.19 but at 9.0 m depth it's value is 25. The coefficient of variation ranges between 0.29 to 0.87 which signifies that variation goes on increasing with depth. The data is negatively skewed with maximum negative value of 0.48 at 1.5 m. Further from 4.5 m to 9.0 m data (%silt and clay content) is positively skewed with maximum positive value of 1.41 at 9.0 m as evident from Table II.

Table II: Variation of Statistical Parameters wrt % of silt and Clay content with depth 1.5m to 9.0m at 1.5m interval

Statistical Parameter / Depth	1.5 m	3.0 m	4.5 m	6.0 m	7.5 m	9.0 m
Minimum %age of silt and clay	21.00	11.00	10.00	8.00	8.00	6.00
Maximum %age of silt and clay	94.00	94.00	94.00	94.00	94.00	94.00
Average %age of silt and clay	69.04	58.44	50.43	40.98	33.23	28.95
Range for %age of silt and clay	21.0-94.0	11.0-94.0	10.0 - 94.0	8.0 - 94.00	8.00 - 94.0	6.0 - 94.0

%Standard Deviation for %age of silt and clay	19.19	27.02	29.26	29.26	27.72	25.23
Coefficient of Variance for %age of silt and clay	0.28	0.46	0.58	0.71	0.83	0.87
Skewness for %age of silt and clay	-0.48	-0.17	0.28	0.78	1.17	1.41

D. Data presentation using GIS:

Thematic maps showing variation of soil type along the depth of soil strata at different locations of Bathinda District, Punjab, India are presented, which have shown appreciable variation. Six zonation maps have been presented in this paper at depths 1.5m, 3.0m, 4.5m, 6.0m, 7.5m, and 9.0m respectively (Fig. 6 to 13). In all the cases depth has been taken from natural surface level NSL. The Inverse Distance Weighting IDW interpolation technique provides better and reasonable representation of data amongst the various interpolation techniques. As per Haider Al-Ani et al (2014), only the IDW technique provides a zonation maps with very close from the original input data. Same methodology has also been used for predicting and mapping of potassium soil by A. Bekele et al (2003). A. Orhan and H. Tosun (2010) have also used this technique.

All the maps are divided into four zones. Each zone is represented by a unique color. Fig. 6, represents a GIS based zonation map for the soil type at a depth of 1.5 m in Bathinda District of Punjab, India. Orange red color signifies that the soil is a mixture of silt and clay with some cohesion. The middle zone is given yellow color which represents silt of low compressibility and occupies most of the area in the map. Sky blue color shows that the soil type in that area is silty sand having sand content more than 50% and again occupies small area representing silty sand. Legend given in each zonation map represents the color given to each type of soil.
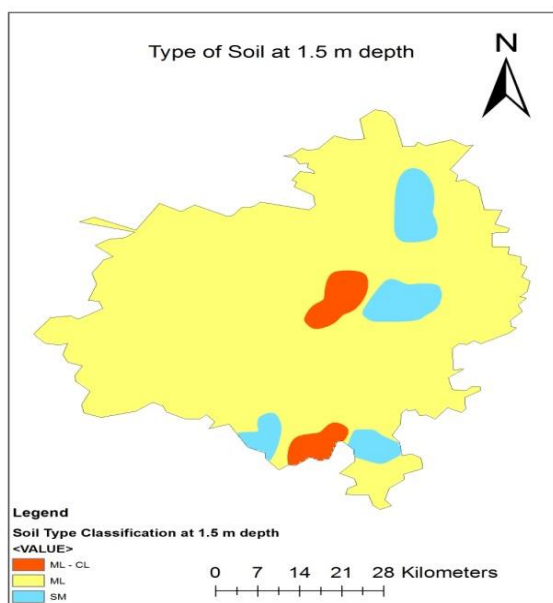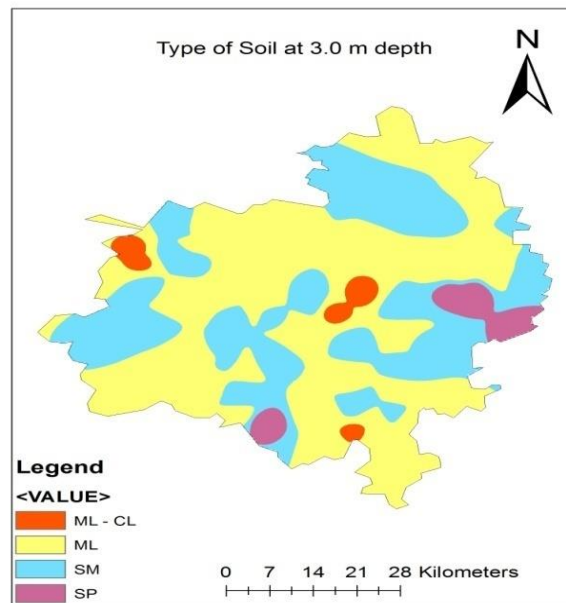

Fig 6: Soil Type Map at 1.5 m depth   **Fig 7: Soil Type Map at 3.0 m**

The type of soil at 3.0 m depth is shown in Fig. 7. At this depth major portion of map is covered with yellow color signifying presence of silt content more than 50%. The portion under silty sand increases as compared to area at 1.5 m depth, as represented by blue color in map. The presence of poorly graded sand can be seen here in ceramic red color.

At the depth of 4.5 m it can be viewed that most of the area is blue which represents silty sand. Yellow colored zones occupying fewer portions on map, represents silt content more. Silt and Clay is present only at very few locations as represented in orange red color. Here the area under poorly graded sand increases as clear from ceramic red color as shown in Fig. 8.
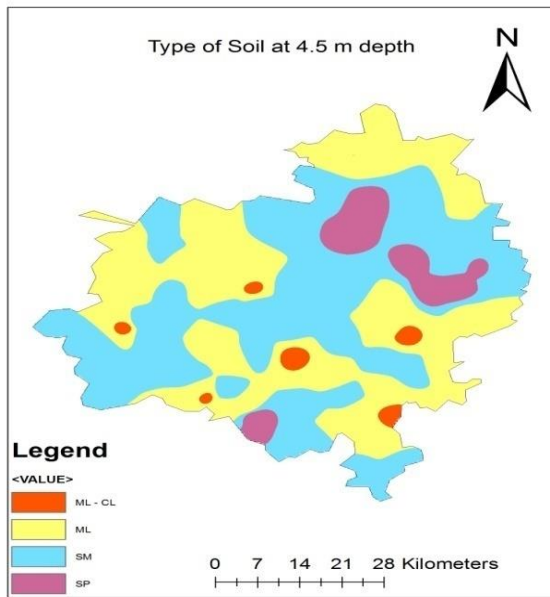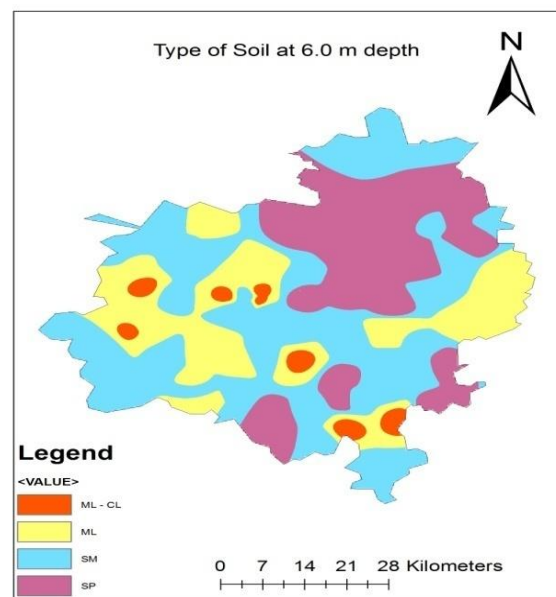
Fig 8: Soil Type Map at 4.5 m depth

Fig 9: Soil Type Map at 6.0 m depth

Similarly, it can be seen from the Fig. 9, 10 and 11 respectively that as we move deeper the area under silty sand in blue color and poorly graded sand in ceramic red color is more and goes on increasing with depth. This depicts that sand content goes on increasing and silt content goes on decreasing with depth.
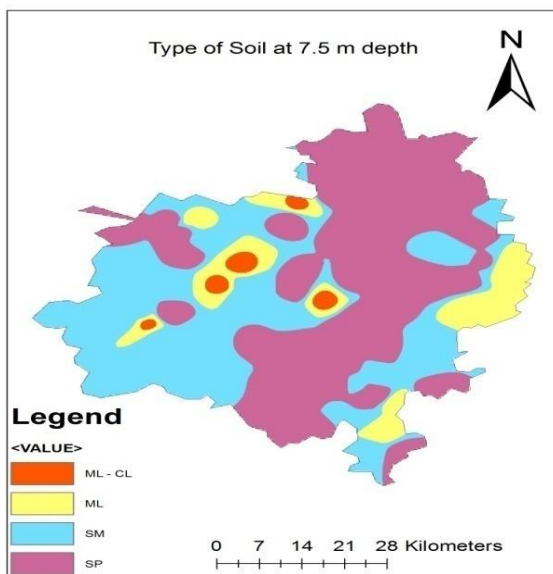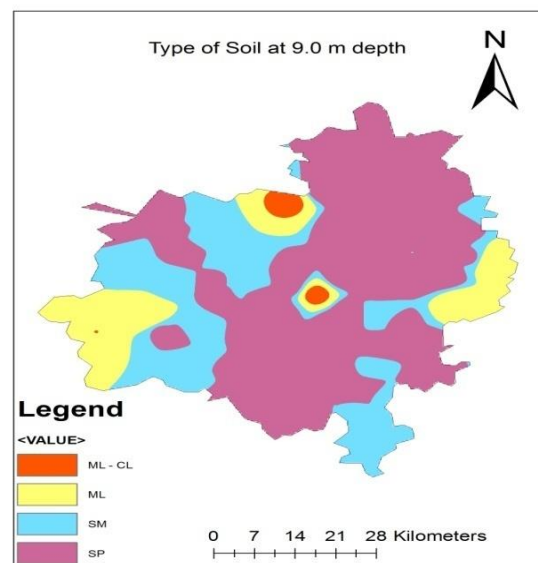

Fig 10: Soil Type Map at 7.5 m depth

Fig 11: Soil Type Map at 9.0 m depth

IV. CONCLUSIONS

The following conclusions have been drawn:

Geographical Information System is an effective tool for collecting, displaying and reading geographically documented information. GIS has shown numerous uses in geotechnical engineering project, and interpolation for exploit statistics at inaccessible places through processed graphs, maps and charts.

The soil in the study area is mostly silt and silty sand at shallow depths. Sand content goes on increasing as we go deeper into the soil. Range of particle size also goes on increasing with depth. Silt and clay content goes on decreasing with depth. Particle size also goes on decreasing with depth.

The majority of soil profile consists of silt of low compressibility to silty sand with a very few trace of clay especially for shallow depths to approximately 6.0 m depth. Then, after 6.0 m below natural ground surface, the amount of sand content increases and become more effective. Poorly graded sand is encountered at noticeable locations at a depth of 4.5 m or more.

These results can help structural and foundation engineers during the process of foundation analysis, estimation of geotechnical investigation cost and planning and execution of different projects associated with civil engineering.

REFERENCES

[1] A. Bekele et al, "Comparative evaluation of spatial prediction methods in a field experiment for mapping soil potassium", Soil Science vol. 168, no. 1, pp. 15–28, 2013.

[2] A. Singh and. G.R. Chowdhary (1990). Soil engineering in theory and practice 2nd edition: geotechnical testing and instrumentation. CBS Publishers and Distributors Pvt. Ltd., New Delhi. India.

[3] A.Orhan and H.Tosun, "Visualization of geotechnical data by means of geographic information system: a case study in Eskisehir city (NW Turkey)", Environmental Earth Science, vol. 61, pp. 455-65, 2010.

[4] B. G. Sowers and S. F. George (1961). Introductory soil mechanics and foundations 21*5 edition. Macmillan Company. New York. USA.

[5] Bathinda District Map. (n.d.). Retrieved from https://www.mapsofindia.com/maps/punjab/districts/bathinda.htm

[6] D. K. Shepherd and M. G. Walsh, "Infrared Spectroscopy: enabling evidence based diagnostic surveillance approach to agricultural and environmental management in developing countries", Journal of near Infrared Spectroscopy, vol. 15, pp 1-19, 2007.

[7] D.R. Nielsen and O. Wendroth, "Spatial and temporal statistics: sampling field soils and their vegetation", Reiskirchen: Catena Verlag, p 398, 2003.

[8] H. Al-Ani et al, "Subsurface Visualization of Peat and Soil by using GIS in Surfers Paradise, Southeast Queensland, Australia", Electronic Journal of Geotechnical Engineering, vol. 18, no. 1,pp. 1761-1774, 2013.

[9] M. I. Harpstead, et al (1997). Soil science simplified 3d Ed. Iowa State University Press. Iowa. USA.

[10] Outline Map of India. (2018). Retrieved from https://www.mapsofindia.com/maps/india/outlinemapofindia.htm

[11] Punjab Districts Map. (n.d.). Retrieved from https://www.mapsofindia.com/maps/punjab/punjab-district.htm

[12] S. W. Buol, et al (1980) Soil genesis and classification, Ames, Iowa: second edition. Iowa State University Press.

[13] T. Lumbe (1979). Soil mechanics: SI version Series in soil engineering. John Wiley and Sons, New York. USA.