JOURNAL OF
ENVIRONMENTAL HYDROLOGY
The Electronic Journal of the International Association for Environmental Hydrology
On the World Wide Web at http://www.hydroweb.com
VOLUME 8 2000

A STUDY OF GROUNDWATER POLLUTION VULNERABILITY USING DRASTIC/GIS, WEST BENGAL, INDIA

Shamsuddin Shahid
Space Research and Remote Sensing Organization (SPARRSO)
Dhaka, Bangladesh

Information about vulnerability of groundwater to contamination is essential to facilitate groundwater planning and management. The vulnerability of shallow groundwater to contamination in and around Midnapur-Kharagpur towns, West Bengal, India, is evaluated using the DRASTIC method within a Geographic Information System (GIS). DRASTIC parameters are calculated from geological, soil and elevation contour maps and groundwater level data of the study area, and thematic maps are prepared. Finally, the maps are integrated through the DRASTIC model within the GIS to demarcate vulnerable zones. In the present study, DRASTIC indices for both generic industrial-municipal and pesticide pollutants are derived and vulnerability maps for both classes are prepared. The result of the study shows that 50 percent of the area is highly vulnerable to industrial and municipal pollutants and more than 81 percent of the area is highly vulnerable to pesticide pollutants.

INTRODUCTION

Groundwater is the main source of drinking water in Midnapur district, West Bengal, India. Because of the known health and economic impacts associated with groundwater contamination, steps to assess the vulnerability of groundwater must be taken for sustainable groundwater protection and management planning. Vulnerability of groundwater refers to the intrinsic characteristics that determine the sensitivity of the water to being adversely affected by an imposed contaminant load. The DRASTIC method (Aller et al., 1987), developed by the U.S. Environmental Protection Agency, is the most widely used method for identifying the areas where groundwater supplies are most susceptible to contamination. It is a fairly quick and simple to use method for assessing susceptibility of a large area. The method has been widely used in several mapping projects in the United states and discussed as a possible tool for such assessments (Hearne et al., 1992; Atkinson and Thomlinson, 1994; Kalinski et al., 1994). In this paper the DRASTIC method is applied in a part of Midnapur district, WB, India to generate a small scale map of uppermost groundwater vulnerability to contamination. The whole area is classified as having relatively poor, moderate, high, or very high susceptibility to pollution. The pollution susceptibility map is developed by using the DRASTIC method in a computer based Geographic Information System (GIS).

THE DRASTIC CONCEPT

The DRASTIC hydrogeologic vulnerability ranking method uses a set of seven hydrogeologic parameters to classify the vulnerability or pollution potential of an aquifer. The parameters are :

(1) depth of groundwater (**D**);

(2) recharge rate (**R**);

(3) the aquifer media (**A**);

(4) the soil media (**S**);

(5) topography (**T**);

(6) the impact of the vadose zone (**I**); and

(7) the hydraulic conductivity (**C**) of the aquifer.

The parameters are weighted according to their relative susceptibility to the pollutant. DRASTIC assigns a rating to each parameter, on a scale of 1 to 10, based on functional curves. This rating is then scaled by a weighting factor, and the weighted ratings are summed to obtain the DRASTIC index (DI). The equation for calculating the DI of a mapping unit is,

$$DI = D_W D_R + R_W R_R + A_W A_R + S_W S_R + T_W T_R + I_W I_R + C_W C_R \quad (1)$$

where

$_W$ = weight and $_R$ = rating.

Within each mapping unit, each of the seven DRASTIC parameters is evaluated and the DI for each mapping unit is calculated using equation (1). The site having a higher DI value can be considered the most likely to become contaminated and the site having a low DI value can be considered the least likely to become contaminated.

For each parameter there are two weights, the first is for application of DRASTIC to generic municipal and industrial pollutants, while the second is for agricultural pesticides. The DRASTIC parameters, their weights, and ratings for each hydrogeologic unit are discussed in the report by Aller et al. (1987). In the DRASTIC method it is assumed that: (1) the contaminant is introduced at the ground surface; (2) the contaminant is flushed into the groundwater by precipitation; (3) the contaminant has the mobility of water; and (4) the area evaluated is 100 acres or larger.

ENVIRONMENTAL SETTING

The study area (87º10´E, 22º27´30”´S to 85º22´30”E, 22º15´S) is a part of Midnapur district, West Bengal, India (Figure 1). Situated in the Kasai river basin, the area is a mild topographic high. Climatically it falls in the Gangetic West Bengal region with an annual average rainfall of 152.5 cm and temperature of 31^0C. Geologically, the area is a soft rock area having three main lithologic units: (a) a lateritic formation, (b) an older deltaic formation, and (c) a younger deltaic formation. From various geological and geophysical investigations (Patra et al., 1993) the area has good potential for shallow groundwater.

DATA QUALITY

Lineage

The seven DRASTIC parameters are derived from geological, soil and slope maps of the area, and groundwater level and vertical electrical sounding data. The geological map is prepared from IRS-IB LISS-II data and the soil map is prepared with the aid of aerial photographs. The slope map is generated from the elevation contours given in the Survey of India toposheet.

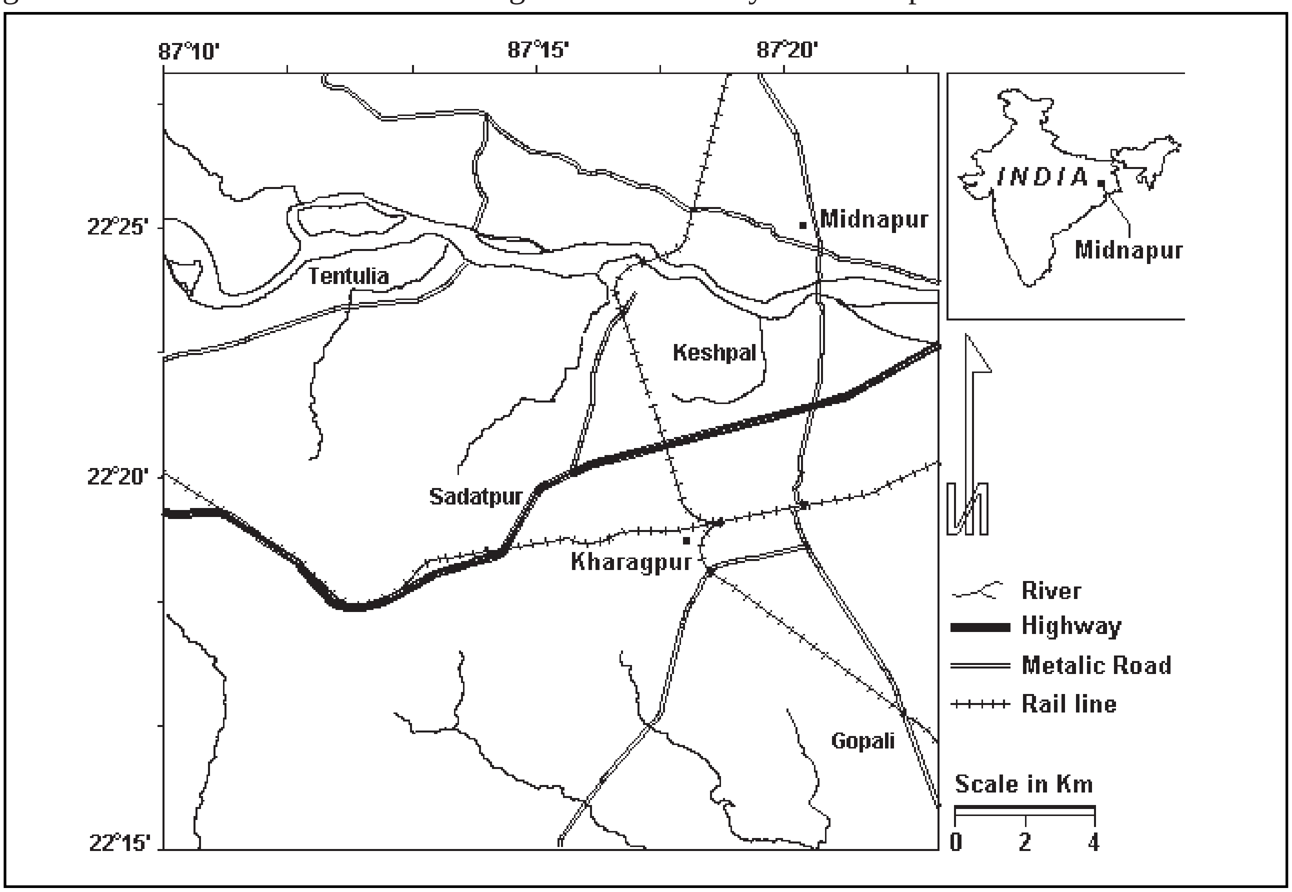

Figure 1. Location map of the study area.

Positional Accuracy

All the coverages are prepared at a scale of 1:50,000. The vulnerability maps are prepared by overlaying different thematic maps with an overlay accuracy of 0.25 sq. km. Areas less than 0.25 sq. km are not shown on the maps.

Attribute Accuracy

Individual polygons of each thematic map are coded with DRASTIC ratings on the computer graphic screen to avoid errors. The ratings were manually added for some polygons of the final susceptibility map to determine if the final score is correct.

DEVELOPMENT OF DRASTIC PARAMETERS

All the thematic maps are digitized in continuous mode and in the vector format. The digitized values are edited to get error free thematic maps. Preparation of thematic maps of seven DRASTIC parameters is described below.

Depth Of Groundwater Table

Average depth of the groundwater table is estimated from the soil map, geological map, and water table data collected from different sites of the study area. The thematic map of the groundwater table of the study area along with the ratings is shown in Figure 2.

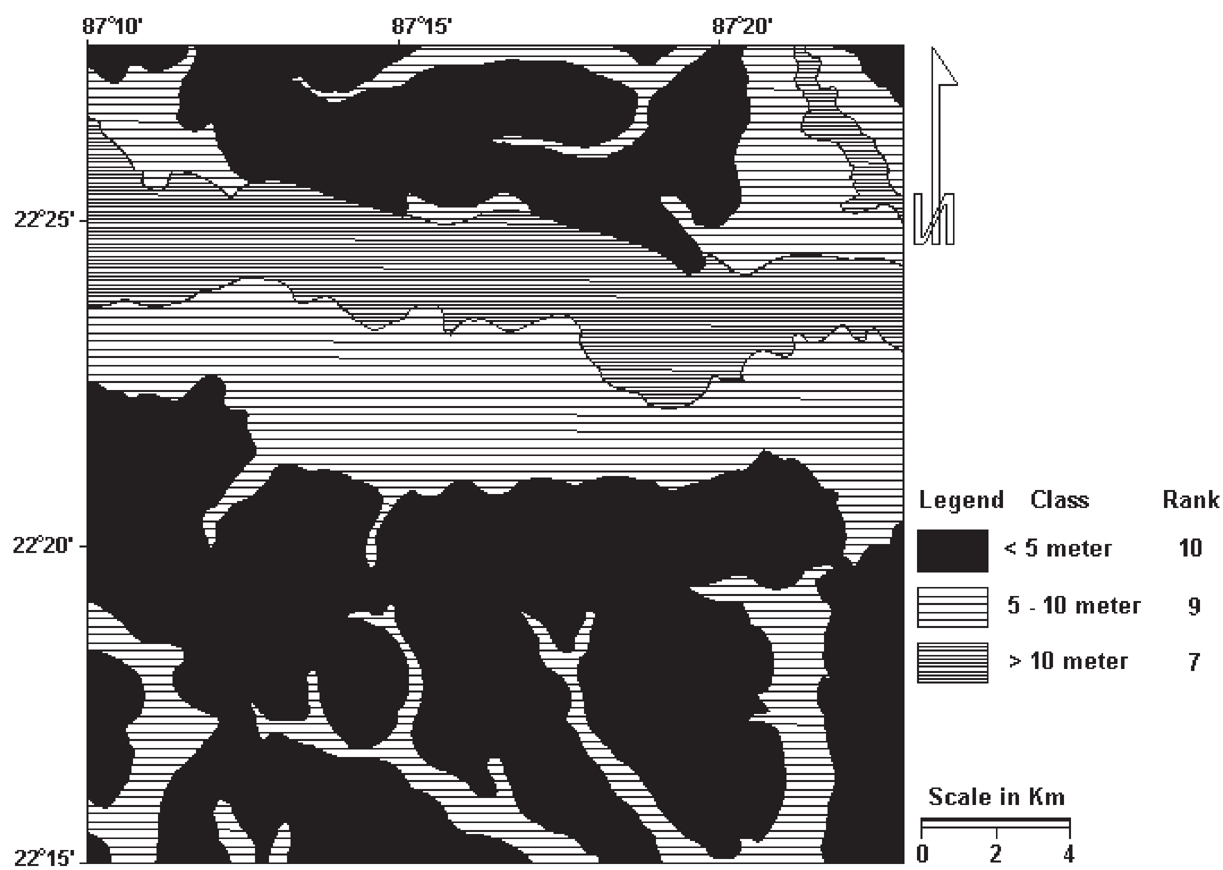

Figure 2. Thematic map of the groundwater level of the study area.

Recharge

Typical recharge of an area can be guessed from annual average rainfall, slope and soil type of the area. The study area is mainly flat and gets an annual average rainfall of 152.5 cm. Except for the calcareous sticky clayey soil over older deltaic formation, the other types of soil in the area are moderately pervious. The net recharge in the study area is assumed to be more than 10 inches per year and the whole area is rated with a value of 9.

Aquifer Media

Aquifer media are identified from the Vertical Electrical Sounding (VES) and borehole data. Almost 200 data points were interpreted using a sophisticated inversion program called Evolutionary Programming (EP). The output lithological data are justified with the existing borehole data. Medium to coarse sand with gravel is found as the groundwater bearing zone in the study area. Following the DRASTIC recommendation, the area is ranked with a value of 8.

Impact Of The Vadose Zone

The vadose zone map of the study area is prepared from the lithologic section obtained from geophysical data. From the geophysical survey, it is found that the aquifers situated in the deltaic formations are unconfined, whereas the aquifers in the lateritic formation are confined. According to Aller et al. (1987), the vadose media for an unconfined aquifer system is the same as the aquifer media. Therefore, sand/gravel is considered as the vadose zone for the area under deltaic formations and is rated with a value of 8. In the lateritic zone, the aquifers are underlain by clayey or silty clay layers. This zone is considered as the vadose zone in the lateritic formation and is rated with a value of 3. The thematic map of vadose zones of the study area is shown in Figure 3.

Hydraulic Conductivity

The aquifer media of this area are medium to coarse sand with gravel, which according to Freeze and Cherry (1979) should have a hydraulic conductivity of 1000 to 2000 gpd/ft2. This is verified by pumping test data collected from various sites of the study area (Patra et al., 1993). Consequently, the whole study area is ranked with a value of 8.

Soil

Four types of soil are mapped from aerial photographs : (a) a lateritic soil of hardcrust horizon, (b) a lateritic soil of mottled clay horizon, (c) a sandy loamy soil, (d) a clayey loamy soil, and (e) a grayish sticky calcareous clayey soil. The soil map of the study area is shown in Figure 4.

Topography

The slope map is generated from elevation contours given in the toposheet of the Survey of India by linking a FORTRAN program with the GIS. As the whole area lies below a slope of 2 percent, and is ranked with 10.

INTEGRATION OF THEMATIC MAPS

After preparation of all thematic maps, different polygons in the maps are labeled with DRASTIC ratings and then scaled with the weights. The ratings are scaled with both the DRASTIC weights for generic industrial-municipal pollutants and pesticide pollutants separately to generate the vulnerability

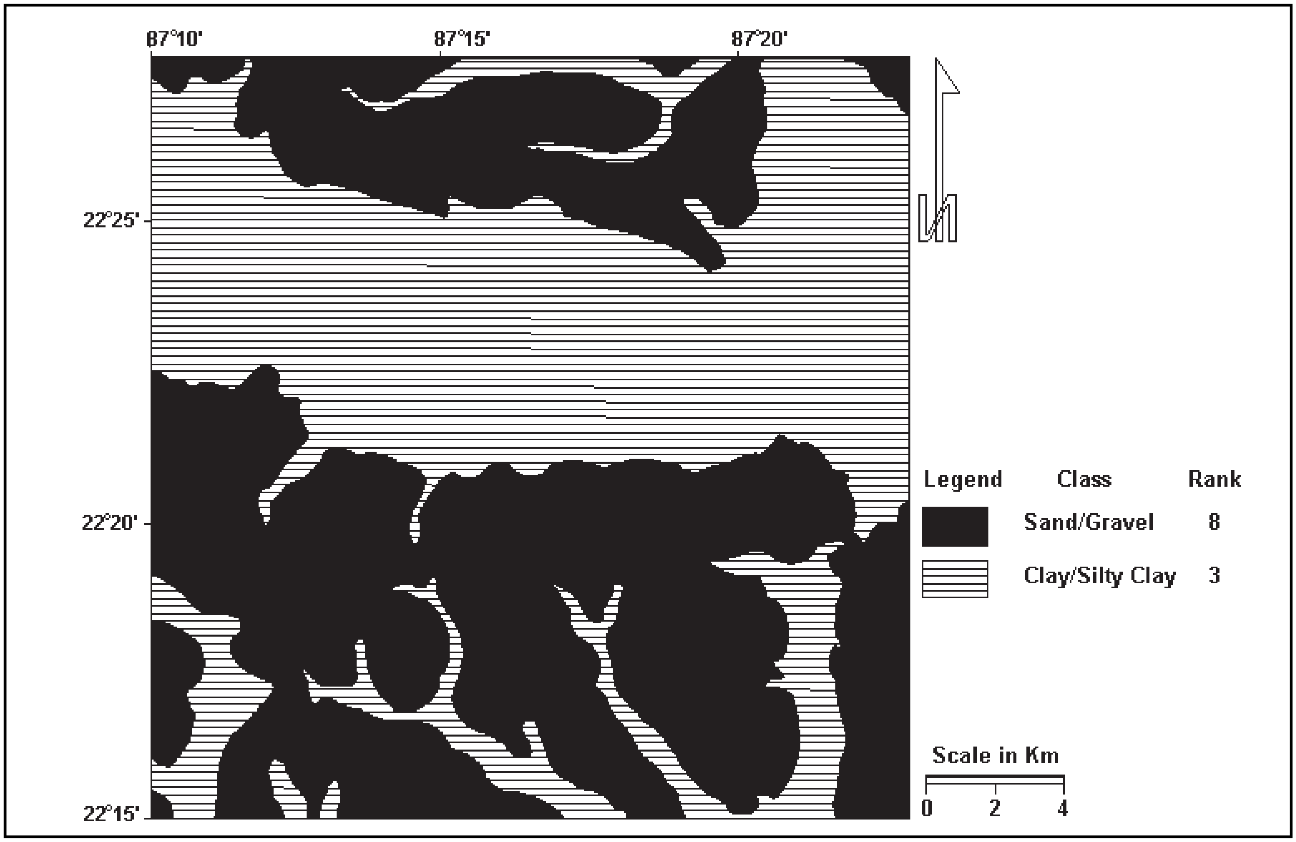

Figure 3. Thematic map of vadose zone of the study area.

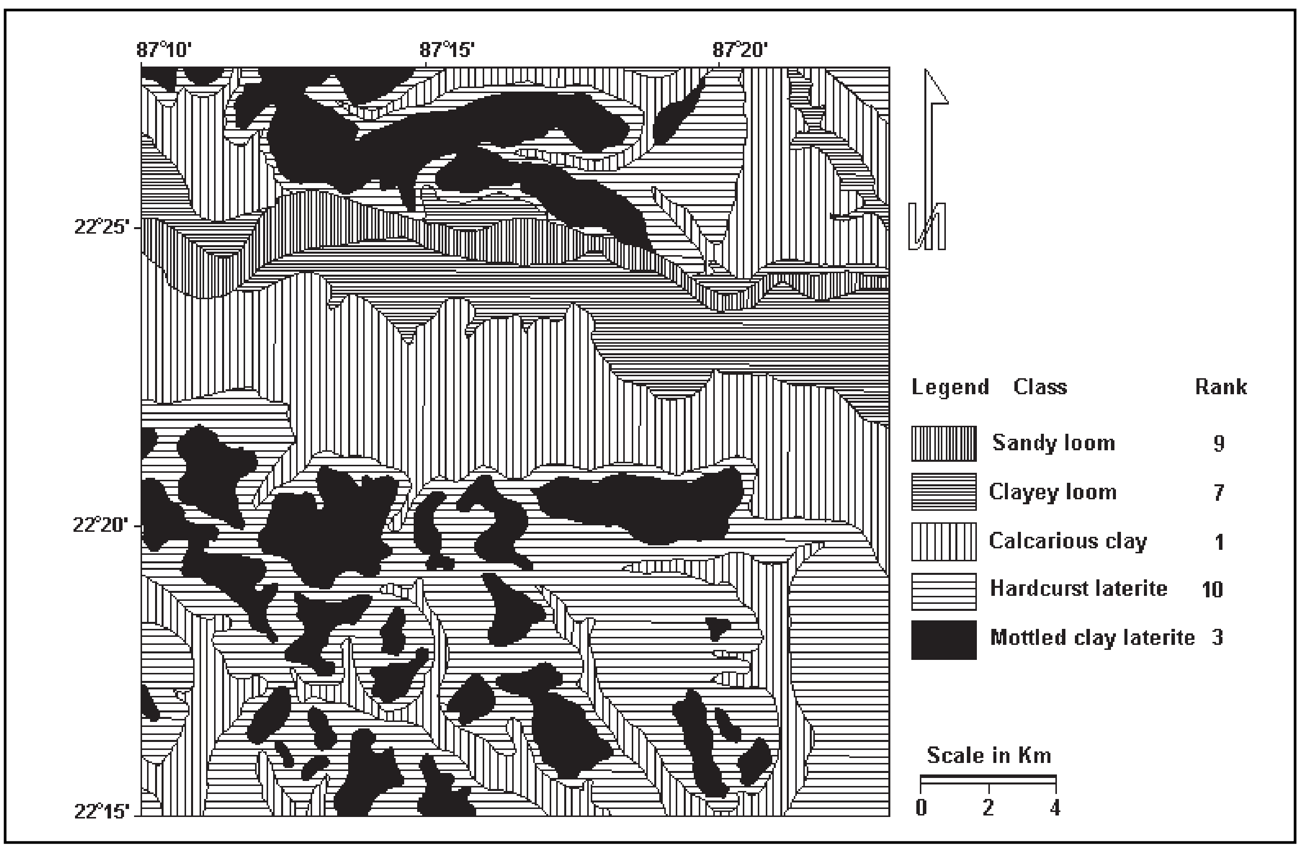

Figure 4. Thematic map of soil type of the study area.

maps of both the classes. The thematic maps are registered with one another using ground control points and integrated using the weighted aggregation method (ESRI, 1992). The integration is done step by step and a maximum of two layers are integrated at a time. The polygons of the final integrated layers contain the composite details of all the thematic layers together numerically, and the DI score of each polygon indicates the groundwater vulnerability of that zone.

RESULT AND CONCLUSION

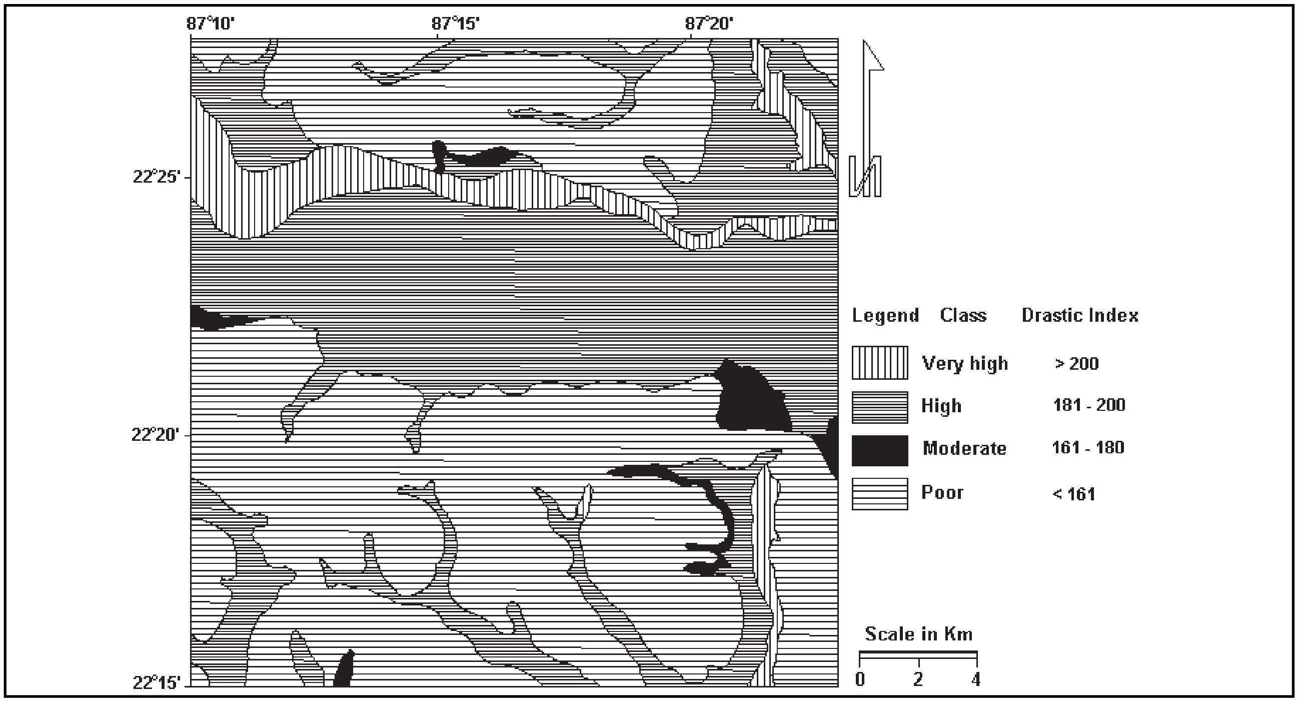

Figure 5a. Thematic map of groundwater vulnerability to municipal and industrial pollutants.

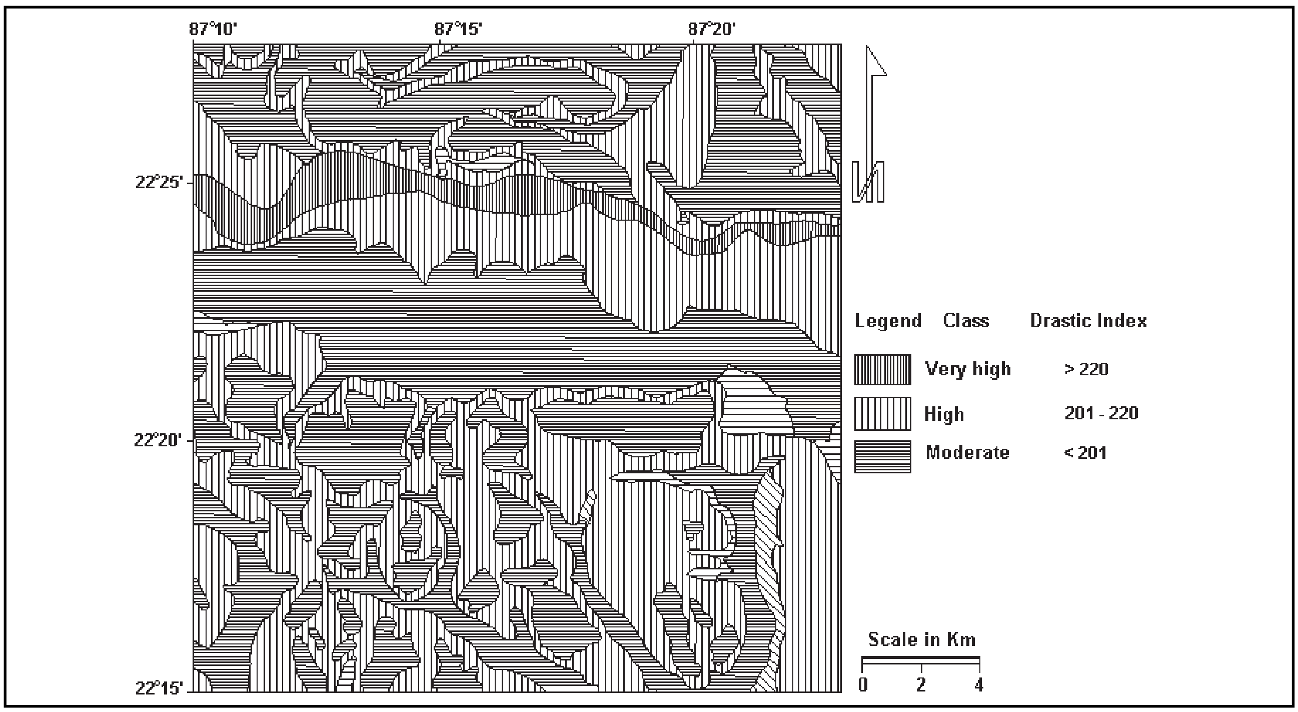

Figure 5b. Thematic map of groundwater vulnerability to pesticides.

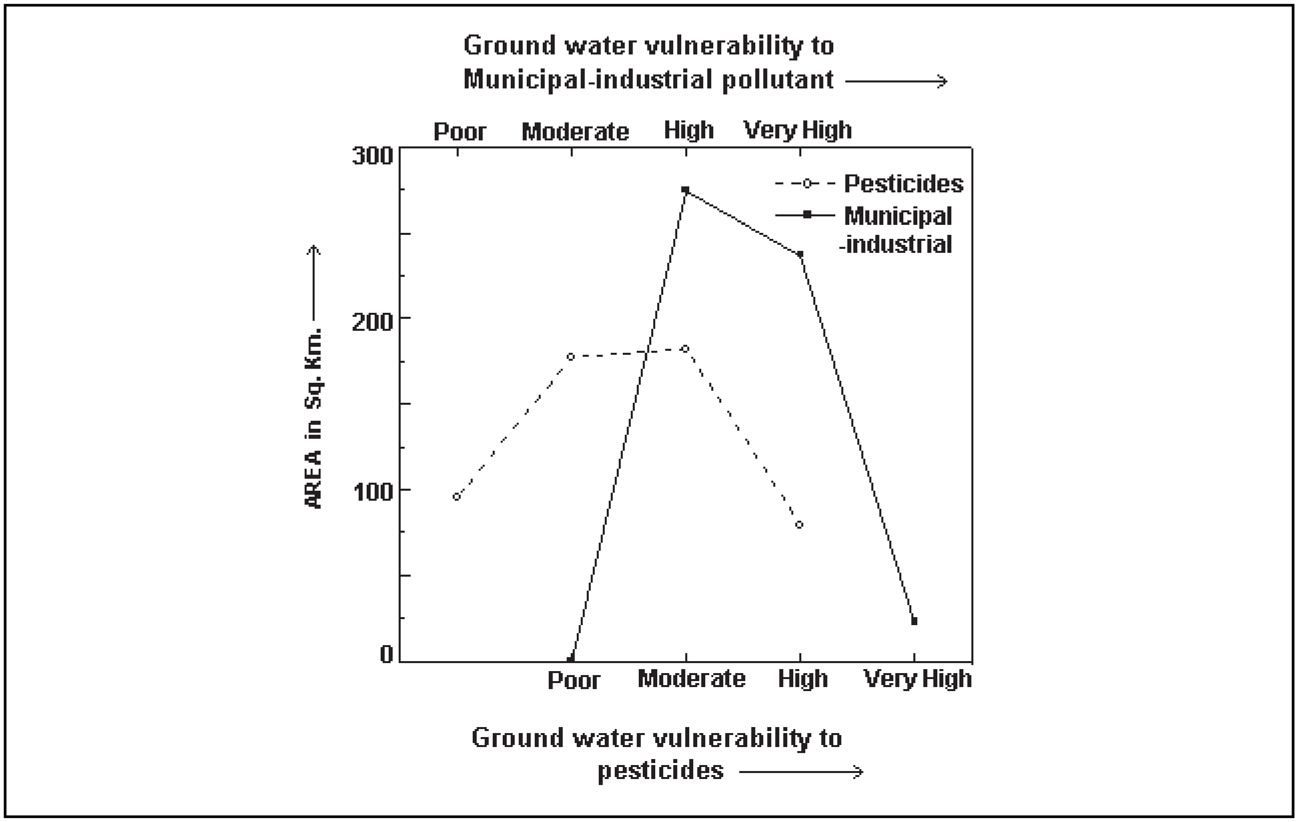

Figure 6. Graphical representation of area versus pollution potential.

The DRASTIC Index (DI) values in the final integrated maps are classified and pollution susceptibility maps for both industrial-municipal pollutants and pesticide pollutants are developed as shown in Figures 5(a) and (b) respectively. The area under each zone displayed by a graph in Figure 6. It can be noted that almost 50 percent of the area is highly vulnerable to industrial-municipal pollutants and more than 81 percent of the area is highly vulnerable to pesticide pollutants. From the pollution susceptibility maps of Figures 5(a) and 5(b), it can be seen that the areas near the Kasai River are more susceptible to pollutants. These are the main groundwater supply zones of Midnapur-Kharagpur town (Patra et al., 1993). Therefore, proper management approaches have to be adopted to provide a long term pollution free groundwater supply in the area

ACKNOWLEDGMENTS

The author gratefully acknowledges the critical discussions and suggestions of Dr. A. Sircar and Dr. J. Roy, Scientist, RRSSC, Kharagpur.

REFERENCES

Aller, L.T., T. Bennett, J.H. Lehr, R.J. Petty, and G. Hackett; DRASTIC - A Standardized System for Evaluating Groundwater Pollution Potential Using Hydrogeologic Settings, U.S. Environmental Protection Agency/600/2-87/035, Washington, DC., pp. 455, 1987.

Atkinson, S.F., and J.R. Thomlinson; An examination of groundwater pollution potential through GIS modeling, ASPRS/ACSM, 1994.

ESRI; Overlay User's Guide, ARC/INFO, Environmental Systems Research Institute, Redlands, CA, USA, 1992.

Freeze, R.A., and J.A. Cherry; Groundwater, Prentice-Hall Press, Austin, TX, pp. 182, 1979.

Hearne, G.A., M. Wireman, A. Campbell, S. Turner, and G.P. Ingersoll; Vulnerability of the uppermost groundwater to contamination in Greater Denver area, Colorado, USGS Water-Resources Investigation 92-4143, 1992.

Kalinski, R.J., W.E. Kelley, I. Bogareli, R.L. Ehrman, and P.D. Yamamoto; Correlation between DRASTIC vulnerabilities and incidents of VOC contamination of municipal wells in Nebraska, Groundwater, vol. 32, No. 1, pp. 31-34, 1994.

Patra, H.P., M. Bandopadhyay, G. Banerjee, S.N. Mukherjee, and M. Chowdhury; Analysis of pump test data on Kasai river bed (W.B.) - A case study, Proceedings of the Intl. Conf. on hydrology and water resources, Dec. 20-22, New Delhi, 1993.

ADDRESS FOR CORRESPONDENCE
Shamsuddin Shahid
Space Research and Remote Sensing Organization (SPARRSO)
Dhaka 1207
Bangladesh

E-mail: su_shahid@mailcity.com