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A CURSORY APPLICATION OF DRASTIC TO THE SAVANNAH RIVER SITE *

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SRS

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Geohydrologists at the National Water Well Association (NWWA) created DRASTIC as a formalized decision-making procedure to assess the potential for groundwater pollution at existing and proposed industrial sites. It is a straightforward, step-by-step method to size up, with existing information, groundwater pollution potential anywhere in the country. DRASTIC is generalized because it is meant to be universal; therefore, NWWA stresses its qualitative nature. Its objectives are: (1) to help direct resources and land use activities to appropriate areas; and, (2) to help prioritize groundwater protection, monitoring and cleanup efforts.

Even though it is a general siting tool, usually applied where only scanty geohydrological information is available, it can be helpful--perhaps in a modified form--for locations like the SRS that have relatively abundant data resources. Consequently, my intention here is to demonstrate its use at the SRS, in a very cursory fashion, only to show how it might be useful if applied in a more rigorous way.

FACTORS CONSIDERED

DRASTIC is an acronym formed from the 7 factors it considers for any hydrogeologic setting:

Depth to the water table,

net Recharge,

Aquifer media,

Soil type,

Topography,

Impact of the vadose zone, and,

hydraulic Conductivity.

Applying DRASTIC amounts to finding information on each factor (e.g., from sources listed in Table 1) in order to assign ratings (numbers from 1 to 10) to each factor, then taking weighted sums of these ratings to get DRASTIC indices, which are comparative measures of pollution potential. Since a rating of 1 represents lowest pollution potential (more favorable siting) and 10 highest (less favorable siting), the lower the DRASTIC index the more suitable the site would be for an industrial or waste site location. Weights vary from 1 for the least influential factor to 5 for the most. Thus, according to Table 2, depth to the water table has more effect on groundwater pollution potential than topography. Table 2 also shows that DRASTIC assigns different weights to the factors if the land under study is primarily agricultural, in which case pollution generally originates from non-point sources. Tables 3 through 9 display the ratings for each factor.

The equation for the DRASTIC index is:

$$\text{DRASTIC INDEX} = D_R D_W + R_R R_W + A_R A_W + S_R S_W + T_R T_W + I_R I_W + C_R C_W \qquad (1)$$

where R is the rating and W the weight. Again, low DRASTIC indices imply relatively more favorable sites than high indices.

LIMITATIONS

Clearly DRASTIC is bare-bones, ignoring factors like the aquifer value; i.e., population served or proximity to cities and towns. It also deals only with water table aquifers, ignoring geologic features which affect groundwater pollution like aquitards overlying deeper aquifers, or anomalous preferential flow paths. DRASTIC pays little attention to land use, and none at all to political considerations. It includes no provisions for seismic activity. In effect, it integrates and smooths out spotty information and provides first approximations. It assumes the following:

- pollutant sources at ground surface,
- miscible pollutants flushed into the groundwater by precipitation, and,
- that it applies to areas 100 acres or larger.

Table 1. Sources of Hydrologic Information

Source	Depth to Water Table	Net Recharge	Aquifer Media	Soil Media	Topo-graphy	Impact of the Vadose Zone	Hydr. Cond. of the Aquifer
State & USGS	X	X	X		X	X	X
State Dept. of Nat./Wat. Res.	X	X	X			X	X
USDA-SCS		X		X	X		
State EPA	X	X	X			X	X
Clean Water Act "208" & other Regional Plan-ning Auth.'s	X	X	X			X	X
County & Regional Water Supply Agencies & Comp.'s	X		X			X	X
Consultants (hydrogeologic, engineering)	X		X			X	X
Related Ind. Studies (mining, well drilling, quarrying)	X		X			X	
Prof. Societies (GSA, NWWA, AGU, ASCE)	X	X	X			X	X
Local Coll.'s & Univ.'s (Dept.'s of Geology, Earth Science, Civil Engineering)	X	X	X			X	X
Other Fed. & State Agencies (Army COE, NOAA)	X	X	X			X	
SRS Reports	X	X	X	X	X	X	X

Table 2. Assigned Weights for DRASTIC Factors

Factor	Weight	Agricultural Weight
Depth to the Water Table	5	5
Net Recharge	4	4
Aquifer Media	3	3
Soil Media	2	5
Topography	1	3
Impact of the Vadose Zone	5	4
Hydraulic Conductivity of the Aquifer	3	2

Table 3. Ranges and Ratings for Depth to Water Table

Depth in feet

Range	Rating
0 - 5	10
5 - 10	9
15 - 30	7
30 - 50	5
50 - 75	3
75 - 100	2
100 +	1

Table 4. Ranges and Ratings for Net Recharge

Recharge in inches/year

Range	Rating
0 - 2	1
2 - 4	3
4 - 7	6
7 - 10	8
10 +	9

Table 5. Ranges and Ratings for Aquifer Media

Range	Rating	Typical Rating
Massive Shale	1 - 3	2
Metamorphic/Igneous	2 - 5	3
Weathered Metamorphic/Igneous	3 - 5	4
Thin Bedded Sandstone, Limestone, Shale Sequences	5 - 9	6
Massive Sandstone	4 - 9	6
Massive Limestone	4 - 9	6
Sand and Gravel	6 - 9	8
Basalt	2 - 10	9
Karst Limestone	9 - 10	10

Table 6. Ranges and Ratings for Soil Media

Range	Rating
Thin or Absent	10
Gravel	10
Sand	9
Shrinking and/or Aggregated Clay	7
Sandy Loam	6
Loam	5
Silty Loam	4
Clay Loam	3
Non-shrinking and Non-aggregated Clay	1

Table 7. Ranges and Ratings for Topography
percent slope

Range	Rating
0 - 2	10
2 - 6	9
6 - 12	5
12 - 18	3
18 +	1

Table 8. Ranges and Ratings for Impact of Vadose Zone

Range	Rating	Typical Rating
Silt/Clay	1 - 2	1
Shale	2 - 5	3
Limestone	2 - 7	6
Sandstone	4 - 8	6
Bedded Limestone, Sandstone, Shale	4 - 8	6
Sand and Gravel w/ significant Silt and Clay	4 - 8	6
Metamorphic/Igneous	2 - 8	4
Sand and Gravel	6 - 9	8
Basalt	2 - 10	9
Karst Limestone	8 - 10	10

Table 9. Ranges and Ratings for Hydraulic Conductivity

Hydr. Cond. in gpd/ft^2

Range	Rating
1 - 100	1
100 - 300	2
300 - 700	4
700 - 1000	6
1000 - 2000	8
2000 +	10

DRASTIC APPLIED TO THE SRS

The creators of DRASTIC designed it for use at places where, unlike the SRS, geohydrologic data are sparse; nonetheless, applying it here yields at least two benefits:

- It reveals how a widely-accepted planning tool for groundwater protection measures relative pollution potential of existing industrial sites and the one chosen for the New Production Reactor (NPR); and,

- It hints at how DRASTIC might be tailored to include more accurate site-specific factors, or more thorough definition of factors to produce a more useful appraisal tool for the SRS.

Accordingly, I have applied DRASTIC to the SRS by way of an introduction to the DRASTIC method. The following paragraphs describe this application.

I began by dividing the Site into 278 square cells roughly 1.7 km x 1.7 km (because the map scale used was 1 cm = 1 km), as shown in Fig. 1. The goal was to determine a DRASTIC index for each cell, then draw a color-coded DRASTIC index map of the SRS. The references used in addition to those listed at the end of this report were a topographic map of SRS, and, soil survey atlas sheets covering SRS (dated 10/13/87). The land on the SRS was assumed to be non-agricultural.

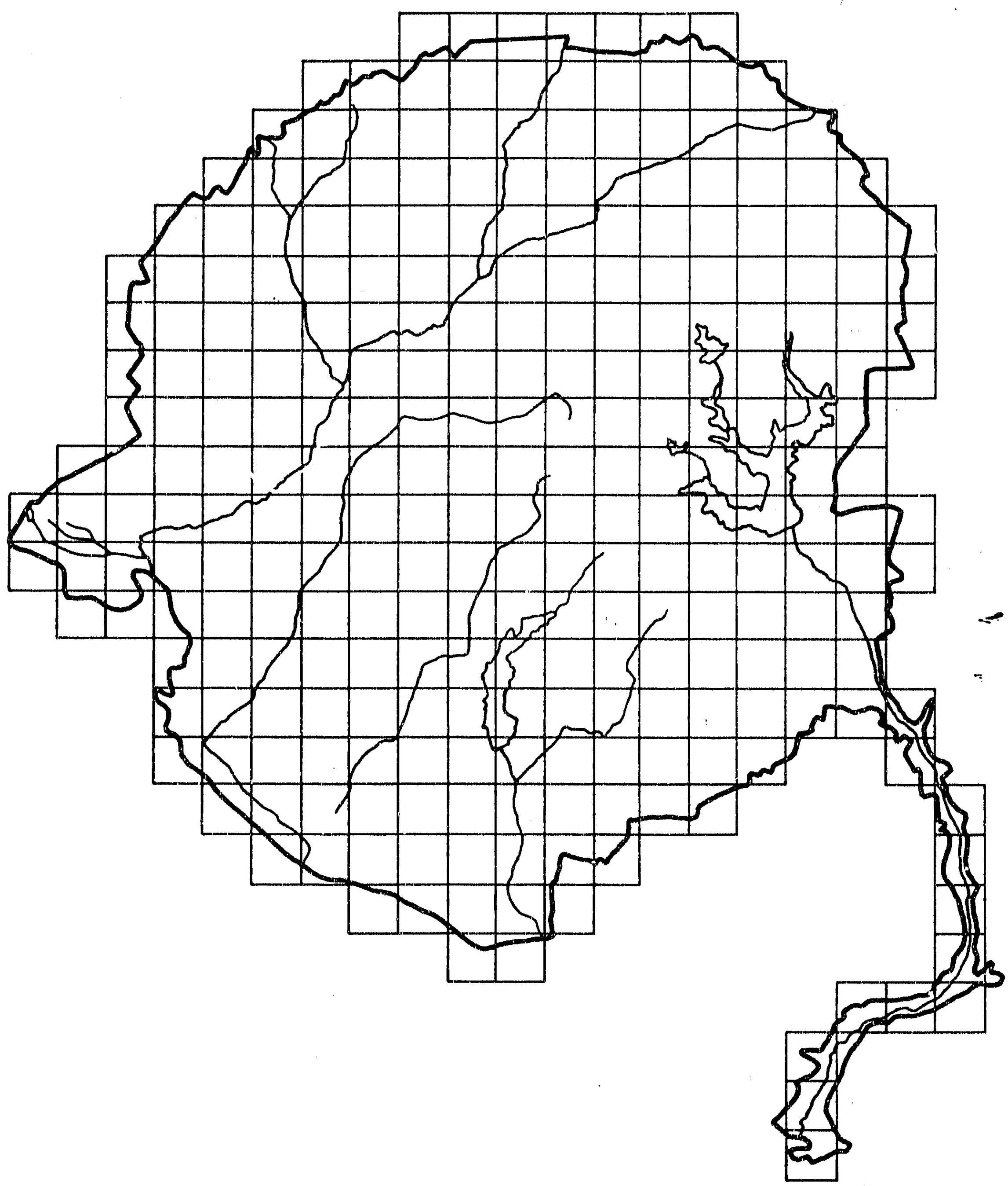

FIGURE 1. 278 Cells Used for DRASTIC

SITEWIDE FACTORS

As shown in Table 10, 4 of the DRASTIC factors, net recharge, aquifer media, impact of the vadose zone, and hydraulic conductivity, received sitewide values. The reason is that there is no convenient documentation containing data on these 4 factors spread uniformly over the entire SRS; for instance, data on hydraulic conductivity mostly come from pump tests done in F, H and M areas. Likewise, Christensen and Gordon (1983) and Andersen et al. (1988) report net recharge at 15 in/yr across the Site, even though it surely varies over hills and plains, forests and parking lots. Moreover, as Tables 4, 5, 8 and 9 show, one must select DRASTIC ratings for these factors from broad categories. I chose "Sand and Gravel" as the aquifer media, for example, because it characterizes the SRS water table aquifers better than any of the other choices.

On the other hand, there is probably sufficient data available somewhere on-site for each of these 4 factors to make a much better estimate of their values. Applying DRASTIC could be seen, if for nothing else, as an impetus for consolidating and improving sitewide geohydrologic information.

The remaining 3 factors can best be covered individually.

DEPTH TO THE WATER TABLE

Using the topographic map with the sitewide map of the water table surface prepared by Andersen et al. (1988, Fig. 2.23), I obtained rough estimates of depth to the water table for all 278 cells. With the help of Table 4, I converted these depths to ratings, which are shown in Fig. 2.

Table 10. Sitewide Factors at SRS

Factor	Characteristic Value	Rating	Weight	Factor Index
Net Recharge	15 in/yr	9	4	36
Aquifer Media	Sand and Gravel	8	3	24
Impact of the Vadose Zone	Sand and Gravel with significant Silt and Clay	6	6	36
Hydraulic Conductivity	1.0 - 7.5 gpd/ft^2	1	3	3

SOIL MEDIA

I gathered data for soil media and topography from the soil survey atlas sheets. Fig. 3 shows the location of the 45 sheets superimposed on top of the grid. I selected the predominant soil types, up to 4 per cell, then used Table 7 to determine ratings for each cell. This led to the Soil Media ratings shown in Fig. 4. The ratings for cells with several soil types are averages of those ratings. For example, suppose a cell's predominant soil types were Troup sand and Fuquay loamy sand, then the rating for that cell would be 8:

$$\frac{9 \text{ (for Troup sand)} + 6 \text{ (Fuquay loamy sand)}}{2} = 7.5 \approx 8.$$

TOPOGRAPHY

The soil survey atlas sheets give not only soil types but also slopes or ranges of slopes, which made them useful for rating the site

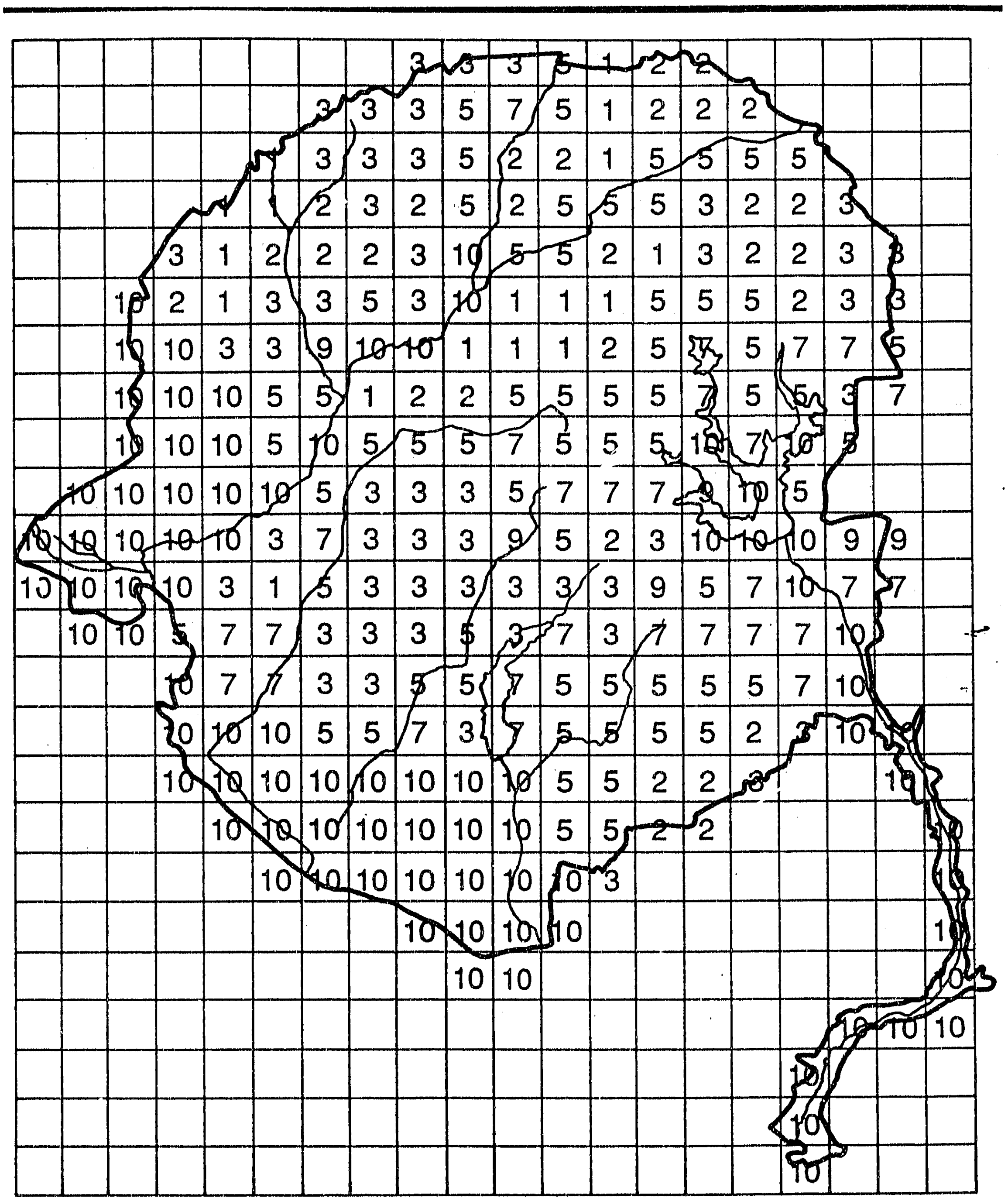

FIGURE 2. Depth to the Water Table Ratings

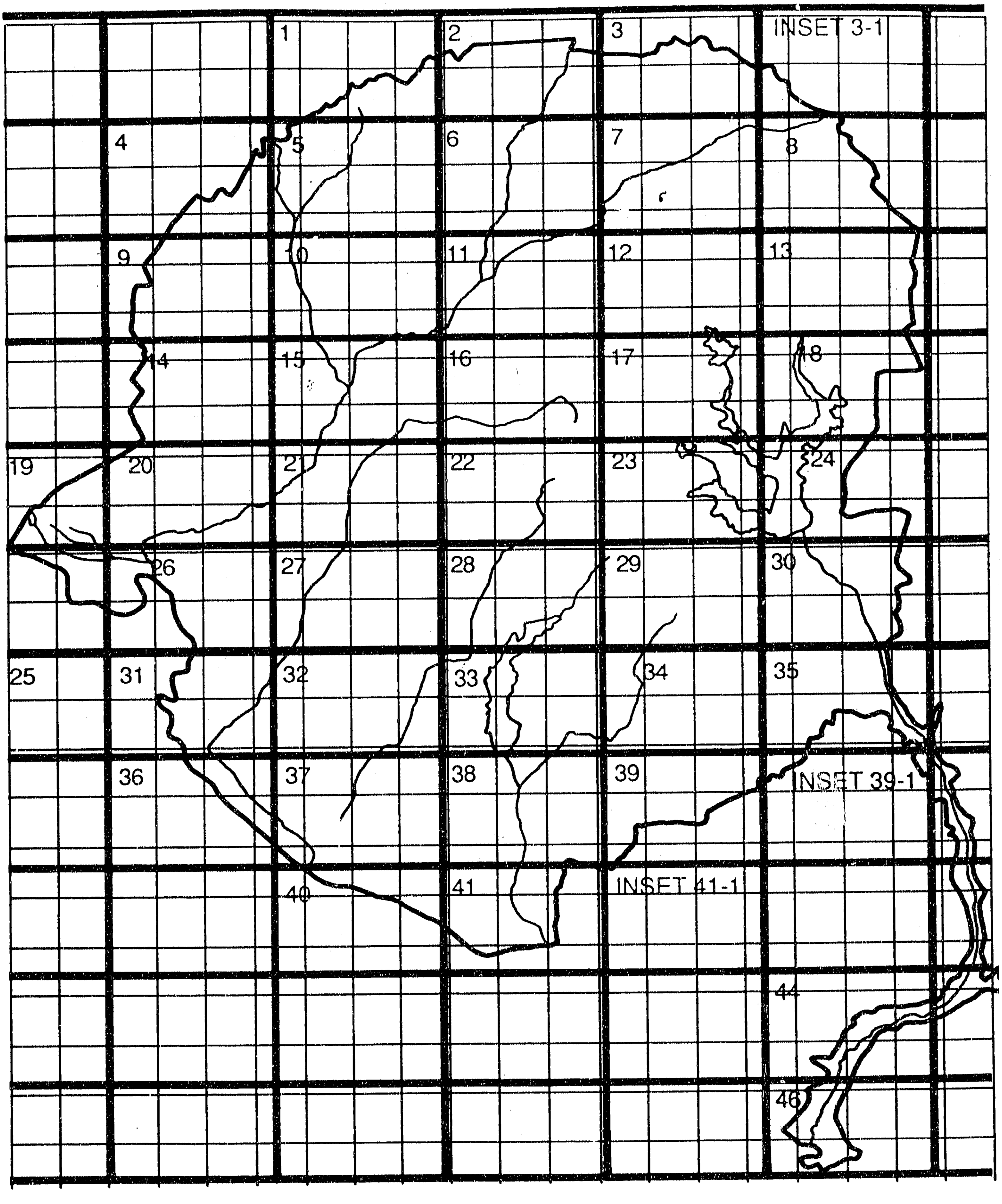

FIGURE 3. Location of Soil Survey Sheets

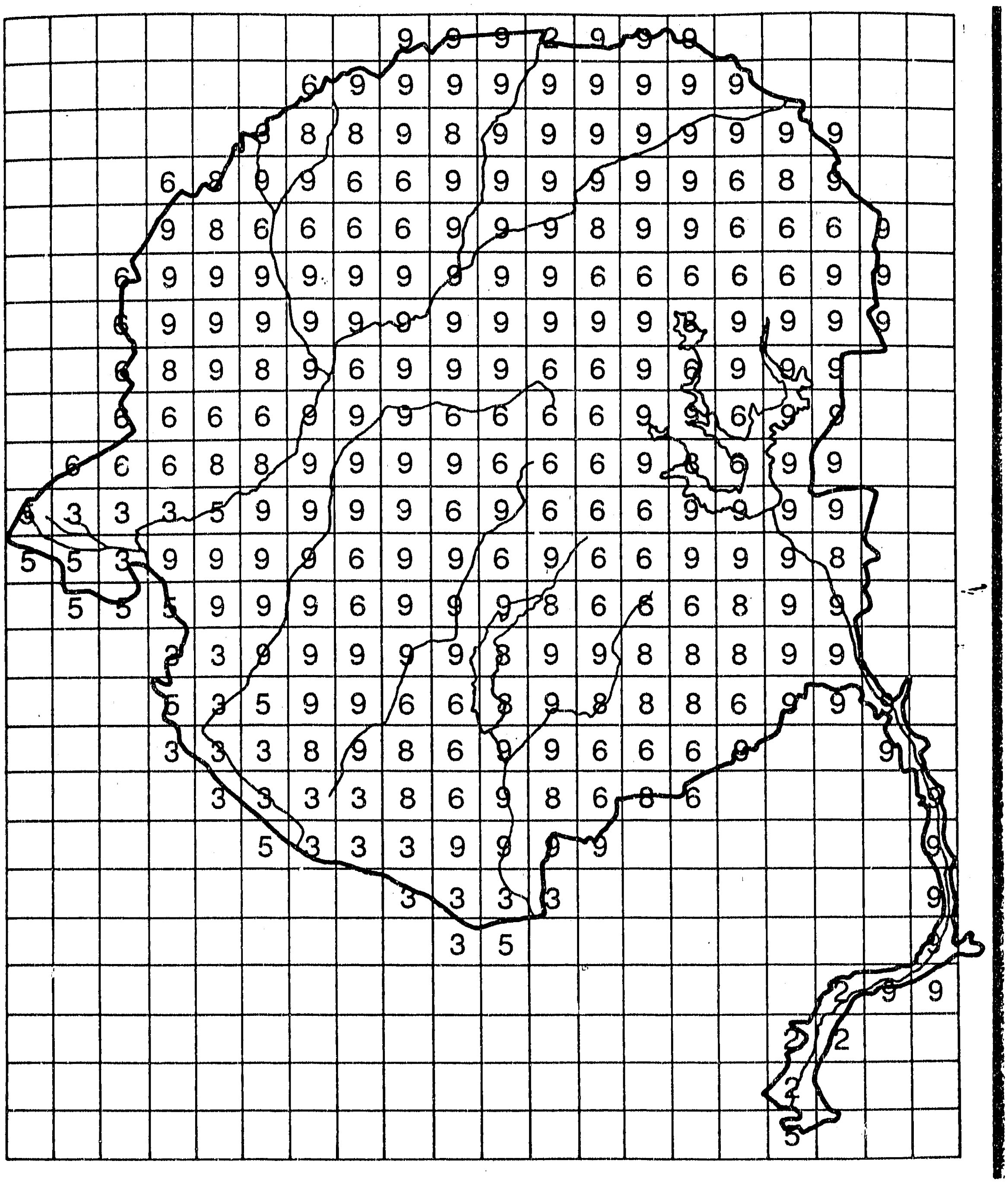

FIGURE 4. Soil Media Ratings

topography since DRASTIC rates topography in terms of slopes. Slopes described as "frequently flooded," ranked as zero slopes; where they were given as ranges, e.g., 0% to 6%, they were averaged (in this case, 3%). Similarly, I computed mean values in cells where slopes varied considerably, like those near Upper Three Runs Creek. I converted mean slopes to topography ratings using Table 7; these appear in Fig. 5.

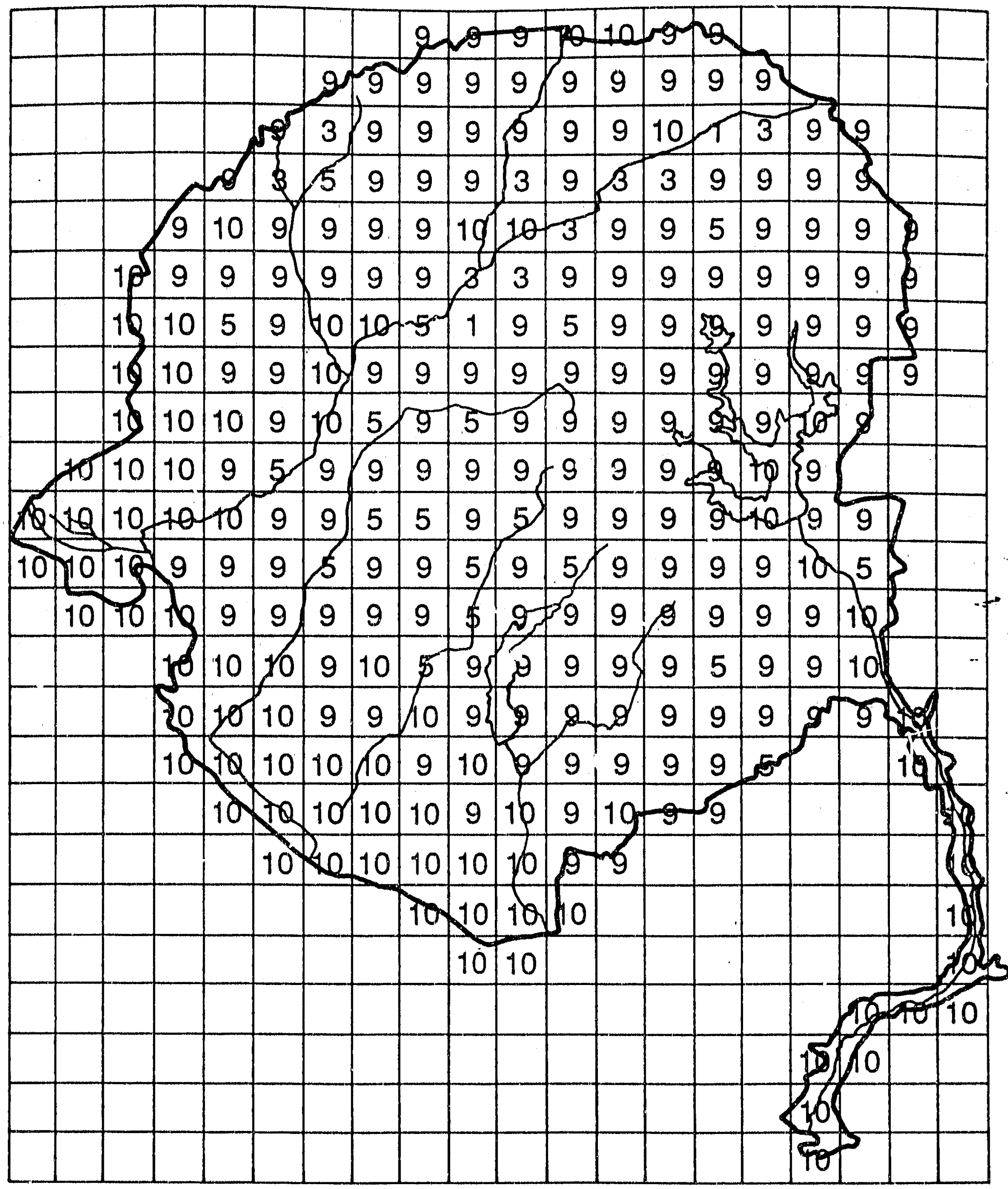

FIGURE 5. Topography Ratings

RESULTS

Once I accumulated ratings for all 7 factors in each of the 278 cells, I recorded them on a spreadsheet and calculated the DRASTIC index for every cell. These results appear in Fig. 6. Finally, Fig. 7 displays the end product, a color-coded DRASTIC index map.

Overall, the SRS appears moderately vulnerable to groundwater pollution relative to other places of comparable size. About a third of it (36%) is in the moderately vulnerable range of 160-179; the rest is in the less vulnerable range below 159. The lowest (best) indices occur at the tops of hills or ridges because that is where the most telling factor, depth to the water table, is the most favorable. The highest (worst) indices appear where the water table is close to the ground surface, as along the Savannah River.

Had I used smaller cells, or differentiated, by cell, more than 3 of 7 factors, there would be finer detail; i.e., there would be more than 3 colors in Fig. 7. For example, Beard and Rowland (1988) applied DRASTIC to an 800 mi^2 county and produced an index map with 6 different color ranges. They used 30 m x 30 m (instead of 1700 m x 1700 m) cells, and had available digital data bases for all 7 factors incorporated on geographical information system (GIS) software. Theirs was a much more thorough application of DRASTIC than the one reported here.

Fig. 7 shows that DRASTIC identifies the reference site for the NPR

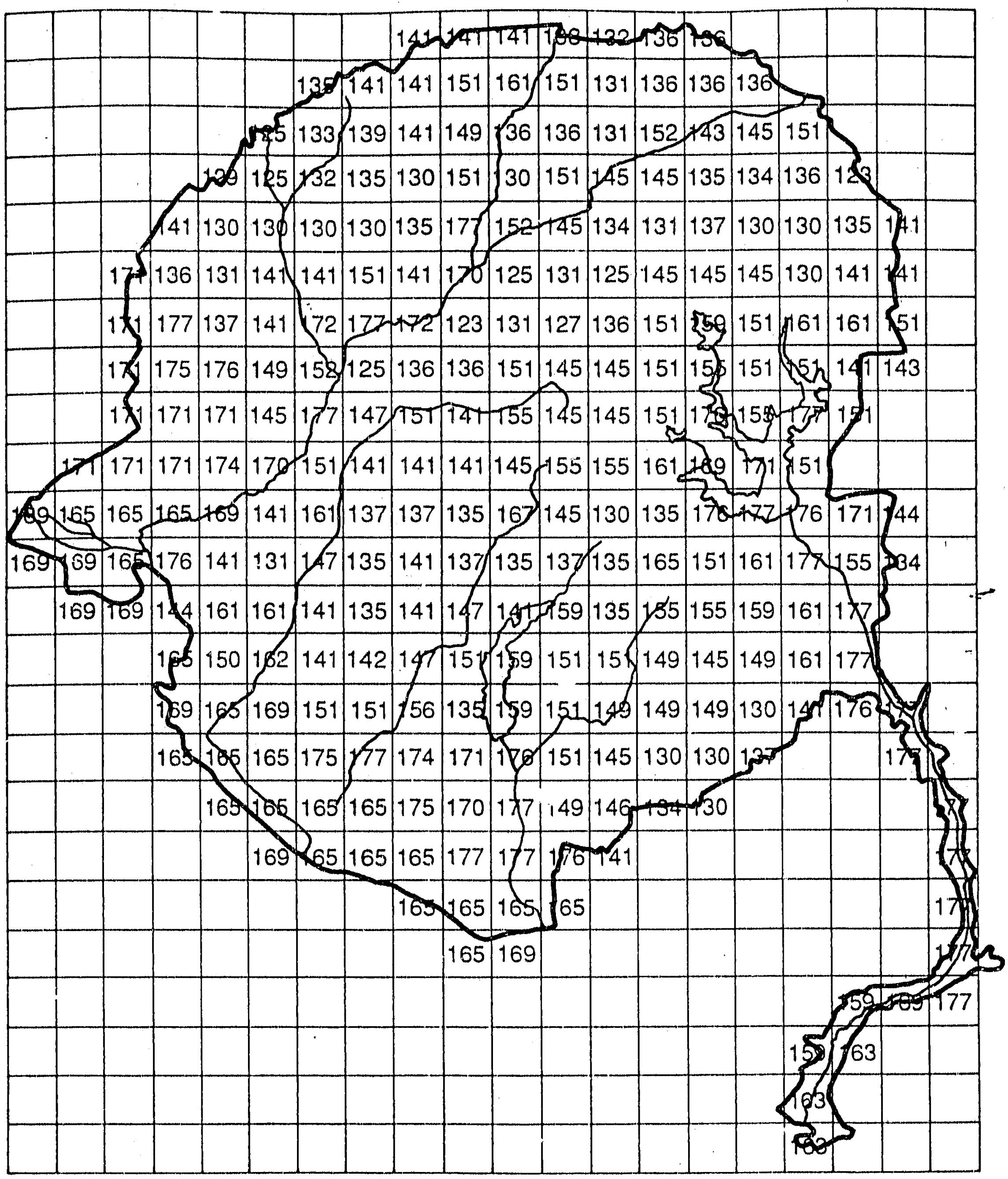

FIGURE 6. Overall DRASTIC Indices for Each Cell

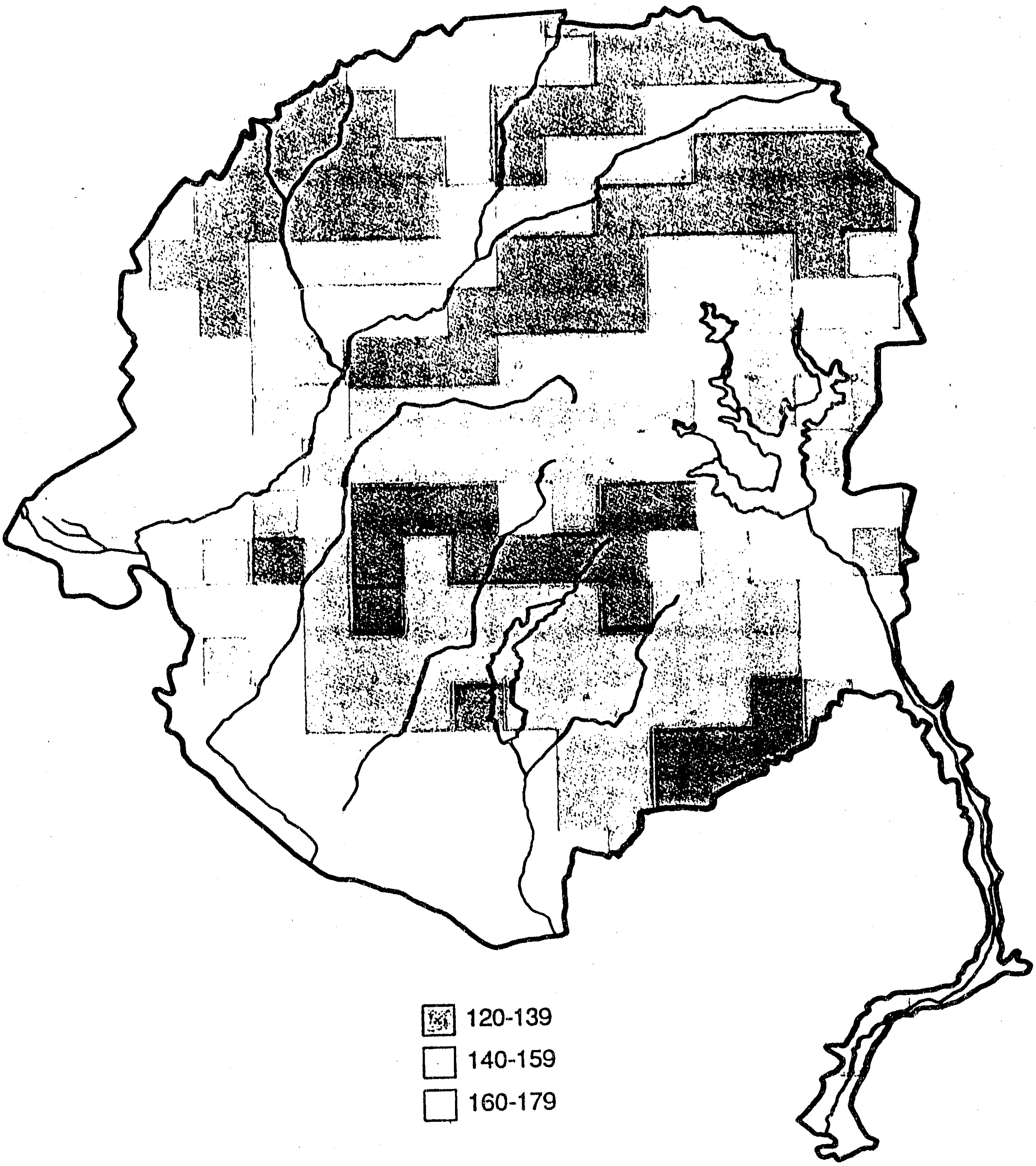

FIGURE 7. Color-coded DRASTIC Index Map

in the less vulnerable range. It also shows that F, H, and M Areas lie in less vulnerable locations. Based upon this cursory DRASTIC analysis, they are well-sited. The other industrial areas appear less well-sited because they are surrounded by regions with higher DRASTIC indices. However, it is very important to note that DRASTIC does not consider distance from the plant boundary, potential seismic activity or preferential flow paths underlying or within water table aquifers, any of which may be more important than all the DRASTIC factors combined.

According to DRASTIC, less vulnerable sites not yet developed are on the wedge of land between Upper Three Runs and Tinker Creeks in the north and at two isolated spots in the southeast. Nevertheless, because of limitations mentioned above, these sites may be less desirable for other reasons that have no effect upon DRASTIC's results.

CONCLUSIONS AND RECOMMENDATIONS

DRASTIC in many respects oversimplifies groundwater pollution potential at the SRS. But it does offer some important insights. Primarily, it provides some evidence that the original siting decisions for SRS facilities were sound ones so far as groundwater protection goes, and that the reference site for the NPR is well-chosen.

On the other hand, this was a cursory application of DRASTIC. It was a rough application of a rough approximation. Because the cells were almost 3 km^2, there was enough room to have influential information slip through the grid, and not be counted. However, this could be avoided by making the grid tighter, perhaps by reducing the cell length from 1700 to 30 m, as in the example noted previously (Beard and Rowland 1988). Also, the 4 factors given sitewide values--net recharge, aquifer media, impact of the vadose zone, and hydraulic conductivity--should be analyzed more carefully to identify variations that surely exist, and that could be pinpointed if the cells were smaller.

In that case, applying DRASTIC by hand would be impractical; a GIS would be essential. Building initial data bases for a GIS is difficult, but that work is progressing at the SRS (and at other agencies), and will most likely include at least some of the data needed to produce a DRASTIC index map. Topography, soil types, and potentiometric surfaces will be some of the first things put into digital form. In fact, for many places in the U.S., the U. S. Geological Survey already has Digital Elevation

Models (DEMs) that are elevations-above-sea-level, in meters, spaced at regular 30 m intervals on the ground, and the Soil Conservation Service has digitized maps of soil types in 3.75" x 3.75" latitude/longitude grid cells.

Furthermore, there is no reason not to tailor the DRASTIC method to include additional factors that are very important at the SRS, or to account for the available data, making it more useful here. Perhaps it ought to be applied to only part of the plant, where most activity takes place, or where the data is more complete.

DRASTIC has been used most often by county planning commissions, particularly in counties served by the Tennessee Valley Authority (TVA). There they use it in conjunction with geographical information systems (GIS) software (although the DRASTIC procedure is not a computer program). In the case of the example mentioned before, Beard and Rowland (1988) applied it to Madison County, Alabama, which is where two large government industrial facilities are located: the U.S. Army's Redstone Arsenal, and, NASA's Marshall Space Flight Center. If DRASTIC were applied similarly to the SRS, at least the results could be used to show to a skeptical or misinformed public that a widely accepted, common sense approach to siting is followed here, just as it was at another place where there are large government facilities.

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