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BIOGRAPHICAL SKETCH

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ABSTRACT

This report describes a computer-based information system designed to assist in the integration of commonly available spatial data for regional planning and resource analysis. The Resource Analysis Program (RAP) provides a variety of analytical and mapping phases for single factor or multi-factor analyses. The unique analytical and graphic capabilities of RAP are demonstrated with a study conducted in Windsor Township, Eaton County, Michigan. For this study, soil, land cover/use, topographic and geological maps were used as a data base to develop an eleven map portfolio. The major themes of the portfolio are land cover/use, non-point water pollution, waste disposal, and ground water recharge.

INTRODUCTION

The geographic analyst has a wide range of new data sources at his disposal; prominent are high altitude aircraft and satellite imaging devices. In addition, traditional data sources, such as soil and topographic maps, are being made available in compatible forms, such as digital magnetic tapes. Much of this technology has developed along separate lines, with various "packages" being available in remote sensing, census data, soil and topographic data.

An area of spatial analysis that is receiving more attention concerns the interface between the packaged data sources and the agencies that use the data. The problem is essentially one of communication; in short, how to get one set of spatial data to "talk" with another. The integration of spatial data into a coherent and applicable theme involves both process (methods of analyses) and form (types of data used in the analyses).

Many information systems concern only data procurement, such as processing LANDSAT raw spectral data into land cover classes. Certain approaches in geo-coding soils data lead to automated mapping of first generation interpretive soil maps. However, few systems have been developed that provide the spatial analyst with the ability to combine the products of elementary information systems into the integrated approaches required by ecological analyses.

This report describes the Resource Analysis Program (RAP), a computer software system designed to assist in the integration of a variety of geographic data. The system features a simple user-language in conversational format for accessing a wide array of analytical and mapping functions (Table 1). The analytical phases provide the process (methods of analyses) for grid-based geocoded resource data. The mapping phases permit the graphic display of the data analyses using either a high-speed line printer or a plotter as the mapping device.

An application in Windsor Township, Eaton County, Michigan, will serve as a medium for discussing the RAP system. The objective of this study was to develop a series of resource maps that focus upon land characteristics relevant to non-point water pollution.

Windsor Township is typical of the planning region, and indeed of much of the country, in that only basic resource data exist: a recent soil and land cover/use map, plus the standard USGS topographic survey. In addition, the State Geological Survey maintains a file of driller-submitted water well records of basic lithology data on the near surface environment. The water well data were used to obtain maps of depth to bedrock and generalized permeability of the glacial drift. These five resource maps were geocoded using a 10-acre dot grid matrix, providing the basic data for the study program and the analyses using the RAP system.

ANALYSIS STRATEGY

A study plan was developed to produce a resource map portfolio. The portfolio was to address four major topics: ground water recharge, nutrient and sediment loading, waste disposal, and selected land use elements. These four themes were chosen because of their relevancy to an on-going regional water quality improvement program.1/

Eleven map themes were identified as being particularly useful for this study (Table 2). Although the eleven maps address very different

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1/Conducted under the auspices of Tri-County Regional Planning Commission and funded through Section 208 of the Federal Water Pollution Control Act Amendments of 1972.

TABLE 1

PHASES OF RAP AND THEIR FUNCTION

	Phase	Function
1.	AGVALUE	Determines State equalized assessment values for agricultural land
2.	DELETE	Delete a factor from the Work File
3.	END	Stops execution of RAP
4.	EROSION	Calculate on-site erosion susceptibility according to the Universal Soil Loss Equation
5.	GROUP	The factor values are grouped and each group is assigned an integer number (mapping directive), default or user specified
6.	INVERT	Invert the numerical range of a factor
7.	LIST	Lists the factor names currently on the Work File
8.	MAPIT	Constructs symbol maps with a plotter
9.	NORMALIZE	Normalize the numerical value of a factor between user specified or default range
10.	OVERLAY	Generates comparative site indices by overlay process with weighting values
11.	PRINTERMAP	Constructs symbol maps from a line printer
12.	SCALE	Generates comparative site indices by a multi-dimensional scaling algorithm
13.	SOILTABLE	Retrieves soil and/or slope related properties
14.	SORT	Assigns a value (mapping directive) to pair-wise combination of factors
15.	STATISTICS	Generates frequency table for factor values
16.	UPDATE	Updates the master file by adding or deleting factors
17.	WORKFILE	Retrieves factors from master file and places them on the Work File

MAP TITLE	DATA USED IN ANALYSIS								PHASES OF RAP USED									
									Analytical							Map Symbols		
	Land cover/ use	Soils	Slope	Elevation	Depth to Bedrock	Drift Permeability	Water bodies	Data developed with RAP	EROSION	GROUP	OVERLAY	SCALE	SOILTABLE	SORT	STATISTICS	Alphabetic	Octagons	Geometric
1. Surface Topography and Natural Features				x														
2. Land Cover/Use	x														x	x		
3. Potential Ground Water Recharge Management Areas	x	x	x		x	x	x			x		x		x				x
4. Soil Phosphorus Availability		x											x				x	
5. Potential On-Site Erosion		x	x						x	x							x	
6. Potential Phosphorus Loading Source Areas		x						x1/					x	x				x
7. Limitations for Septic Tanks	x	x	x										x	x				x
8. Limitations for Sanitary Landfills	x	x	x					x2/		x		x		x				x
9. Limitations for Spray Irrigation	x	x	x					x2/		x		x		x				x
10. Soil Stability		x											x				x	
11. Limitations for General Agriculture	x	x	x										x	x				x

1/ Potential On-Site Erosion

2/ Limitations to Ground Water Recharge

TABLE 2. MAP PRODUCTS AND DATA ANALYZED BY RAP FOR THE WINDSOR TOWNSHIP STUDY

subjects, each was produced from the same base data file using various analytical and mapping options of the RAP system. This type of flexibility with RAP provides a powerful tool for the spatial analyst.

For each of the eleven maps, an analysis strategy was outlined, then detailed as to type of data (form) and method of analyses (process) to be used (Table 2). An analysis strategy consists of linking the program phases in some logical order. Since the phases operate independently of each other, the analyst is not restricted in this sequencing, within, of course, the limitations and data requirements of each phase.

Included in the analysis strategy was the choice of mapping option to display the results. RAP contains two major mapping options. The PRINTERMAP phase uses a line printer to produce a grey-tone map using one of fourteen density shades (including a blank) for each cell. The MAPIT phase uses a pen-and-ink plotter to draw discrete symbols (including a blank) for each cell. Since the maps of the Windsor Township study were to be reproduced and used in formal presentations, the MAPIT phase was chosen for all cartographic products.

Within the MAPIT phase, the user has a choice of three standard symbol sets (additional, non-standard symbols may be developed during the RAP session). For the Windsor Township Portfolio, the standard symbol sets were chosen so that nominal scale data, such as soil type or land cover/use, were represented by alphabetic characters, with line boundaries drawn around contiguous cells of the same data class (Figure 1). Maps which display a range of map factor values (ordinal scale data), such as potential on-site soil erosion were drawn using concentric octagons yielding a visual density effect (Figure 2). Maps which portray the co-occurrence of data elements, such as limitations for sanitary landfills and existing land use, were drawn using discrete symbols and symbol combinations (square, triangle, octagon, etc.) for each data class (Figure 3).

METHODS OF ANALYSIS

The analytical methods used to produce the Windsor Township portfolio ranged from simply retrieving a factor from the data file and mapping it to developing rational multi-factor analyses schemes. The RAP system provides several analytical phases for multi-factor analyses. The results from one analytical phase may be used as input into another, thus permitting fairly sophisticated data manipulation.

The land cover/use map (Figure 1) demonstrates the most straightforward and easiest data manipulation technique. Twenty-one categories of land cover/use were coded by a simple integer sequence number (i.e., 1 = residential, 2 = commercial, 3 = industrial, etc.). By using the standard alphabetic symbols of the MAPIT phase, each land cover/use category was portrayed as a letter code (A = residential, B = commercial, C = industrial, etc.). The analyst needed only to retrieve the land cover/use codes from the data file and proceed directly to the MAPIT phase.

In preparing the soil phosphorus availability map, the soil type code (nominal scale) for each cell had to be transformed in the appropriate availability rating (ordinal scale). In order to accomplish this task, the analyst called the SOILTABLE phase after

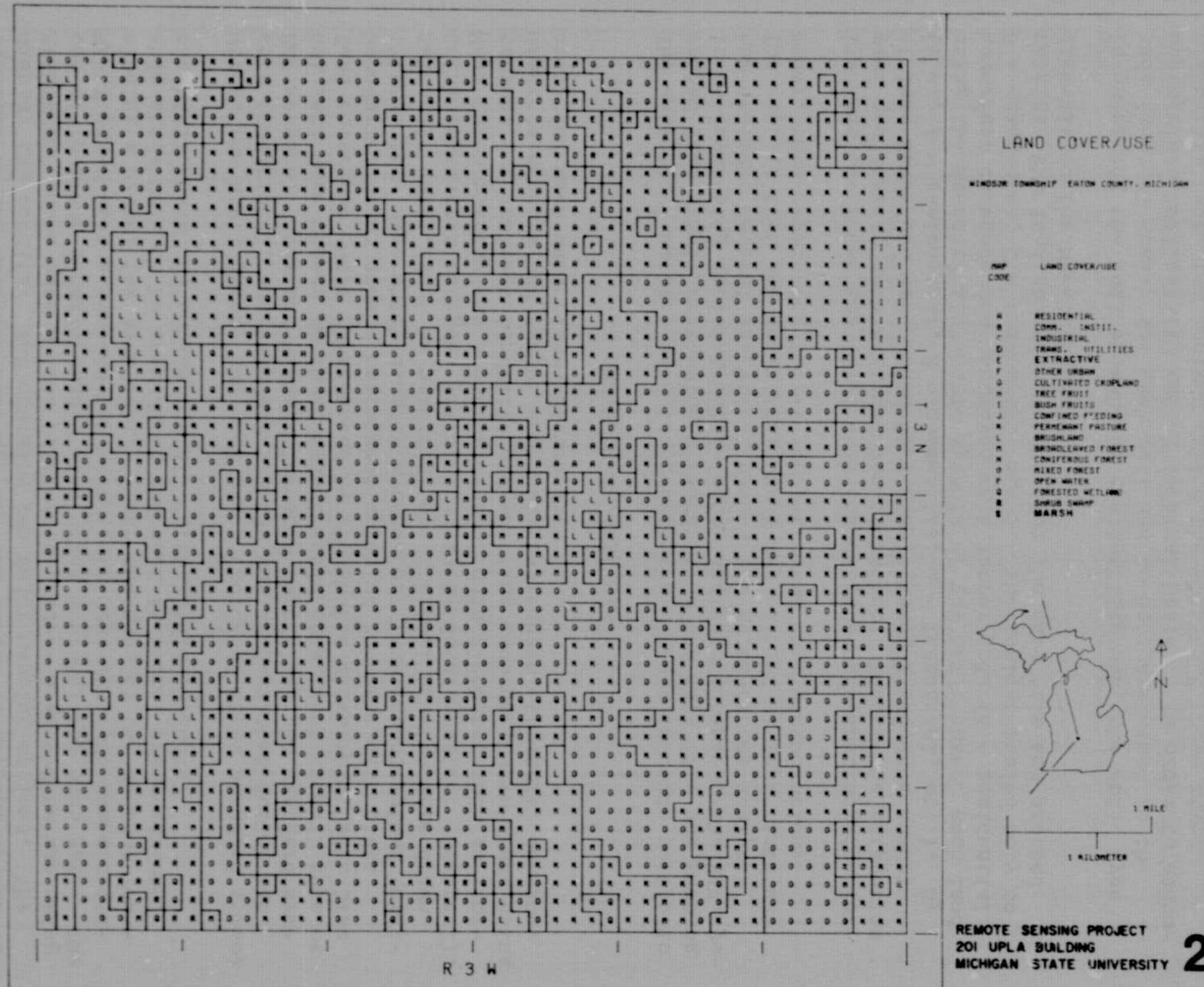

Figure 1: Example of a plotter map produced with the RAP system showing land cover/use (nominal scale data). Contiguous cells of the same land cover/use category are outlined with a boundary.

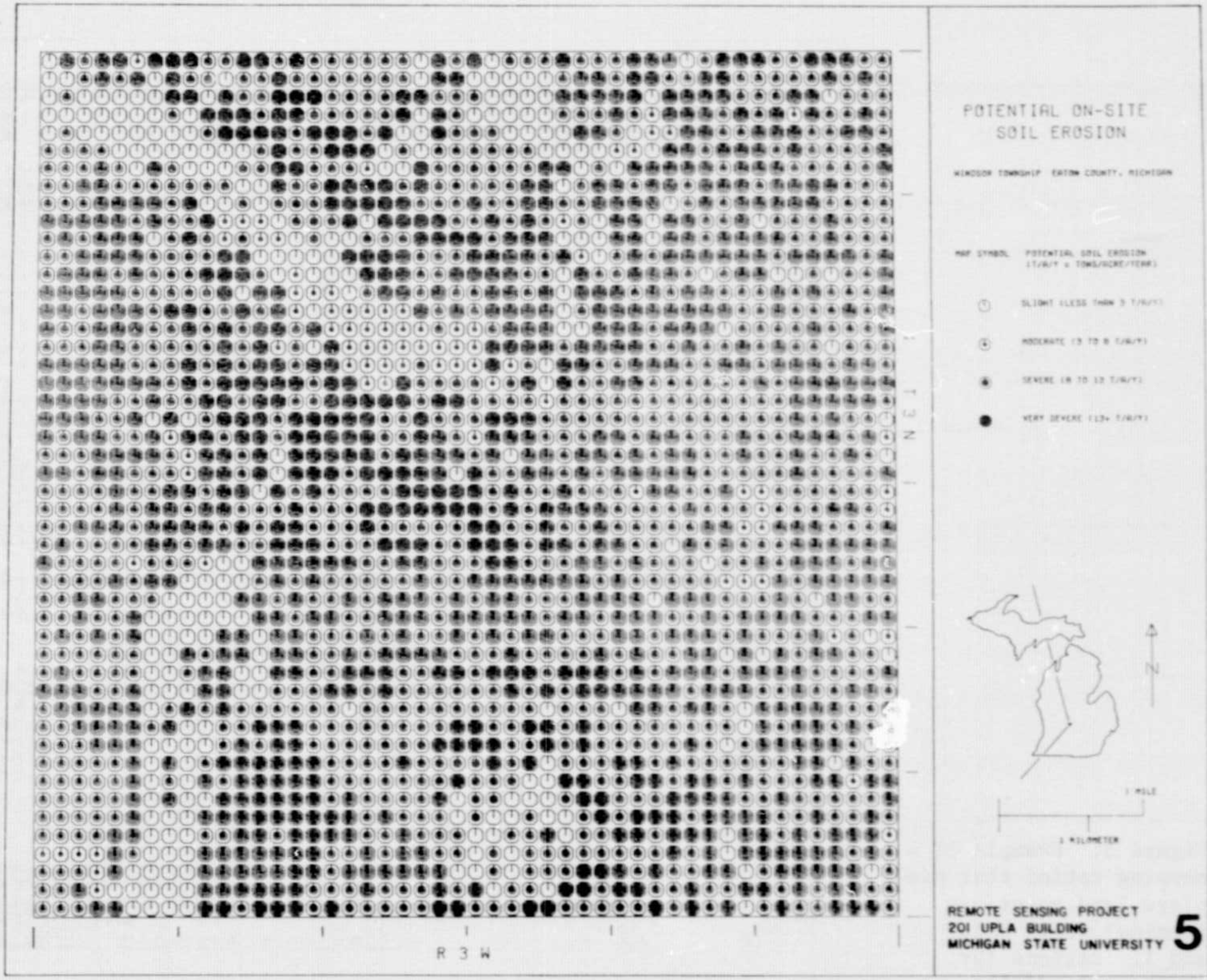

Figure 2: A map of potential on-site soil erosion classes (ordinal scale data) was obtained using a combination of analyses and mapping phases of the RAP system.

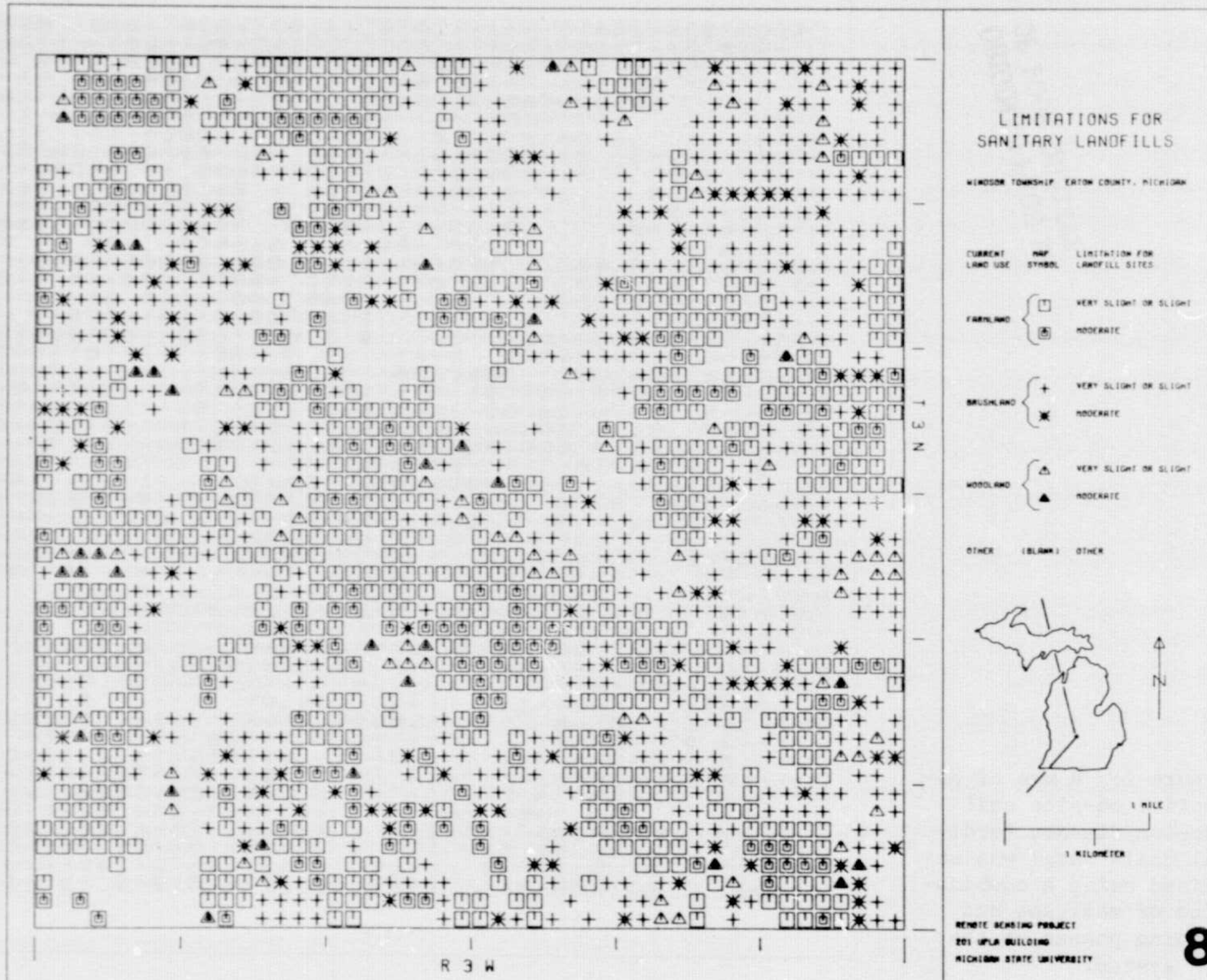

Figure 3: Example of a mapping option that displays land cover/use (nominal scale data) and limitations for sanitary landfills (ordinal scale data).

retrieving the soil code from the data file. The SOILTABLE phase is an internal library of RAP containing twenty soil interpretation ratings for a variety of soil engineering properties, crop productivity indices, and nutrient levels (Table 3). The soil ratings are returned as an integer number, ranging from 1 through 6 (e.g., 1 = 60 lbs of P/acre, 2 = 60-80 lbs of P/acre, 3 = 80-100 lbs of P/acre, etc.). The analyst can then proceed to the MAPIT phase, using the standard symbol set of increasing-density octagons to portray the increasing phosphorus availability rating of the soil.

The EROSION phase provided the analyst the capability of determining the on-site erosion susceptibility of each 10-acre site (Figure 2). The erosion susceptibility is calculated according to the Universal Soil Loss Equation:2/

$$A = R \times K \times L \times S$$

The value A is the erosion potential, in tons/acre/year; R is the rainfall factor (generally uniform over a county-wide study area); K is the soil erodibility factor; and L and S are the slope length and steepness factors, respectively. The soil and slope factors are determined for each cell from the data file; while the rainfall factor is supplied by the analyst during phase execution.

The erosion potential expresses the mean annual soil loss under maximum adverse conditions (no vegetative cover or erosion control practices) such as is likely to occur at unprotected construction sites, fallow fields, or clearcut forest tracts. Not only does the erosion potential help to focus regional water quality improvement plans, this information can also be used in on-going agency reviews of ordinance-required sediment control permits.

After the analyst had determined the erosion susceptibility and phosphorus level for the soils in each 10-acre site, these data were combined to provide an insight into potential source areas for non-point phosphorus loading. By using the SORT phase, the co-occurrence of specific erosion and phosphorus levels were identified. The combinations of interest were assigned an integer sequence number (i.e., 1 = highly erodible soils with a high phosphorus content, 2 = highly erodible soils with a moderate phosphorus content, etc.). Each sequence number was then assigned a unique symbol type in the MAPIT phase to map the spatial distribution of the erosion/phosphorus levels.

Many of the individual map themes had to be developed through a multi-factor analysis strategy. For example, there are no single map documents for Windsor Township showing generalized areas suitable for waste disposal sites or ground water recharge. Yet these subjects are crucial in developing alternative regional water quality management plans.

In order to get around these data limitations in Windsor Township, the spatial analyst used several of the multi-factor analysis phases

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2/Tilmann, S.E., and D.L. Mokma, Soil Management Groups and Soil Erosion Control, Mich. Agr. Exp. Sta. Res. Rep. 310, Michigan State University, 1976.

TABLE 3

SOIL PROPERTIES AVAILABLE ON THE NRIS TESTED IN WINDSOR TOWNSHIP
Bearing capacity
Corrosion to underground concrete conduits
Compaction
Compressibility
Limitations for cropland suitability
Limitations for low building foundations
Susceptibility to frost heave
Permeability
Phosphorus availability
Phosphorus adsorption capacity
Seepage rate
Limitations for septic tank disposal fields
Shear strength
Shrink-swell potential
Corrosion to underground steel conduits
Stability on thawing
Water holding capacity
Limitations for woodland suitability
Workability

of RAP to generate site indices for limitations to ground water recharge, sanitary landfills, and spray irrigation waste treatment. The SCALE phase is particularly useful for this task since ordinal scale data, as well as interval and ratio scale data, may be used in developing the site index.

The SCALE phase generates a comparitive site index for each cell by a multidimensional scaling algorithm. Multidimensional scaling consists of establishing an n-space, where n is the number of factors in the analysis. The numeric values of each factor for each cell establishes a point for that cell in the n-space.

The site index is the Euclidean distance between that point, and a point representing an optimum or desired set of conditions (user specified). As this index decreases (the distance between the points decreases), the conditions for that cell approach that of the desired or optimum site conditions. The distance index may also be thought of as a similarity index.

The Potential to Ground Water Recharge map demonstrates the use of the SCALE phase for multi-factor analysis. Ground water recharge is particularly important in the study area since all domestic and municipal water supplies are obtained from glacial and bedrock aquifers. For this analysis, the optimum conditions for ground water recharge were defined in terms of soil permeability and slope, depth to bedrock, gross permeability ratings of the glacial drift, and the locations of surface water bodies.

Each cell was evaluated relative to a set of defined optimum recharge conditions and rated from 1 through 100. A low site index number corresponds to slight limitations for ground water recharge. The recharge site indices were grouped into five qualitative classes with the GROUP phase.

The groups were then sorted into categories according to the site's dominant land cover with the SORT phase. Specific combinations were mapped with the cover type determining the type of geometric symbol (farmland=square; wetland=cross; woodland=triangle). The limitation ratings determined the symbol density (slight=single symbol, moderate= double, concentric symbol).

In addition to the ground water recharge map, the SCALE phase was used to obtain site indices for limitations to sanitary landfills and spray irrigation waste water disposal. These indices were mapped (Figure 3) according to the dominant land cover for each site.

For the Windsor Township study, the analyst did not use the full range of analytical phases available with RAP. The OVERLAY phase performs an operation on a set of factors which is analogous to "overlaying" (sometimes called compositing) factor maps. The AGVALUE phase determines current assessment values for land in an active agricultural use. These phases could have been used (had the analysis strategy called for them), providing even more flexibility for the spatial analyst.

SUMMARY

The unique analytical and graphic capabilities of the Resource Analysis Program provide a powerful tool to regional planning and resource management agencies. The computer software system described in this report is user oriented, providing a free-field, conversational format for access to a wide range of spatial data manipulation techniques. The general utility analytical phases of RAP can integrate commonly available data sources for multi-factor resource analyses. Either line printer or plotter maps can be used to display the results of data analysis.

The RAP system was used in Windsor Township, Eaton County, Michigan, to produce an eleven map portfolio specifically oriented toward water quality management. Available resource data that included soils, land cover/use, and topographic maps, were grid-geocoded to a 10-acre cell size. The data were analysed with the various phases of RAP to provide the regional planning agency with a clearer insight into the area's physical environment and its relationship to land cover/use, non-point water pollution, waste disposal, and ground water recharge.

ACKNOWLEDGEMENTS

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