ENVIRONMENTAL ASSESSMENT WITH BASIS

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ABSTRACT

The use of automated techniques for environmental assessment has developed significantly in the past two decades. Although there has been equally rapid advancement in the practice of geographic data handling, the techniques of this field have been infrequently applied to assessment projects. This is particularly true of large area data systems created for regional or statewide planning applications. One regional data base - BASIS in the San Francisco Bay Area - has recently been used for several local and subregional environmental assessment projects. These applications illustrate the technical and institutional barriers which must be overcome to use geographic data bases in environmental assessment work.

INTRODUCTION

During the past two decades, there has been a growing awareness of man's relationship to the natural and manmade environment. Events such as earthquakes and volcanic eruptions have shown the awesome destructive potential of natural forces. Pollution problems and chemical spills act as frequent reminders of other dangers. A greater understanding of ecological relationships has developed, and this understanding has increased the ability to systematically analyze proposed human actions and to predict their effect on the natural and human environment.

Federal and state legislation to require such study (beginning with the National Environmental Policy Act of 1970) has lead to the development of a discipline which studies the potential environmental effects of human actions and proposes steps to mitigate these effects. This field, known as environmental assessment, has created many complex techniques for predicting impacts and for identifying mitigation measures.

Developments in the field of geographic data handling have been equally rapid in this period. Advances in computer hardware and software have made possible innovative applications in such diverse areas as mineral exploration and regional planning; a new acronym, GIS (for Geographic Information System) has come into common use to describe computer mapping and related data storage and manipulation techniques.

Many of these GIS applications have dealt with single environmental issues. There have been, however, few examples of the use of GIS techniques in formal environmental assessment projects. This is somewhat surprising, given the many similariities in the two fields. Both have utilized computer methods heavily. Both deal with data that is largely spatial in nature; a comparison of the data types used in a typical environmental impact report and a major GIS would show much in common. Analytical tools are also similar; each field may deal with operations such as distance calculation and overlaying. Finally, the ability to output mapped data is central to each.

There are clear advantages to a combination of the two disciplines. The concepts of data integration would seem to offer substantial cost savings: one possibility is the creation of a Master Environmental Assessment, where an areawide data base is used to process data for individual projects as they are proposed. The mapping and display capabilities of a GIS offer enhancements to the usual tabular output of environmental models. The use of an areawide GIS would also be helpful in promoting consistent policies; use of the same data by different agencies would tend to remove some of the initial differences in many environmental disputes.

A number of technical and institutional factors have acted to restrict this use. Elements such as data structure, positional accuracy, and the availability of detailed source data for large areas are major technical barriers. Other roadblocks are institutional in nature. Large GISs have usually been built by government agencies; their motivation is the need to study their area of jurisdiction over a long period of time. On the other hand, most environmental assessment work has been performed by private consultants. In most cases, the preparation of an environmental review is treated as a standalone project; data is collected and analyzed for a specific project, with little concern for building a data base which could be used for other applications.

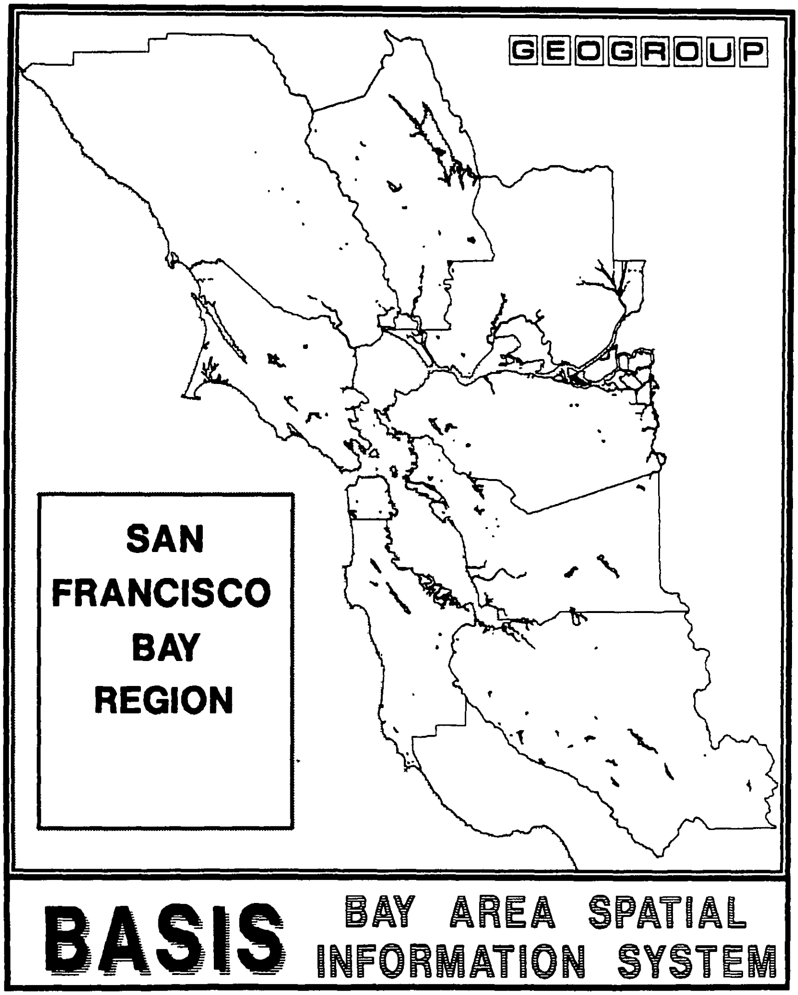
TWO BASIS EXAMPLES

Some recent applications of BASIS, the Bay Area Spatial Information System, illustrate these advantages and limitations. BASIS is a large GIS containing physiographic and socioeconomic data for the 7000-square mile San Francisco Bay region (Figure 1). It was created by the Association of Bay Area Governments (ABAG) in 1974, and was designed to support a variety of regional and local planning applications. The system is now maintained and operated by Geogroup Corporation, and is available for use by both governmental and private organizations.

The primary unit of data representation in BASIS has been the one-hectare grid cell. Coverage of the region (nine counties, the Bay, and ocean areas of interest) requires 2.1 million cells. This hectare cell structure was chosen after extensive debate about anticipated applications of the system. It was clear that a larger cell would support any project that was regional in scope, as well as many which had a subregional scope. Using a smaller cell (or a more complex data structure) would allow for more detailed local studies, but would increase the costs of implementing and maintaining the system. The hectare cell was chosen as a structure that maximized the number of potential applications while assuring a good chance of making the system work. (Since small area projects were a recognized long-term goal, it was concluded that all original data encoding and digitizing would be retained. This would allow for conversion to other structures or to a smaller cell where appropriate.)

BASIS has been used for many applications at the regional scale, as well as a smaller number of local projects (see References). Although these applications have included many which look at complex environmental issues, until recently none approached the breadth of a full environmental assessment project; the focus was always on one type of hazard or resource rather than on bringing together a variety of information for one site. An effort initiated in 1980 has led to the development of two BASIS/environmental assessment programs, one used for projects of *regional* scope and the other directed at the specific needs of one city.

FIGURE 1


GEOGROUP
SAN FRANCISCO BAY REGION
BASIS
BAY AREA SPATIAL INFORMATION SYSTEM

AREA: the Regional Approach

One program is called AREA, for Automated Regional Environmental Assessment. It was designed for use by either regional agencies or local governments, and relies on the BASIS data base to support analytical models and tabulations. This capability was originally developed to summarize impacts of projects which had regional importance, such as noise reduction programs at major airports. Other examples of AREA use include listings of environmental hazards for BART stations and sewage treatment plants, included in a study of earthquake danger to critical lifeline facilities (Figure 2).

A common characteristic of all these regional analyses is the use of one-hectare BASIS cell data. All of the above examples were performed using the cell structure to store environmental data. (Other lifeline data sets, including linear features such as highways and rail lines, were treated as vectors and then overlayed on the cell data.) Most of the effort (and cost) of this type of project is in the data collection phase, since study of regional systems usually requires a large data volume. The analysis itself is straightforward: the location of the critical facility is digitized and converted to the BASIS coordinate system; the cell or cells which it occupies are calculated; and relevant data values are extracted for those cells.

This process has obvious limitations when dealing with specific sites. Since the overlayed environmental data sets are generalized to hectare cells (usually in a dominant area procedure, although data types such as landslides may be coded for the presence of any amount in the cell), precise location of small features can be hidden. The other limiting factors noted in the previous section are often present also; for example, the detail of data classification in a file such as geologic materials is often less than required for a full environmental assessment.

The real value of this application lies in its ability to bring together a large number of potential environmental hazards. Information about different types of hazards exits in different places and in different forms, so it is usually very difficult to summarize and compare risks for a set of sites (such as the lifeline facilities described above). Use of a common data base for storing and analyzing many environmental factors makes it possible to readily access information about each location.

The Petaluma System

The level of analysis described above, while often useful for studies at a regional scale, is clearly inadequate for most local government needs. A city planning agency will usually need data concerning parcel-specific land use and individual street links as part of its analysis. This level of detail is difficult to capture and maintain in regional data bases. Not only is the cell structure unsuitable for parcel data, there are very substantial technical and institutional barriers to the collection of detailed local data by an areawide entity.

Petaluma is a city of 34,000 population located in Sonoma County north of San Francisco. It is widely known for its innovative planning programs, particularly its pioneering efforts in growth management. The city's planning department, needing a more comprehensive tool for environmental assessment as well as for other applications, initiated a project to use BASIS as a foundation for local geoprocessing needs.

FIGURE 2

EXAMPLE OF AREA TABULATION FOR CRITICAL FACILITIES

BART: GLEN PARK STATION	
Surface Rupture Fault Zone	OUT OF ZONE
Maximum Earthquake Intensity	C
Risk of Damage: wood frame	29
Risk of Damage: concrete/steel	46
Risk of Damage: tilt-up	76
Liquefaction Potential	1
Earthquake-Induced Landslide Susceptibility	3
Rainfall-Induced Landslide Susceptibility	2
Dam Failure Inundation	NO
Tsunami Inundation	NO
BART: 16TH ST / MISSION STATION	
Surface Rupture Fault Zone	OUT OF ZONE
Maximum Earthquake Intensity	C
Risk of Damage: wood frame	29
Risk of Damage: concrete/steel	46
Risk of Damage: tilt-up	76
Liquefaction Potential	1
Earthquake-Induced Landslide Susceptibility	1
Rainfall-Induced Landslide Susceptibility	1
Dam Failure Inundation	NO
Tsunami Inundation	NO
BART: CIVIC CENTER STATION	
Surface Rupture Fault Zone	OUT OF ZONE
Maximum Earthquake Intensity	D
Risk of Damage: wood frame	12
Risk of Damage: concrete/steel	13
Risk of Damage: tilt-up	25
Liquefaction Potential	14
Earthquake-Induced Landslide Susceptibility	1
Rainfall-Induced Landslide Susceptibility	1
Dam Failure Inundation	NO
Tsunami Inundation	NO
BART: POWELL ST STATION	
Surface Rupture Fault Zone	OUT OF ZONE
Maximum Earthquake Intensity	D
Risk of Damage: wood frame	12
Risk of Damage: concrete/steel	13
Risk of Damage: tilt-up	25
Liquefaction Potential	14
Earthquake-Induced Landslide Susceptibility	1
Rainfall-Induced Landslide Susceptibility	1
Dam Failure Inundation	NO
Tsunami Inundation	NO

The current Petaluma system integrates regional-level hectare data with more detailed local data sets. The city has digitized parcel boundaries and built a file of parcel attributes (assessor's number, land use, zoning, general plan designation, presence of historic or other special feature) for each parcel. Other locally-produced data (such as vegetation cover) has replaced the BASIS hectare data when available. This combined data base is used to support a series of models and tabulations (Figure 3) which form a preliminary environmental assessment for all proposed development projects in the city. These report sections fall into several categories. Some, such as elevation and vegetation, are simple tabulations of single data sets. Others (such as the tables of earthquake risk and maximum groundshaking shown in Figure 4) represent derived data sets, or the output of models which are stored semipermanently in the BASIS data base. A third category includes models that are rerun for each new project, since they are dependent on characteristics of the proposed development (Figure 5).

The Petaluma system operates in a distributed data base environment. The city's planning department operates a small graphics computer system, which is used for input and storage of all local data sets (parcel file, street network, vegetation, permits). The BASIS data and most of the models are maintained by Geogroup. Project-specific data sets are transmitted over telephone lines as each assessment is run. The city collects basic data on a development schedule and sends it (along with the digitized site boundary and any special files) to Geogroup, where it is combined with BASIS data and selected models are run; results can be printed and mailed or sent back over phone lines. Eventually, copies of relevant BASIS data sets and some of the analytical models will be transferred to the city's computer; this will give it a largely independent capability.

There are several important points to be made about this arrangement. Data sets are collected and stored at the most appropriate organizational level. The city maintains the detailed types such as parcels, while those derived from regional studies are kept at that level. Most institutional problems (such as costing of data base maintenance) are avoided in this way. Also, those characteristics (such as land use) which are subject to frequent change are maintained as a normal function by city staff. Finally, the system is designed to be flexible; only those sections appropriate for a particular project (as determined by the city) are run.

FIGURE 3

AREA / PETALUMA **PROJECT: Westridge** **DATE: February 24, 1982**

LISTING OF REPORT SECTIONS

LAND USE / GENERAL PLAN	EXISTING LAND USE
	GENERAL PLAN DESIGNATION
SITE PHYSICAL CHARACTERISTICS	TOPOGRAPHY
	LANDSLIDES
	VEGETATION
	GEOLOGIC MATERIALS
	SOIL ASSOCIATIONS
HAZARDS	SLOPE STABILITY
	LIQUEFACTION POTENTIAL
	DAM FAILURE INUNDATION AREAS
EARTHQUAKE HAZARDS	FAULT STUDY ZONES
	MAXIMUM EARTHQUAKE INTENSITY
	RISK OF DAMAGE
HYDROLOGY	ANNUAL PRECIPITATION
	BASINS ON SITE
	STREAM STATUS
WATERSHED DATA	PRIMARY STREAM
	RECEIVING WATERS
	EXISTING LAND USE
	SURFACE RUNOFF IMPACT
EROSION	EROSION CALCULATION
	MITIGATION
WATER SUPPLY	WATER SOURCES
	WATER CONSUMPTION FACTORS
	DEMAND CREATED BY PROJECT
	STATUS OF WATER SUPPLY AT SITE
	MITIGATION: WATER CONSERVATION
WATER QUALITY / SEWAGE DISPOSAL	WASTEWATER
	STATUS OF SEWERAGE AT SITE
	RECEIVING WATERS
	IMPACTS
SOLID WASTE	COLLECTION INFORMATION
	DISPOSAL SITE INFORMATION
	WASTE GENERATION
FIRE PROTECTION	EMERGENCY RESPONSE ZONES
	STATUS OF WATER SUPPLY AT SITE
	WILDFIRE HAZARD
EDUCATION	SCHOOLS AFFECTED BY PROJECT
	STUDENTS GENERATED BY PROJECT
ENERGY	ENERGY CONSUMPTION FACTORS
	SOLAR WATER HEATING OPTION
TRAFFIC	BASE YEAR
	TARGET YEAR ALTERNATIVES
AIR QUALITY	BASE YEAR
	TARGET YEAR ALTERNATIVES

FIGURE 4

AREA / PETALUMA PROJECT: Westridge

EARTHQUAKE HAZARDS

FAULT STUDY ZONES

	(Acres)
OUTSIDE STUDY ZONE	12

MAXIMUM EARTHQUAKE INTENSITY

	(Acres)
A (4)-Very Violent	0
B (3)-Violent	0
C (2)-Very Strong	12
D (1)-Strong	0
E (0)-Weak	0
-Negligible	0

RISK OF DAMAGE

Expected risk of ground-shaking damage for building types proposed for site. Estimate based on statistical procedures using major fault earthquake recurrence intervals and average building damage.

Percent Damage of Present Value		Wood Frame Dwellings	Concrete/Steel Buildings	Tilt-Up Concrete
		(Acres)	(Acres)	(Acres)
0.0-1.0 %	Moderate	0	0	0
1.1-2.0 %	*	12	0	0
2.1-3.0 %	*	0	0	0
3.1-4.0 %	High	0	7	0
4.1-5.0 %	*	0	5	0
5.1-6.0 %	*	0	0	0
Over 6.0 %	Very High	0	0	12

FIGURE 5

AREA / PETALUMA

PROJECT: Fireman's Fund

AIR QUALITY

2000 - TARGET YEAR WITH PROJECT

CONTAMINANT	AVERAGING TIME	STANDARDS (ug/m3)	REGIONAL IMPACTS (ug/m3)	LOCAL IMPACTS (ug/m3)
CO	1 hour	40,000	1	1400
	8 hour	10,000	0	766
HC	3 hour	160	0	84
NO2	1 hour	470	0	189
	1 year	100		17
SO2	1 hour	1,310	0	21
	24 hour	105	0	8
	1 year	80		1
TSP	24 hour	100	0	11
	1 year	60		2

SENSITIVE RECEPTORS AFFECTED

Name	CO Concentration at receptor 1 hour (ug/m3)	8 hours (ug/m3)
CASA DE ARROYO 2	5348.	700.

CONCLUSIONS

It is clear that major advantages can be derived from the application of GIS techniques to environmental assessment. It is equally obvious that the advantages are balanced by several limitations. These include technical factors, which are based on the nature of current GIS practice, and institutional factors, which arise from the organizational setting in which the two fields have developed.

How can geographic data handling systems be made more useful for assessment work? A first requirement is a clear understanding by GIS designers that assessment applications are different in data needs and resolution from projects that are regional in scope. Also, more attention must be paid to the fundamental issues of map accuracy and data sources. Data base structures must allow for distributed data collection and storage.

These technical barriers can normally be overcome; the availability of better computer hardware and software will continue to provide powerful new tools. Institutional factors are likely to prove more difficult. A major issue is overcoming the one-shot nature of most assessment data collection; viewing scattered projects as components of an areawide data base requires a major change in the way most GISs are designed and implemented.

It seems clear that the GIS concept offers much potential to support environmental assessment projects. It cannot replace the field work and detailed analysis required for impact assessment of a small site, but it can provide a useful framework for spatial data handling. Computer mapping techniques can greatly improve the display of source data and of model output. The advantages of this combination - more effective presentation of results, potential cost savings, and a greater consistency of information for making decisions - are strong arguments for better integration of the two disciplines.

REFERENCES

One of the better treatments of environmental assessment techniques is Environmental Impact Analysis Handbook, edited by John G. Rau and David C. Wooten (McGraw-Hill, 1980). The best method for understanding assessment practices is to review a variety of impact reports for different types of projects (and, if possible, for different geographic areas). Reports are usually filed with a state or regional clearinghouse agency.

Descriptions of BASIS applications are available from Geogroup Corporation or from the Association of Bay Area Governments. Several ABAG reports on earthquake mitigation are particularly good illustrations of GIS techniques being used at different levels of geography. Other examples of BASIS application to environmental assessment work include models of sites for disposal of hazardous solid wastes, airport noise analysis, and listings of environmental constraints on vacant industrial sites.

Information about applications of the Petaluma system can be obtained from the city's Planning Department.