PREFACE

This packet of resources has been designed primarily to aid universities, colleges, and other institutions with Geographic Information System (GIS) expertise and equipment in reaching out to their local schools in an effort to increase teacher and student awareness of this high-growth technology and its spatial analysis core. The method presented in these materials is a one week workshop at the institution in which teachers are brought in for a GIS immersion including a GIS short course and other GIS activities. Once teachers have gained this experience, they can apply it in their teaching. They can utilize their new partnership with the key individuals at the institution as a source of support. In addition to activities involving the institution, the teacher can also begin to independently use GIS software and instructional materials in their courses.

Since this packet contains a variety of elements focused on the use of GIS concepts and software in the secondary school classroom, it also is an appropriate resource for secondary school teachers and others who are attempting to implement GIS activities at this educational level. Some of the materials might even appeal to college level educators.

This packet includes: background information on the NCGIA Secondary Education Project; a detailed description of the prototype workshop used to develop these resources; summaries of GIS oriented projects developed by the workshop participants; a suggested workshop format with helpful hints for working with the schools; lecture notes for the short course; a list of available software packages, instructional materials, and other educational resources of use to teachers attempting GIS activities in their classes; and a simple GIS glossary. These materials provide a model and a set of base materials from which to develop a GIS workshop for teachers. Of course, the actual nature of workshops at different sites will vary depending on available resources, institutional setting, and personnel; however, this packet should provide a foundation for the development of this type of workshop. The lecture notes excerpted from the NCGIA Core Curriculum in GIS serve as a base for the short course, but will often be augmented by the lecturer.

This first edition of the "GIS in the Schools" Workshop Resource Packet is based on a prototype workshop. During the Summer of 1993, an additional six workshops will be held to further refine the workshop model and this resource packet will be updated in a second edition. Suggestions for additions to the second edition can be routed to the NCGIA Education Projects Manager.

These materials have been created by the NCGIA which is funded by the National Science Foundation. Many people have helped put on the prototype workshop and have been instrumental in the Secondary Education Project activities. First and foremost is Dr. Michael Goodchild, the Director of the NCGIA and a constant source of guidance for the Secondary Education Project. A special thanks goes to the teacher/consultants (listed on the next page) who enthusiastically participated in the workshop. The help of graduate students, Karen Beardsley and Bjorn Svensson in their roles as workshop assistants was invaluable. Recognition is also due to the many geography department and NCGIA faculty, graduate students, and staff who gave time, resources, and suggestions to the workshop. The support of specialists on education, Dr. Fiona Goodchild and Dr. Willis Copeland, was also very helpful.
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BACKGROUND

The NCGIA Secondary Education Project is an outgrowth of the National Center for Geographic Information and Analysis (NCGIA) Education Program. More specifically, the NCGIA was established by the National Science Foundation in 1988 to advance the theory, methods and techniques of geographic analysis based on geographic information systems (GIS) in the many disciplines involved in GIS–based research; to augment the nation's supply of experts in GIS and geographic analysis in participating disciplines; to promote the diffusion of analysis based on GIS throughout the scientific community, including the social sciences; and to provide a central clearing house and conduit for disseminating information regarding research, teaching, and applications. One aspect of fulfilling this mandate was to aid efforts to provide current education in GIS. The NCGIA Education Program has provided support to GIS education efforts in hundreds of colleges and universities by creating and distributing a Core Curriculum in GIS and other GIS educational materials and by offering workshops at various professional conferences. Until 1992 most of the Education Program's efforts were centered on higher education.

Secondary Education Project

In 1992, the NCGIA responded to suggestions that the Center's educational efforts might be expanded to include the secondary schools. The Secondary Education Project (SEP) was established in order to probe the role GIS may play in the secondary school curriculum and to support relevant GIS activities at this level. The initial investigations of the SEP, in what we are now labeling Phase I, have indicated great potential and even outright need for educational methods which can combine a resurgent interest in geography and an understanding of environmental processes with computer–based learning opportunities that promote analytical thinking. GIS, with its spatial analysis core, provides an excellent synthesis of these components. GIS has traditionally been confined to large computers running complex software utilizing memory hungry data sets, but with the tremendous and sustained reductions in price and size of powerful computers, the main remaining impediments to GIS as a classroom tool are the lack of educational materials and teacher awareness.

A bridge must be built from the powerful GIS applications operating in industry, government agencies, businesses, and university research labs to the schools in order to realize the educational potential inherent in the GIS conceptual model. This bridge will include information on GIS for teachers and students, instructional materials designed for school–based computer hardware, and appropriate software solutions. A few existing software packages are amenable to educational uses, especially Clark University's IDRISI. Even these packages could use extra support to enhance their application in a secondary school setting. Following the clear establishment of GIS usefulness to the schools, the primary aim of the SEP has become the facilitation of efforts to match GIS activities to the needs of the secondary school teacher and student.

In Phase I, which corresponded to the first year and a half of the SEP (September '91 – March '93), extensive efforts were made to identify existing GIS activities in schools both in the United States and other parts of the world. The SEP began to compile a list of interested institutions and individuals to whom a quarterly progress report is distributed. Since GIS, mirroring advances in computing, has only recently reached a point at which it is reasonable to imagine GIS in a secondary school classroom, activities identified during Phase I were understandably limited. Interest, however, is high. Much of what has been done so far has been initiated by higher education faculty with GIS research and application backgrounds, and has taken place at their institutions. This reflects the low level of GIS awareness in the ranks of the secondary educators and the lack of GIS materials tailored to the rather constrained demands of existing school curricula.
The SEP must be responsive to the true needs of the secondary school students and teachers, therefore inquiry into the place of GIS in the schools was an active part of Phase I. The primary mode for this inquiry was to involve secondary school educators directly in the SEP. This was achieved through the GIS workshop/brainstorming session reviewed in this document.

To summarize the findings of Phase I: The potentials for GIS activities in the schools seem quite high, but the challenge is to communicate the potential to teachers, design the activities, and identify the avenues by which they will be appropriately incorporated into the school curriculum.

Phase II

A second phase of the SEP has been initiated. It is based on the insight gained in Phase I, especially from the "GIS in the Schools" workshop and the continued input from the teacher/consultants who attended the workshop. The two–year Phase II has deliberately moved to a nationwide scope. There are two major components. The first is a series of workshops that test a refined workshop model derived from the Phase I workshop. In order to meet the clear need for GIS instructional materials tailor–made for the schools and matched with appropriate software, the second component is a collaborative effort to produce GIS companion modules to existing instructional materials from subject areas which have a geographical element that would be enhanced by a GIS treatment. In addition to these two main components, the SEP is continuing, during this two–year phase, to act as the communication node for those interested in GIS in the schools, to support those attempting GIS activities in their courses, to report on the progress of GIS in the classroom, to provide an administrative backbone to the Project components, and finally, to investigate the various areas in which GIS concepts and software have potential to aid the educational mission of our nation's schools.
Early in the efforts of the SEP, it became apparent that the input of classroom teachers would be invaluable; however, for teachers to give advice relevant to GIS they would need some experience with GIS. In order to provide this experience, to receive significant teacher input, and to correct our preconceptions, the NCGIA hosted a seven day workshop for ten high school teachers in the summer of 1992. The workshop was developed around the goal of providing a stimulating learning experience in GIS for the teachers, but also acknowledged their ability to give practical advice on GIS use in the schools. Thus their title, teacher/consultant, was appropriate in our effort to convey a sense of collaboration between professionals with different areas of expertise.

Flyers announcing the workshop and applications were distributed to teachers in fifteen high schools within a radius of approximately sixty miles from the NCGIA's University of California, Santa Barbara site. Teachers were identified by calling the area high schools and asking for the names of teachers in the science, social studies, and computer departments. The workshop was also announced at a school district wide in–service for science teachers. Since a comprehensive look at GIS at this point in its development requires the type of hardware, software, data sets, and experience found in the university setting, a close tie between the university and the local teachers was desired. This desire motivated a limited selection area. The proximity of the workshop participants to one another also encourages continued interaction following the workshop. A side benefit of offering the workshop to local teachers was the savings in accommodation, transportation, and food costs.

Due to the relatively late date of the workshop's official announcement, we received only 15 applications. From this pool, efforts were made to select a balance of teachers from the sciences and social studies. Teacher/consultants were all expected to have some computer experience; however, a deliberate effort was made to have varying experience levels represented in the workshop. Teachers were also asked to list any other curriculum development experience. The final group of teacher/consultants consisted of six in science, three in social studies, and one in computers. They were picked to reflect a range of teaching experience from long–term seasoned teachers to newer teachers familiar, from more recent university training, with trends in teaching and use of computers in education. This diverse group with its mix of strengths provided an excellent range of perspectives on the role of GIS in the high schools.

In addition to description included in the initial flyer, the selected teachers were contacted personally and were sent a more detailed explanation of workshop goals and content. The teacher/consultants were also sent a short introduction to GIS. Good examples of introductory material appropriate for pre–workshop reading are often found at the beginning of GIS software manuals or GIS educational materials written for specific software packages. It was a very simple overview of GIS and its applications. It was assumed that any material of greater detail might not be effective until teacher/consultants had the opportunity to observe GIS visually. For a workshop of shorter duration, however, a packet of GIS materials including an overview, visuals, and more detailed materials might be an appropriate preparation for the workshop.

In order to aid the consultation efforts of the selected teacher/consultants, the workshop included a ten hour short course in GIS, many demonstrations of GIS applications, and hands–on work with various GIS software packages. Following mornings of GIS activities, the teacher/consultants provided crucial feedback in the afternoons on various issues related to efforts to implement GIS concepts and software in the secondary classroom. They also helped the NCGIA begin to identify the types of materials and support teachers would need in order to successfully use GIS in their classes. As a result of the workshop, the teacher/consultants developed GIS projects for use in their fall, 1992 classes.

Workshop Elements
This seven-day prototype workshop was held in July, 1992. The first five days concentrated on providing information on and experience with GIS and on receiving feedback from the teacher/consultants. The primary focus of the last two days was teacher/consultant project planning. The weekend dividing the seven days gave the teacher/consultants some time to digest the volume of information they had received and to outline potential GIS projects for their classrooms. The workshop days began at 8am and ended between 4:30 and 5pm. The workshop was staffed by Dr. Michael Goodchild, the Director of the NCGIA and the primary geography faculty member teaching GIS, by the SEP manager Steve Palladino, an NCGIA graduate student researcher, and by two graduate student assistants, Karen Beardsley and Bjorn Svensson.

There were five major components to the workshop: a ten hour short course in GIS, demonstrations of faculty and graduate student GIS projects, GIS software practice sessions, discussion sessions on various aspects of GIS in the schools, and project planning sessions. Continual evaluation of the workshop was also a daily activity.

**Short Course**

The course was broken up into ten hour-long sessions taught two hours at a time. These two hour sessions began in the morning after a short daily briefing and a period for teacher/consultant evaluation of the previous days activities. As noted on the Workshop Schedule, four hours of lecture was necessary one morning due to a conflict in the presenter’s schedule. The course was primarily taught by Dr. Goodchild with a portion taught by Steve Palladino. The lectures were presented in the following order:

- **Introduction to Geographic Information Systems**  
  1st hour - General Introduction  
  2nd hour - Computer and map basics for GIS

- **How a GIS Works I:**  
  1st hour - Raster GIS  
  2nd hour - Spatial Objects and Their Relationships

- **How a GIS Works II:**  
  1st hour - Vector GIS  
  2nd hour - Begin discussion of GIS applications

- **GIS Applications:**  
  Both hours - more examples of various GIS applications

- **GIS in the Schools, Workplace, and World:**  
  1st hour - History and future trends of GIS  
  2nd hour - GIS opportunities in the workplace, in the universities, and in the schools

**GIS Demonstrations**

The GIS demonstrations were on various platforms utilizing different software packages. The scope and subject areas of the demonstrations also varied considerably. Faculty and graduate students were asked to give 15 to 90 minute demonstrations of their GIS projects. These concentrated on the use of GIS as a tool in various application areas rather than research on GIS development and computer programming. The following demonstrations were provided for the teacher/consultants:
A tour of the UCSB Map & Imagery Laboratory in the Library. This included a
demonstration of ArcView on a Unix workstation and of a simple prototype of a GIS
application for tracking environmental problems in Central Europe using Atlas*GIS on
an IBM PC.

An overview of various Biodiversity Lab projects mainly utilizing ARC/INFO and
ERDAS. These include a California Condor recovery project, a study of a large,
undeveloped parcel of university land intended for research purposes but threatened by
development, and a large project mapping the plant and animal species distribution in
the state of California for determination of areas to be set aside for preservation.

A United Nations Environmental Program project to map various indicators for the
African Continent using the IDRISI software on a PC.

An Arc/Info representation of various demographic variables in Los Angeles County.

A large project mapping potential soil contamination by leaks in underground fuel tanks
on the Vandenberg Air Force Base using Intergraph and 3–D graphing software.

An anthropological study of Aztec Indian culture utilizing Arc/Info to analyze spatial
distribution of artifacts.

A oceanographic project mapping the mid–ocean spreading zone and volcanically active
sites on the ocean bottom using Arc/Info on a workstation.

A demonstration of the use of Arc/Info and ArcView to aid a study of labor
characteristics in the garment industry in Los Angeles.

Also the teacher/consultants were treated to spontaneous demonstrations of the internal
components of a computer and of the PC/Globe and AutoMap software packages by the
computer teacher participating in the workshop.

GIS Software Use

The teacher/consultants interacted with several GIS packages over the seven day period (see
Software Guide). The teacher/consultants were supported by the Project Manager and the two
workshop assistants in their efforts to use and understand the GIS software. On the first day they
worked through the HyperCard Tutorial GISTutor on Macintosh computers. They came back to
the tutorial near the end of the workshop in order to fill gaps in their understanding of GIS.

The first GIS package used was MAPII on the Macintosh. This is a simple, inexpensive raster
based software package. Teacher/consultants were each given a demonstration disk which can be
obtained for $5. They worked through the demo of the GIS features, then completed a short
exercise adapted for the workshop by the SEP from an example sequence suggested by one of the
MAPII creators.

The next software package investigated was Atlas*GIS, a moderately price vector package for
DOS systems. The teacher/consultants received a copy of the Atlas*GIS Introductory Package.
This $20 package is a fully functioning GIS but will only work with the provided data.

Atlas*GIS was followed by another package for the IBM PC & compatible world. This raster
based package, IDRISI, was designed for educational purposes and is only $200 and has many
educational materials developed around it.

Last, the teacher/consultants used ArcView on a IBM PC. This is a software package which
allows for interactive display and query of data sets in the Arc/Info GIS format. Due to the
popular use of Arc/Info, many data sets in this format exist. During the final two days of the
workshop the teacher/consultants were given access to all of the software packages for further investigation, especially with respect to the use of these packages in their GIS projects. They also received a short lesson and practice session on using a digitizing table to input map data into a computer.

In addition to the examination of various software packages, a session on Friday morning was devoted to independent perusal of various GIS educational materials and related items that have been collected by the SEP. These included special GIS education workbooks developed by ESRI and TYDAC/SPANS. Teacher/consultants were also able to review the NCGIA Core Curriculum in GIS and lab exercises developed for IDRISI and Arc/Info by the Center. During this time teacher/consultants also brought some of their curriculum materials to share with the other teacher/consultants.

Discussion & Planning

The first discussion session began with an overview of computers in the classroom. The teacher/consultants had come prepared with a list of the computer resources of their schools, highlighting those resources that were actually available for their use. These lists were reviewed during this session and the general trends of computers in the classroom were discussed. A short overview of platforms for GIS software was included in this session. The second discussion session focussed on the place for GIS in the secondary school curriculum. Also discussed as concomitant issues were the nature of geography and technology education in the schools. Teacher/consultants were asked to list where and how GIS could be taught in various courses. The third session was a question and answer session with Dr. Goodchild about aspects of GIS that had come up in the course or in the other activities. The fourth session was an open session discussing the opportunities for, and obstacles to GIS, activities in the schools. A fifth session encouraged the teacher/consultants to brainstorm about where they could teach a GIS component or integrate GIS activities in their specific courses.

The fifth session began the teacher/consultants' project planning process. A sheet describing project planning and implementation activities was handed out. On the last two days, the morning was reserved for project planning sessions. During these sessions the teacher/consultants worked in groups with the workshop staff. The first day they presented their lesson/project plan ideas from the weekend of brainstorming. The second day they described the outline of their project based on the feedback received on the previous day. Other activities of the final two days were a session defining what should be a part of a GIS project/lesson and a session evaluating SEP ideas for GIS educational materials.

Each day included an evaluation component aimed at helping the SEP improve the workshop model. At the end of each day, the teacher/consultants received a one page evaluation form asking for feedback on each of the day’s activities. They filled out the forms at the end of the day or in the evening. The next morning, at the briefing session, their comments on the effectiveness of the previous days activities were solicited. The morning evaluation times were very helpful in adjusting the workshop as we went. They also helped foster a sense of accountability of the workshop staff to the teacher/consultants, giving the workshop the desired interactive format. At the end of the workshop, the concluding session included a period of verbal evaluation. As a final workshop activity the teacher/consultants were given a three page evaluation form which they were to return in a week with their GIS lesson/project description. Each evening in addition to filling out the daily evaluation form, the teacher/consultants took home a copy of one of the GIS trade magazines (GIS World or Geo Info Systems) to peruse.

Since one of the primary goals of the workshop was to get the opinions on GIS potential in the schools from teachers who had a reasonable exposure to GIS, we felt that compensation was in order for their consultation efforts. Each teacher/consultant was paid $100 per day. Those who completed their GIS project activities including an evaluation of their field test and a final report on their project received an additional $300. Generally expenses were fairly low. The two graduate student workshop assistants were each paid $500 for about 40 hours of work. Both Dr.
Goodchild and Steve Palladino were not specifically compensated, but include all the efforts towards the workshop in their normal duties. Some money was spent acquiring demonstration packages, making photocopies, mailing letters, and the like, but it was not a large amount.

In addition to compensation for their consultation efforts, the teacher/consultants were given the opportunity to earn 3 quarter units of Extension credit for the short course in GIS and other learning activities that were part of the workshop. Six of the teacher/consultants chose to pay the extension fees and receive credit. The extension credit, the compensation, and the general design of the workshop activities were geared to acknowledging the professionalism of the secondary teachers. As noted, we were not interested in establishing a two-tiered partnership – NCGIA "experts" and teacher "students" – but rather, we attempted to emphasize contributions by all workshop participants. This collegial treatment was greatly appreciated by the teacher/consultants and added to the effectiveness of the workshop.

In the summer months following the workshop, the teacher/consultants returned a workshop evaluation package and worked independently on their GIS projects. The Project Manager continued to be in contact with the teacher/consultants to aid their efforts and to provide additional information on GIS materials, data, and software that become available. One item that the teacher/consultants requested during the workshop was a slide set on GIS. The Project Manager compiled a set of 40 slides which can be used for a quick introduction to GIS. Many of the teacher/consultants used this resource as part of their GIS projects. In December, 1992, the workshop participants met on a Saturday to report on the results of their classroom trial of their GIS projects, to make final evaluations of Phase I of the SEP, and to finalize the format for the summaries of their projects.

Workshop Evaluation

The workshop got off to a good start with an introductory session in which the goals for the workshop were expressed, the workshop schedule was reviewed, and introductions were made. The teacher/consultants generally appreciated the clear presentation of what we hoped to accomplish as a group in the seven days. Following the orientation session, the first class session was held. For the most part the teacher/consultants found this "General Introduction to GIS" session very informative. Despite a positive response to the material in the sessions, most of the teacher/consultants expressed a desire for the introductory sessions to give a stronger overview of GIS including slides of GIS applications and a simple demonstration of a working GIS application. They also noted that it was important to clarify the impact GIS might have on their teaching and lives right at the beginning.

For some teacher/consultants, it took a couple of days before they began to understand what GIS actually was and how it might fit into their teaching. By the fourth day of the workshop, however, all of the teacher/consultants became excited about the possibilities that GIS might hold for their courses. They began to dream up all sorts of GIS activities for their classes, some of them quite involved. As the teacher/consultants began to assess what data, software, and materials they would need to begin implementing these ambitious plans, they realized that putting together a GIS lesson might require quite a bit of effort. This was especially true for projects that would have students use multiple data sets from the local area. Though obviously appealing to both teacher and students, this type of project would require extensive efforts in identifying existing data sources and obtaining the data or in compiling data themselves. Like a red-hot stock market eventually cooling off, there was a discernible "correction" in their expectation level. Nevertheless, the teacher/consultants were still very positive towards GIS use in the classroom at the end of the workshop.

Short Course

Most of the material in the short course in GIS was drawn from the NCGIA Core Curriculum in GIS with adaptations made for the audience. For the most part the information was appropriate, though at times it was hard for some of the teacher/consultants to follow. This was especially true
for some of the more technical discussion. Some of the teacher/consultants found the technical discussion a good base for answering student questions; however, other teacher/consultants felt that the content should be streamlined. Generally not all lecture topics planned for a session were covered (see previous list of course topics). This was in part due to the positive emphasis on interactive lecturing in which questions were encouraged. This slowed down the presentation of the material, but it also increased comprehension and interest. It turned out that the computer discussion flowed over into the second day. The discussion on Spatial Objects and Relationships was dropped. Some of the more technical discussion on Raster and Vector GIS was omitted.

Many of the teacher/consultants suggested that some of the last day's information on "GIS in the Schools, Workplace, and World" could have been included in some of the earlier lectures. It was also suggested that some of the application examples be presented at the beginning to cement the purposes for GIS in their minds. Some of the applications, however, would be best understood following the technical information in the Raster and Vector lectures. The background on computers and maps was appreciated by the teacher/consultants. The portion of the short course that got the highest marks from the teacher/consultants was the section with accompanying slides which clarified the various ways GIS can be applied. A suggestion was made that outlines of lecture materials be given to the teacher/consultants at the beginning of the lectures. This aid to note taking would help the teacher/consultants compile the information as reference material for their own teaching.

Based on the experience of this workshop, a future lecture series might be reduced to four two-hour sessions. The initial session would make a greater attempt to provide the necessary overview for teachers to grasp both the nature of GIS and its relevance to their efforts as educators. This first lecture would incorporate discussion on the background of GIS, its use with appropriate examples (slides), its potential for the classroom, and other general information about GIS. A second lecture would review computer and map concepts that are essential to GIS. The third lecture would present the Raster/Vector world views and some of their details. A final lecture would tie together the various components through a more in depth examination of GIS applications. In order to shorten the series some of the more technical discussion would be dropped. The large amount of material that might seem appropriate for the introductory lecture could be reduced by a more extensive discussion in the opening session on the nature of GIS in relation to the goals of the workshop. Wise choice of a simple GIS demonstration immediately preceding or following the first lecture could also help provide a greater sense of the big picture by the end of their first day.

GIS Demonstrations

The various demonstrations of graduate student and faculty GIS applications were the highlight of the workshop for many of the teacher/consultants. They appreciated the "real world" connection that the demonstrations provided. They also enjoyed seeing some cutting edge uses of GIS. The most successful demonstrations were clearly organized with a visual introduction, a clear explanation and graphic representation of the use of GIS in the application, and a minimum of information extraneous to the needs of teachers. Examples of good introductions included a video showing the research area for the ocean bottom mapping application and slides showing the area being studied on Vandenberg Air Force Base. This fits with the general consensus that there should be an emphasis on "show, over talk". Talk especially to be avoided includes excessive use of acronyms that have no meaning to teachers and use of very technical terminology either from GIS methodology or the presenter's area of study.

When making presentations around a computer screen certain space issues need to be considered. Only 4 or 5 individuals can crowd closely enough around the monitor to see what is happening. Large groups may need to be split up in order for the demonstration to be successful. It is helpful if the presenter has an adequate mastery of the software. It was frustrating for the teacher/consultants to watch an individual "playing" with the software. Batch files (computerized slide shows) are often a good presentation method. When demonstrating the capabilities of GIS software packages, it helps if the demonstrator can either involve the observers in some sort of
“hands-on” manner or at least allow them to provide input to the demonstrator's actions. Some of these difficulties were encountered in the tour of the Map & Imagery Laboratory. Too much time was spent discussing what was available rather than showing the operation of the machinery and software. Also the other resources of the lab, such as the large map collection, were overlooked. At a later point in the workshop, the teacher/consultants were able to go back to the Map & Imagery Lab in order to fill in the gaps and explore the resources available to them. It was noted that a more conscious effort should be made to match demonstrations chronologically with lectures covering material relevant to the particular demonstrations. As a whole the demonstrations were highly valued and served as fodder for teacher/consultant discussions with friends, family, and fellow teachers. The teacher/consultants also noted that the demonstrations provided good examples of "GIS in action" which they could relate to their students.

GIS Software Use

The teacher/consultants were exposed to quite a few software packages in a fairly short period. This was intentional. We desired to get a relatively unbiased view of what types of systems might go over well in the schools. In future workshops, it may be more efficient to pick a just a couple of packages that have potential in the schools for teacher use. The capabilities of other packages could be displayed in quick overviews. Teacher/consultants noted that before they worked with the packages, a short demonstration of the software's capabilities, the operating system, and key steps would be very helpful. It was valuable to have some open lab time near the end of the workshop for teacher/consultants to work with the packages that interested them and had potential in their classrooms. In picking software to use, it is important to keep in mind the hardware that teachers have available to them at their schools. Having them work with both a raster and a vector package drives home the distinction and provides a distinctive option for the classroom. In most cases vendor-provided demonstration packages and their accompanying manuals will not work in the classroom. Students will need specific lessons and steps to fully utilize GIS software.

GISTutor receive mixed reviews. Some teacher/consultants really appreciated its HyperCard format which allowed them work at their own speed and to choose what topics to investigate. Since this was the first package used, an introduction to the Macintosh operating system would have been helpful for some of the teacher/consultants. GISTutor assumes that the user understands the general purpose of GIS and knows what a GIS application is made up of. It picks up the story with the technical workings of GIS software. Some found this discussion too detailed or “boring”. Teacher/consultants returned to redo the tutorial at the end of the workshop as a review of some of the material covered in the lectures. This was generally viewed as helpful activity, though going through the whole thing twice was a bit too repetitive for some of them. A possible use for the GISTutor in future workshops would be a short (1/2 hour?) interaction with it at the beginning of the workshop as practice on the Mac, as an example of the utility of hypertext programs in education, and as an overview of information that is available to them. At the end of the workshop, a full review of the GISTutor would serve as a valuable review of some of the concepts covered. GISTutor appears to be more of a teacher rather than a student resource. Most of the topics are too detailed for the average student and many of the animations are too slow to hold their attention.
MapII also had a mixed reception. It has the advantage of being a cheap and fairly simple to use (though not always intuitive) raster package. What it gains in simplicity, it loses in being simplistic. It is not a very powerful system and its raster representation of some data sets may be hard for students to comprehend. Some of the teacher/consultants, especially those with Mac computers, could envision students using this package. Like virtually all packages, educationally oriented exercises would increase its utility. The teacher/consultants who managed to work through the demonstration materials were able to try some exercises developed for the demonstration data sets. They tended to find working on the exercises more valuable than learning how to change colors and adjust the size of the windows.

Atlas*GIS was more attractive at first to the teacher/consultants due to its vector representation. A soon-determined drawback was the limited nature of the marketing oriented data set of Manhattan zip code areas that was provided in the tutorial. Also the manual emphasized how to operate the GIS, but did not have the users work through a clear, mock project that would make their efforts meaningful. Despite its nice user interface, the package may be harder to use for students familiar with the Mac OS or Windows. Since the package costs a couple thousand dollars, it may be out of the range of most educators.

The relatively inexpensive IDRISI package received the most favorable comments. Since this package was designed for educational purposes, its features seemed more user friendly to the teacher/consultants. These perceptions were aided by a few factors. Preceding the use of IDRISI, a comprehensive demonstration of its capabilities was provided by a graduate student. Since it is a package for GIS education, exercises with accompanying data sets have been developed for it. The teacher/consultants used an African data exercise designed for classroom use by the NCGIA. This allowed the them to utilize the GIS power right away and to do their own analysis. Most of the teacher/consultants identified this as the GIS with the most potential. To use IDRISI, however, students will need an explicit set of steps and commands. It cannot be effectively "played with" like MAPII or Atlas*GIS, due to its more difficult interface.

Teacher/consultants only got limited exposure to ArcView due to technical difficulties (i.e., it will not run on low power and limited memory computers; a 386 PC with 6MB RAM would be the minimum configuration.) ArcView is not a fully operable GIS, but rather is a data display and query system developed to access data sets created in the powerful, but complex Arc/Info software. Despite not having all the features of a "full" GIS, ArcView can powerfully manipulate the display of data. The teacher/consultants who were able to spend time with this software recognized this power and possible use of ArcView in the schools (e.g., as a resource in the school library). Materials for the use of ArcView in the classroom are being developed by the company, ESRI, that produces ArcView and Arc/Info. This should make the use of ArcView more appealing to teachers.

In addition to these five packages, teacher/consultants used PC/Globe, PC/USA, and AutoMap. These programs are map–based data sets with very limited analytical capabilities and would not qualify as GIS packages. Many of them saw these packages as more amenable to classroom use than the GIS software and as potential lead–ins to the use of GIS software. They may be an example of the "face" that GIS packages will need to wear in order to be of practical value in a school setting. On the other hand, with their exposure to the powerful analysis capabilities of GIS, some teacher/consultants saw these packages as nothing better than expensive "electronic almanacs" or road atlases.

The teacher/consultants liked the session in which various GIS educational materials, accumulated by the NCGIA, were laid out for teacher/consultant inspection. They mainly appreciated being able to access address and other basic information about these resources. Many other potential resources were mentioned during the course of the workshop. The teacher/consultants noted that it would be helpful to have been given a directory of these available resources (see Resource List).

Discussion & Planning
On the whole, teacher/consultants found the discussion times very helpful. Some sessions were more valuable to some teacher/consultants than others, but all sessions were identified by at least a few teacher/consultants as important workshop elements. Discussion sessions were split between whole group and small group activities. The combination of these two formats seemed to work well. It was especially helpful in project/lesson planning at the end of the week to spend time in small, same discipline groups. There was one group of social science teachers and two groups of science teachers. The latter groups were divided by level of computer use likely in their respective classrooms.

Teacher/consultants appreciated being exposed, in the "Computers in the Schools" discussion, to the range of computer use and availability in the various schools. It might have been more helpful to tie this discussion in with a more complete overview of GIS computer requirements. The "Course Placement" discussion showed that GIS could be adapted creatively to fit in many secondary school subjects, though science and social studies courses were the most obvious. This discussion helped some of the teacher/consultants realize that GIS had a greater potential than just a tool for a "geography or geology course". The "Question and Answer" session with Dr. Goodchild was an appropriate follow-up to the short course. Teacher/consultants liked having an opportunity to have their GIS questions answered. They also appreciated the candid assessment of the minimum hardware requirements for GIS provided by Dr. Goodchild (see Hardware section below). The "Obstacles and Opportunities" session allowed the teacher/consultants to express their perceptions on GIS in the schools. In general, this open format discussion was appreciated.

The remaining sessions were mainly focussed on the teacher/consultants' use of GIS in their own classroom. They found the first activities, identifying specifically where in their own courses GIS would fit in and reviewing the outline of the lesson planning stages, very helpful in getting them into the planning mode. Following the incubation of ideas on the weekend, there were two planning sessions, "brainstorming" and "polishing". These small group work sessions helped the teacher/consultants narrow down and clearly define GIS projects that would work in their classrooms. A few teacher/consultants did find the second session a bit redundant, since they had their plans pretty well defined by the end of the first lesson planning session. Time was spent in a couple of the sessions trying to define a universal format for the lesson plans. It became apparent that with the broad scope of teacher/consultant projects and with the great variety in personal lesson planning styles, that a strict lesson format would not be feasible. Instead, we decided as a group to produce project summaries rather than matching lesson plans. Overall the time spent on lesson planning activities seemed adequate. Some teacher/consultants thought it was overdone. Many of the teacher/consultants, however, would have liked to have more time to access the university resources that were needed for their projects.

The teacher/consultants also gave other input that changed the course of some of the SEP activities. A prototype outline of an "Introduction to GIS Workbook" was presented to the teacher/consultants. They pointed out that the workbook was too focussed on teaching GIS rather than the use of GIS as an auxiliary teaching tool. Teacher/consultants brainstormed and came up with a plan for a resource that would introduce GIS into a variety of courses. The working title of this resource was "GIS City". It would encourage teacher use by having a set of pre-packaged activities that would fit into the existing curriculum of various courses. Teachers would use a set of overlays of various "GIS City" features and variables to teach concepts related to their current course content. Students would work through a series of worksheets using GIS analysis concepts to reinforce subject area learning, but at the same time would be slowly exposed to GIS. Support materials in the workbook would allow the teacher to expand the lessons to a more direct use of GIS concepts. Though the SEP will not develop this specific resource, this teacher/consultant defined model helped clarify the types of GIS teaching materials that would be of value in the classroom.

The teacher/consultants gave excellent feedback in the verbal evaluation sessions, on the daily evaluations, and in the final evaluation form. This type of on-going evaluation was a critical element of the workshop. Not only did the teacher/consultant feedback meet the goal of providing
the SEP with a baseline for GIS in the school efforts, but it helped us see the needs of the schools in a clear light and enabled us to change course in some of our activities.

General Workshop Evaluations

The teacher/consultants found the introduction to GIS technology, the demonstration of many GIS applications (showing the wide range of GIS use), the hands–on work with software, and the interaction among the teachers and workshop staff extremely rewarding. They liked the daily mix of activities and the organized structure of the workshop. Other positives were:

- the broad group of teachers (science, social studies, computers, and ESL)
- the openness to teacher questions
- the adequate time for discussion
- the small working groups for lesson planning and other teacher–teacher interactions (including eating lunch together)
- the trade magazines as evening reading
- the cookies and other treats brought in by the workshop participants.

As noted, the first days activities could have been structured to give teacher/consultants a better sense of what GIS was all about and how it related to them. Despite the attempts to foster a sense of partnership, a couple of the teacher/consultants still sensed a clear division between the teacher–students and the NCGIA–orchestrators. They would have liked to see the teacher/consultants more involved with planning the directions of the workshop. The Center appeared to have some pre–conceived plans for developing materials and was a bit slow in responding to the recommendations of the teacher/consultants. These teacher/consultants would have liked to be more involved in a joint project, rather than being the testing ground for the NCGIA's ideas.

Many of the teacher/consultants suggested that there be a specific project that the teachers would work on during the course of the workshop. The project would progress through the steps of creating a GIS application. The resource developed could then be used in the teachers' classrooms. Some parts of the project such as a data set and software package might be prepared ahead of time, but teachers should get the sense that they are the creators. This might ameliorate the feeling by some of the teacher/consultants that they did not have a great say in the outcome of the workshop. For this to work the project would have to be fairly simple, but would have the result of producing an active interest in the GIS information being presented. It would also give the teachers an immediate "result" that could be applied to their teaching.

Suggested changes to the workshop include:

- shortening the day by an hour, because many of the teacher/consultants reached a point of information overload and fatigue by the time of the late afternoon discussion sessions
- a shorter workshop (5 days?), but with some way of extending access to the university resources (perhaps some sort of follow–up, SEP staff supported workdays)
- a consolidated listing of data, software, and materials sources with basic information including addresses
- continued access to knowledgeable individuals after the workshop (perhaps some sort of working partnership between a teacher and a graduate student)
show GIS as a tool for limited projects, not just large research activities

clearer presentation of SEP goals for materials development and teacher/consultant projects.

GIS in the Schools

One of the main goals of the workshop was to gather teacher input on the usefulness of GIS in the schools. The following information is a summary of comments on this topic from the workshop. On the issue of the productivity of a GIS component in high school courses, the teacher/consultants were unanimously enthusiastic. GIS was seen as an excellent tool for improving the problem solving and critical thinking skills of students. GIS could be a part of "higher order thinking activities that are often so hard to come up with." GIS is also a natural way of providing an avenue for practicing project management and group working skills. GIS would help introduce high technology as an exciting example of computer use in society. Concern for the environment could be matched by GIS–based environmental case studies. GIS was also seen as a powerful tool for linking disciplines. By including some form of GIS activity in the secondary schools, students could be inspired to follow up with further college or university work in GIS and to seek employment in GIS related fields.

Place in the Curriculum

The teacher/consultants identified many places for GIS in the present school curriculum. Obvious subjects were geography, physical and life science, and earth science. Other subject areas which the teacher/consultants thought might benefit include: history, government, economics, business, environmental studies, computers, and math. Vocational arts classes might even be the closest to GIS with their use of CAD software. With a little imagination the teacher/consultants were able to dream up a use of GIS in just about any course. Despite the many opportunities, the teacher/consultants noted that practical demonstrations of GIS use in the various courses would need to be available to teachers before they would embrace GIS.

Two subject areas were identified as the early targets for GIS activities: science and geography. Some teacher/consultants thought that the sciences with their technological bent would be the best place for GIS introduction. Others argued that the "G" in GIS stood for geography and that the systems are inherently geographical in nature, therefore they should be part of a modern geography program. The "GIS/geography relationship [would be] similar to the high school English class where grammar and English literature go together." Despite a long absence, geography classes are becoming more common in the secondary schools and might provide the ground for at least a first look at GIS. This initial exposure to GIS in a geography course could be translated to the use of GIS as a general resource in various other courses. On the other hand, GIS could be the focus of new multi–disciplinary classes "made up of earth science and history classes as they discuss nuclear warfare and its history" or study the modern pollution problem. Another place for GIS may be in the school library as an information base and project resource.

Teaching Methods

Many methods for teaching GIS in the various courses were mentioned. As a precursor to any form of GIS use, a visual presentation (slides, video, posters, magazine articles) could prepare the students by emphasizing the nature of GIS and its effect on their lives. If this connection is made at the beginning, it is more likely that the students will be motivated to learn. Considering the state of computing in the schools, it was suggested many times that there be a set of "manual" GIS activities that could be completed without computers, but would lead into the use of the computers where possible. Even before "manual" GIS work, some teacher/consultants noted that some student training in map use would be helpful. This map practice, however, might be designed to occur as part of the GIS activities. In fact, GIS might be an appropriate method for introducing map reading and use into a course. For the most part the teacher/consultants saw and wanted their
students to see GIS primarily as a tool to enrich the study of existing curriculum, with some learning about GIS and its methodology as a by–product.

One set of GIS concepts that the teacher/consultants thought was very valuable was that of data layers and the combinations of those layers. They also pointed out that the raster/vector data models were a useful concept that would be clearly presented on a computer. The manipulation of information (aided by the graphic confirmation provided by the GIS) was another subject that had a broad appeal. It was noted that students having the ability to "compose" their own solutions was an excellent educational method. An obvious mode of GIS use identified was as the platform for a class/team project. A problem would be presented to the students who would then use the GIS to find solutions. Specific information about the operation and power of GIS would be an outgrowth of this type of project work. Another mode would be an easy–to–use GIS with an adequate database as an information and quick analysis supplier for various courses. One way GIS could be presented would be as a job opportunity. GIS users from the community could be utilized as guest speakers. These users could be encouraged to consider taking some students on as interns. Another suggestion was for a local university or business to sponsor a local contest for geographically based information projects with modest prize money for the winners.

Teaching Materials

Whether computers are used or not, material such as slides, videos, overhead projector transparencies, posters, examples of GIS output, aerial photography, and satellite imagery would be helpful in introducing GIS to students. When computers are used, it is still advisable to have a non–technological component. Materials designed for GIS in the schools need to have the following characteristics:

- geared to the existing curriculum
- simple
- ready to use (if teachers suspect that this "new" material is a black hole for their time it will go on the back–burner)
- adaptable to differing approaches and time periods (with various levels of complexity built–in)
- developed with teacher feedback
- clear as to time and resource requirements
- task oriented
- include support materials such as a glossary, teacher notes, and lists of sources of software and data.

An example of a non–computer dependent GIS activity previewed during the workshop was that of different data layers on transparencies. Various overlays of the layers were made to answer questions about the relationships between the data. The teacher/consultants liked this model as an introduction to GIS methodology and as a general teaching technique which could be employed in many areas of the curriculum. Transparency overlays can also be used to model other GIS functions such a buffering and reselection.
Software

For GIS classroom activities that will be computer–based there is still a need for either sets of educational materials designed for existing, inexpensive GIS packages or a new, simple GIS package created with the schools in mind. The IDRISI model seems to be the best, though existing educational materials would need to be tailored to secondary school requirements. Software packages need to be straight forward, easy–to–use, and have “classy looking” graphics. This is extremely important since teachers, even if they are not computer neophytes, will not have the time to learn sets of complex commands and students will probably not have patience for difficult packages.

Various surrogates to a full–blown GIS could be employed to introduce students to GIS concepts. These include demonstration packages to existing software, so long as the demonstrations are designed to promote GIS education and utilize simple, comprehensible data sets. Demonstrations that are merely a walk through the commands and capabilities of the GIS will not go over well. Pseudo–GIS packages such as PC/Globe, Mac/USA, and AutoMAP, drawing packages such as CorelDraw and Aldus Freehand, and other map oriented packages could function as introductions to maps and, with a little creative teaching, GIS. Hypertext tutorials could be designed to explain and demonstrate GIS to students. Some portions of the HyperCard based GISTutor might be employed as a text for some of the technical aspects of GIS in more advanced classroom projects. Hypertext applications could even be wedded to GIS packages in order to provide a familiar, simple to use interface for viewing data in the GIS package. Other media may also be employed in the effort to utilize GIS with students such as CD–ROM, Laserdiscs, and multimedia systems. A key subject in any attempted use of GIS software in the schools is appropriate data. Teachers for the most part will not have the energy to compile their own data. Special data sets will need to be created for GIS educational software and instructional materials.

Hardware

Computer hardware in the schools at this point is a very inconsistent mix of PC/XT, 286, & 386 IBMs and clones; Apple Ile and IIgs machines; and Macintosh Plus, SE, Classic, LC, and, in some cases, various types of MacIIs. A minimum for comfortable GIS operation at a beginning level would be 386–based machines with VGA monitors, or Macs preferably with color monitors. For advanced GIS class activities, sharing a small digitizing tablet and a laser printer would be helpful. For whole class GIS based lessons, a student/computer ratio of 1:1 or 2:1 would be best, with 3:1 acceptable. For group projects, there should be a computer per group unless some sort of rotation could be worked out. Comparing the have and need lists, it is clear that in many cases schools are not prepared for computer–based GIS activities. With budgetary problems, schools may not be updating their computer resources any time soon. This means that new packages running best on 486 and MacII machines will be out of reach of the secondary educators.

Directions for GIS in the Schools

The teacher/consultants noted many present impediments to the easy introduction of GIS content into the secondary schools including instructor inertia and dwindling budgets. Some teachers have put up resistance to the use of computers in the classroom chiefly due to the time involved in learning basic computer skills and partly due to fear of change. For most teachers, the present state of GIS materials, software, and hardware would prevent attempts to use GIS in their classes. This situation can be partially remedied through the design of good teaching materials and GIS software/demonstrations/modules. The other component to break down teacher resistance would be teacher training in GIS. The time and support required for GIS activities will be still be a drawback to some teachers; however, with computers becoming a major classroom tool, sets of
curriculum materials with GIS components eventually being developed, GIS intersecting our lives on a daily basis, and GIS–based educational methods being taught in teacher preparation courses, GIS use will be prevalent in future schools.

The question remains: how will GIS be made a useful tool for teachers and students? The teacher/consultants identified the following efforts:

- offer more workshops similar to the prototype they experienced
- develop GIS modules that would integrate well with the existing curriculum
- emphasize teacher/consultant led in–services on GIS
- continue to develop partnerships between teachers and GIS users in universities, government agencies, and businesses
- push for GIS inclusion in textbooks (even at the level of a side bar)
- educate school administrators on the potentials of GIS as an aid to teaching
- establish a communication network for teachers attempting to use GIS
- encourage organizations such as the NCGIA to act in the role of advocate for educational uses of GIS including efforts to convince software developers to participate

A couple of teacher/consultants noted that GIS should be slowly, but strategically introduced into different subject areas. At first it might be seen as a novelty, but efforts should be made for GIS to gain the stature of a key educational tool. Despite the many challenges still remaining, the teacher/consultants eagerly attempted their GIS oriented projects in their fall semester classes.
# TEACHER GIS PROJECT SUMMARIES

The teacher/consultants who attended the "GIS in the Schools" workshop each formulated a GIS project that they could try in their fall classes. Since GIS concepts were still very new to the teachers and since there were not very many GIS resources for use in the schools, the teachers were not required to utilize an actual GIS program in their projects. In some cases, the actual GIS component was limited due to various constraints imposed by the existing curriculum and especially the scarcity of supportive instructional materials for teaching about or with GIS. For this reason, the goals of the Secondary Education Project include efforts not only to appropriately place GIS activities in the curriculum, but also to stimulate the creation of GIS-oriented instructional materials.

Some of these teacher/consultants are beginning to investigate transferring their pencil and paper exercises to GIS computer software. Teachers supplemented their projects with a GIS slide show and general discussion of GIS in their classes. The short project summaries included are not intended to serve as fully developed GIS curriculum materials for teachers or even as formal lesson plans, but rather are demonstrations of the types of simple GIS activities that may be attempted in the classroom. The summaries can be used to stimulate brainstorming on the development of GIS projects appropriate to a teachers particular teaching situation.

The workshop participants were drawn from high schools in Santa Barbara and Ventura counties in California. Some of the teacher/consultants were not able to finish writing up their projects. Those who submitted summaries are:

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<tr>
<th>#</th>
<th>Name</th>
<th>Project Title</th>
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<tr>
<td>1.</td>
<td>Gary Gettings</td>
<td>Lompoc to Santa Barbara Bike and Van Pool</td>
<td>22</td>
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<tr>
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<td>Lompoc High</td>
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<td>Casey Roberts</td>
<td>GIS and the Fulfillment of the Abrahamic</td>
<td>31</td>
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<td>James Furlong</td>
<td>GIS and Bakery Siting in Solvang</td>
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<td>An Introduction to Geography and to GIS</td>
<td>36</td>
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<tr>
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<td>Oxnard High</td>
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<td>6.</td>
<td>Kevin Callaway</td>
<td>A Look at California Through GIS Overlays</td>
<td>41</td>
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<td>Port Hueneme High</td>
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7. Newman Whitmire  
46  
Cabrillo High  
Science Dept.  

8. David Sanchez  
47  
Santa Barbara High  
Science and ESL Depts.  

A Hypertext Introduction to GIS  

River's Side Project
**Project #1**

In this project, students are asked to use information on the location of the homes of potential van pool riders to assign riders to the "best" van. Students use maps of Lompoc to identify potential van rider pick-up routes. Students also need to coordinate the use of bicycles provided by the city.

**Lompoc to Santa Barbara Bike and Van Pool**

The federal government has given the city of Lompoc a grant to cut down on the use of smog producing automobiles. It has been determined that over 2000 people commute from Lompoc to Santa Barbara daily. This grant is different in the fact that it also encourages the use of bikes. Vans will pick up riders at five centralized, all day parking facilities and at nine neighborhood schools. Riders will have the option of driving to an all day parking lot or riding a bike to one of the schools. The use of bikes should lower the emission levels even more and improve the physical condition of the riders.

Those van pool riders who choose to use a bike to get to the pick up point will have two options. They can either ride their own bike or use one provided by the city. Secured and covered bike barns will be built by the regional occupational students at Lompoc High School. They will be placed at the nine schools that are van pool pick-up sites. During the day, the bikes will be conveniently stored in the barns. The regional occupational students will also construct covered areas at the five all day parking sites. These will give the riders a dry place to wait for the van.

Four vans have been purchased. Two will leave Lompoc at 7:00 a.m. One will travel highway 246 to Buelton to pick up 5 riders at the bus stop. The other van will travel Highway One. Two vans will leave at 8:00 a.m. One will travel to Buelton to pick up four people at the bus stop. The other van will travel Highway One. The capacity of each van is ten people. The city will pay one rider in each van to drive.

**Your Mission**

You will be given a list of names and address of each person that must leave Lompoc at either 7:00 or 8:00 a.m. The drivers have been chosen. They will pick up their van at the Lompoc airport, where they are stored each night.

You must determine the closest bike barn if the person chooses to use the bike provided by the city. They will need a key to the secured area. There is a different key for each area. You will also have to determine the closest all day parking lot for each rider.

The Lotus 123 computer program will be used to keep track of all expenses and records. Things like van expenses bike and bike barn service, frequency of use, etc.

As this assignment evolves, an actual GIS software package could be used to compute distances and do route computation. The GIS would also allow students to experiment; for example, see if it would be more efficient to allow the drivers to keep their van at home each night. This might cut down on smog emission and be more cost effective.
Objectives of this GIS lesson

This lesson will teach students how to read a city map. They will be able to find address by reference numbers. Also they will have to determine the different routes for the vans.

Students will learn to work in groups and use problem solving skills. They will be required to give a presentation to the class justifying the routes chosen by each bike and van.

The use of GIS principles with overlays will be demonstrated. The students will see how geographic analysis helped them in their decision making. The use of GIS software will also show how these decisions can be made with greater speed and precision.

Setup

Clear overheads of the maps will be used to help students understand the advantages of a GIS analysis. These overlay will be used to show where each person lives and the location of the closet bike storage and all day parking areas. Each overlay can be made by photo copying the base maps. By combining the various overlay transparencies, the students can determine the van routes. The students will need to be trained in how to read a city map using the reference grid (example B-3).

These maps will be scanned and used in computer studies and social studies classes at Lompoc High School. [One of these city maps has been included as an example. It shows the acceptable roads for van travel (main streets) marked on the city map. Other city maps with markings include: location of all day parking lots, location of schools with bike storage facilities, location of 7 a.m. riders homes, and 8 a.m. riders homes. There is also a map of the local schools with a legend giving their names. A final transparency includes a set of different sized concentric circles which when placed on the riders home can help determine the nearest van pick up site]

Students will try various rider/van/route permutations. They will be required to select a "preferred" rider grouping and route assignment. Following student presentations of their solutions, the teacher and student will discuss the ways a GIS could help in this type of decision making. Students will then get an opportunity to try to solve the same problem using a simple GIS software package with the Van Pool Exercise in its database. [The Van Pool exercise has not been put into a GIS software package yet.]
7:00 a.m. Leave Time To Santa Barbara

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<td>Tom Rossi</td>
<td>1135 E. Alden</td>
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<td>Mike Evans</td>
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<td>Mary Woods</td>
<td>1210 E. Chestnut</td>
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<td>Bill Singer</td>
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<td>Tom Green</td>
<td>225 E. Fir</td>
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<td>Susan Williams</td>
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<td>Kyle Smith</td>
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<td>Robert Jackson</td>
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<tr>
<td>Dan Johnson</td>
<td>603 W. Laurel</td>
<td>D-5</td>
</tr>
<tr>
<td>Katie Lange</td>
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<tr>
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<td>1407 W. Nectarine</td>
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<tr>
<td>Jim Keeling</td>
<td>1103 W. Tangerine</td>
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</tr>
<tr>
<td>Bill Dorty</td>
<td>605 E. Chestnut</td>
<td>C-5</td>
</tr>
</tbody>
</table>

Plus one van is to pick up 5 people in Buelton at the bus stop.

Each van has a 10 passenger capacity.

Ron Fairbanks and Jim Keeling are drivers of the vans.

The vans are stored at the Lompoc airport.

There will be two vans used on this time route.

8:00 A.M. Leave Time

<table>
<thead>
<tr>
<th>NAME</th>
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</thead>
<tbody>
<tr>
<td>Mike Somerfield</td>
<td>205 E. Barton</td>
<td>C-3</td>
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<tr>
<td>Bill Elliot</td>
<td>936 E. Barton</td>
<td>D-3</td>
</tr>
<tr>
<td>Susan Marks</td>
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<td>John Peterson</td>
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</tr>
<tr>
<td>Debbie Waterman</td>
<td>307 S. 6TH Street</td>
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</tr>
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<td>George Mckinney</td>
<td>605 W. College</td>
<td>D-5</td>
</tr>
<tr>
<td>Larry Kaehn</td>
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<td>Bill Aries</td>
<td>907 W. Oak</td>
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<td>Bob Lusby</td>
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<td>Kathy Sawyer</td>
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<td>Jeff Culver</td>
<td>1143 W. Prune</td>
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<tr>
<td>Roger Maner</td>
<td>1209 W. Locust</td>
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</tr>
<tr>
<td>Mary Stich</td>
<td>401 S. K Street</td>
<td>C-6</td>
</tr>
</tbody>
</table>

One van will need to pick up 4 people in Buelton at the bus stop.

Each van has a 10 passenger capacity.

Jeff Culver and Bob Lusby are also drivers.

The vans are stored at the Lompoc airport.
There will be two vans used on this time route.
In this exercise students shade maps to correspond with the values of a series of environmental factors in order to identify the factor that is responsible for an elevated death rate on a third world, Pacific Ocean island country. The teacher substituted maps of the Hawaiian Islands, since that is what she had available.

**Death Rates and Environmental Factors**

**Background:** this lesson is similar to a study completed in Japan in the 60's and 70's on selenium and how it interacts with the human heart.

**Target Group:** 9th/10th general biology.

**Group Description:** Wide variety of learning styles, maturity levels vary, reading skills are average or below. This is a graduation requirement. These students will probably not attend a 4 yr. college or go on to the junior college system.

**Lesson Length:** 4 days (Optional day five)

**Pre-lesson Skills:** Students need prior knowledge of reading data charts and x/y graphs. Students are familiar with the American Heart Association information on heart disease and death rates due to heart disease in the United States. Students are also familiar with the anatomy of a healthy adult human heart

**Supplies Needed:** Overhead, box of clear acetate plastic sheets or access to a copier, colored pencils or makers.

**Lesson Objective**

Using maps and data on sea water composition, air composition, ground water composition, soil composition and death rates students are to determine the cause of death in an island population. Descriptive information is presented on island death rates and how they deviate from the norm.

**Day 1**

Students are given a drawing of the human heart and are told to label it correctly. Students are given information on death rates in the US from heart attacks and heart disease. Students are given a map of the Hawaiian Islands and told that it is third world country. It is explained to the students that we will be looking at the several factors to determine which, if any, could be causing the early, unusually high death rate in this country. Factors studied in order are:

- Sea Water
- Air Composition
- Ground Water
- Soil Composition

**Day 2**

Students are divided into groups of 3. Data Sheet 1 and blank maps are passed out to each group. Investigation 1 is assigned for students to work on the remainder of class time. [See Data and Investigations on following pages.]

**Day 3**

Each group gives a 2 minute summary on their interpretation of the answers they found after completing Investigation 1. Many student teams will focus on the high concentration of Fe in both the ground water and the soil. For the remainder of class students divided up into groups and are assigned Investigation 2 and given blank maps and Data Sheet 2.
Day 4
Once students divide the islands into thirds and start mapping the death rates at the different locations on the islands, a pattern begins to appear. Almost all groups will see that the death rate is the highest in the mountain area and lowest in the coastal area. In a class discussion, we examine Fe at all three areas on each island and conclude that it has little to do with the death rate. In fact, we graph out all elements sodium through zinc and realize that all are constant except selenium. We conclude, by comparing our maps and the percent of selenium, that the areas of lowest selenium concentration have the highest death rates.

Optional Day Five
For closure, I ask my students a series of questions about the study and the way the information was presented to them. Three questions I focus on are:

1) what other information would have been helpful to us in determining the cause of death on the islands,

2) what other maps would have been helpful in determining the cause of death on the islands,

and 3) as a researcher, what other studies or test would I now conduct to test my theory relating low amounts of selenium to high death rates due to heart failure.

The students like maps, in fact they suggest the use of maps that seem to have nothing to do with the study! [The use of the Hawaiian Islands map was just for convenience. The data doesn't actually come from these islands. Instead of using real islands (Oahu, Maui, and The Big Island, Hawaii), a teacher could produce a fictional map of any three volcanic islands for this study.]

INVESTIGATION ONE

1. What are the most abundant elements in the sea water?

2. Which island has the highest concentration of all 6 elements? (ANSWER: 2)

3. Which island has the lowest concentration of elements? (ANSWER: 3)

4. For sea water, use green to color the island that has the highest chlorine concentration.

5. Which of the islands has the highest concentration of all 3 air pollutants: carbon dioxide, sulfur dioxide, and ozone?

6. For air composition, color the islands as follows:
   red = ozone highest
   blue = carbon dioxide highest
   yellow = sulfur dioxide highest

7. For ground water, map out the following information as follows:
   green = highest concentration Selenium
   red = highest concentration Iron
   yellow = highest concentration mercury

8. In soil composition which two elements have the highest concentration and which have the lowest concentration?

9. For death rate, color the islands as follows:
   red = highest rate
   yellow = lowest rate
1970 Heart Attack Study: Data by island (Data 1)

Included in the study was testing on the following:
- ground water (fresh)
- top soil (first 3 feet)
- air
- ocean water (2 mile radius)
- fish (main food source)

**Sea Water:** The sea water surrounding all islands was very similar in composition:

<table>
<thead>
<tr>
<th></th>
<th>Island 1</th>
<th>Island 2</th>
<th>Island 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>280ppm</td>
<td>281ppm</td>
<td>277ppm</td>
</tr>
<tr>
<td>Cl</td>
<td>196ppm</td>
<td>199ppm</td>
<td>198ppm</td>
</tr>
<tr>
<td>Al</td>
<td>45ppm</td>
<td>42ppm</td>
<td>46ppm</td>
</tr>
<tr>
<td>Si</td>
<td>17ppm</td>
<td>18ppm</td>
<td>17ppm</td>
</tr>
<tr>
<td>Mg</td>
<td>4ppm</td>
<td>6ppm</td>
<td>4ppm</td>
</tr>
<tr>
<td>Mn</td>
<td>7ppm</td>
<td>9ppm</td>
<td>5ppm</td>
</tr>
</tbody>
</table>

**Air Composition:** The air samples collected on all islands was very similar:

<table>
<thead>
<tr>
<th></th>
<th>Island 1</th>
<th>Island 2</th>
<th>Island 3</th>
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</thead>
<tbody>
<tr>
<td>CO2</td>
<td>134ppm</td>
<td>130ppm</td>
<td>133ppm</td>
</tr>
<tr>
<td>SO3</td>
<td>35ppm</td>
<td>30ppm</td>
<td>33ppm</td>
</tr>
<tr>
<td>O3</td>
<td>6ppm</td>
<td>7ppm</td>
<td>4ppm</td>
</tr>
</tbody>
</table>

**Ground Water:** Ground water (drinking water) showed the following:

<table>
<thead>
<tr>
<th></th>
<th>Island 1</th>
<th>Island 2</th>
<th>Island 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>6ppm</td>
<td>7ppm</td>
<td>5ppm</td>
</tr>
<tr>
<td>Fe</td>
<td>145ppm</td>
<td>83ppm</td>
<td>90ppm</td>
</tr>
<tr>
<td>Pb</td>
<td>4ppm</td>
<td>7ppm</td>
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<tr>
<td>Hg</td>
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<td>29ppm</td>
<td>31ppm</td>
<td>30ppm</td>
</tr>
<tr>
<td>Zn</td>
<td>20ppm</td>
<td>19ppm</td>
<td>21ppm</td>
</tr>
<tr>
<td>Se</td>
<td>458ppm</td>
<td>201ppm</td>
<td>251ppm</td>
</tr>
</tbody>
</table>

**Soil Composition:** Overall soil composition of each island showed the following:

<table>
<thead>
<tr>
<th></th>
<th>Island 1</th>
<th>Island 2</th>
<th>Island 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>16ppm</td>
<td>17ppm</td>
<td>15ppm</td>
</tr>
<tr>
<td>Fe</td>
<td>150ppm</td>
<td>88ppm</td>
<td>93ppm</td>
</tr>
<tr>
<td>Pb</td>
<td>3ppm</td>
<td>8ppm</td>
<td>11ppm</td>
</tr>
<tr>
<td>Hg</td>
<td>4ppm</td>
<td>8ppm</td>
<td>10ppm</td>
</tr>
<tr>
<td>Se</td>
<td>12ppm</td>
<td>6ppm</td>
<td>7ppm</td>
</tr>
</tbody>
</table>

The study on 17 common species of fish showed all within the acceptable range on protein, fats, oils, salts, and trace minerals. No difference was isolated from any sample caught at any island.

**Death Rates** were as follows:

<table>
<thead>
<tr>
<th></th>
<th>Island 1</th>
<th>Island 2</th>
<th>Island 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963</td>
<td>181</td>
<td>97</td>
<td>103</td>
</tr>
<tr>
<td>1966</td>
<td>79</td>
<td>71</td>
<td>65</td>
</tr>
<tr>
<td>1969</td>
<td>167</td>
<td>88</td>
<td>101</td>
</tr>
<tr>
<td>1972</td>
<td>168</td>
<td>75</td>
<td>94</td>
</tr>
</tbody>
</table>
INVESTIGATION TWO

Use data set 2 to complete the following items:

1. Total all deaths on Island 1 - Coastal Area only. Do the same for Islands 2 and 3.

2. Total all deaths on Island 1 - Intermediate Area only. Do the same for the other islands.

3. Total all deaths on Island 1 - Mountain Area only. Do the same for the other islands.

On one map, divide the islands up by 3rds; 1/3 coastal, 1/3 intermediate, and 1/3 mountain. 
(Demonstrate creating zones by drawing concentric rings. Discuss volcanic topography.)

4. On the map divided into thirds, illustrate the highest death rates per island by the following colors:
   yellow = lowest
   blue = mid
   red = highest

5. Total the selenium and find where it is lowest and highest on each island.

6. On a different map create the 3 zones as you did with the other map. On this map illustrate the selenium concentration with the following colors:
   yellow = highest
   blue = mid
   red = lowest

7. Compare the color patterns of the two maps. What do the similar colors illustrate?

1970 Heart Attack Study: Data by island zone (Data 2)

Ground Water

<table>
<thead>
<tr>
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<th>Island 1</th>
<th>Island 2</th>
<th>Island 3</th>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na</td>
<td>6ppm</td>
<td>7ppm</td>
<td>5ppm</td>
</tr>
<tr>
<td>Fe</td>
<td>148ppm</td>
<td>83ppm</td>
<td>90ppm</td>
</tr>
<tr>
<td>Pb</td>
<td>4ppm</td>
<td>7ppm</td>
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<tr>
<td>Hg</td>
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<tr>
<td>Ca</td>
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</tr>
<tr>
<td>Zn</td>
<td>20ppm</td>
<td>19ppm</td>
<td>21ppm</td>
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<tr>
<td>Se</td>
<td>470ppm</td>
<td>247ppm</td>
<td>291ppm</td>
</tr>
<tr>
<td><strong>intermediate</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na</td>
<td>6ppm</td>
<td>7ppm</td>
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</tr>
<tr>
<td>Fe</td>
<td>148ppm</td>
<td>83ppm</td>
<td>90ppm</td>
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<td>Pb</td>
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<td>7ppm</td>
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<tr>
<td>Fe</td>
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</table>
### Soil Composition

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<td>7ppm</td>
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</tr>
<tr>
<td>Se</td>
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</tbody>
</table>

### Death Rate

<table>
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<th>Island 1</th>
<th>Island 2</th>
<th>Island 3</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1963</td>
<td>36</td>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td>1966</td>
<td>16</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>1969</td>
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</tr>
<tr>
<td>1972</td>
<td>34</td>
<td>15</td>
<td>19</td>
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<td><strong>intermediate</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1963</td>
<td>38</td>
<td>23</td>
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<tr>
<td>1966</td>
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<tr>
<td>1972</td>
<td>38</td>
<td>19</td>
<td>23</td>
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<tr>
<td><strong>mountain</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1963</td>
<td>107</td>
<td>55</td>
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</tr>
<tr>
<td>1966</td>
<td>46</td>
<td>41</td>
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<tr>
<td>1969</td>
<td>99</td>
<td>50</td>
<td>59</td>
</tr>
<tr>
<td>1972</td>
<td>96</td>
<td>41</td>
<td>52</td>
</tr>
</tbody>
</table>
Project #3

Students are faced with the dilemma of finding a new "promised" land for the Jewish race. This is an exercise for a World Civilization class studying the early inhabitants of the Middle East. Students have to identify both positive and negative factors on a series of world maps. By drawing the areas represented by each factor on acetate, students are able to simulate a GIS overlay operation and find a "solution" to their problem.

GIS and the Fulfillment of the Abrahamic Covenant

In Western Civilization classes it had always been problematic explaining why and how the current land dispute between Israelis and Palestinians originated. What method could I use to convey thirty-eight hundred years of history in a way that would have meaning and lasting value for teenage Americans. "Why should I be studying about this or care what has gone before in that part of the world?" was the utterance of my students. How could this be made interesting, fun, and relevant to their own experience and maybe even their future?

The solution came in the form of presenting the students with awesome responsibility of rewriting history so that the final outcome between Israelis and Palestinians would be less hostile. The students would be given the task of relocating the first monotheistic people Abraham's family, to any area of the world that fit the criteria of soil fertility and precipitation as described in the book of Genesis. This approach would encourage problem solving and direct involvement in one of the world's longest land disputes.

After an initial exposure to Geographic Information Systems technology and its problem solving approach, it became apparent that not only could we expose students to the "Gordian Knot" of the Middle East but we could also expose them to spatial decision making technology used by so many different industries today. Our students would have to think at a higher level so as to make the best possible fulfillment of the Abrahamic Covenant. Utilizing a GIS became my answer as how to unite thirty-eight hundred years of history and eighteen year olds.

Ultimately, if I had access to a state of the art computer lab with all the software loaded into the computer and an assistant available, my objectives would have been more easily achieved. However, I had no lab, no software, and no assistant so I chose the next available route. I was able to procure a transparency of the world for every student in my class of thirty-six and some overhead felt tip pens. I asked the students to divide up into groups of six and within these groups each student was to choose one of the following tasks and place the information on a blank world map:

a. Religions of the World/Historical anti-Semitic movements.
   Students will find already existing civilizations or religions that might be hostile towards an influx of Judaic peoples. Be sure to account for those countries that have an historical tie to anti-Semitic tendencies. Avoid them! List at least eight places.

b. Vegetation Growth and Soil Fertility.
   Look for soil and vegetation maps that can detail positive or negative agricultural requirements for Abraham's family. List at least seven zones.

c. Rainfall and Climate Zones.
   Look for rainfall/precipitation maps. Climate and food potential maps may also be helpful. List at least ten different zones.

d. Travel Routes.
   List Major rivers, oceans, seas, and other well known routes of ancient travel. List at least twenty.
e. Mountains and Elevation.
   List at least fifteen major mountain ranges.

f. Deserts.
   List at least twelve of the world's major deserts.

After each student in each group had selected one of the above tasks, they were given blank maps of the world corresponding exactly to the transparency they would be given later in the week. Their initial research would be first placed on the xeroxed map and then the following day carefully placed onto the transparency. All of our work was going to take place through research in our school library. Our library has limited resources so it became essential that every person researching deserts work with the five others who also had the same task. This was the case for each of the global land traits. In this setting, students collaborated with five others from the five other groups. Here is the time frame that was used for our GIS week.

Prior to and Day 1
General introduction to the inception of the religion of Judaism. Include basic terms such as poly and monotheism, Abrahamic Covenant, Hebrews, Jews, Judaism, B.C. and A.D., Mesopotamia, Tigris and Euphrates rivers, Sumeria, Canaanite, Akkadians, Babylonians and fertile crescent.

Day 2
Students will divide into groups of 5 and begin researching the world for important geographical traits: rivers, lakes, mountain ranges, deserts, oceans, seas, fertile coastal and river plains, and where hostile polytheists live or where places of anti-Semitism have existed in history. Each student will record their findings on a paper map of the world.

Day 3
Each student will be given a world map transparency in which to detail their specific research they found the day before, i.e., river locations mountain ranges etc. Half way through the period students should then be finishing their maps and then begin to overlay their transparencies on those of their teammates and begin to notice where potential living sites for Abraham's family may be. Remind students to write in an accurate legend on each transparency. (This must be done in a way that ensures that legend elements on the various transparencies will not conflict when overlaid.)

Day 4
Each group analyzes their findings by overlaying their transparencies and begins the discussion and decision making process. When all groups have selected four sites (and ultimately the place they would have Abraham's descendants go) each group will then go before the class and state why they came to the location/conclusion that they did using the transparencies that they made. This process will begin on day 4 but will overlap into day 5.

Day 5
Finish presentations and then teacher closure regarding the incredibly difficult problem of solving who's land it really is. Allow time for student discussion about the "Gordian Knot" of all religious land disputes. Can the students explain why this land called Canaan, Palestine etc. was the land chosen for Abraham's descendants? Teacher explains/illustrates the difficulty in making decisions with spatially involved characteristics. Explain how some 911 emergency services, Southern California Edison, and the E.P.A. use GIS. Other current examples may come from military exercises in Iraq such the use of a GIS based navigation systems to guide Tomahawk and cruise missiles to their targets with pinpoint accuracy. Current uses for GIS may also spill over into a day six depending upon student involvement and the ability to bring in speakers from the community who may be currently using a GIS.
Assessment
Within their groups students graded themselves as to their thoroughness and seriousness to which they addressed the assignment. The teacher had final say as to what grade the student finally received. This grade was derived from individual consultations with students in the library during days 1-4. As the teacher filtered through the groups it became apparent who was really on task and those who were not. Of course, students were tested on vocabulary presented prior to and on the first day that included the beginnings of Judaism, the Abrahamic Covenant etc. Further testing included applications and how a GIS is beneficial in making spatially relevant decisions.

On the last day, the teacher/student discussion on the ramifications and applications of a GIS can be as creative as their collective brainstorming and knowledge of the computer world will permit them. Hopefully both parties will examine our society to see what fields are already using GIS and what businesses etc. could use them? Are there environmental, societal, economic, political, athletic, religious uses for GIS?

The California State framework in social studies calls for a renewed commitment to geography and an interdisciplinary approach to social studies. Could a sophisticated or simple (or as my students have used) approach to GIS and history begin addressing our state framework? I think without a doubt that social science and science teachers could unite in this area. I believe that English teachers and social science teachers could collectively discuss topics like "Big Brother," censorship and today's capabilities with a GIS. How about partnering with businesses in your local community that are already using GIS?

This five to six day historical application of GIS has enabled my students to link geography, politics, history, and religions into one unit of study. I fully believe that this has helped my students to retain more information, think at a higher level, and envision their future world as it will be affected by GIS.
Project #4

The problem of where to locate a new bakery in a town is presented to students. These students attempt to find a good location for the bakery using various criteria. An overview of GIS precedes the bakery locating exercise. Following the exercise, the teacher and students discuss how a GIS might have aided their analysis.

GIS and Bakery Siting in Solvang

Summary

A two day lesson plan was formulated to teach students about Geographic Information Systems and their applications. The first day of the lesson was an overview of what GIS is, how it is being used, and how it may be used in the future. The second day of the lesson was a "hands on" activity to demonstrate how GIS is being used today. The lesson was worked into a world history class that had been discussing the plight of undeveloped countries. Throughout the lesson, the benefits and uses of GIS in undeveloped countries was pointed out. Even though the lesson's purpose was to introduce students to GIS, there were many opportunities to tie in the lesson with what the class had been learning about over the previous weeks.

Lesson Plan Purpose

To introduce students to Geographical Information Systems.

Time and Resource Requirements

Two class periods were needed to give students a good understanding of what GIS is and how it is used. A map of the local town was needed along with a slide projector.

Lesson Design

The lesson was broken into two components. The first component was an introductory lesson to GIS: Who uses it?; How is it used?, What are some of its applications?, etc. A set of slides was used to help illustrate GIS applications. The second component of the lesson was an activity that used the GIS concept of layering. Because the history class did not have access to computers, the layering project would have to be done without the use of computers.

Detailed Summary

The first step in the lesson was to introduce GIS. What GIS is, the history behind it, who uses it, and the different types of GIS were some of the topics discussed. Each topic was followed with student questions and a teacher check for understanding. After the students had a basic understanding of GIS, a slide presentation followed. The slides were borrowed from the National Center for Geographic Information and Analysis at UCSB. Approximately forty slides were shown to the students.

The second part of the lesson, on day two, was a "hands on" activity. The students were given the task of locating a bakery in the town of Solvang, Ca. (Solvang is a tourist town with a Danish theme and already has numerous bakeries.) The students were put into groups of two and three, and were given the role of developers who wanted to build a prosperous business. They were given a map of Solvang and told to find the best location for opening a Danish bakery.
The students were given no initial guidelines. After five minutes the teacher announced that the developers must follow town rules and could not build in a residential area. (The teacher arbitrarily picked where residential zones were.) The students were given the information as to where the residential zones were, and given five minutes to make any necessary changes to the location of the bakery.

The teacher then announced that successful businesses were located at least one block away from a similar business. The names and addresses of bakeries in Solvang were given to the students along with five more minutes to allow for changes.

The teacher then announced there were two convenience stores and one supermarket that sold bakery items. A buffer zone of one block around these stores would be a good idea for a new business. Five minutes were given to the groups to make any changes to the bakery location.

The groups are then given the location of two coffee/espresso shops that are in town. A location near one of the coffee houses may increase business. The last bit of information given to the groups is the location of easy access parking lots. The groups were given five minutes to decide exactly where they wanted to build their bakery.

In closing the lesson, the teacher explained the ability of a GIS software program to bring up all the information given in the lesson in just a matter of seconds. If one of the groups had had a computer with the Solvang database, they could have chosen a location in a couple minutes, instead of twenty five minutes. The class was then given a homework assignment of writing down how many ways could GIS technology help undeveloped countries plan for their futures.
An Introduction to Geography and to GIS

Five Themes of Geography: Review

The lesson was designed to be a brief review of the key components of Chapter 1 in our geography textbook (World Geography, Baerwald & Fraser, Prentice Hall, 1993). The key components are the 5 Themes of Geography and the 5 elements of a map. The intent was also to have students begin to apply the textbook material to their own community and neighborhoods. This was also the first opportunity for the class to participate in group work/cooperative learning activities with their new classmates. The follow-up activity was a presentation of the GIS slides and a discussion of the variety of uses of "geographic" information and the role of a geographer in today's world.

Time & Resource Requirements:

The lesson is designed for 2 to 3 days; this time frame assumes that the activities to establish your groups have already taken place.

Each group must have:

1 plastic overlay map of the community or area to be discussed
1 marker for an overhead
1 street map of the area
1 topographic map of the area (optional)
1 copy of the above map on paper for each student
1 copy of the review worksheet for each student

The most time consuming activity for the teacher is obtaining/creating a workable map. Street maps may be obtained from AAA. Inexpensive topographical maps may be acquired from stores that supply hikers and campers. I found a ready supply at:

Pacific Travellers Supply
529 State Street
Santa Barbara, CA 93102 Phone: (805)963-4438

[Through its wholesale warehouse, this store can obtain a map of just about any region of the world and USGS topographic maps for the entire US. Another good source of maps and map information is the USGS. Their number is 1-800-USA-MAPS.]

The map was reduced to normal paper size with a xerox machine by copying it in sections, trimming and then taping the reduced sections together, and then re-xeroxing them to create a clear, clean master copy. I then traced what I considered to be the key reference points onto clean paper which had to be xeroxed to create a master which could go through the thermofax machine to create the plastic overlays.
Lesson Objectives:

Students are to:

1. demonstrate an understanding of the "5 Themes" of geography and relate them to their own community.
2. identify positive and negative effects of "man" on their own community/neighborhoods.
3. read, interpret, construct, and interrelate maps of their local community/neighborhoods.
4. identify physical features of the surrounding area as they apply to human use.
5. be made aware of the role of geography in the work place and the modern world; students are to acquire an appreciation of the variety of activities and endeavors "geographers" may be involved in.

Teaching Design:

The lesson was designed to occur at the end of the work for Chapter 1: The Study of Geography in a new freshman class called Geography -- Non-tracked. The class is a mixture of all ability levels and several grade levels (primarily freshmen and juniors, and I was looking for an activity that would allow this varied group of individuals to begin to interact with each other while reviewing for a chapter exam. I also wanted an activity that could easily be followed with a discussion of GIS and the roles played by geographers in today's world.

Detailed Summary Of Lesson Plan/Project:

Day 1: [See instructions and worksheet following this lesson outline]

10-15min. to organize the groups, select leaders and secretaries, and to pass out worksheets, overlays, and copies of street and topographic maps.

40-50min. to have students brainstorm and complete the worksheet. The teacher should circulate throughout the room giving hints, encouragement, and structure to the search for examples. Encourage the leader to fulfill a guidance role making sure that all members of the group participate and that the examples are as diverse as possible.

Day 2:

10min. for the groups to reorganize and re-evaluate their previous day's work -- hopefully some of the students will have reconsidered more options.

15min. for the groups to help the secretary decide which examples are the best and put them on the group's overlay.

30min. for the groups to make a brief presentation to the entire class. Have each group present their overlay on top of the previous groups' sheets. Group leaders should make the presentation, explaining the location of their choices, and the class can then discuss the accuracy of the examples.
**Day 3:**

The class participated in a guided discussion of the 5 themes and the examples, briefly reviewing any specifics that the class may have overlooked (for example, not one group thought to mention a gravel mining operation that exists in the Santa Clara River). A slide presentation on GIS was presented, and the class then discussed the role of geography/geographers and the tools they use (for example, GIS and remote sensing).

This class only covered GIS in a very general way. A next step would be to continually refer back to the GIS discussion on Day 3 as the students continue to work with maps and other geographical data. The use of the local base map could be developed into a discussion of the way a GIS organizes map features into coherent layers. Students could then try to form various information layers on acetate copies of the base map. I will be experimenting with re-introducing GIS later in the quarter when the students have developed more knowledge about and skills to deal with geographic data.

**Assessment:**

The lesson was followed immediately with the chapter examination which included both objective and essay questions dealing with the 5 Themes. I did not test on GIS since this was presented strictly from an informational point of view, and I was hoping to spark an interest in the growing role of geography.
FIVE THEMES OF GEOGRAPHY: ACTIVITY INSTRUCTIONS

1. Select a group leader. This individual will be responsible for keeping the group on schedule and being the group spokesperson. Select a group secretary. This individual will be responsible for preparing the final copy of the groups findings. Both of these individuals will receive extra credit for the extra effort they put forth.

2. On worksheet A1 list the 5 themes of geography in the appropriate spaces. Under each theme, list as many specific examples from our local area as you can think of. An example has been given for each theme; if you need more space, use the reverse side of the worksheet.

3. Group leaders: review with your group the 5 components of a map. Have your group indicate these 5 components on their map of Oxnard. Each may be placed according to the individual's personal/artistic taste.

4. Using the street map of Oxnard, have your group members locate the examples of the 5 Themes listed in step #2 on their maps.

5. Group leaders: have the secretary create a group map on the plastic overlay using the symbols your group developed for its legend.
THE FIVE THEMES OF GEOGRAPHY:

A. ____________________________________________

1. ABSOLUTE LOCATION:
   a. Latitude of Oxnard: 34 degrees 10 minutes north
   b. Longitude of Oxnard: __________________________

2. RELATIVE LOCATION:
   a. near the mouth of the Santa Clara River
   b. ____________________________________________
   c. ____________________________________________
   d. ____________________________________________

B. ____________________________________________

1. Physical:
   a. Oxnard Plain
   b. ____________________________________________
   c. ____________________________________________
   d. ____________________________________________

2. Cultural:
   a. Buddhist Church on H Street
   b. ____________________________________________
   c. ____________________________________________
   d. ____________________________________________
   e. ____________________________________________

C. ____________________________________________

1. Landfill on the Santa Clara river
   2. ____________________________________________
   3. ____________________________________________
   4. ____________________________________________

D. ____________________________________________

1. Port of Hueneme
   2. ____________________________________________
   3. ____________________________________________
   4. ____________________________________________
   5. ____________________________________________

E. ____________________________________________

1. Southern California
   2. ____________________________________________
   3. ____________________________________________
   4. ____________________________________________
This project focused on California was designed for a general physical science course. It would also be appropriate for an earth science, ecology, or geography lesson. The project demonstrates the power of the GIS concept of combining different data layers. Different combinations of data layers allow the teacher to pose a wide array of thought provoking question to the students.

A Look at California Through GIS Overlays

Goals

To demonstrate the advantages of GIS using geographical overlays of various features of California. The basic concepts of computer-based GIS may be simulated by overlaying acetate overhead projector transparencies with the map data photocopied on them.

Objectives

Three groupings of overlays (transparencies) will be used to pursue particular questions in this lesson plan. Students will be required to make connections between different collections of data on the overlays by overlapping the sheets and observing new combinations of information not readily apparent when looking at the data sets separately.

Data Layers

The three groups of overlays are as follows:

1. Hydrology
   - Overlay #1: Lakes and Reservoirs
   - Overlay #2: Dams and Reserving
   - Overlay #3: Rivers and Streams
   - Overlay #4: Wild and Scenic Rivers

2. Geology
   - Overlay #5: Faults and Earthquakes
   - Overlay #6: Volcanic Areas
   - Overlay #7: Hot Springs and Pools
   - Overlay #8: Landforms

3. Public Lands and Conservation
   - Overlay #9: Counties and County Seats
   - Overlay #10: National Forests
   - Overlay #11: Natural Vegetation
   - Overlay #12: Habitat Sites
   - Overlay #13: Nature Conservancy Areas

[Overlay maps 5,6, and 7 have been included in the packet as examples.]

Tables of information are also provided for the students to add to map data. These could possibly be made into acetate transparencies.

Questions

The following questions represent only a few of the many possible questions that could be asked using these overlays. In addition, the combination of overlays could be varied, thus creating a totally different set of permutations representing new information for the students to interpret. This wide range of possible combinations of overlays and questions a teacher could ask further demonstrates the great versatility of the GIS data analysis model. By scanning these base maps for
the overlays into a computer, the information could become even more useful and inspiring to the students. These scanned data layers could be entered into a Hypertext program for students to do the overlaying electronically. With a little more effort the scanned data could be incorporated into a GIS software package providing an even greater range of analyses that could be carried out on these California data sets.

Hydrology Overlays

1. What rivers are still available for California as possible dam sites? (overlays 2, 3, and 4)
2. What region has the highest number of dams? (overlays 2 and 3)
3. Using your knowledge of the major population areas in California, which areas do you think would be the highest water users? (overlays 2 and 3)
4. Referring back to questions #2 and #3, where must water be diverted to meet the water needs of the state? (overlays 2 and 3)
5. What might be the political and social considerations in damming and diverting water in the state of California?

Other possible overlays that could be useful in questions about hydrology would be #9 (Counties), #11 (Natural Vegetation), and #12 (Habitat Sites).

Geology Overlays

1. Are there any connections between fault lines and volcanic areas? What are they? (overlays 5 and 6) [Overlays included]
2. If you were looking for a hot spring to bathe in, would a map of California earthquakes be of assistance? Why or why not? (overlays 5 and 7) [Overlays included]
3. What fault line has the greatest number of recorded earthquakes? (overlay 5)
4. What landforms are associated with this fault line? (overlays 5 and 8)
5. Are there any connections between fault lines and mountain ranges? What are they? (overlays 5 and 8)
6. Are there any connections between volcanic areas, faults, and the production of geothermal hot springs? What are they? (overlays 6 and 8)
7. Describe the relationship between landforms and volcanic activity. (overlays 6 and 8)

Other possible overlays for geology discussions might be #10 (National Forests), #9 (Counties), and #13 Nature Conservancy Areas.

Public Lands and Conservation

1. What areas of California are most heavily conserved when looking at plant communities (vegetation)? (overlays 10, 11, and 12)
2. How do the public (National Forest) and private (Conservancy) conservation efforts differ and how are they similar? (overlays 10 and 13)
3. Which areas have the least public conservation? (overlay 10)
4. Which areas have the most private conservation? (overlay 13)

5. What are some possible reasons why there are differences in the two conservation efforts?
Hot Springs and Pools (7)
One teacher chose to begin to develop a Hypertext software application that would be designed to help high school teachers and students understand various GIS terms and concepts. The package, which is still under development, integrates definitions and images in a user controlled learning environment. Hypertext software allows for multiple routes through the information base. In the case of GIS a Hypertext program would most likely include quite a few visuals such as satellites images, photos of GIS use, and images of the GIS computer screen.

**A Hypertext Introduction to GIS**

Teachers when confronted by GIS or any new topic may respond with "what is it, do I have time to do this, will the students profit from the information, how can I use it, what is there to use, is this ready to use now, does it fit into the framework, and how much do I have know to use it in the classroom?"

GIS is a new field which will have impact on our lives now and in the future in all subjects. What would be the best way to help teachers have the information they would need to reduce their preparation time and what could be used by advanced students for a self study?

The normal method for information to be given to teachers and students is in written form. The drawbacks are that it must be text and static images, the amount of information is limited due to practicality, the information is designed to be accessed in a linear form, and it is difficult to reference single pieces of information within the document. A teacher could use materials which would be easy to learn, easy to review, and easy to look up information without having to read all of text. A student might want an information database which, if questions occurred while studying this database, could quickly be queried for answers to the specific question without wandering too far from their place of study.

What might be the best answer to all of these needs is to produce the materials in a Hypertext format. (Hypertext is a format used on computers which allows the user either to move through the material in a linear fashion or move about in the information as ideas interest them. Often terms or concepts are "hot"; that is, the user can select the item and the computer will access the requested information.) The format allows references and related subject matter to be included in the material but only seen if the reader wishes to view the material. At the present time there are only a few formats which allow this method to be used. The other problem is which system (Mac or IBM format) would allow the most widespread usage for teachers and students. I chose the IBM format which runs under the Windows format.

The program is set up to cut a large amount of material down to the basics which when explored can open up into as much depth as the reader wishes to explore. One of the problems I have experienced is, having been brought into the "GIS in the schools" workshop with little advanced information on GIS, I was not really prepared for the information flood that came in our first sessions (even with my background as a Geologist). It was only after the first day, that the general ideas began to form concerning the concepts to which we were being introduced. When we were asked to think about a project, I wondered how much more I would have gained from the workshop if I had arrived with at least a very basic background in the subject? One way that I may have been better prepared would have been to have worked through a Hypertext program on GIS before the workshop.

I have made several attempts at trying to produce such a Hypertext program. When attempting to create the information "web", I found that I often wanted more information. Being a teacher, one is always trying to learn more about the subject matter. So instead of throwing something together and letting it go, I will continue to work carefully on this project so that maybe in the future, teachers new to the subject matter of GIS will have this information for their use. The program will include overviews of GIS applications that have been created so that a teacher can introduce students to real examples or GIS in use. A glossary will also be included for reference and
clarification. Problems may exist for teachers who do not have access to the "GIS in the schools" workshops or the upcoming introductory software programs and materials. This would result in a lack of classroom activities which could and should be the heart of any good program. (Other challenges include, the lack of a computer or computers for students or the teacher to use and the widely varying backgrounds of teachers.) GIS has so many applications that no program no matter how big could ever cover all the possibilities or suggested methods of using a GIS.

At this time I am still collecting additional information to include in the program. The UC system libraries will be used as well as information from the members of NCGIA staff at UCSB. The next development will include having the teachers of the first seminar use the program and give feedback as to how the program could be improved.

For the teachers who wish to build a Hypertext program for their students, I would suggest first that you acquire or borrow a few good texts on the subject of Hypertext. In addition to the GIS textual information, contact your university for sources for visuals (e.g., satellite images, air photos, etc.) which could be used in your introduction to GIS.

[A project like this could be as involved as the teacher would like to make it. In this case, this teacher is trying to create a broad GIS resource which will require many hours of input. For those versed in a Hypertext program (e.g., HyperCard on the Macintosh), a very simple, lesson-oriented Hypertext application could be created. It would allow students to look at a part of GIS and the associated images. Below is an example of one of the hypertext screens created by this teacher.]
G.I.S.

*Geographic Information Systems*

Information contained in this hypertexted system
now follows rather than summary form, will be in
previous text.

Definitions of GIS
Who is a Geographic Information System
Who uses a Geographic Information System
The advantages of geographic systems
Uses of geographic systems
Uses of Geographic Information Systems built
Examples of a geographic based GIS project
Resources
Project #8

This teacher has developed an exercise based on the classic example of a pre-computer GIS analysis, Snow's Cholera Study. He has students plot information on a map of a hypothetical company town. Students overlay information and attempt to determine the cause of a epidemic of a flu-like disease. The integration of the maps with geographical dependent information in this project is one way to begin to introduce students to geographic analysis and, eventually, to GIS software. This teacher would like to move this pencil-and-paper exercise to a computer. Initially to a HyperCard stack and perhaps in time to a simple GIS package.

River's Side Project

Title: River's Side Project: The Spread of an Epidemic

River's Side Project is a problem-solving simulation loosely based on the study by Dr. John Snow of a cholera epidemic in London, England in 1854. Dr. Snow's study demonstrated the value of mapping techniques and their analysis in the solution of problems. The goal is to isolate the primary reason for the spread of the illness.

This activity extends the use of mapping to include extensive reference to information data bases and stresses the scientific method of problem definition, development of a hypothesis, prediction, data analysis, conclusion, and reevaluation of hypothesis. The use of extraneous information in the simulation encourages students to expand their perception of possible sources for spread of the illness, to evaluate trends, research possible avenues of solution and to reject unrewarding courses of investigation.

Follow-on issues:

Social issues, child labor, company towns, health and hygiene, and the development of medical research

Time & Resource Requirements:

Time requirement: Three to five days. Thirty to forty-five minutes each day.

Resources: Program materials - handouts, teacher overheads and informational files.
Other materials - writing instruments, overhead sheets, overhead pens and journals.
Compatible computer(s) if the computer version of this program is used.

Overall Objectives: Develop an appreciation of cooperative/group learning.
Understand how maps and other geographic based information (demographic, etc.) can be used to solve problems related to spatial location.

Specific Objectives: Understand how to use information data bases for research.
Understand how epidemics can spread.
Understand the value of computers in problem solving.
Reinforce the value of the scientific method.
Expand their understanding of company towns.

Teaching Design:
A cooperative activity (interactive learning) for several groups of three to four students.

*Teaching level:* Grades 6 - 12.

*Connection with the school curriculum:* Science, geography, environmental studies and problem-solving methodology.
At present this activity is an off-line activity, but was initially designed to run on a micro-computer, i.e., personal computer, using a graphic data base system similar to HyperCard. The activity makes extensive use of informational data files.

The activity is constructed as nine teaching cycles -- seven cycles of investigation, each representing a simulated 24 hour period in the town; and introduction and closure activities. It takes about 4 days to complete the activity. The typical pattern of instruction is to do two cycles a day, each cycle taking about 20 minutes.

The first and last days include introductory material and closure cycles respectively. At the beginning of each investigation cycle students are given information regarding new cases of illness. This includes patient location, gender, age, environmental conditions, and medical recommendations to patients. At this point in the cycle, students are encouraged to map this information, make hypotheses and then seek answers from the teacher and/or research the information files. Each group is asked to keep a journal of their activities and hypothesis. At the end of each cycle students are to submit to the teacher their status. The status report includes the assumed source of illness spread and the reason for this assumption. The teacher's role throughout this time is to encourage student use of information files, to suggest different possibilities and avenues of investigation, and to direct students into doing research in the information files.

The value of this simulation is not only in the solution of the problem using maps and geographical information files, but in the breadth of discussion regarding the attitudes, beliefs, and conditions of a hundred years ago.

**Detailed Summary of Project:**

**First day of the simulation:** Preparatory instruction begins with the grouping of students into small groups and the distribution of a handout on epidemics and how illness is transmitted. (refer to Handout 1: Handout Questions)

Students are asked to brainstorm in their groups about epidemics and to answer the questions in the handout. After five to ten minutes, class discussion is initiated to develop a common base of "known" information or knowledge. This phase is noted as the first stage of scientific study, getting the background to be able to make an educated guess about a possible solution or cause.

The following steps are given as the scientific method of investigation:

1. Accumulation of Prior Knowledge
2. Collecting Facts and Defining the Problem
3. Making a prediction (hypothesis) of Cause or Solution
4. Testing the prediction (hypothesis)
5. Evaluating the results (test)
6. Arriving at a conclusion an/or Making a more refined hypothesis and repeating steps 2-6 if necessary

Following this the class is introduced to the outbreak of illness in the factory community of River's Side. Comparison is made between the current medical thinking and the medical thinking in the late 19th century. Emphasis is given to the limited medical knowledge and tools available a hundred years ago. (refer to Handout 2: Background Information)

The students are then given some specifics about the community of River's Side, the factory for which the community works and for the differences between current labor laws and those of late 19th century. The groups are given a map of the community. (refer to community map) An overhead is used to point out the major aspects of the community. Over the course of the activity they will fill in house addresses, indicate the location of services, plot the spread of the illness in the community and indicate environmental effects, on the community map and map overlays. The
students are also made aware of a variety of information files available to them in their attempt to
determine the manner in which the illness is being spread.
The first cycle (Day 1) of the exercise then begins with a listing of the first group of illness. (refer to Handout 3: Day One)

Students are instructed to access information files to mark these locations on the community map. Next they are encouraged to investigate the information files for ideas about the illness and environmental conditions that could be involved in the spread of the illness.

An overhead of the community map with house numbers and an overhead listing the various information files is used to show the types of information available in the information files. (refer to Handout 4, Information Files and to illustration: Community Map)

The students are encouraged to mark the locations of illness on the maps and to access the information files to get additional information they think they may need. Following this students are given a status sheet to indicated what the group feels is the probable agent and on what reason(s) they have reached this position. The students are reminded that their assumption will probably change as they received more data in the "days" to come. (refer to Handout 5, Group Status Report)

**The second day of the simulation:** This day is used to introduce the second and third cycles (days 2 and 3) of this simulation. Additional illness outbreaks are given and information from the information files is highlighted to encourage further research. (refer to Handout 6: Day Two)

Overlays for the maps are encouraged to help plot the variety of information. Company newsletter and water department reports are highlighted at this time. At the end of 15 to 20 minutes groups are requested to submit their status reports for day 2 of the simulation and they are then given day 3 and the investigative process is repeated.

The pattern for the rest of the simulation is the same as the previous day. It is not necessary to use consecutive days for this simulation. The simulation was developed so that by the end of the seven days of the simulation, the reason or agent for the spread of the illness is very apparent.

The final cycle of this simulation is devoted to a overall review of the simulation, discussion on how early and why some groups arrived at the correct reason, and situations or information that lead to incorrect solutions. Students are encouraged to pursue other medical studies and to apply this technique to other problems. Students are asked to provide problems that this technique lends itself well.

**Other resources:**


Examples/Sample Pages

**Handout 1:** Handout Questions

What illness or epidemic can you think of that have effect a large number of persons?
List the conditions that could lead to wide-spread illness or epidemic.
List the things that can cause illness.
List the ways an illness can be spread.
How would you investigate an epidemic?

**Handout 2:** Background Information

River's Side: A Neighborhood Epidemic

Investigation Team: __________________________   Period _____   Date: __________

Task: You are on an public health team that is investigating a large number of reported cases of a flu-like illness in a specific community. The industries that the people work for have hired your team to get the people back to work.

Setting: A working-class community in Eastern United States in the mid-1800's

Environment: Homes are located close to employment. Thus the community is a mixture of crowded apartments and industries. Industrial contamination is a common problem. Work hours are long. Not all houses have running water.

Current medical thought: Chills, bad food, poor health, hunger, superstitions and air borne mists are believed by the populace and by science to be the most common source of illness.

Tools available: Observation, information files and your own intelligence are the only investigative tools you have.

Records: A few records are to be found in the Town Hall or the company's records office.

Daily reports regarding reported illness will be issued.

**Handout 3:** Day One

Day One:

Six cases of flu-like illness reported. Most elderly.
Temperatures have been in the low forties.
Windy. Foul air from the river.

Addresses:  14,  25,  27,  17,  42

Medical recommendations: Restrict activities, drink plenty of water, rest.

**Handout 4:** List of Information Files

Medical Report
Daily Reports (teacher use)
City Water Distribution Report
Wind Direction and Speed
Sewage

Operation
<table>
<thead>
<tr>
<th>Disposal</th>
<th>River's Side Address Plan</th>
<th>Human Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warehouse Contents</td>
<td>Public Well Operation</td>
<td></td>
</tr>
<tr>
<td>Health Quality Report</td>
<td>River Department</td>
<td></td>
</tr>
<tr>
<td>Report</td>
<td>Water Plant Operation 1</td>
<td>Trash/Rubbish Report</td>
</tr>
<tr>
<td></td>
<td>Water Plant Operation 2</td>
<td>The River's Mill Local</td>
</tr>
<tr>
<td>Newsletter</td>
<td>Biological Contamination</td>
<td>Milk Service</td>
</tr>
<tr>
<td>Rents</td>
<td>The River's Side Community</td>
<td>Rules for</td>
</tr>
<tr>
<td>Office</td>
<td>The Company Yardage Mill</td>
<td>Mill Health</td>
</tr>
</tbody>
</table>
Handout 5: Group Status Report

River's Side: A Neighborhood Epidemic

Investigation Team: Period _______ Date: _______ Day ______

Probable source for spread of illness:

Prediction based on:

Handout 6: Day Two

Day Two:

Nine new cases of illness reported. Some elderly, some very young.
Temperatures have been in the forties.
Windy. Foul air still present.

Addresses: 15, 24, 29, 36, 41, 31, 34, 44, 43

Medical recommendations: Same as day one and to stay at home.

Community Map
Information Files:
[The format of these files has been changed to save space. For a HyperCard version of this exercise, each of these files could be a card in the HyperCard stack.]

River's Side Warehouse Report
Warehouse Contents

Left side rented by stock yard, contains feed for cattle. Has had problems with mice and occasional rats. Is using traps and cats to keep this problem down.

Left middle side rented by Water Plant 1. Used to store charcoal and gravel supplies. Renter has complained of gravel being used by cats. Some theft of charcoal also indicated.

Right middle side and right side rented by yardage mill across the river. Cotton (raw) bales and finished yardage are kept in this area. This section has a night security guard.

Health Quality Report

Subject Water Samples:

Well 1 - high salt level.

Well 2, cloudy (air bubbles), low salt level, occasional slight sulfur odor.

Water Plant Operation 1

This water provider uses a filtration process which relies on charcoal and gravel filtration.

Coal used to power pump and heat water to 115 degrees.

Average time in storage tank 36 hours.

Pipe line approximately 3 years old. Construction: cast iron and lead seals. No known breaks.

Water tested for odor and sedimentation.

Water Plant Operation 2

This water provider uses a filtration process which relies on charcoal and gravel filtration.

Source of water is a deep well which goes below a thick layer of clay.

Coal used to power well pump and distribution pump.

Average time in storage tank is 48 hours.

Pipe line approximately 12 years old. Occasional breaks and slight leakage. Construction is cast iron with lead or pitch seals.

Water tested for odor and sedimentation.

Biological Contamination

Stockyard. Approximately 1000 cattle and 200 sheep kept for slaughter.
Occasional outbreaks of cowpox. The diseased animals are quickly disposed. Contamination extends 12 inches into the ground.

Odors are quite strong at times.

Animals are herded once a week over the main road and across the bridge to the slaughter houses. This usually occurs in the early morning.
The River's Side Community

River's Side is a company developed housing complex. At least two persons in each apartment work at the company's mills. Men are employed in heavy lifting occupations and machine repair. Women and children usually tend the cloth machines. A few women work in the cafeteria. At least one half of the workers eat in the company cafeteria.

The housing complex is administered by Karl Marx, nephew of the owner Jonathan Tread Bear. Mr. Marx, runs the supply section of the Mill and oversees the operation of the housing complex. His housing residence and office is #41.

The Company Yardage Mill

The yardage mill is located across the river from River's Side. Over three fourths of the employees come from the River's Side apartment complex. About 150 of the company's 200 employees.

Health services available on Wednesdays afternoons. Illness policy does not provide pay for days not worked.

Company provides a company store and slightly reduced priced and credit.

A small school is provided at the company.

City Water Distribution Report

Water on the east side of the river is provided by private water companies at plants 1 and 2. They use different sources for their water.

Plant 1 is about 3 years old. Plant 2 is about 12 years old. Piping is cast iron for both systems. Plant 1 uses lead seals. Plant 2 uses lead and pitch seals. Most recent seals are lead.

Some homes are without water plumbing and rely on wells provided by the water companies.

See charts for details of water lines and hookups.
The following suggestions are based on the prototype GIS workshop for secondary school teachers and the evaluations of that workshop. Of course, each site that puts on a similar workshop for teachers will be unique and will probably only incorporate parts of the workshop model described in the packet. Nevertheless, the following comments can serve as resource to the workshop planner.

**The Workshop Model**

GIS workshops for teachers can incorporate the following activities:

- a short course in GIS focussing mainly on basic concepts and applications of GIS,
- demonstrations of working GIS applications and research activities using GIS,
- hands-on work with GIS software,
- a focused GIS exercise during the week that will provide a sense of the GIS analysis process,
- and ample time to discuss the appropriate role for GIS concepts and activities in the secondary school classroom.

The model workshop is five full-time days. Each day combines a mix of the activities listed above. [Refer to the calendar on page 51] Each day begins with a short briefing session that prepares the teachers for the activities of the day. During the briefing session teachers are given an opportunity to comment on the previous days activities.

The last activity of the day is to give out a daily evaluation form. This form provides space for teachers to write a few sentences or a short paragraph on each of the day's activities. They can fill the form out in this debriefing time or take it home with them. We encourage them to fill out the daily evaluations on that same day. When they fill out a more extensive final evaluation at the end of the week, they will be able to refer back to the daily evaluations. Another function of the daily evaluations is to stimulate discussion in the next morning's briefing session.

The GIS exercise for the workshop should give the teachers a feel for the creation and use of a GIS application. Teachers should get a chance to input some data (digitize, scan, keyboard entry) and then manipulate that data to solve some sort of problem. Obviously, there will not be time to do a whole quarter/semester of GIS lab exercises, but the level of depth for this exercise might not be the same as that in a GIS course. The teachers will not need to explore some of the less common GIS operations. The exercise might have them do a straightforward analysis using just a few operations (reclassify, buffer, add/overlay).

Hold a follow-up meeting during the school year. This is an excellent way to keep the teachers thinking about GIS. It also will enhance the sense of partnership between the teachers and the university (or college or institution) personnel. An "open door" policy at the university will also strengthen this connection. The input from the teachers mid-year will remind the GIS experts and materials developers of the challenges faced in the secondary school environment.
Suggestions

1. Have teacher take home a copy of Geo Info Systems or GIS World magazine every evening in order to get more exposure to GIS applications and the rest of the GIS universe.

2. Consider arranging for the workshop (or parts of the workshop) to count for college credit. If your university has an community education or extension program, they might be able to provide credit for the course. Teachers are often looking for tangible professional growth activities both for personal enrichment, but also for credential renewal and course credit-based salary increases.

3. In addition to a final written evaluation (which can be submitted after the workshop ends), consider devoting some time in the concluding session to verbal comments and evaluation.

4. If possible, let the teachers serve in the role of consultants. Utilize their expertise in the classroom as input for any GIS activities or materials that you might develop jointly with the teachers. If you will be developing materials outside of the workshop, the advise of the teachers may be a key element in producing truly useful instructional materials.

5. Also if possible, offer the teachers a small stipend for their efforts, especially if they are actively involved in material creation or review.

6. Tour campus facilities related to GIS (e.g., campus map library, computer labs, etc.)

7. Try to keep the teacher/computer ratio at a level of 2:1. Although a 1:1 ratio is optimum in most cases, some of the teachers may prefer to work in groups of two for the collegial support.

8. Try to keep the staff/teacher ratio during hands-on computer use as low as 3:1.

9. You may consider eating lunch as a group in order to increase the comfort level in the group.

10. Be prepared for teacher burn out near the end of the day. If the final activities of the day are designed as optional or able to be shortened, adjustments can be made to end early on particularly "heavy" days.

11. Expect that the teachers, even those that are "computer literate", will need help with even "simple" computer tasks, especially since they may not have used the particular operating system on the institutions computers and may typically only use their home or school computers for a very limited set of tasks.

12. Spend some time exposing the teachers to other geographic and scientific materials and software that may serve as a pre-GIS resources for their classrooms. (e.g., PC globe, maps, HyperCard, satellite images, etc.)

13. During demonstrations of GIS software and applications, attempt to limit the number of teachers gathered around one computer monitor (5 is usually the maximum that can get close enough to interact with the demonstrator and see the screen clearly). By splitting the workshop teachers into smaller groups and cycling them through the demonstration, they will have a much more positive perspective on what they are seeing.

14. If possible, expose teachers to software on both Macintosh and IBM/compatible machines, since there probably will be significant differences in what is available to them at their school.

15. If there are GIS users in the community, invite them to address the teachers or give a demo.
Model Workshop Schedule

This is one example of how the different activities of the week workshop might be arranged.
# Workshop Schedule

<table>
<thead>
<tr>
<th>Time</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
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<tbody>
<tr>
<td>8:00</td>
<td>Briefing</td>
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<td>Introductions</td>
<td>Class</td>
<td>Class</td>
<td>Class</td>
<td>Demos</td>
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<td>8:30</td>
<td>WS Overview</td>
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<td>9:00</td>
<td><strong>Class</strong></td>
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<tr>
<td>9:30</td>
<td>Session 1: Introduction to GIS</td>
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<td>10:00</td>
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<tr>
<td>10:30</td>
<td>Break</td>
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<td>11:00</td>
<td>Demos</td>
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<td>IDRISI</td>
<td>Class</td>
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<td>2:00</td>
<td>GISTutor</td>
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<td>MAPII</td>
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<td>3:00</td>
<td>Group Project</td>
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<td>4:00</td>
<td>Materials Lab</td>
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<tr>
<td>4:30</td>
<td>Written Materials (Workshop Resource Packet)</td>
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<td>Magazine</td>
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</table>
INTRODUCTION

A fundamental component of the "GIS in the Schools" workshop is the short course in GIS. The material covered in the course provides the teachers with a base level of knowledge that will allow them to maximize their learning and inform their discussion in the other workshop activities. This knowledge will also allow them to utilize GIS software and concepts with confidence in their teaching.

These course notes include a suggested format based on the prototype workshop and on teacher evaluations. Since those who teach the short course are for the most part experience GIS users and educators, these materials will most likely be modified greatly by the different instructors. These notes serve as one possible outline that has worked with teachers.

The model course includes five two-hour instructional sessions. These sessions can be spread over a five-day workshop or could be doubled up if their are constraints from a shorter time line or conflicting workshop activities.

Most of the prototype workshop short course material was drawn from the NCGIA Core Curriculum in GIS. The Core Curriculum units that were used are included in this section of this resource packet. The Core Curriculum units have been edited to eliminate extra material. The remaining material is still probably more than can be covered in the ten-hour course, especially with the addition of materials of greater interest to the individual course instructor. Each unit is followed by the masters for overhead transparencies mentioned in the text. The Core Curriculum units are in outline form providing one possible presentation order for this material. Some of the sub-headings have been eliminated from this short course version.

THE COURSE OUTLINE

Session 1 - Introduction to GIS

1. Core Curriculum (CC) Unit 1 - What is a GIS?
2. GIS slides, videos, and other visuals
3. Overview of the uses of GIS
4. Discuss the ways GIS might impact the secondary school classroom (see Workshop Review)

One of the criticisms of the first day of the prototype workshop was the lack of connection of GIS to the needs of teachers. Teachers wanted a broad overview of GIS and a justification of "Why it is important to them and their students".

Session 2 - A Foundation for GIS: Maps and Computers

1. CC Unit 2 - Maps and Map Analysis
2. CC Unit 3 - Introduction to Computers

Although these topics may seem to be too basic, they were of great interest to most of the teachers. Their knowledge on both of these topics will probably vary greatly from teacher to teacher, with the average level being quite low.
Session 3 - Raster GIS, Data Sources, Data Entry Methods

1. CC Unit 4 - The Raster GIS
2. CC Unit 5 - Raster GIS Capabilities

Discuss various sources of GIS data (field sampling, remote sensing, reference and thematic maps, digital maps, databases, etc.) [these topics correspond to CC Unit 6 page 7, not included with these notes]

Discuss data entry methods (keyboard entry, digitizing, scanning, conversion of existing digital data, voice input?) and the challenges of developing a digital database [CC Unit 7, not included]

The level of depth that the teachers will be able to handle will vary depending on the group. Be sure to communicate with them to check that they are understanding. Probably not all of this material can be covered in the two-hours. Some might have to be deleted. Some topics could be moved into the next session.

Session 4 - Vector GIS

1. CC Unit 13 - The Vector GIS or Object GIS
2. CC Unit 14 - Vector GIS Capabilities

In addition to covering vector GIS and finishing up any remaining information from session 3, any other "technical" issues that seem appropriate could be covered: more information on data (e.g., TIGER and census data, remote sensing, cadastral records), dangers of error introduction and propagation, 3-D data models (e.g., DEM and TIN), raster/vector comparison, GIS output options, etc.

Session 5 - GIS Applications, History, Trends, and Use in the Schools

1. More GIS applications: Resource management, urban planning and management, cadastral records and LIS, facilities management, demographic and networking applications, etc.
2. CC Unit 23 - History of GIS
3. CC Unit 25 - Trends in GIS
4. GIS in the schools (see Existing GIS Activities following the Unit 25 notes)

In the first session, the teachers are introduced to the range of GIS applications. Now that they have had almost a week of interaction with GIS concepts and software, they should be able to handle more detailed discussion of various GIS applications. Some of the application areas are listed above. [For instructors with access to the full Core Curriculum, there is discussion of these types of applications in Units 51-56.]

By the end of the week the teachers are more able to appreciate a quick overview of GIS history. Although this topic is optional, it provides an interesting example of the evolution and implementation of a modern computer-based technology. The discussion of trends in GIS can be augmented with more current "prophesies". A final topic, which may have been introduced at a more general level on the first day, is that of other teachers who have been exposed to GIS and have attempted some activities in the schools. This is covered in the Existing GIS Activities unit. If more current information of the use of GIS in the schools is desired, the Secondary Education Project Manager can be reached at NCGIA, Santa Barbara.
UNIT 1 - WHAT IS GIS?
Compiled with assistance from David Cowen, University of South Carolina

A. INTRODUCTION

Objectives of this unit
- to examine various definitions of GIS - what factors uniquely differentiate it from other forms of automatic geographical data handling?
- to determine origins of the field - how does GIS relate to other fields such as statistical analysis, remote sensing, computer cartography?
- to give a brief overview of the relevant application areas

What is a GIS?
- a particular form of Information System applied to geographical data
- a System is a group of connected entities and activities which interact for a common purpose
  - a car is a system in which all the components operate together to provide transportation
- an Information System is a set of processes, executed on raw data, to produce information which will be useful in decision-making
  - a chain of steps leads from observation and collection of data through analysis
  - an information system must have a full range of functions to achieve its purpose, including observation, measurement, description, explanation, forecasting, decision-making
- a Geographic Information System uses geographically referenced data as well as non-spatial data and includes operations which support spatial analysis
  - in GIS, the common purpose is decision-making, for managing use of land, resources, transportation, retailing, oceans or any spatially distributed entities
  - the connection between the elements of the system is geography, e.g. location, proximity, spatial distribution
- in this context GIS can be seen as a system of hardware, software and procedures designed to support the capture, management, manipulation, analysis, modeling and display of spatially-referenced data for solving complex planning and management problems
  - although many other computer programs can use spatial data (e.g. AutoCAD and statistics packages), GISs include the additional ability to perform spatial operations

Why is GIS important?
- "GIS technology is to geographical analysis what the microscope, the telescope, and computers have been to other sciences.... (It) could therefore be the catalyst needed to dissolve the regional-systematic and human-physical dichotomies that have long plagued geography" and other disciplines which use spatial information.
- GIS integrates spatial and other kinds of information within a single system - it offers a consistent framework for analyzing geographical data
- by putting maps and other kinds of spatial information into digital form, GIS allows us to manipulate and display geographical knowledge in new and exciting ways
- GIS makes connections between activities based on geographic proximity
  - looking at data geographically can often suggest new insights, explanations
  - these connections are often unrecognized without GIS, but can be vital to understanding and managing activities and resources
    - e.g. we can link toxic waste records with school locations through geographic proximity
- GIS allows access to administrative records - property ownership, tax files, utility cables and pipes - via their geographical positions
Why is GIS so hot?
- high level of interest in new developments in computing
- GIS gives a "high tech" feel to geographic information
- maps are fascinating and so are maps in computers
- there is increasing interest in geography and geographic education
- GIS is an important tool in understanding and managing the environment

Market value of GIS
- *Fortune Magazine*, April 24, 1989 published a major, general-interest article on the significance of GIS to business:
  - GIS is described as a geographical equivalent of a spreadsheet, i.e. allows answers to "what if" questions with spatial dimensions
  - an example of the value of GIS given in the article is the Potlatch Corporation, Idaho
    - controls 600,000 ac of timberland in Idaho - 4,900 separate timber stands
    - old method of inventory using hand-drawn maps meant that inventory was "hopelessly out of date"
    - $180,000/year now being spent on GIS-based inventory "a bargain"
    - GIS "gives Potlatch up-to-the-minute information on the status of timber.... A forest manager sitting at a terminal can check land ownership changes in a few minutes by zooming in on a map"
    - $650,000 on hardware and software produces more than 27% annual return on investment
- GIS market
  - Dataquest projected a market of $288 million in 1988, $590 million in 1992 for GIS, growing at 35% per year
  - ESRI of Redlands, CA, developers of ARC/INFO, had 350 employees and sales of $40 million in 1988 and a reported 42% increase in sales in 1989
  - Intergraph had 1988 sales of $800 million in a more diverse but GIS-dominated market
  - the 1989 edition of *GIS Sourcebook* listed over 60 different "GIS" programs (though not all of these have complete GIS functionality) and over 100 GIS consultants (US)

B. CONTRIBUTING DISCIPLINES AND TECHNOLOGIES
- GIS is a convergence of technological fields and traditional disciplines
- GIS has been called an "enabling technology" because of the potential it offers for the wide variety of disciplines which must deal with spatial data
  - each related field provides some of the techniques which make up GIS
    - many of these related fields emphasize data collection - GIS brings them together by emphasizing integration, modeling and analysis
  - as the integrating field, GIS often claims to be the science of spatial information

Geography
- broadly concerned with understanding the world and man's place in it
- long tradition in spatial analysis
- provides techniques for conducting spatial analysis and a spatial perspective on research

Cartography
- concerned with the display of spatial information
- currently the main source of input data for GIS is maps
- provides long tradition in the design of maps which is an important form of output from GIS
- computer cartography (also called "digital cartography", "automated cartography") provides methods for digital representation and manipulation of cartographic features and methods of visualization
Remote Sensing
- images from space and the air are major source of geographical data
- remote sensing includes techniques for data acquisition and processing anywhere on the globe at low cost, consistent update potential
- many image analysis systems contain sophisticated analytical functions
- interpreted data from a remote sensing system can be merged with other data layers in a GIS

Photogrammetry
- using aerial photographs and techniques for making accurate measurements from them, photogrammetry is the source of most data on topography (ground surface elevations) used for input to GIS

Surveying
- provides high quality data on positions of land boundaries, buildings, etc.

Geodesy
- source of high accuracy positional control for GIS

Statistics
- many models built using GIS are statistical in nature, many statistical techniques used for analysis
- statistics is important in understanding issues of error and uncertainty in GIS data

Operations Research
- many applications of GIS require use of optimizing techniques for decision-making

Computer Science
- computer-aided design (CAD) provides software, techniques for data input, display and visualization, representation, particularly in 3 dimensions
- advances in computer graphics provide hardware, software for handling and displaying graphic objects, techniques of visualization
- database management systems (DBMS) contribute methods for representing data in digital form, procedures for system design and handling large volumes of data, particularly access and update
- artificial intelligence (AI) uses the computer to make choices based on available data in a way that is seen to emulate human intelligence and decision-making - computer can act as an "expert" in such functions as designing maps, generalizing map features
- although GIS has yet to take full advantage of AI, AI already provides methods and techniques for system design

Mathematics
- several branches of mathematics, especially geometry and graph theory, are used in GIS system design and analysis of spatial data

Civil Engineering
- GIS has many applications in transportation, urban engineering

C. MAJOR AREAS OF PRACTICAL APPLICATIONS

overhead - Major areas of practical application

Street network-based
- address matching - finding locations given street addresses
- vehicle routing and scheduling
- location analysis, site selection
- development of evacuation plans

Natural resource-based
- management of wild and scenic rivers, recreation resources, floodplains, wetlands, agricultural lands, aquifers, forests, wildlife
- Environmental impact analysis (EIA)
- viewsshed analysis
- hazardous or toxic facility siting
- groundwater modeling and contamination tracking
- wildlife habitat analysis, migration routes planning

Land parcel-based
- zoning, subdivision plan review
- land acquisition
- environmental impact statements
- water quality management
- maintenance of ownership

Facilities management
- locating underground pipes, cables
- balancing loads in electrical networks
- planning facility maintenance
- tracking energy use
Street network-based
  address matching
  vehicle routing and scheduling
  location analysis, site selection
  development of evacuation plans

Natural resource-based
  forest management
  wildlife habitat, migration routes management
  wild and scenic rivers preservation
  recreation resources planning
  floodplains management
  wetlands preservation
  agricultural lands management
  groundwater modeling and contamination tracking
  environmental impact analysis (EIA)
  viewshed analysis

Land parcel-based
  zoning, subdivision plan review
  land acquisition
  environmental impact statements
  water quality management
  maintenance of ownership

Facilities management
  locating underground pipes, cables
  balancing loads in electrical networks
  planning facility maintenance
  tracking energy use

Major Areas of Practical Application of GIS Technology
UNIT 2 - MAPS AND MAP ANALYSIS
Compiled with assistance from David Rhind, Birkbeck College, University of London

A. INTRODUCTION
- maps are the main source of data for GIS
- the traditions of cartography are fundamentally important to GIS
- GIS has roots in the analysis of information on maps, and overcomes many of the limitations of manual analysis
- this unit is about cartography and its relationship to GIS - how does GIS differ from cartography, particularly automated cartography, which uses computers to make maps?

B. WHAT IS A MAP?
Definition
- according to the International Cartographic Association, a map is:
  - a representation, normally to scale and on a flat medium, of a selection of material or abstract features on, or in relation to, the surface of the Earth
Maps show more than the Earth's surface
- the term "map" is often used in mathematics to convey the notion of transferring information from one form to another, just as cartographers transfer information from the surface of the Earth to a sheet of paper
- the term "map" is used loosely to refer to any visual display of information, particularly if it is abstract, generalized or schematic
Cartographic abstraction
- production of a map requires:
  - selection of the few features in the real world to include
  - classification of selected features into groups (i.e. bridges, churches, railways)
  - simplification of jagged lines like coastlines
  - exaggeration of features to be included that are too small to show at the scale of the map
  - symbolization to represent the different classes of features chosen
Types of maps
- in practice we normally think of two types of map:
  - topographic map - a reference tool, showing the outlines of selected natural and man-made features of the Earth
    - often acts as a frame for other information
    - "Topography" refers to the shape of the surface, represented by contours and/or shading, but topographic maps also show roads and other prominent features
  - thematic map - a tool to communicate geographical concepts such as the distribution of population densities, climate, movement of goods, land use etc.
Thematic maps in GIS
- several types of thematic map are important in GIS:
  - a choropleth map uses reporting zones such as counties or census tracts to show data such as average incomes, percent female, or rates of mortality
    - the boundaries of the zones are established independently of the data, and may be used to report many different sets of data
  - an area class map shows zones of constant attributes, such as vegetation, soil type, or forest species
    - the boundaries are different for each map as they are determined by the variation of the attribute being mapped, e.g. breaks of soil type may occur independently of breaks of vegetation
  - an isopleth map shows an imaginary surface by means of lines joining points of equal value, "isolines" (e.g. contours on a topographic map)
    - used for phenomena which vary smoothly across the map, such as temperature, pressure, rainfall or population density
Line maps versus photo maps
- an important distinction for GIS is between a line map and a photo map
- a line map shows features by conventional symbols or by boundaries
- a photo map is derived from a photographic image taken from the air
  - features are interpreted by the eye as it views the map
  - certain features may be identified by overprinting labels
  - photomaps are relatively cheap to make but are rarely completely free of distortions

Characteristics of maps
- maps are often stylized, generalized or abstracted, requiring careful interpretation
- usually out of date
- show only a static situation - one slice in time
- often highly elegant/artistic
- easy to use to answer certain types of questions:
  - how do I get there from here?
  - what is at this point?
- difficult or time-consuming to answer other types:
  - what is the area of this lake?
  - what places can I see from this TV tower?
  - what does that thematic map show at the point I'm interested in on this topographic map?

The concept of scale
- the scale of a map is the ratio between distances on the map and corresponding distances in the real world
  - if a map has a scale of 1:50,000, then 1 cm on the map equals 50,000 cm or 0.5 km on the Earth's surface
- the use of the terms "small scale" and "large scale" is often confused, so it is important to be consistent
  - a large scale map shows great detail, small features
    - representative fraction is large, e.g. 1/10,000
  - a small scale map shows only large features
    - representative fraction is small, e.g. 1/250,000
- the scale controls not only how features are shown, but what features are shown
  - a 1:2,500 map will show individual houses and lamp posts while a 1:100,000 will not
- different scales are used in different countries
  - in the US, 1:100,000 is the largest scale at which complete coverage of the continental states exists, but there is limited coverage at 1:62,500 and 1:24,000
  - in the UK, there is complete coverage at much larger scales (1:1,250 to 1:10,000)

Map projections
- the Earth's surface is curved but as it must be shown on a flat sheet, some distortion is inevitable
  - distortion is least for when the map only shows small areas, and greatest when a map attempts to show the entire surface of the Earth
- a projection is a method by which the curved surface of the earth is represented on a flat surface
  - it involves the use of mathematical transformations between the location of places on the earth and their projected locations on the plane
  - numerous projections have been invented, and arguments continue about which is best for which purposes
- projections can be identified by the distortions which they avoid - in general a projection can belong to only one of these classes:
  - equal area projections preserve the area of features by assigning them an area on the map which is proportional to their area on the earth - these are useful for applications which require measuring area, and are popular in GIS
conformal projections preserve the shape of small features, and show directions (bearings) correctly - they are useful for navigation
- **equidistant** projections preserve distances to places from one or two points

C. WHAT ARE MAPS USED FOR?
- traditionally, maps are used as aids to navigation, as reference documents, and as wall decorations
- maps have four roles today:
  - maps provide useful ways of displaying information in a meaningful way
    - in practice, the cost of making and printing a map is high, so its contents are often a compromise between different needs
  - maps are used as means of storing data, maps can be very efficient, high density stores
    - a typical 1:50,000 map might have 1,000 place names on it
      - the distances between all possible pairs of these 1,000 places would run to $(1,000 \times 999 / 2)$ or 499,500 numbers if stored in a table instead of scaled off the map when needed
    - the information printed on the typical 1:50,000 topographic map sheet in the UK requires 25 million bytes of storage when it is converted to digital form, equivalent to one standard computer tape, or 10 full-length novels
      - the information on all British topographic maps would require 150 gigabytes (150x10^9 bytes)
  - a map can show the boundaries of areas (e.g. land use zones, soil or rock types) and identify each area with a label
    - a separate manual with corresponding entries may provide greater detail about each area
  - maps are used in analysis to:
    - make or test hypotheses, such as the identification of cancer clusters
    - examine the relationship between two distributions using simple transparent overlays

D. THE USE OF MAPS FOR INVENTORY AND ANALYSIS
- the following examples demonstrate how maps have been used for sophisticated applications in inventory and analysis, and point out some limitations
  - example, two major land use surveys were carried out in the UK, in the late 1930s by Sir Dudley Stamp and in the 1960s by Professor Alice Coleman
    - the results were published as maps
    - in order to compare changes in land use between 1930s and 1960s, the area of each land use type was measured using a hand planimeter and counting overlaid dots
  - despite interest in measuring the amount of change of land use through time, particularly from agricultural to urban, few results were produced using this method because the traditional techniques are slow and tedious, and because of the difficulty of overlaying or working from very different map sources
  - Ian McHarg pioneered the use of transparent map overlays for planning locations of highways, transmission corridors and other facilities in environmentally sensitive areas (McHarg, 1969)
  - despite the popularity of this technique and numerous applications, this method remains cumbersome and imprecise
E. AUTOMATED AND COMPUTER-ASSISTED CARTOGRAPHY

Changeover to computer mapping
- personalities were critically important in the 1960s and early 1970s - individual interests determined the direction and focus of research and development in computer cartography (see Rhind, 1988)
- impetus for change began in two communities:
  1. scientists wishing to make maps quickly to see the results of modeling, or to display data from large archives already in digital form, e.g. census tables
    - quality was not a major concern
    - SYMAP was the first significant package for this purpose, released by the Harvard Lab in 1967
  2. cartographers seeking to reduce the cost and time of map production and editing
    - hardware costs limited interest in this technology prior to 1980 to the major mapping agencies
    - the costs of computing have dropped dramatically, by an order of magnitude every six years
      - what costs $1 to compute in 1989 would have cost $10 in 1983 and $100,000 in 1959
      - the development of the microcomputer and the launch of the IBM PC in 1983 have had enormous influence
      - an early belief that the entire map-making process could be automated diminished by 1975 because of difficulties of generalization and design
        - has resurfaced in the context of Expert Systems where the computer chooses the proper techniques based on characteristics of the data, scale, map purpose, etc.
- today, far more maps are made by computer than by hand
  - now few mapmakers are trained cartographers
- also, it is now clear that once created, digital data can serve purposes other than map-making, so it has additional value

Advantages of computer cartography
- lower cost for simple maps, faster production
- greater flexibility in output - easy scale or projection change - maps can be tailored to user needs
- other uses for digital data

Disadvantages of computer cartography
- relatively few full-scale systems have been shown to be truly cost-effective in practice, despite early promise
- high capital cost, though this is now much reduced
- computer methods do not ensure production of maps of high quality
  - there is a perceived loss of regard for the "cartographic tradition" with the consequent production of "cartojunk"

GIS and Computer Cartography
- computer cartography has a primary goal of producing maps
  - systems have advanced tools for map layout, placement of labels, large symbol and font libraries, interfaces for expensive, high quality output devices
- however, it is not an analytical tool
  - therefore, unlike data for GIS, cartographic data does not need to be stored in ways which allow, for example, analysis of relationships between different themes such as population density and housing prices or the routing of flows along connecting highway or river segments
F. GIS COMPARED TO MAPS

Data stores
- spatial data stored in digital format in a GIS allows for rapid access for traditional as well as innovative purposes
- nature of maps creates difficulties when used as sources for digital data
  - most GIS take no account of differences between datasets derived from maps at different scales
  - idiosyncrasies (e.g. generalization procedures) in maps become "locked in" to the data derived from them
  - such errors often become apparent only during later processing of digital data derived from them
- however, maps still remain an excellent way of compiling spatial information, e.g. field survey
  - maps can be designed to be easy to convert to digital form, e.g. by the use of different colors which have distinct signatures when scanned by electronic sensors
  - as well maps can be produced by GISs as cheap, high density stores of information for the end user
    - however, consistent, accurate retrieval of data from maps is difficult
    - only limited amounts of data can be shown due to constraints of the paper medium

Data indexes
- this function can be performed much better by a good GIS due to the ability to provide multiple and efficient cross-referencing and searching

Data analysis tools
- GIS is a powerful tool for map analysis
  - traditional impediments to the accurate and rapid measurement of area or to map overlay no longer exist
  - many new techniques in spatial analysis are becoming available

Data display tools
- electronic display offers significant advantages over the paper map
  - ability to browse across an area without interruption by map sheet boundaries
  - ability to zoom and change scale freely
  - potential for the animation of time dependent data
  - display in "3 dimensions" (perspective views), with "real-time" rotation of viewing angle
  - potential for continuous scales of intensity and the use of color and shading independent of the constraints of the printing process, ability to change colors as required for interpretation
- one of a kind, special purpose products are possible and inexpensive
A. INTRODUCTION
- the environment in which a GIS operates is defined by:
  - hardware - the machinery, including:
    - a host computer
    - ranging from a stand-alone microcomputer to a large mainframe supporting many users
    - several devices for handling input and output
  - software
    - the programs that tell the computer what to do
    - the data the programs will use
- this unit provides a brief overview of computer hardware and software so that students will have a basic understanding of how computers operate and will recognize some of the common computer terminology
  - important topics are covered in greater detail in later units

B. COMPUTER DATA
- computer data is coded, manipulated and stored by use of an exclusive two-state condition
  - in English such two-state forms of information can include yes/no, on/off, open/closed, hole/no hole
  - in simple electronic terms this two-state condition can be translated for the computer into "switch open/switch closed", meaning that "there is electricity passing through the circuit/there is no electricity passing through the circuit"
  - note that one of the two exclusive states always exists
- if one switch provides two different datum, how much data can we obtain from two switches?
  - four - there are four combinations of open and closed switches

Binary notation
- in computer terminology, this two state condition is represented in binary notation by the use of 1s and 0s
- thus, two switches produce four codes - 00, 01, 10, 11
- three switches produce eight codes - 000, 001, 010, 011, 100, 101, 110, 111
- in mathematical terms:
  - 1 binary digit provides $2^1 = 2$ alternatives
  - 2 binary digits provide $2^2 = 4$ alternatives
  - 3 binary digits provide $2^3 = 8$ alternatives
  - 8 binary digits provide $2^8 = 256$ alternatives

Bits and bytes
- each binary digit is called a bit
- the complexity of computer circuitry is described in terms of the number of bits that can be transmitted simultaneously
- this is determined by the number of wires that run parallel to one another on the circuit-boards
- current PCs use 8, 16 and 32 bit paths
- a group of 8 bits is called a byte
- bytes are the standard unit of measurement of computer data

ASCII coding system
- to maximize efficiency, most computers store data in their own internal formats
  - however, transfer of data requires the use of standard codes which are understood by all systems
the most successful standard is ASCII (pronounced ass-key)
- ASCII originated well before computer communication as a code for Teletypes
- ASCII assigns the numbers 0 through 127 to 128 characters, including the upper and lower case alphabets, numerals 0 through 9 and various special characters
- 128 different patterns can be generated using 7 bits in different combinations of on and off
  - any ASCII character can therefore be coded with 7 bits
- in practice, 8 bits (one byte) are used, the extra bit may be used to extend the code to 128 extra characters, or it simply may be redundant
- by using binary notation, these codes can be converted into decimal numbers
- counting from the right, the 8 bits are numbered 0 through 7, and signify as follows:
  Bit: 7 6 5 4 3 2 1 0
  128s 64s 32s 16s 8s 4s 2s units
- e.g. the combination 01010101 is
  no 128s, one 64, no 32s, one 16, no 8s, one 4, no 2s and one unit
  i.e. 64+16+4+1 = 85
- in the ASCII code system, code number 85 is an upper case U
  - thus to store a U, the system stores a byte with the bit pattern 01010101
- in ASCII, characters 0 through 32 often perform special functions
  - e.g. character 7, 00000111, is the BEL character and rings a bell if received by many terminals or devices
  - e.g. character 12, 00001100, is the FF character and produces a form feed (new page) if received by many printers
- computer files which contain information coded in ASCII are easily transferred and processed by different computers and programs
  - such files are often called "ASCII" or "text" or "coded" files
  - ASCII characters are the dominant basis for communication between different systems, and communication with peripherals
  - files which are not ASCII are often coded in "binary" and generally can be processed or understood only by specific programs

C. COMPUTER HARDWARE
- computers consist of several different hardware components
  Central processing unit (CPU)
  - the central processing unit is the essential component of a computer because it is the part that executes the programs and controls the operation of all the hardware
    - powerful computers may have several processors handling different tasks, although there will need to be one central processing unit controlling the flow of instructions and data through the subsidiary processors
  - the CPUs of PCs are based on a series of processors or "chips" from Intel
    - "PC" models use the 8088 (8 bit)
    - "AT" models use the 80286 (8/16 bits)
    - current high powered machines use the 80386 (full 16 bits) and 80486
  - the Macintosh CPUs are based on the 68000 series of chips from Motorola
Memory
- memory stores input for and output from the CPU as well as the instructions that are followed by the CPU
- the amount stored is measured in bits, bytes, Kbytes (K, Kb, 10^3 bytes), Megabytes (Mb, 10^6 bytes), Gigabytes (Gb, 10^9), Terabytes (Tb, 10^12)
- there are two kinds of memory:
- **main memory** (or internal or primary memory) is essential for the operation of the computer, all data and instructions must be in main memory first before it can be processed by the computer
  - most costly memory
  - in the form of microchips integrated with the computer's central processor
  - fastest access - any byte can be accessed equally rapidly (random access, hence it is called RAM)
  - temporary - since data and instructions are stored in main memory as electrical voltages, power failures cause the loss of all data in main memory
  - ranges from several hundred Kbytes for typical PC to many Megabytes for mainframes
- **secondary memory** (or auxiliary memory or secondary storage) is used for large, permanent or semi-permanent files
  - GIS programs and data generally require very large amounts of storage
  - data storage is covered after this overview of the components of computers

**Peripherals**
- **peripherals** refer to all the other devices attached to computers that handle input and output
  - input devices include keyboards, mice, trackballs, digitizers, disk drives
  - output devices include screens, printers, plotters
  - those devices important to GIS are examined in later units

**D. DATA STORAGE**

**Storage media**
- computers can use several different media for storing information
  - needed to store both raw data and programs
  - media differ by
    - storage capacity
    - speed of access
    - permanency of storage
    - mode of access
    - cost

**Fixed disks**
- most costly memory next to main/internal memory is fixed disk memory
- ranges from 10 Megabytes for typical PC to hundreds of Gigabytes in large "disk farms"
- random access but slower than internal memory
- permanent (i.e. does not disappear when power is turned off), though data can be erased and modified

**Dismountable devices**
- dismountable devices can be removed for storage or shipping, include:
  - floppy diskettes
  - magnetic tapes
  - optical compact disks (CDs)

**Volumes**
- a volume is a single tape, CD, diskette or fixed disk, i.e. a physical unit of storage

**Files**
- a file is a logical collection of data - a table, document, program, map
- many files can be stored on a single volume
- files are given names
  - the rules for naming files vary among types of systems
- the computer operating system keeps track of files stored in a volume by using a table called a **directory**
  - files are identified in the directory by name, size, date of creation and often type of contents
  - files can be organized in subdirectories so that the user can group files under specific topics

**E. SOFTWARE**

**Programs**
- a program is a sequence of related instructions, performed one step at a time by the CPU to accomplish some task
  - programs determine how computers respond to input, what will be displayed and output
- there are three types of programs: operating systems, language interpreters and compilers and applications programs

Operating systems
- an operating system (OS) is the software which controls the operation of the computer from the moment it is turned on or "booted"
  - the OS controls all input and output to and from the peripherals as well as the operation of other programs
  - allows the user to work with and manage files without knowing specifically how the data is stored and retrieved
- common operating systems include:
  - IBM PCs and clones use MS-DOS (often called DOS), although there is some movement to OS/2
  - UNIX (and similar operating systems such as AIX, XENIX) is the dominant operating system for workstations
  - mainframes commonly use proprietary operating systems developed by their manufacturers - VMS on DEC's VAX series, PRIMOS on Prime, CMS on IBM mainframes, etc.
- although functions performed by operating systems are similar, it can be very difficult to move files or software from one to another
  - many software packages run under only one operating system, or have substantially different versions for different operating systems

Compilers and languages
- most programs are created using standard high level languages such as C, Pascal, FORTRAN, BASIC which are common across most computer systems, from micro to mainframe
  - such programs are referred to as source code
  - these languages generally use English words and familiar mathematical structure
  - a compiler is a program designed to convert a program written in a high level language to the machine instructions of a specific computing system or "platform"

Applications programs
- applications programs are programs used for all purposes other than performing operating system chores or writing other programs
  - includes GIS, word processors, spreadsheets, statistics packages and graphics programs, airline reservation systems, payroll systems

F. EDITORS AND WORD PROCESSORS
- are packages designed to modify or edit the contents of files
- are most often used to edit written text or programs
- well-known word processors for the IBM PC include Wordstar, WordPerfect and Microsoft Word

G. DATABASES
- are packages designed to create, edit, manipulate and analyze data
- to be suitable for a database, the data must consist of records which provide information on individual cases, people, places, features, etc.
- each record may contain several fields each of which contains one item of information
  - the number and interpretation of the fields must be constant for each class of records
  - e.g. each record in the class of "streets" may contain fields for name, length, surface, type.
  - field contents can be of many types - numeric or text, fixed or variable length
- there can be several classes of records in a database
- e.g. an airline reservation database might have the following classes of records and associated items:
  passengers: name, phone, flight numbers
  aircraft: type, registration number, number of seats
  crew: names of pilot, copilot, cabin crew, home city
  flight: number, departure and arrival times, aircraft

Functions of a database
- creating and editing records, using customized screens
- printing reports (summarizes of groups of records), using customized report forms, including subtotals and totals
- selecting records based on user-specified rules
- updating records based on new information
- linking records, e.g. to determine arrival time for a passenger by linking the passenger's record with the correct flight record

H. SPREADSHEETS
- are systems which allow the user to work with numerical data in tabular form
- column and row totals, percentages etc. are automatically updated as data items are changed
- Lotus 1-2-3 is a well-known spreadsheet for the IBM PC

I. STATISTICAL PACKAGES
- offer a range of types of statistical analysis
- data is primarily numerical
A. THE DATA MODEL

- geographical variation in the real world is infinitely complex
- the closer you look, the more detail you see, almost without limit
- it would take an infinitely large database to capture the real world precisely
- data must somehow be reduced to a finite and manageable quantity by a process of generalization or abstraction
- geographical variation must be represented in terms of discrete elements or objects
- the rules used to convert real geographical variation into discrete objects is the data model
- Tsichritzis and Lochovsky (1977) define a data model as "a set of guidelines for the representation of the logical organization of the data in a database... (consisting) of named logical units of data and the relationships between them."
- current GISs differ according the way in which they organize reality through the data model
- each model tends to fit certain types of data and applications better than others
- the data model chosen for a particular project or application is also influenced by:
  - the software available
  - the training of the key individuals
  - historical precedent

- there are two major choices of data model - raster and vector

overhead - Major GIS data models
- raster model divides the entire study area into a regular grid of cells in specific sequence
  - the conventional sequence is row by row from the top left corner
  - each cell contains a single value
  - is space-filling since every location in the study area corresponds to a raster cell
  - one set of cells and associated values is a layer
  - there may be many layers in a database, e.g. soil type, elevation, land use, land cover

- vector model uses discrete line segments or points to identify locations
  - discrete objects (boundaries, streams, cities) are formed by connecting line segments
  - vector objects do not necessarily fill space, not all locations in space need to be referenced in the model

- a raster model tells what occurs everywhere - at each place in the area
- a vector model tells where everything occurs - gives a location to every object
- conceptually, the raster models are the simplest of the available data models
  - therefore, we begin our examination of GIS data and operations with the raster model and will consider vector models after the fundamental concepts have been introduced.

B. CREATING A RASTER

- consider laying a grid over a geologic map
  - create a raster by coding each cell with a value that represents the rock type which appears in the majority of that cells areas
  - when finished, every cell will have a coded value

overhead - Creating a raster
  - this illustrates a more complex example
  - in most cases the values that are to be assigned to each cell in the raster are written into a file, often coded in ASCII
  - this file can be created manually by using a word processor, database or spreadsheet program or it can be created automatically
  - then it is normally imported into the GIS so that the program can reformat the data for its specific processing needs

- there are several methods for creating raster databases

Cell by cell entry
  - direct entry of each layer cell by cell is simplest
- entry may be done within the GIS or into an ASCII file for importing
- the process is normally tedious and time-consuming
- layer can contain millions of cells
- average Landsat image is around $7.4 \times 10^6$ pixels, average TM scene is about $34.9 \times 10^6$ pixels

Digital data
- much raster data is already in digital form, as images, etc.
- however, resampling will likely be needed in order that pixels coincide in each layer
- because remote sensing generates images, it is easier to interface with a raster GIS than any other type
- elevation data is commonly available in digital raster form from agencies such as the US Geological Survey

C. CELL VALUES
Types of values
- the type of values contained in cells in a raster depend upon both the reality being coded and the GIS
- different systems allow different classes of values, including:
  - **overhead** - Raster data values
  - whole numbers (integers)
  - real (decimal) values
  - alphabetic values
  - many systems only allow integers, others which allow different types restrict each separate raster layer to a single kind of value
- if systems allow several types of values, e.g. some layers numeric, some non-numeric, they should warn the user against doing unreasonable operations
  - e.g. it is unreasonable to try to multiply the values in a numeric layer with the values in a non-numeric layer
- integer values often act as code numbers, which "point" to names in an associated table or legend
  - e.g. the first example might have the following legend identifying the name of each soil class:
    0 = "no class"
    1 = "fine sandy loam"
    2 = "coarse sand"
    3 = "gravel"

D. MAP LAYERS
- the data for an area can be visualized as a set of maps of layers
- a map layer is a set of data describing a single characteristic for each location within a bounded geographic area
- only one item of information is available for each location within a single layer - multiple items of information require multiple layers
  - on the other hand, a topographic map can show multiple items of information for each location, within limits
    - e.g. elevation (contours), counties (boundaries), roads, railroads, urbanized areas (grey tint)
    - these would be 5 layers in a raster GIS
- typical raster databases contain up to a hundred layers
  - each layer (matrix, lattice, raster, array) typically contains hundreds or thousands of cells
- important characteristics of a layer are its resolution, orientation and zone(s)
Resolution
- in general, resolution can be defined as the minimum linear dimension of the smallest unit of geographic space for which data are recorded
- in the raster model the smallest units are generally rectangular (occasionally systems have used hexagons or triangles)
- these smallest units are known as **cells**, **pixels**
- note: high resolution refers to rasters with small cell dimensions
  - high resolution means lots of detail, lots of cells, large rasters, small cells
Orientation
- the angle between true north and the direction defined by the columns of the raster
Zones
- each zone of a map layer is a set of **contiguous** locations that exhibit the same value
- these might be:
  - ownership parcels
  - political units such as counties or nations
  - lakes or islands
  - individual patches of the same soil or vegetation type
  
  **overhead** - Example raster database
  - note that not all map layers will have zones, cell contents may vary continuously over the region making every cell’s value unique
  - e.g. satellite sensors record a separate value for reflection from each cell
  - major components of a zone are its value and location(s)
Value
- is the item of information stored in a layer for each pixel or cell
- cells in the same zone have the same value
Location
- generally location is identified by an ordered pair of coordinates (row and column numbers) that unambiguously identify the location of each unit of geographic space in the raster (cell, pixel, grid cell)
- usually the true geographic location of one or more of the corners of the raster is also known

E. **EXAMPLE ANALYSIS USING A RASTER GIS**
Objective
- identify areas suitable for logging
- an area is suitable if it satisfies the following criteria:
  - is Jackpine (Black Spruce are not valuable)
  - is well drained (poorly drained and waterlogged terrain cannot support equipment, logging causes unacceptable environmental damage)
  - is not within 500 m of a lake or watercourse (erosion may cause deterioration of water quality)

Procedure
  
  **overheads** - Example project steps (1 page) and details (3 pages)
  - **recode** layer 2 as follows, creating layer 4
    - y if value 2 (Jackpine)
    - n if other value
  - **recode** layer 3 as follows, creating layer 5
    - y if value 2 (good)
    - n if other value
  - **spread** the lake on layer 1 by one cell (500 m), creating layer 6
  - **recode** the spread lake on layer 6 as follows, creating layer 7
    - n if in spread lake
    - y if not
- **overlay** layers 4 and 5 to obtain layer 8, coding as follows
  - y if both 4 and 5 are y
  - n otherwise
- **overlay** layers 7 and 8 to obtain layer 9, coding as follows
  - y if both 7 and 8 are y
  - n otherwise

Result
- the loggable cells are y on layer 9

Operations used
- recode
- overlay
- spread

- we could have achieved the same result using the operations in other sequences, or by combining recode and overlay operations
  - e.g. overlay layers 2 and 3, coding as follows
    - y if layer 2 is 2 and layer 3 is 2, n otherwise
    - this would replace two recodes and an overlay
  - e.g. some systems allow layers to be overlaid 3 or more at a time
- the names given to operations vary from system to system, but most of the operations themselves are common across systems
Major GIS Data Models
Creating a Raster
0 0 1 1 1 2 3  INTEGER VALUES
0 1 1 1 2 2 3  e.g. soil class
0 0 1 1 1 2 2  or # of farms
0 0 0 1 1 1 2
0 0 0 0 0 0 1

2.1 2.3 2.4 2.7 2.9 3.2 3.4  REAL (DECIMAL) VALUES
1.9 2.1 2.4 2.6 3.0 3.3 3.4  e.g. elevation
1.8 2.0 2.3 2.5 2.8 3.1 3.2
1.8 1.9 1.9 2.3 2.5 2.8 3.0
1.8 1.8 1.8 1.9 2.1 2.3 2.7

a a b b c c a  NON-NUMERIC VALUES
a b b b c c a  e.g. vegetation class
a b b b b c c
da a b b b c c
da a a b c c c

Raster Data Values
Raster description
- resolution is 500 m
- entire array is 2.5 km by 2.5 km
- columns are aligned North-South

LAYER 1: LAKE
1 = lake, 0 = not lake

1 1 0 0 0
1 1 0 0 0
1 0 0 0 0
0 0 0 0 0
0 0 0 0 0

LAYER 2: FOREST SPECIES
1 = Black Spruce, 2 = Jackpine, 0 = no forest

0 0 2 2 2
0 0 2 2 2
0 1 1 1 2
1 1 1 1 1
1 1 1 1 1

LAYER 3: SOIL DRAINAGE
0 = waterlogged, 1 = poor, 2 = good

0 0 2 2 2
0 0 1 1 2
0 0 1 1 2
0 1 1 1 2
1 1 1 2 2

Example Raster Database
Example Project Steps
OBJECTIVE: Identify areas suitable for logging

An area is suitable if it satisfies the following criteria:
- is Jackpine
  - Black Spruce are not valuable
- is well drained
  - poorly drained and waterlogged terrain cannot support equipment, logging causes unacceptable environmental damage
- is not within 500 m of a lake or watercourse
  - erosion hazard

PROCEDURE:
Recode layer 2 - y if value 2 (Jackpine), n if other value

<table>
<thead>
<tr>
<th>LAYER 2: FOREST SPECIES</th>
<th>LAYER 4: LOGGABLE SPECIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0 2 2 2</td>
<td>n n y y y</td>
</tr>
<tr>
<td>0 0 2 2 2</td>
<td>n n y y y</td>
</tr>
<tr>
<td>0 1 1 1 2</td>
<td>n n n y y</td>
</tr>
<tr>
<td>1 1 1 1 1</td>
<td>n n n n n</td>
</tr>
<tr>
<td>1 1 1 1 1</td>
<td>n n n n n</td>
</tr>
</tbody>
</table>

Recode layer 3 - y if value 2 (good), n if other value

<table>
<thead>
<tr>
<th>LAYER 3: SOIL DRAINAGE</th>
<th>LAYER 5: DRAINED SOIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 0 2 2 2</td>
<td>n n y y y</td>
</tr>
<tr>
<td>0 0 1 1 2</td>
<td>n n n n y</td>
</tr>
<tr>
<td>0 0 1 1 2</td>
<td>n n n n y</td>
</tr>
<tr>
<td>0 1 1 1 2</td>
<td>n n n n y</td>
</tr>
<tr>
<td>1 1 1 2 2</td>
<td>n n n y y</td>
</tr>
</tbody>
</table>

Example Project Details
(Page 1 of 3)
Spread the lake on layer 1 by one cell (500 m)

<table>
<thead>
<tr>
<th>LAYER 1: LAKE</th>
<th>LAYER 6: NEAR LAKE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1 0 0 0</td>
<td>1 1 1 0 0</td>
</tr>
<tr>
<td>1 1 0 0 0</td>
<td>1 1 1 0 0</td>
</tr>
<tr>
<td>1 0 0 0 0</td>
<td>1 1 0 0 0</td>
</tr>
<tr>
<td>0 0 0 0 0</td>
<td>1 0 0 0 0</td>
</tr>
<tr>
<td>0 0 0 0 0</td>
<td>0 0 0 0 0</td>
</tr>
</tbody>
</table>

Recode layer 6 - if in spread lake, y if not

<table>
<thead>
<tr>
<th>LAYER 6: NEAR LAKE</th>
<th>LAYER 7: AWAY FROM LAKE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1 1 0 0</td>
<td>n n n y y y</td>
</tr>
<tr>
<td>1 1 1 0 0</td>
<td>n n n y y y</td>
</tr>
<tr>
<td>1 1 0 0 0</td>
<td>n n y y y y</td>
</tr>
<tr>
<td>1 0 0 0 0</td>
<td>n y y y y y</td>
</tr>
<tr>
<td>0 0 0 0 0</td>
<td>y y y y y</td>
</tr>
</tbody>
</table>

Overlay layers 4 and 5 - if both 4 and 5 are y, n otherwise

<table>
<thead>
<tr>
<th>LAYER 4: LOGGABLE SPECIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>n n y y y y</td>
</tr>
<tr>
<td>n n y y y y</td>
</tr>
<tr>
<td>n n n n y y</td>
</tr>
<tr>
<td>n n n n n n</td>
</tr>
<tr>
<td>n n n n n n</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LAYER 5: DRAINED SOIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>n n y y y y</td>
</tr>
<tr>
<td>n n n n y y</td>
</tr>
<tr>
<td>n n n n n y</td>
</tr>
<tr>
<td>n n n n y y</td>
</tr>
<tr>
<td>n n n n y y</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LAYER 8: SPECIES AND SOILS</th>
</tr>
</thead>
<tbody>
<tr>
<td>n n y y y y</td>
</tr>
<tr>
<td>n n n n y y</td>
</tr>
</tbody>
</table>

Example Project Details
(Page 2 of 3)
Overlay layers 7 and 8 - if both 7 and 8 are y, n otherwise

**LAYER 7: AWAY FROM LAKE**

n n n y y  
n n n y y  
n n y y y  
n y y y y  
y y y y y

**LAYER 8: SPECIES & SOILS**

n n y y y  
n n n n y  
n n n n y  
n n n n n  
n n n n n

**LAYER 9: LOGGABLE SITES**

n n n y y  
n n n n y  
n n n n y  
n n n n n

RESULT: The loggable cells are y on layer 9

Example Project Details
(Page 3 of 3)
UNIT 5 - RASTER GIS CAPABILITIES
Compiled with assistance from Micha Pazner, University of Manitoba

A. INTRODUCTION
- a raster GIS must have capabilities for:
  - input of data
  - various housekeeping functions
  - operations on layers, like those encountered in the previous unit - recode, overlay and spread
  - output of data and results
- the range of possible functions is enormous, current raster GISs only scratch the surface
  - because the range is so large, some have tried to organize functions into a consistent scheme, but no scheme has been widely accepted yet
  - the unit covers a selection of the most useful and common
- each raster GIS uses different names for the functions

B. DISPLAYING LAYERS

Basic display
- the simplest type of values to display are integers
  - on a color display each integer value can be assigned a unique color
  - there must be as many colors as integers
- if the values have a natural order we will want the sequence of colors to make sense
  - e.g. elevation is often shown on a map using the sequence blue-green-yellow-brown-white for increasing elevation
- there should be a legend explaining the meaning of each color
  - the system should generate the legend automatically based on the descriptions of each value stored with the data layer

overhead - Simple display (IDRISI) [You may want to use a better visual]
- on a dot matrix printer shades of grey can be generated by varying the density of dots
- if there are too many values for the number of colors, may have to recode the layer before display

Other types of display
- it may be appropriate to display the data as a surface
- contours can be "threaded" through the pixels along lines of constant value
- the surface can be shown in an oblique, perspective view

overhead - Perspective view
- this can be done by drawing profiles across the raster with each profile offset and hidden lines removed
- the surface might be colored using the values in a second layer (a second layer can be "draped" over the surface defined by the first layer)
- the result can be very effective
  - "LA The Movie" was produced by Jet Propulsion Lab by draping a Landsat image of Los Angeles over a layer of elevations, then simulating the view from a moving aircraft

C. LOCAL OPERATIONS
- produce a new layer from one or more input layers
- the value of each new pixel is defined by the values of the same pixel on the input layer(s)
- note: arithmetic operations make no sense unless the values have appropriate scales of measurement
  - you cannot find the "average" of soils types 3 and 5, nor is soil 5 "greater than" soil 3
Recoding
- using only one input layer
- examples:
  1. assign a new value to each unique value on the input layer
     - useful when the number of unique input values is small
  2. assign new values by assigning pixels to classes or ranges based on their old values
     - e.g. 0-499 becomes 1, 500-999 becomes 2, >1000 becomes 3
     - useful when the old layer has different values in each cell, e.g. elevation or satellite images
  3. sort the unique values found on the input layer and replace by the rank of the value
     - e.g. 0, 1, 4, 6 on input layer become 1, 2, 3, 4 respectively
     - applications: assigning ranks to computed scores of capability, suitability etc.
     - some systems allow a full range of mathematical operations
     - e.g. newvalue = (2*oldvalue + 3)^2

Overlaying layers
- an overlay occurs when the output value depends on two or more input layers
- many systems restrict overlay to two input layers only
- examples:
  1. output value equals arithmetic average of input values
  2. output value equals the greatest (or least) of the input values
  3. layers can be combined using arithmetic operations
     - x and y are the input layers, z is the output
     - some examples:
       \[ z = x + y \]
       \[ z = xy \]
       \[ z = x / y \]
  4. combination using logical conditions
     - e.g. if \( y > 0 \), then \( z = y \) , otherwise \( z = x \)
     - note: in many raster packages logical conditions cannot be done directly from input layers
     - must first create reclassified input images so that cells have 0 if they do not meet the condition and 1 if they do

overhead - Logical operations on rasters (2 pages)

5. assign a new value to every unique combination of input values
- e.g. LAYER 1 LAYER 2 OUTPUT LAYER

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>B</td>
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<td>3</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>4</td>
</tr>
</tbody>
</table>

D. OPERATIONS ON LOCAL NEIGHBORHOODS
- the value of a pixel on the new layer is determined by the local neighborhood of the pixel on the old layer

Filtering
- a filter operates by moving a "window" across the entire raster
- e.g. many windows are 3x3 cells
- the new value for the cell at the middle of the window is a weighted average of the values in the window
  - by changing the weights we can produce two major effects:
    - smoothing (a "low pass" filter, removes or reduces local detail)
    - edge enhancement (a "high pass" filter, exaggerates local detail)

Slopes and aspects
- if the values in a layer are elevations, we can compute the steepness of slopes by looking at the difference between a pixel's value and those of its adjacent neighbors
- the direction of steepest slope, or the direction in which the surface is locally "facing", is called its **aspect**
  - aspect can be measured in degrees from North or by compass points - N, NE, E etc.
- slope and aspect are useful in analyzing vegetation patterns, computing energy balances and modeling erosion or runoff
  - aspect determines the direction of runoff
    - this can be used to sketch drainage paths for runoff

E. OPERATIONS ON EXTENDED NEIGHBORHOODS

Distance
- calculate the distance of each cell from a cell or the nearest of several cells
  - each pixel's value in the new layer is its distance from the given cell(s)
Buffer zones
- buffers around objects and features are very useful GIS capabilities
  - e.g. build a logging buffer 500 m wide around all lakes and watercourses
- buffer operations can be visualized as spreading the object spatially by a given distance
- the result could be a layer with values:
  1 if in original selected object
  2 if in buffer
  0 if outside object and buffer
- applications include noise buffers around roads, safety buffers around hazardous facilities

Visible area or "viewshed"
- given a layer of elevations, and one or more viewpoints, compute the area visible from at least one viewpoint
  - e.g. value = 1 if visible, 0 if not
  - useful for planning locations of unsightly facilities such as smokestacks, or surveillance facilities such as fire towers, or transmission facilities

F. OPERATIONS ON ZONES (Groups of Pixels)

Identifying zones
- by comparing adjacent pixels, identify all patches or zones having the same value
Areas of zones
Perimeter of zones
Distance from zone boundary
Shape of zone
- commands like this are important in landscape ecology
  - helpful in studying the effects of geometry and spatial arrangement of habitat
    - e.g. size and shape of woodlots on the animal species they can sustain
    - e.g. value of linear park corridors across urban areas in allowing migration of animal species

H. ESSENTIAL HOUSEKEEPING

- list available layers
- input, copy, rename layers
- import and export layers to and from other systems
  - other raster GIS
  - input of images from remote sensing system
  - other types of GIS
- identify resolution, orientation
- "resample"
  - changing cell size, orientation, portion of raster to analyze
- change colors
- provide help to the user
- exit from the GIS (the most important command of all!)
Simple Display (IDRISI)

Eastern Massachusetts Land Use (USGS CTC Data)
Perspective View

(IDRISI)
What cells are both A and 7?

<table>
<thead>
<tr>
<th>A</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>C</td>
<td>C</td>
<td>B</td>
</tr>
</tbody>
</table>

Reclassify

<table>
<thead>
<tr>
<th>1</th>
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</tr>
</thead>
<tbody>
<tr>
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<td>0</td>
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</table>

Multiply

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<tr>
<th>1x0</th>
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</thead>
<tbody>
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</tr>
<tr>
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</table>

Reclassify

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>1</th>
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</thead>
<tbody>
<tr>
<td>0</td>
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<td>1</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Logical Operations on Raster: LOGICAL AND
Logical Operations on Raster: LOGICAL OR
UNIT 13 - THE VECTOR OR OBJECT GIS
Compiled with assistance from Holly Dickinson, State University of New York at Buffalo

A. INTRODUCTION
Vector data model
- based on vectors (as opposed to space-occupancy raster structures)
- fundamental primitive is a point
- objects are created by connecting points with straight lines
  - some systems allow points to be connected using arcs of circles
- areas are defined by sets of lines
  - the term polygon is synonymous with area in vector databases because of the use of straight-line connections between points
overhead - Example of vector GIS data
- very large vector databases have been built for different purposes
  - vector tends to dominate in transportation, utility, marketing applications
  - raster and vector both used in resource management applications

B. "ARCS"
- when planar enforcement is used, area objects in one class or layer cannot overlap and must exhaust the space of a layer
- every piece of boundary line is a common boundary between two areas
- the stretch of common boundary between two junctions (nodes) has various names
  - these arcs (chains/edges) are fundamental in vector GIS

C. DATABASE CREATION
- database creation involves several stages:
  - input of the spatial data
  - input of the attribute data
  - linking spatial and attribute data
- spatial data is entered via digitized points and lines, scanned and vectorized lines or directly from other digital sources
  - once the spatial data has been entered, much work is still needed before it can be used
Editing
- during this topology generation process, problems such as overshoots, undershoots and spikes are either flagged for editing by the user or corrected automatically
Relationship between digitizing and editing
- digitizing and editing are complementary activities
  - poor digitizing leads to much need for editing
  - good digitizing can avoid most need for editing
  - both can be very labor-intensive
Edgematching
- compares and adjusts features along the edges of adjacent map sheets
- some edgematches merely move objects into alignment
- others "join" the pieces together logically - conceptually they become one object
  - the user "sees" no interruption
- an edgematched database is "seamless" - the sheet edges have disappeared as far as the user is concerned
D. ADDING ATTRIBUTES
- once the objects have been formed by building topology, attributes can be keyed in or imported from other digital databases
- once added to the database, attributes must be linked to the different objects
  - attributes can be linked by pointing to the appropriate object on the screen and coding its corresponding object ID into the attribute table
- unlike many raster GIS systems, attribute data is stored and manipulated in entirely separate ways from the locational data

E. EXAMPLE ANALYSIS USING VECTOR GIS
- compare with example analysis in Unit 4 (The Raster GIS)

Objective
- identify areas suitable for logging
- an area is suitable if it satisfies the following criteria:
  - is Jack pine (Black Spruce are not valuable)
  - is well drained (poorly drained and waterlogged terrain cannot support equipment, logging causes unacceptable environmental damage)
  - is not within 500 m of a lake or watercourse (erosion may cause deterioration of water quality)

Procedure
  overhead - Vector database
  - database consists of three layers
    - note: polygons do not entirely fill the space in each case
      - hence, areas not included fall in polygon ID 0
  overhead - Analysis steps
  - **buffer** hydrography out to 500 m
  - **merge** buffer and lake
  - **extract** Jack pine polygons (species = Jack pine)
  - **extract** drained soil polygons (drainage = 2, therefore soil = A)
  - **overlay** buffer, Jack pine and soil polygons
  - **build topology**
  - **extract** polygons not in the buffer but in others (buffer = n, Jack pine = y, drainage = y)

Result
- loggable area shown in final map
Example Attributes:

- city: population, name
- wells: depth
- highway: number
- political boundary: type
- streams: name
- ag. land: growth potential, acreage
- urban land: urban landuse type, acreage
- airport: name

Example of Vector GIS Data
Vector Database
Analysis Steps
UNIT 14 - VECTOR GIS CAPABILITIES
Compiled with assistance from Holly J. Dickinson, State University of New York at Buffalo

A. INTRODUCTION
- analysis functions with vector GIS are not quite the same as with raster GIS
  - more operations deal with objects
  - measures such as area have to be calculated from coordinates of objects, instead of counting cells
- some operations are more accurate
  - estimates of area based on polygons more accurate than counts of pixels
  - estimates of perimeter of polygon more accurate than counting pixel boundaries on the edge of a zone
- some operations are slower
  - e.g. overlaying layers, finding buffers
- some operations are faster
  - e.g. finding path through road network

B. SIMPLE DISPLAY AND QUERY
Display
- using points and "arcs" can display the locations of all objects stored
- attributes and entity types can be displayed by varying colors, line patterns and point symbols
overhead- Vector display
- may only want to display a subset of the data
  - e.g. want to display areas of urban landuse with some base map data
    - select all political boundaries and highways, but only areas that had urban land uses
- how would the user do this?
  - e.g. one of the layers in a database is a "map" of land use, called USE
  - area objects on this layer have several attributes
  - one attribute, called CLASS, identifies the area's land use
  - for urban land use, it has the value "U"
  - need to extract boundaries for all areas that have CLASS="U"

C. RECLASSIFY, DISSOLVE AND MERGE
- reclassify, dissolve and merge operations are used frequently in working with area objects
  - these are used to aggregate areas based on attributes
- consider a soils map:
  - we wish to produce a map of major soil types from a layer that has polygons based on much more finely defined classification scheme
Steps
overhead - Reclassify, dissolve and merge
1. reclassify areas by a single attribute or some combination
   - e.g. reclassify soil areas by soil type only
2. dissolve boundaries between areas of same type
   - by delete the arc between two polygons if the relevant attributes are the same in both polygons
3. merge polygons into large objects
   - recode the sequence of line segments that connect to form the boundary (i.e. rebuild topology)
   - assign new ID #s to each new object
Forestry example
- consider a forestry GIS where the forest is divided into "stands", average size 10 ha:
  - each stand carries a list of attributes, including tree species and average tree age
  - attributes apply homogeneously to area of each stand
  - boundary occurs between stands whenever at least one attribute changes
- problem: identify all cuttable areas of white spruce
  - assign new attribute "cuttable" to each stand
    - value = "y" if white spruce AND age > 50 years
    - value = "n" otherwise
  - after assigning new attribute, all others can be dropped
- now wish to identify cuttable areas, each may be merger of several individual stands
  - dissolve boundaries between polygons with same value of "cuttable" attribute
  - merge polygons into larger objects

City zoning example
- need to know how many individual landuse zones have been created in the city and how
  these are distributed geographically
- each land parcel in the city has a zoning attribute attached to it
- dissolve boundaries between parcels if the zoning is the same
- result can be a map showing large areas of similar zoning classes

D. OVERLAY
Point in polygon
- Overlay - Point in polygon
  - overlay point objects on areas, compute "is contained in" relationship
  - result is a new attribute for each point
  - e.g. combine wells and planning districts, find district containing each well

Line on polygon
- Overlay - Line on polygon
  - overlay line objects on area objects, compute "is contained in" relationship
  - lines are broken at each area object boundary
    - number of output lines is greater than number of input lines
  - containing area is new attribute of each output line
  - e.g. combine streams and counties, find county containing each stream segment

Polygon on polygon ("Polygon overlay")
- Overlay - polygon on polygon
  - overlay two layers of area objects
  - boundaries are broken at each intersection
  - number of output areas likely greater than the total number of input areas
  - e.g. input watershed boundaries, county boundaries, output map of watershed/county combinations
  - after overlay we can recreate either of the input layers by dissolving and merging based on
    the attributes contributed by the input layer

Spurious polygons
- during polygon overlay, many new and smaller polygons are created, some of which may
  not represent true spatial variations
- Sliver or spurious polygons (3 pages)
  - physically overlay pages 1 and 2, page 3 shows resulting spurious polygons
  - the small, invalid polygons are called spurious or sliver polygons and can be a major
    problem in polygon overlay
- spurious polygons arise when two lines are overlaid which are actually slightly different versions of the same line
  - if the same line occurs on two input maps, the digitized versions may be slightly different
  - in many cases the lines on the source maps have been compiled from different sources, but are nevertheless the same line on the ground
  - e.g. a road may be part of a county boundary, also the boundary between two fields or two soil types or two vegetation types
- the problem cannot be removed by more careful digitizing - more points simply leads to more slivers
- some GISs allow the user to set a tolerance value for deleting spurious polygons during overlay operations

E. BUFFERING
- a buffer can be constructed around a point, line or area
  - buffering creates a new area, enclosing the buffered object
overhead - Buffering
- applications in transportation, forestry, resource management
  - protected zone around lakes and streams
  - zone of noise pollution around highways
  - service zone around bus route (e.g. 300 m walking distance)
  - groundwater pollution zone around waste site
- sometimes, width of the buffer can be determined by an attribute of the object
  - e.g. buffering residential buildings away from a street network:
    - three types of street (1, 2, 3 or major, secondary, tertiary) with the setbacks being 600 feet from a major street, 200 feet from a secondary street, and only 100 feet from a tertiary street
Soil Types A, B and C with growth potentials d and f

Soil Types A, B and C

Soil Types A, B and C

Steps

1. Reclassify Soil Areas by Soil Type Only
2. Dissolve Boundaries between Areas of Same Soil Type
3. Merge Polygons into Large Objects

Reclassify, Dissolve and Merge
Overlay - Point in Polygon
Overlay - Line on Polygon
Overlay - Polygon on Polygon
Sliver or Spurious Polygons
(page 1 of 3)
Sliver or Spurious Polygons
(page 2 of 3)
Sliver or Spurious Polygons
(page 3 of 3)
Buffering a Point

eg. All area within one mile of a city.

Buffering a Line

eg. All areas within 1000 meters of a road.

Buffering an Area

eg. All areas within 500 meters of a wetlands area.
UNIT 23 - HISTORY OF GIS

A. INTRODUCTION
- development of GIS was influenced by:
  - key groups, companies and individuals
  - timely development of key concepts
- content of this unit is concerned with North America
- outside North America, significant developments occurred at the Experimental Cartography Unit in the UK
  - history of this group has been documented by Rhind (1988)
- this unit draws on a preliminary "genealogy of GIS" assembled in 1989 by Donald Cooke of Geographic Data Technologies Inc.
  [See overhead - GIS History Time Line]

B. HISTORIC USE OF MULTIPLE THEME MAPS
- idea of portraying different layers of data on a series of base maps, and relating things geographically, has been around much longer than computers
  - maps of the Battle of Yorktown (American Revolution) drawn by the French Cartographer Louis-Alexandre Berthier contained hinged overlays to show troop movements
  - the mid-19th Century "Atlas to Accompany the Second report of the Irish Railway Commissioners" showed population, traffic flow, geology and topography superimposed on the same base map
  - Dr. John Snow used a map showing the locations of death by cholera in central London in September, 1854 to track the source of the outbreak to a contaminated well - an early example of geographical analysis

C. EARLY COMPUTER ERA
- several factors caused a change in cartographic analysis:
  - computer technology - improvements in hardware, esp. graphics
  - development of theories of spatial processes in economic and social geography, anthropology, regional science
  - increasing social awareness, education levels and mobility, awareness of environmental problems
  - integrated transportation plans of 1950s and 60s in Detroit, Chicago
    - required integration of transportation information - routes, destinations, origins, time
    - produced maps of traffic flow and volume
  - University of Washington, Department of Geography, research on advanced statistical methods, rudimentary computer programming, computer cartography, most active 1958-61.

D. CANADA GEOGRAPHIC INFORMATION SYSTEM (CGIS)
- Canada Geographic Information System is an example of one of the earliest GISs developed, started in the mid '60's
  - is a large scale system still operating today
  - its development provided many conceptual and technical contributions
Purpose
  - to analyze the data collected by the Canada Land Inventory (CLI) and to produce statistics to be used in developing land management plans for large areas of rural Canada
- the CLI created maps which:
  - classify land using various themes:
    - soil capability for agriculture
    - recreation capability
    - capability for wildlife (ungulates)
    - capability for wildlife (waterfowl)
    - forestry capability
    - present land use
    - shoreline
  - were developed at map scales of 1:50,000
  - use a simple rating scheme, 1 (best) to 7 (poorest), with detailed qualification codes, e.g. on soils map may indicate bedrock, shallow soil, alkaline conditions
  - product of CLI was 7 primary map layers, each showing area objects with homogeneous attributes
    - other map layers were developed subsequently, e.g. census reporting zones
  - perception was that computers could perform analyses once the data had been input

Technological innovations
- CGIS required the development of new technology
  - no previous experience in how to structure data internally
  - no precedent for GIS operations of overlay, area measurement
  - experimental scanner had to be built for map input
- very high costs of technical development
  - cost-benefit studies done to justify the project were initially convincing
  - major cost over-runs
  - analysis behind schedule
- by 1970 project was in trouble
  - failure to deliver promised tabulations, capabilities
- completion of database, product generation under way by mid 1970s
  - main product was statistical summaries of the area with various combinations of themes
  - later enhancement allowed output of simple maps
- CGIS still highly regarded in late 1970s, early 1980s as center of technological excellence despite aging of database
  - attempts were made to adapt the system to new data
  - new functionality added, especially networking capability and remote access
  - however, this was too late to compete with the new vendor products of 1980s

E. HARVARD LABORATORY
- full name - Harvard Laboratory For Computer Graphics And Spatial Analysis
- Howard Fisher, moved from Chicago to establish a lab at Harvard, initially to develop general-purpose mapping software - mid 1960s
- Harvard Lab for Computer Graphics and Spatial Analysis had major influence on the development of GIS until early 1980s, still continues at smaller scale
- Harvard software was widely distributed and helped to build the application base for GIS
- many pioneers of newer GIS "grew up" at the Harvard lab

F. BUREAU OF THE CENSUS
- need for a method of assigning census returns to correct geographical location
  - address matching to convert street addresses to geographic coordinates and census reporting zones
  - with geographic coordinates, data could be aggregated to user-specified custom reporting zones
- 1970 was the first geocoded census
- DIME files were the major component of the geocoding approach
- precursor to TIGER, urban areas only
- DIME, TIGER were influential in stimulating development work on products which rely on street network databases
- automobile navigation systems
- driver guides to generate text driving instructions (e.g. auto rental agencies)
- garbage truck routing
- emergency vehicle dispatching

Urban atlases
- beginning with the 1970 census
- production of "atlases" of computer-generated maps for selected census variables for selected cities
- demonstrated the value of simple computer maps for marketing, retailing applications
- stimulated development of current range of PC-based statistical mapping packages
- based on use of digital boundary files produced by the Bureau

G. ESRI
- Jack Dangermond founded Environmental Systems Research Institute in 1969 based on techniques, ideas being developed at Harvard Lab and elsewhere
- 1970s period of slow growth based on various raster and vector systems
- early 1980s release of ARC/INFO
  - successful implementation of CGIS idea of separate attribute and locational information
  - successful marriage of standard relational database management system (INFO) to handle attribute tables with specialized software to handle objects stored as arcs (ARC) - a basic design which has been copied in many other systems
  - "toolbox", command-driven, product-oriented user interface
  - modular design allowed elaborate applications to be built on top of toolbox
- ARC/INFO was the first GIS to take advantage of new super-mini hardware
  - GIS could now be supported by a platform which was affordable to many resource management agencies
  - emphasis on independence from specific platforms, operating systems
- initial successes in forestry applications, later diversification to many GIS markets
  - expansion to $40 million company by 1988
GIS HISTORY

Yorktown
Irish Atlas
Snow's Data

Early Computers
Transportation Planning

U. Wash.

CGIS
Harvard Lab
DIME
ESRI

Computer Revolution
GIS Takes off
UNIT 25 - TRENDS IN GIS
Compiled with assistance from Jack Dangermond, ESRI

A. INTRODUCTION
- this unit discusses
  - trends in computer hardware and software for GISs
  - new applications of GIS technology
  - new sources of data

B. HARDWARE
Fast geoprocessing
- to this point, advances in computing power have always found new areas of application.
  - What new applications of GIS will take advantage of higher speeds?
    - larger data sets, higher levels of spatial resolution
    - more complex models
    - more complex analysis for decision-making
    - better methods of display and visualization
Parallel Processing
- trend toward different computer architectures
  - away from single processors operating on data in sequence
  - parallel processors can perform tasks on several different processors simultaneously within the same computer
  - what GIS processes will be suitable for parallel processing?
    - analyses which require repeating the same steps everywhere on the map
    - easier to see applications for raster data than for vector since each pixel is independent
    - e.g. finding route for a vehicle across a rugged terrain
    - e.g. image processing applications such as image classification, visualization, scene generation
Memory
- trend is toward lower costs for ever larger computer memories
  - cost of storing large GIS datasets will come down
  - more data can be placed "on-line" for faster access
  - the nature of geographical data (high volume, infrequent update) is suitable for optical storage
    - once written, cannot be changed
    - CD-ROM - 5 1/4 inch disks with 250 MBytes, enough to store all streets in Los Angeles
    - once a "master" has been created, the unit cost of CD-ROM data is only about $10
    - optical WORM - 12 inch disks with 2 GBytes, enough for the contents of 100 topographic maps
    - erasable optical disk is available
    - very high density of data
Workstations
- "dumb" terminals connected to a central processor are gradually being eliminated in favor of desk top computers
  - especially popular are "workstations", which have excellent graphic performance and sophisticated user interfaces
    - the exact distinction between personal computers and workstations is unclear
    - workstations are generally more powerful
    - workstations are generally more expensive ($10,000 vs. $4,000)
    - workstations generally use UNIX operating system rather than DOS
    - workstations have more powerful graphics capabilities (1280x1024 rather than 640x480)
    - originally, workstations developed for the scientific and engineering market
Peripheral devices
- excellent raster devices are now available (e.g., electrostatic and laser printer/plotters) for graphic/cartographic output
  - costs of these systems are directly related to the size of the product
- scanning has not taken over from digitizing in GIS applications, and is unlikely to do so until some means, perhaps artificial intelligence, can be applied to separating extraneous information

Specialized workstations
- workstations specialized for particular uses (e.g., land planning, water resources, forestry) are likely to be developed as the number of users increases in such specialized fields
  - analyzing data on the globe (e.g., oceans, atmosphere) will require a specialized workstation which can display data on the globe's curved surface
  - e.g. the globe could be "browsed" using a track-ball to rotate the image
- as GIS becomes a standard decision support technology, entire conference rooms will be devoted to its use
  - containing specialized GIS workstations, large GIS display devices, and GIS planning/conference tables

C. SOFTWARE
GIS system integration
- the marketplace increasingly demands compatibility between diverse hardware and GIS software
- at the same time, GIS software needs to interface to an increasing diversity of DBMSs, because different applications often require different DBMSs
  - in many applications, records are already stored in a DBMS
  - when the GIS capability is added to allow geographical access to these records, it must interface with the existing DBMS

Display products
- improved cartographic products are certain, since there is both intense user demand and the technology required to support such improvements
  - map output will continue to be judged against hand-made products
- 3D displays, overlaid with both cartographic data and representations of the built environment, are likely early developments in GIS technology

Interfaces to other technologies
- interfaces between GIS, CADD, remote sensing, image processing, architectural graphics, and other technologies are going to be increasingly easy to create
- the differing data types produced by these technologies will be more frequently combined in shared databases

User interfaces
- more sophisticated, flexible and well managed graphic user interfaces are inevitable
- users are becoming increasingly impatient with software which requires any training or support from the vendor
  - training and support add high and probably continuing costs to GIS acquisitions

D. NEW APPLICATIONS OF GIS TECHNOLOGY
- because GIS technology is becoming more affordable, more reliable, more widely used and better known, new applications of GIS technology are likely to rapidly increase, just as the applications of computer graphics have increased

Modeling and decision support
- Geographic Information Modeling System (GIMS) technology will be developed and used in providing decision support in a growing number of fields
- can applications in areas as different as transportation planning and forestry be served by the same GIS software?
  - will there be fragmentation of the GIS field by area of application?
Sciences and mathematics
- GIS technology will be applied widely in the sciences in the near and middle term future
  - e.g. 3D capabilities for geology, geophysics, hydrology, mining
  - GIS modeling in landscape ecology
- in the longer term, applications for GIS technology may develop in areas of image processing, e.g. X-rays, other types of medical imaging, where superimposition of data, analysis may have similar importance
- global issues - tropical deforestation, acid rain, greenhouse effects, endangered and threatened species, and similar problems are likely to be analyzed using GIS technology in the 1990s
  - GIS networks, similar to the global weather monitoring and prediction network, may evolve
  - they will probably make use of super computers, parallel processing, and artificial intelligence to cope with the massive databases and the complex models involved
  - such models are currently in very rudimentary form, e.g. global climate models used to predict greenhouse warming effects use very large cell sizes (5 degrees lat/long)
  - GIS will play a role in managing the global environment, perhaps used to identify the world’s most sensitive habitats; then a country’s agreement to conserve these habitats may be exchanged for forgiveness of international debts

Education
- GIS now being taught in various departments at many universities and colleges
  - GIS courses focus on GIS as a element in modern scientific research, as an important decision making tool in government and industry, and as frontier in computer software and geographic analysis methodology development
  - GIS is increasingly being used as a educational tool to support other topics

E. NEW SOURCES OF DATA
Remote sensing
- following Landsat, ERTS, Thematic Mapper and now EOS, and competing with them to supply the demand for satellite-borne imaging systems are the SPOT system and systems which the Japanese, Russians, and others may bring on line in the 1990s
- as data resolution increases, costs fall, service becomes more reliable, and user demand increases, satellite remote sensing will become more important in supplying data for GIS
  - already the supply of data vastly exceeds our ability to analyze it
  - better methods of scanning, archiving large amounts of data will be needed
Data sharing
- essential to reduce costs, solve widespread problems, and fully utilize available technology
- security considerations, political divisions, and other factors will continue to inhibit sharing
- because problems will increasingly be recognized as crossing international boundaries and having global implications, and because the necessary technology is now becoming available, more global databases will be built
- in some situations, private businesses will compete with government agencies in supplying data to both government and the public
  - questions will increase about how to best serve the public interest in such cases
  - data gathering by government will always be under fire because of its cost

F. CONCLUSION
- the immediate future will be a time of explosive growth in the development and use of GIS technology
  - the signs are that current growth rates will continue
- it is very likely that these predictions about the period will prove to have been too conservative
  - predictions about the value of technological change often prove to be totally wrong
  - e.g. the development of microchip technology which was the key to cheap computers was driven first by the need to save space and weight in space vehicles
EXISTING GIS ACTIVITIES

A definite role for GIS in the schools is apparent and it is quite possible that the "new" geography courses may even demand a GIS component. Providing a clear path for "school friendly" GIS is the object of the second phase of the SEP. The SEP project is not the only activity attempting to introduce GIS to teachers and students, however, it is the only comprehensive GIS education project for the schools in the nation at this point.

Various foreign countries have initiated GIS projects. Most of these are on the local level tied to a particular institution. An exception is an effort in the United Kingdom to produce a GIS software package for the country's schools. This AEGIS software seems to still be in the development stages. In the process of designing a GIS only for the schools, some have noted that the system has lost much of the functionality that distinguishes it as a GIS. Nevertheless, this is an admirable effort which benefitted from the strong position of geography in the United Kingdom schools. Still a clear body of materials and documented use of GIS in education is yet to be seen from the U.K. and it is questionable if much from these examples would be transferable to our schools. In Canada there are a few university faculty who have extended their GIS activities to partnerships with local school boards (districts). The activities have included weekend seminars for teachers and in one case a short workshop for students. Other smaller scale activities and investigations have been carried out in Austria, Ireland, and New Zealand.

In the US, most GIS activities are like those abroad, tied closely to a particular faculty member at a single university. They often are actually geography seminars in which there is a small GIS component (often viewing an application with an explanation of GIS capabilities). One of the university based activities that stands out is Dr. Bill Huxhold's summer course for local high school students. He had 8 students attend a 20 hour course in his GIS lab at the University of Wisconsin. The students used GIS concepts to look at various urban problems and issues in the city of Milwaukee. Another project that is reaching high school students is the Oregon State Department of Education Workforce 2000 program. This program is attempting to provide training in use of GIS and Global Positioning System technology in the community colleges and high schools. This project is taking place in areas of Oregon that need individuals trained in forestry. There are a few teachers at progressive high schools which are attempting student projects that utilize GIS. At the University High School (private) in Ohio, Rhinehold Freibertshauser is having his students use GIS to manage the 200 acre campus ecological reserve. The geoscience department at the Thomas Jefferson High School for Science and Technology (public, magnet) also is trying to integrate GIS into some of their activities. There are some other small projects around the country and many individuals who are interested in doing something in the future, but none of these efforts purport to have a national impact.

Though there are not any other large projects to bring GIS to the schools, there are some related projects. One project is the GEO/SAT project of Dr. Duane Nellis at the University of Kansas. He and his colleagues have produced a set of lessons and an image processing software package for remote sensing data. Remote sensing (satellite and airborne sensor imagery) is another technological development that has potential in the schools, though, for educational purposes, it is much more narrow of a technology and thus has more limited applications for the schools. Remote sensing data is often used in a GIS so these exercises may be one way in which teachers and students may be steered towards GIS. Since Remote Sensing developed first, it had head start on GIS in many respects, but in the case of the schools it is quite likely that GIS type activities will become common with remote sensing being relegated to special topic status. Another remote sensing oriented project is the Joint Education Initiative based out of the University of Maryland. This project is producing student materials to go with a CD-ROM data disk compiled by the USGS, NOAA, and NASA. The disks contain various types of remotely sensed images and other
visual data sets. The disk does make use of a subset of the IDRISI GIS software, but is not a GIS teaching vehicle. Rather it represents a nice compilation of some of the types of data that can be used by a GIS. This is another set of materials which might be a used as a sub-component of broader scope GIS classroom activities.

A third large project is sponsored by the GIS industry giant, ESRI, and the National Council for Geographic Education. They are developing a set of instructional materials to go with ESRI's ARCVIEW software. ARCVIEW is not a GIS software package, but rather is a vehicle for displaying data compiled in ESRI's ARC/INFO, a very expensive, complicated, and powerful GIS software. These ARCVIEW materials will be a definite boon to the teacher trying to introduce GIS in the classroom, that is if that teacher has access to the relatively powerful personal computer required (386 or, better, 486 chip; 6 or more MB RAM). The ARCVIEW software can be used with USA and world demographic data compiled by ESRI on CD-ROM disks. There is no doubt that this is a useful educational tool, but it again is limited and only points to potentials inherent in GIS. ARCVIEW is a good introduction to the type of geographic data used in some GIS software packages and is one of the packages we had the teacher/consultants interact with in last summer's workshop.

All of these projects provide a good introduction for GIS, but do not have the same educational potential. Other software developers are also noting the possible uses for GIS software for the schools, but are waiting to see where GIS will fit in before embarking on development efforts.

For more information check these sources or contact the NCGIA Education Projects Manager:


Resource List

This list is divided into four sections: GIS Software for Teaching, Other Software Packages, GIS Teaching Materials, and Geography Teaching Materials. Though not exhaustive, the list provides a starting point in the search for appropriate resources for teaching with or about GIS in the schools.

GIS Software for Teaching

Name: MAP II: Map Processor
Description: A simple raster GIS package for the Macintosh.
Available from: John Wiley & Sons, Inc.
Order Department
Eastern Distribution Center
1 Wiley Drive
Somerset, NJ 08875
Cost: $99.95 for educators, $5 for a demo disk, $125 for a classroom pack
Information: This is one of the cheapest GIS packages available. As a raster package, it doesn't have the nice "map-like" graphics of the vector packages, but could be an excellent tool for demonstrating decision making through combining sets of gridded data. The demo disk mainly shows how to operate MAP II, but with a little creativity a lesson plan could be designed utilizing the data sets included in the demo. These data sets are a hypothetical terrain scene, sample data layers from S.E. Manitoba, and satellite imagery for St. Norbert's, Canada.

Name: Atlas*GIS, Atlas*PRO, Atlas*MapMaker
Description: A series of software packages ranging from a true GIS, Atlas*GIS, to a thematic mapping package, Atlas*MapMaker.
Available from: Strategic Mapping, Inc.
4030 Moorpark Ave., Suite 250
San Jose, CA 95117
Phone: (408)985-7400
FAX: (408)985-0859
Cost: Atlas*GIS is $2595, Atlas*Pro is $795, Atlas*MapMaker is $395
Information: The Atlas product line is vector based. Atlas*GIS runs under DOS. Atlas*PRO works with DOS and Macs. Atlas*MapMaker works in MicroSoft's WINDOWS environment. Atlas*GIS allows for quite a bit of analysis and for data import and export. Atlas*PRO has some GIS data analysis capabilities, but is geared more to data applied to geographic regions provided. Atlas*MapMaker is primarily for displaying maps with different regions colored differently depending on the data for that region (i.e., a thematic map). Atlas*GIS has a $20 demo package which is nice for demonstrating a vector-based GIS to students, except that the data provided is not very exciting. Any of these products might be used to demonstrate a vector GIS or at least some GIS concepts.
Name: Mac GIS
Description: A simple raster GIS package for the Macintosh.
Available from: Education Version
Bonnie Roesch, Editor
Harper/Collins Publishers
10 East 53rd Street
New York, NY 10022
Phone: (212)207-7306
FAX: (212)207-7314
Commercial Version & Inquiries
David W. Hulse
Department of Landscape Architecture
University of Oregon
Eugene, OR 97403
Phone: (503)346-3660
FAX: dhulse@oregon.uoregon.edu
Cost: $100 for educational institutions, $30 for students, $10 Demo Disk
Information: This software can be run on a MacPlus or higher. Can import scanned input, but not digitized information.
Name: IDRISI
Description: A raster GIS with vector overlay designed with educational uses in mind.
Available from: IDRISI Project
Graduate School of Geography
Clark University
950 Main Street
Worcester, MA 01610-1477
Phone: (508)793-7526
FAX (508)793-8842
email: idrisi@ollie.clarku.edu
Cost: $200 for educational institutions, $100 for students, $9 shipping cost
Information: IDRISI was popular with "GIS in the Schools" teacher/consultants for its ease of use, nice raster graphics (including 3-D display). Since IDRISI was developed for educational uses, there have been educational materials developed for this software package. The NCGIA has also developed some lab materials based on this software package. (See later entry).
Name: ARCVIEW
Description: A software package for displaying and querying GIS data.
Available from: ESRI
380 New York St.
Redlands, CA 92373
Phone: (714)793-2853
FAX: (714)793-5953
Cost: $495 school/library site license and data bundle, $295 personal/family pack
Information: ARCVIEW is an excellent presenter of geographic data. The data has to be in the format of ESRI's GIS package, ARC/INFO. ARCVIEW does come bundled with some data. ESRI is supporting ARCVIEW for educational uses. Classroom materials and additional data sets are being created for and tested by teachers. For more information contact Mr. Charlie Fitzpatrick of ESRI's K-12 Education Program. ARCVIEW is available for both Macs (LC and higher) and for WINDOWS on IBM-PCs and compatibles (386SX or higher). It is a fairly memory hungry application. At least 8 Megabytes of RAM memory is suggested. Also at least 9 Megabytes of hard disk space is required. A math coprocessor is required. Color Monitors and CDROMs are also recommended.
### Other Software Packages

<table>
<thead>
<tr>
<th>Name:</th>
<th>GISTutor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>A HyperCard stack for investigating the terminology and concepts of GIS.</td>
</tr>
</tbody>
</table>
| **Available from:** | Longman Geoinformation  
307 Cambridge Science Park  
Milton Road  
Cambridge CB4 4ZD  
United Kingdom |
| **Phone:** | 0223 423020 |
| **Fax:** | 0223 425787 |
| **Cost:** | GISTutor II is due out in the summer of 1993. Price has not been announced. |
| **Information:** | This is an excellent tool for learning the basics about GIS. For teachers that have been exposed to GIS and may want to occasionally incorporate GIS concepts in their teaching, this is a great review. It may be a little too difficult for most secondary school students, though. The stack includes uncomplicated graphics and animations. The first version is no longer being distributed, but the second version, due out shortly, should be even better. |

<table>
<thead>
<tr>
<th>Name:</th>
<th>Understanding GIS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>A Microsoft Windows 3.0 based tutorial on GIS terminology and concepts.</td>
</tr>
</tbody>
</table>
| **Available from:** | Understanding Systems, Inc.  
10300 Globe Road  
Morrisville, NC 27560 |
| **Phone:** | (919)544-9434 |
| **Cost:** | $149 |
| **Information:** | This is a large set of definitions of GIS terms and concepts with associated graphics. It is geared more to the manager and professionals than towards students. It requires 4 Megabytes of RAM storage and 15 megabytes of hard disk space. This would probably be an information overload for most teachers, but some might find it useful. |

<table>
<thead>
<tr>
<th>Name:</th>
<th>AAG Microcomputer Software</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>A variety of inexpensive public domain software collected and distributed by the Association of American Geographers microcomputer specialty group.</td>
</tr>
</tbody>
</table>
| **Available from:** | A list of available software can be obtained from:  
Dr. Frank Gossette  
Geography Department  
Cal State University, Long Beach  
Long Beach, CA 90815 |
| **Phone:** | (310)985-7808 |
| **Email:** | gossette@beach.csulb.edu |
| **Cost:** | $1-$6 cost of distribution. Varies with each software package. |
| **Information:** | There are about 50 different software packages available from the microcomputer specialty group. There are a few simple GIS systems, including Dana Tomlin's Map Analysis Package on which a group of commercial raster GIS packages were based. Also included are simple computer mapping programs, map projection programs, and 1990 census data by county. Since these programs are not commercial, support for the use of the programs may be minimal. For teachers comfortable with the use of public |
domain software and shareware on their microcomputers, this may be a perfect starting point in an effort to do some creative geography with their students.
Name: PC Globe, PC USA, Mac Globe, Mac USA

Description: Electronic atlases

Available from: PC Globe, Inc.
4440 South Rural Road
Tempe, AZ 85282 Phone: (800)336-6314
(and from software retailers and mail order companies)

Cost: PC Globe: $65.95, PC USA: $49.95, MacGlobe: $79.95, MacUSA: $59.95

Information: These products provide a wealth of geographic, demographic, and economic information about the countries of the world and the US states. The database can not be changed as in a GIS, nor can it do sophisticated analysis, but for general geographic education these are excellent resources. This company also makes other educational packages including one that runs on the Apple II series.

Name: AUTOMAP

Description: Computer-based highway atlas of the United States

Available from: AUTOMAP Incorporated
9830 South 51st Street
Phoenix, AZ 85044 Phone: (800)545-6626

Cost: $99.95, AUTOMAP EUROPE $149.95

Information: This software allows the user to visually select highway routes from city to city in the United States. The program will calculate route distance, display the shortest route, or highlight a suggested route. In addition to 350,000 miles of roadway, the software can add additional layers of information such as mountains, points of interest, national parks, and rivers. These layers can be displayed simultaneously which can serve as a simple example of the GIS data model and overlay operation. The software is available for both DOS and WINDOWS. There is also a European version, AUTOMAP EUROPE.

Name: PEDAGeOG (Pictures of Earth - Display and Analysis GeOGraphy)

Description: Software for displaying LANDSAT satellite images. For use with the NCGE Geo/SAT project teaching modules (See NCGE in Geography Materials Section)

Available from: Eidetic Digital Imaging LTD.
1210 Marin Park Drive
Brentwood Bay
British Columbia V0S 1A0 Phone: (604)652-9326
CANADA FAX: (604)652-5269

Cost: $150 plus shipping (Includes school site license)

Information: This is a software product designed especially for use in the schools. It allows students to view and work with satellite images on the computer. The National Council for Geographic Education has designed a set of teaching modules that can make use of PEDAGeOG. The software can run on all IBM or compatible PCs down to the PC/XT. It needs 10 Megabytes of hard disk
space, but more is preferable (images take up a lot of space!). VGA graphics are also required.
**Name:** GEOSCOPE  
**Description:** Interactive global change encyclopedia  
**Available from:** LMSOFT  
1280 Bernard Street West  
Suite 401  
Outremont, Québec  
CANADA H2V 1V9  
FAX: (514)948-0511  
**Cost:** Check with vendor above.  
**Information:** This is a hypermedia program with more than 150 datasets on the atmosphere, oceans, vegetation and human activities. GEOSCOPE integrates images from 10 satellites, maps, and socio-economic data with software to help you analyze and understand these phenomena. This program needs a minimum of a IBM compatible with 640K, VGA graphics, and a hard disk. A CD-ROM reader will allow for utilization of the complete data set.

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**GIS Teaching Materials**

**Name:** USGS GIS Poster  
**Description:** A large 2-sided poster/information sheet on GIS.  
**Available from:** The United States Geological Survey Earth Science Information Center  
1-800-USA-MAPS  
**Cost:** Free  
**Information:** This is an excellent resource. The poster is composed of a series of images demonstrating GIS and accompanying text explaining the images. The text and images are broken up into the following categories: What is a GIS?, How does a GIS work?, What's special about a GIS?, GIS through history, Using GIS, Graphic display techniques, and The future of GIS. The USGS also has other educational/reference posters including one on map projections and another listing types of available digital cartographic data.

**Name:** Geographic Information and Your Future: Careers for a fragile planet  
**Description:** A small brochure describing careers using geographic information and GIS and the training required for these careers.  
**Available from:** NCGIA at either of these two sites:  
NCGIA/Dept. of Geography  
3510 Phelps Hall  
University of California  
Santa Barbara, CA 93106-4060  
NCGIA/Dept. of Surveying Engineering  
5711 Boardman Hall, Room 348  
University of Maine  
Orono, ME 04469-5711  
**Cost:** No cost for small numbers.  
**Information:** This brochure provides a concise overview for students and teachers looking at careers dealing with geographic information. Specific high school and college educational paths are suggested. This would be a good resource for
distribution at the end of a set of lessons on GIS or as part of a review of careers in geography.
Name: NCGIA Secondary Education Project GIS Materials

Description: A set of resources for teaching about GIS in the classroom.

Available from: Mr. Steve Palladino
Secondary Education Project Manager
NCGIA/Dept. of Geography
3510 Phelps Hall
University of California
Santa Barbara, CA 93106-4060
Phone: (805)893-8652
FAX: (805)893-8617
email: spalladino@ncgia.ucsb.edu

Cost: Cost of reproduction and shipping. Actual prices vary.

Information: In response to the request of teachers/consultants from the first SEP "GIS in the Schools" workshop, the SEP manager has begun to put together some materials for teachers to use in the classroom. A slide set of 40 GIS slides has been assembled. A disk of African environmental data sets and the IDRISI display modules to view them is available for familiarizing students with digital data and a GIS user interface. A computer independent exercise has been developed which introduces students to the GIS concepts of geographic analysis using multiple layers of data. All of these resources and others are in the process of being revised or created. Contact the Secondary Education Project Manager to check on the status of these resources.

Name: Teaching GIS: Resources for the Laboratory

Description: NCGIA materials for teaching GIS at the post-secondary level

Available from: NCGIA Publications Office
3510 Phelps Hall
University of California
Santa Barbara, CA 93106-4060
Phone: (805)893-8224
FAX: (805)893-8617
email: nciapub@ncgia.ucsb.edu

Cost: Varies, most publications range from $10-$30. The Core Curriculum is $200.

Information: The NCGIA Education Program has developed a series of resources for the classroom and the computer laboratory. The NCGIA Core Curriculum in GIS is a set of lecture outlines for a year long sequence of GIS courses for university students. There is some information that may be useful to secondary school teachers, but the vast majority of the material is much too involved for the average high school student. GIS Videos: An Annotated Bibliography lists available videos on GIS. GIS Laboratory Exercises: Volumes 1 & 2 complement the first two courses outlined in the core curriculum. Half of the exercises in Volume 1 are IDRISI based and may be useful in a secondary school course. The NCGIA Guide to Laboratory Materials – 1991, although geared mainly to university level courses, might provide some ideas for GIS activities in the schools. Another resource available from the NCGIA is GIS Teaching Facilities: Six case studies on the acquisition and management of laboratories. These case studies outline the procedures followed and purchases made in creating computer laboratory facilities for GIS teaching at six universities and colleges.
Name: GIS County: A Classroom Exercise in Urban Geographic Information Systems

Description: An exercise introducing students to the use of geographic information systems in city planning and urban resource management.

Available from: William E. Huxhold
School of Architecture and Urban Planning
University of Wisconsin - Milwaukee
Milwaukee, Wisconsin  53201

Cost: Contact author regarding costs of reproduction and shipping.

Information: A series of data lists and worksheets that move the student through the process an urban planner might use in building and using a GIS database for a city or urban county. Can be preformed entirely in manual mode: need only pencil, paper, calculator and brain. For university level, but could be used with advanced high school students. It has a heavy focus on formats and uses of urban land record information.

Name: Joint Education Initiative Images

Description: A set of satellite and space probe images on CD-ROM

Available from: Joint Education Initiative Office
3433 A.V. Williams Bldg.
University of Maryland
College Park, MD  20742-3281

Cost: Check with JEI

Information: The Joint Education Initiative (JEI) has been funded by the National Science Foundation to improve teacher competence in the classroom use of scientific data sets. The initial resource which JEI has helped teachers use was the JEdI CD-ROM which has satellite images of both the earth and various planets. The JEI is facilitating the access to various images. The JEI puts out an occasional newsletter and moderates a Internet discussion list (JEI-L). Contact the JEI Office for more information.

Name: GIS Curriculum Development Toolkit

Description: A set of SPANS based GIS learning materials

Available from: CCGISE/IGISE
P.O. Box 3737
Station C
Ottawa, Ontario
CANADA K1Y 4J8

Cost: Check with CCGISE

Information: This Toolkit was designed to complement the SPANS GIS. It is a set of curriculum materials that can be used in GIS courses. The introduction and background units provide good basic information on GIS. There are also GIS case studies which can be viewed on most DOS machines. The rest of the units require the use of SPANS GIS. These materials were developed for the college level, but may have some use in an advanced high school course.
Name: GIS Concepts Kit  
Description: A PC ARC/INFO based tutorial on GIS concepts  
Available from: ESRI  
380 New York St.  
Redlands, CA 92373  
Phone: (714)793-2853  
FAX: (714)793-5953  
Cost: $150 (requires PC ARC/INFO 3.4D)  
Information: This is a GIS concepts teaching vehicle for those with PC ARC/INFO. It includes database of Redlands, California and a set of labs with full documentation and exercises. This resource is more appropriate for college level students, but advance high school students may all benefit from it.

Name: Geo Info Systems Magazine  
Description: A GIS trade magazine  
Available from: Geo Info Systems  
PO Box 1965  
Marion, OH 43305-2052  
Phone: (614)382-0886  
Cost: $59 for 1 year. May be free for educators.  
Information: This magazine provides a good overview of the uses of GIS. Many of the articles focus on applications of GIS technology. Geo Info Systems annually includes a listing of universities and colleges offering course work in GIS.

Name: GIS World Magazine  
Description: A GIS trade magazine  
Available from: GIS World, Inc.  
155 E. Boardwalk Dr., Suite 250  
Fort Collins, CO 80525  
Phone: (303)223-4848  
FAX: (303)223-5700  
Cost: $60 for 1 year. Check with GIS World for special educator rates.  
Information: This magazine provides a good overview of the uses of GIS. Many of the articles focus on applications of GIS technology. GIS World annually publishes a GIS Sourcebook, which an excellent overview and source of information about the GIS industry and available software packages.

Geography Teaching Materials

Name: Directions in Geography: A Guide for Teachers  
Description: A resource packet for teachers of geography  
Available from: National Geographic Society's Geography Education Program  
To order, call 1-800-368-2728  
Cost: $29.95
Information: This 176-page notebook explores geography's multiple dimensions, provides a series of simple-to-sophisticated lesson plans, and contains numerous reproducible outline maps for classroom use.
Name: National Geographic Society  Geography Education Program

Description: Various materials and support to teachers of geography in the nation's schools

Available from: Geography Education Program
National Geographic Society
P.O. Box 37138
Washington, DC, 20013-7138.

Information: The Geography Education Program, or GEP, is the heart of the National Geographic Society's effort to restore geography to the nation's classrooms. Working in tandem with the National Geographic Society Education Foundation, the GEP mobilizes a wide range of Society resources to improve geography instruction. It focuses these resources in five strategic areas: grass-roots organization, teacher education, materials development, public awareness, and outreach to educational decision-makers. The Geography Education Program is built upon a network of state geographic alliances. A geographic alliance is a grass-roots organization that brings together the content expertise of academic geographers and the classroom experience of teachers. Alliances are the energy centers from which spring local and statewide efforts to improve the quality of geography education.

Name: National Council for Geographic Education Materials

Description: A variety of geography instructional materials and frameworks for geography education.

Available from: National Council for Geographic Education
Indiana University of Pennsylvania
Indiana, PA 15705

Cost: Varies, most under $20

Information: Here are some of the materials available:
- NASA Satellite Imagery Posters
- K-12 Geography: Themes, Key Ideas and Learning Opportunities
- Guidelines for Geographic Education: Elementary and Secondary
- Teaching Map Skills: An Inductive Approach
- Secondary-Level Geography Test Materials
- Map Product Sources and Publications List
- Software Materials List, Textbook List
- Games and Activities List
- Environmental Information List

Name: NASA Teacher Resource Center Materials

Description: Videos and slide sets on a variety of subjects including topics that use LANDSAT and other remote sensing images.

Available from: Teacher Resource Center
John C. Stennis Space Center
Building 1200
Stennis Space Center, MS 39529-6000
Phone: (601)688-3338

Cost: You provide the blank video tape or slide film. They will use these materials to make copies at no charge.
Information: Write to the TRC for a catalog listing the video and slide sets available.
**Name:** Geographic Inquiry into Global Issues Modules

**Description:** Issue-based geography education modules for 10 world regions in the final stages of development.

**Available from:** For information on the modules and availability in published form contact:
A. David Hill, Project Director
Center for Geographic Education
Department of Geography, Box 260
University of Colorado Phone: (303)492-6760
Boulder, CO 80309-0260 FAX: (303)492-7501

**Cost:** To be determined

**Information:** The modules are being developed under a 3-year grant from the National Science Foundation. Each module is developed around a current geographical, often environmental, issue in a particular region of the world; for example, one module developed for the South Asian region is on Population and Resources. It works through the questions: "How Does Population Growth Affect Resource Availability?" and, more specifically, "What are the consequences of overpopulation on resources in Bangladesh?". Together the 22 modules could constitute an entire course on global geography. The modules were tested in the classroom during the 1992/1993 school year and should be available commercially at the end of 1993.

**Name:** ARGUS Materials

**Description:** Hands-on learning activities and directed readings on US geography

**Available from:** Information on these materials and their availability in published form contact:
Dr. Osa Brand, ARGUS Project Coordinator
Association of American Geographers
1710 16th Street, NW
Washington, DC 20009-3198

**Cost:** To be determined

**Information:** This National Science Foundation funded curriculum development project is finishing up the creation of various student activities and collection of accompanying readings. These materials will consist of a concise text, a set of related readings, a book of student activities, and a teacher's guide. These resources focus on geographical and environmental issues in the United States.

**Name:** SPACESHIP EARTH: Geography for the 90s

**Description:** A series of 10 half-hour videos for junior high to college-aged students

**Available from:** To buy: For information on off-air taping rights:
SC ETV Marketing PBS Elementary/Secondary Service
Box 11000 1320 Braddock Place
Columbia, SC 20211 Alexandria, VA 22314-1698
1-800-553-7752 (703)739-5019

**Cost:** $39.95 each or $300 for the whole set, $5 for an instructor's guide
Information: SPACESHIP EARTH's ten 30-minute programs use satellite technology to explore and explain the interaction of Earth's dynamic human and physical systems. Footage shot in 12 countries is juxtaposed with satellite-generated remote sensing images, aerial photographs, dynamic maps and computer models.
BASIC GIS TERMINOLOGY

This glossary has been created to help teachers and students wade through some of the GIS terminology. The definitions are designed to communicate effectively to the non-technician, rather than to be authoritative. For more detailed or precise definitions see the references at the end of this section. This information had been organized according to subject (General Terms, Elements, Data Structures and Formats, GIS Analysis Operations, Data Input and Output, GIS Data Sets, Common GIS Software). This glossary may be copied in its entirety and distributed free of cost for educational uses. Italicized words are defined in this glossary.

GENERAL TERMS

AM/FM - Automated Mapping/Facilities Management
A GIS designed to manage utility and industry infrastructure such as water pipes, power lines, telephone lines, and similar networks.

GIS - Geographic Information System
Computer software (which may include the hardware) for capturing, storing, manipulating, analyzing, and displaying various forms of geographic information.

LIS - Land Information Systems
A GIS based on land records such as cadastral maps often showing land use and other relevant geographic features (roads, streams, etc.).

ELEMENTS

Arc - Lines on maps (roads, city boundaries, etc.) are represented in the GIS data base as arcs. These arcs connect two nodes and are defined by a mathematical equation. (e.g., a segment of road between two intersections might be represented as an arc)

Centroid - The geometric center of a polygon.

Coordinates - A set of values used to locate a point in space. The coordinates may be two dimensional (e.g., \(x, y\) or \(\text{Latitude, Longitude}\)) or three dimensional \(\{x, y, z\}\), where \(z\) often refers to elevation). The existence of coordinates describing the locations of items in the database is what distinguishes a GIS. It stores and displays geo-referenced information rather than just being a computer map or a database of geographic names.

Network - A set of linked linear map features form a network (e.g., streams and rivers join to form a drainage network, highways form a transportation network). GIS software is often used to do analysis of networks. This may include analysis of flow direction or volume, relationships between neighboring pieces of the network, maintenance needs, or just about any other characteristic of the network.

Node - Nodes define the endpoints of line segments (arcs). A node is represented by a coordinate pair, \(\{x, y\}\).

Point - A point is use to represent map features that are too small to be shown as a line or an area. A point is represented as a coordinate pair, \(\{x, y\}\). (e.g., a fire station may be represented by a point on a city map or a city might be represented as a point on a state map)

Polygon - A polygon is used by the GIS to represent an area feature on a map (e.g., a city park may be represented as a polygon). The polygon is made up of a set of arcs joined together at their nodes.
Thiessen Polygons - Non-overlapping Polygons built around a set of points. The polygons contain the area around the point that is nearest to that particular point. The polygon boundaries bisect the line segment between two neighboring points.
DATA STRUCTURES AND FORMATS

ASCII - American Standard Code for Information Interchange
The binary codes (made up of zeros and ones) that represent each of the letters of the alphabet and other symbols commonly used in the English language. The computer usually stores text information in ASCII. This format is usually portable between computers.

Attribute - A characteristic of a map feature. This may be its name, its number, some value it has, or any other form of ancillary information (e.g., a section of road may have attributes describing its name, its number, speed limit, last date of maintenance, what jurisdiction it is in, number of lanes, year built, etc.).

DBMS - Database Management System
The portion of GIS software that manages the attribute data. The GIS DBMS is often able to import and export data from some of the standard database software packages that are used widely.

DTM - Digital Terrain Model
Any method by which a GIS database stores earth surface relief (elevation!) data. Examples include TINs and DEMs.

Entity - A real world phenomenon (city, mountain, highway intersection) that cannot be further subdivided and maintain its identity. In the GIS database, the entity is called an object and is the feature and its attributes.

Feature - In a GIS, this is the geographic component of a real world entity (e.g., a road represented as a line or an airport represented as an airplane symbol).

Layer - In a GIS, geographical information is often grouped logically by type. One type of feature or a set of related features is stored in a single computer file which is considered a layer (e.g., school sites = school layer, streams + lakes + wells = a hydrological layer, roads + railways = a transportation layer, cities + unincorporated developed areas = an urban layer). Layers can be combined in various ways depending on what is needed for a particular presentation or analysis.

Pixel - A pixel (cell) is the unit for the raster grid used in many GIS applications. It is usually square or rectangular and will be assigned a uniform value. [note: A computer screen presents information in raster format. Thousands of pixels are arranged in a grid and are each illuminated individually to show a particular color.]

Projection - A map projection is the transfer of surface information from the roughly spherical earth to a flat map. Some projections may preserve distances, directions, shape, or area, but they cannot preserve all of these characteristics on the same map. The most common shape preserving projection is the Mercator projection which was designed for navigators since a straight line on the map represents a course which will have a constant compass heading. Mercator projections stretch out areas close to the North and South Poles (note the exaggerated size of Greenland), but do not include the poles. A GIS will often allow various projections to be used.

Raster - One of two major ways (the other is vector) to represent geographical information in a computer. A raster divides a surface into a grid of pixels (like graph paper). Each pixel is assigned a value which is stored in the GIS database.

Tics - Points on a map with known location which are selected as reference points when inputting map data into a GIS. This ensures that all the geographic features on the computer map in the GIS receive a set of coordinates based on the tics.

TIN - Triangulated Irregular Network
A method to represent elevation data. Elevation data points are connected to form triangles. These triangular faces are not unlike the facets on a diamond. Since many landforms have a roughly triangular shape (ridges, peaks, valleys), this is often a good representation of the land surface.
Topology - The spatial relationships between connecting or adjacent map features (e.g., which arc comes next, which polygons are next to each other). Some vector GIS software keeps track of these relationships which allows for more sophisticated data analysis.

UTM - Universal Transverse Mercator
An earth location referencing system (another is Latitude/Longitude!) which uses a series of Transverse Mercator projections. The coordinates are expressed as \{x,y\} values in meters and are often found marked on the edges of topographic maps (i.e., maps that show elevation such as the United States Geological Survey Topographic Quads).

Vector - One of two major ways (the other is raster) that geographical information is represented in a computer. Each real world entity such as a town, road, and city is defined as a map feature by the use of a point, arcs (lines), or polygon. The coordinates of these features are stored in the GIS database. In this case, it is not necessary to give every spot a value as is true with raster GIS. Only the desired map features need to be stored. Vector representation can be compared with a child's "follow-the-dots" activity, whereas raster would be more like "paint-by-numbers".

GIS ANALYSIS OPERATIONS

Address Matching - A geocoding process in which street addresses are assigned geographic coordinates so they can be located in a GIS.

Buffer Generation (Corridor creation) - A type of analysis in which zones of equal distance are created around various map features. (e.g., In Tacoma, Washington, police are using a GIS to keep track of 1000 foot zones around schools. State law doubles penalties for illicit drug sales within 1000 feet of a school.)

Data Query - The process of extracting specific information from the database. The GIS may have various modes of query; the GIS user may select a feature and a record of all information for that map element might appear or the GIS might give the user a dialog box in which to enter specific conditions for searching the data (e.g., one query might be "find all homes which were built before 1925 and are valued greater than $250,000").

Edge Matching - The process of joining features along the edges of two adjoining maps.

Geocoding - The process of identifying \{x,y\} coordinate locations for map features.

Map Overlay - The combination of two or more GIS layers for the purpose of analysis or creating new information.

Neighborhood Analysis - A variety of analytical procedures for relating the value of a cell in a raster to its neighboring cells. This is often used in remote sensing image processing (e.g., change values of cells to increase contrast).

Point-in-Polygon - An operation in which the GIS determines if a certain point feature lies within a polygon. Often this operation will create links between the point and polygon information in the GIS database. For example, a GIS user at a phone company might want to display all properties that have a public phone booth without having to look for the points representing phone booths on the screen and highlighting the properties one by one.

Viewshed Analysis - The use of elevation data in a GIS to determine visibility between two points. This type of analysis may be used when siting a new structure (such as a water tank) to ensure it is hidden from view.
DATA INPUT AND OUTPUT

**CAD** - Computer Aided Design
A computer system for input and manipulation of graphical information related to industrial design and manufacturing. CAD systems are often used to create base *layers* for a GIS such as gas pipeline *networks*.

**Digitizing** - A manual process of extracting information off maps and photos for input into the GIS database. This is done on a digitizing table or tablet. The map is placed on this digitizing surface and the *features* desired for the GIS database are traced or pinpointed with a cursor which records the feature locations into the database. Though slower than *scanning*, digitizing allows the GIS user to choose to enter only the map information that is needed for the particular application. Another advantage over scanning is that much of the information about the new digital features digitized into the GIS is entered as the digitizing process is occurring.

**GPS** - Global Positioning System
A satellite-based navigation system that enables the GPS user to find his position on the earth with great accuracy. GPS determined coordinates are often entered into a GIS.

**GUI** - Graphical User Interface
The set of software tools and graphics that define the modes of interaction between the GIS user and the software and hardware. Well designed user interfaces make the system more user-friendly.

**Plotting** - A output device for creating hard copy (e.g., paper) maps from the geographic information stored in the GIS and viewed on the computer screen.

**Scanning** - An automated process of taking a non-computerized maps (i.e., paper or mylar) or photos and converting them to digital (computer) form. A scanner, somewhat like a photocopy machine, converts the input maps or photos to a digital *Raster* image. The scanner will usually copy everything on the map into the GIS database, but after scanning the GIS user will need to "tell" the database what is what.

**Sliver Polygons** - Small *polygons* created when two *layers* of data are *overlayed* in the GIS. These polygons do not exist as real *features* with unique characteristics, but rather are artifacts of the same boundary being represented differently in the digital database (i.e., a county boundary digitized on two different maps will not match up exactly due to differences in the original maps and in the *digitized* lines created).

**Snapping Distance** (Tolerance) - When line segments are being *digitized* or manipulated on the computer screen, they will often need to be joined. The snapping distance is the distance within which two endpoints will join. This aids the GIS user, since it is hard to get two endpoints to coincide exactly.

**Weeding** - Linear map *features* (such as roads) and areal features (such as city boundaries) are stored in a GIS as a series of *points* connected by line segments or *arcs*. Weeding is the process of reducing the number of points defining the linear feature. This may be done to save space in the computer since every point displayed takes up space. This is also known as Line Thinning or Smoothing.

GIS DATA SETS

**Aerial Photograph** - A photograph of the earth surface taken from the air. These are often used in a GIS for extracting various types of information or as a backdrop for a digital map.
Cadastral Map - A map of property boundaries used for taxation and establishing ownership. These are often used in city or county government GIS applications.
DCW - Digital Chart of the World
A complete digital coverage of the world created by the Defense Mapping Agency from 1:1,000,000 scale Operational Navigation Charts (ONC). It is available on 4 CD-ROMs from the United States Geological Survey (USGS).

DEM - Digital Elevation Model
A grid based computer file that contains elevation data for the area represented by each of the grid cells (pixels). The USGS has DEMs available for the elevation information on their topographic maps.

Dime Files - These were the US Census Bureau's precursor to the Tiger Files.

DLG - Digital Line Graph
These digital files contain the non-elevation features (such as roads, streams, and cities) found on the USGS topographic maps.

Orthophoto - An aerial photo which has had the distortions, due to varying view angle and different surface elevation, removed. Some orthophotos are combined with topographic map information to create annotated (names and important features marked) orthophotoquads.

Remote Sensing - The process of collecting information about the Earth's surface from distance. Satellite imagery and aerial photographs are examples of remotely sensed images. These images of the earth are often used in and analyzed by GIS software.

Tiger Files - The geographic reference files used in the 1990 census by the US Census Bureau. Each of the reporting units (Census Blocks) is linked to a wide range of attributes (demographic information).

COMMON GIS SOFTWARE (Company Name)

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<th>Software</th>
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<tr>
<td>ARC/INFO</td>
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<td>Generation 5 Technology</td>
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<td>US Army Corps of Engineers</td>
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(See NCGIA Workshop Resource Packet Resource List for more information on software packages that may useful in pre-collegiate classrooms)

REFERENCES