Internet Based Geographic Information Systems

and Decision Support Tools

Quick Study URISA

INTERNET-BASED GEOGRAPHIC INFORMATION SYSTEMS

AND DECISION-SUPPORT TOOLS

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TABLE OF CONTENTS

INTRODUCTION

Rapid growth of the Internet over the past decade has opened up exciting new ways to supply data, tools, models, and other information to potential users. Internet delivery provides opportunities to increase the involvement of stakeholders in the decision-making and planning process by providing knowledge and data through a widely accessible, fast, cost-effective, and easy-to-use medium.

There are significant advantages to making planning and decision-support tools accessible on the Internet. The wide availability of models, decision-support tools, and databases on the Internet has the potential to empower users, allowing them to identify site-specific options that meet their needs and to perform analyses of alternative scenarios. In addition, users of Internet-based decision-support tools do not need expensive software such as Geographic Information System (GIS) tools or large databases on their local systems, rather they have access to these resources through their web browser. Thus, even when users have very limited resources, decisions can still be made that take advantage of decision-support tools including GIS capabilities, advanced models and tools, and spatial data at various scales.

This Quick Study provides readers with an understanding of the availability and the potential of utilizing existing Internet resources, and prepares them to use the next generation of Internet-based decision-support tools. For readers interested in developing new Internet-based tools, this Quick Study discusses approaches and challenges involved in setting up and implementing a decision-support tool, using a Purdue University project as an in-depth case study. The Quick Study is intended both for professionals interested in learning about currently available types of Internet-based decision-support tools and for those involved in developing or extending geographic information and analytical capabilities over the Internet.

CHAPTER 1:

THE INTERNET, GEOGRAPHIC INFORMATION SYSTEMS, AND DECISION-SUPPORT TOOLS

There has been a phenomenal increase in the use of the Internet over the past decade, across a wide variety of fields. The Internet has emerged as a major force in global communications, journalism, commerce, science, publishing, and many other fields (Plewe 1997). Similarly, the use of GISs has also increased dramatically, moving from being a tool used largely in academics by researchers in the fields of spatial analysis, geosciences, and planning to a tool used in commercial organizations and by the general public to locate addresses, homes, businesses, and perform various other spatial queries as the basis for decision-making. GIS data and functionalities available over the Internet are rapidly changing the way people obtain, retrieve, share, and use spatial information to make decisions.

The Internet has emerged as an essential technology for allowing the public to access, process, and disseminate all kinds of information to the public. It serves as a tool for various agencies and organizations including local, state, and federal authorities to disseminate information, it has helped raise awareness levels and it has increased participation leading to more informed and democratically made decisions (Craig 1998). The broad base and wide access of the Internet offers the promise of increased levels of public participation that will help sustain more competent decision-making (Klein 1999). The rapidly increasing number of individuals going on-line and the even faster growth in the number of companies going on-line have made the Internet an integral part of society. Access to the Internet and the easy usability of the World Wide Web (WWW) have created a powerful means for persons to exchange and process information (Peng 1999). The Internet presents numerous possibilities to supply data, tools, models, and other information to potential users. It provides a ready-made platform in the sense that it offers an interface that the vast majority of persons understand and one that is intuitive rather than taught. Reaching GIS clients on the Internet allows developers to leverage widespread existing knowledge (Singh 1999). This approach also provides opportunities to increase the involvement of stakeholders in the decision-making and planning process by providing knowledge and data through a widely accessible, cost-effective, and easy-to-use medium. Making GIS-based tools accessible on the Internet allows a much larger dissemination of the analysis and results compared to the traditional stand-alone desktop GIS. By making such information easily available, the general public can directly access the information and be a part of the decision-making process.

Access to spatial data over the Internet for use on a GIS located on a personal computer was an important first step. However, accessing GIS capabilities without having data and GIS software on a computer, but instead through the web, is becoming the next major advance. With the growth of application service providers in other industries, a similar trend in the geospatial industry is logical. McKee (2000) in his paper "Catch the Internet Wave" recommends encouraging new businesses to solve existing problems using GIS and suggests the concept of GIS application service providers. As this idea is adopted, there will likely be a boom in the use of spatial data for an array of decisions, ranging from finding new homes and locating schools and hospitals in neighborhoods to managing and providing utilities and other services on-line. For example, several applications involving dynamic mapping, information distribution, and on-line decision-support tools were used by the South Carolina Department of Transportation when Hurricane Hugo struck in the early 1990s.

The time, cost, and responsibilities involved in operating and maintaining a web site have been greatly reduced in recent years because of services now being offered by web-hosting services. Small organizations can use these service companies to maintain Internet sites and to get access to high-bandwidth connections, programmers, and other support staff. Thus, with the increase in GIS use by the general public in the form of identifying fastest and shortest traffic routes (http://www.mapquest.com/), locating automatic teller machines (http://www.visa.com/pd/atm/main.html), and providing neighborhood facilities information and an increase in web-hosting services that ease the burdens of providing such services, a dramatic increase in the availability of GIS applications through the Internet is the inevitable next step.

CHAPTER 2:
ADVANTAGES OF INTERNET-BASED TOOLS

Making GIS-based planning and decision-support tools Internet accessible provides several significant advantages over more traditional approaches including:

- Users are not required to have GIS software and other database analysis tools on their desktop computers, and users with limited resources can make decisions that take advantage of GIS capabilities and spatial data at various scales.
- Clients of a centralized Internet-based GIS or decision-support tool are not required to frequently upgrade or change software on their desktop computer. Combined with savings from initial software set-up costs, this can result in significant economic advantages, especially for small organizations.
- Providing models and other such decision-support tools from a centralized system or over the Internet significantly simplifies the maintenance and distribution of such tools. It also ensures that all users are using the same version of a particular model or tool.
- Databases are stored and maintained at centralized locations. This provides for uniform data access and use. In addition, the job of maintaining, updating, and changing such datasets is considerably simplified. Users of such databases are not burdened with preparing and storing large datasets on their desktop computers.
- Data used for running and obtaining results from such models can be verified. This reduces errors due to discrepancies in input data.
- Applications requiring intensive computation and data can be run on powerful servers accessible through the Internet rather than less adept desktop computers.
- The availability of models, decision-support tools, and databases on the Internet has the potential to empower users, allowing them to identify site-specific options that meet their needs and perform analyses of alternative scenarios. It provides the public with tools with which to reach an informed decision on a given problem.
- The availability of significantly advanced capabilities with a simple Internet connection at no extra cost for software, data acquisition, and an easy-to-use Graphical User Interface (GUI) provides tremendous advantages for increasing use of such tools.

CHAPTER 3:

SERVING WEB-BASED GIS FUNCTIONS AND DECISION-SUPPORT TOOLS

Internet GIS, Web-based GIS, or On-line GIS

The Internet is a world-wide interconnected network infrastructure that hosts several applications and facilitates the sharing of information around the globe. It has been particularly valuable in encouraging interoperability and promoting the concept of open and free exchange of data and information. The Internet is composed of multiple, geographically widespread networks connected through communications devices and sets of common communications protocols. The World Wide Web (WWW) is a specific HyperText Transfer Protocol (HTTP) that runs on the Internet along with other applications such as e-mail and File Transfer Protocol (Peng 1999). Terms such as Internet GIS (Peng 1999), web-based GIS (Doyle et al 1998), on-line GIS, and Distributed Geographic Information (Plewe 1997) describe GIS functionalities that are increasingly available via the Internet. Although in the strictest sense, each of these terms represents something slightly different, they are all used to denote similar functions. For a detailed discussion of technical terms used to describe Internet-accessible GIS terms, see Peng (1999).

The Structure of a Web-based GIS

The basic structure of a web-based GIS or decision-support tool begins with a client who sends a request to a server via a web browser using a Graphical User Interface (Figure 1). A Map Server then activates the GIS software and decision-support tool and processes the request. Figure 1 shows the basic structure of the relationship between the clients, the tools used for serving the maps and functionalities, and the GIS software and databases that are used.

The two basic methods of serving GIS and decision-support tools over the Internet are the server-side approach and the client-side approach. Server-side applications rely on a GIS server to manage GIS data and perform analyses. A client-side application processes requests and GIS functionalities on the user's desktop computer.

Server-Side Approach

With the server-side approach, the GIS software resides on the server and the browser acts as a GUI at the client end. The client accesses GIS functionalities through the browser. The user requests or initiates a function over the Internet to the server, which then activates GIS software which in turn processes the

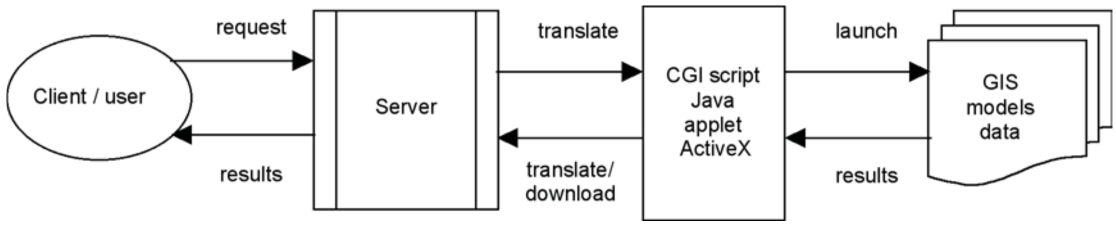

Figure 1. Client Server architecture for a Web-Based GIS

request and sends results back to the user via the browser. A mediator is needed in this process because the HyperText Markup Language (HTML), which forms the building blocks for the WWW, cannot communicate with GIS software directly. The most commonly used interpreter is the Common Gateway Interface (CGI). The CGI receives user input and parses (translates) this into a usable format for GIS programs. It facilitates the handling of information requests and acts as a gateway for providing appropriate information and creating documents on the fly. By using CGI scripts, the web server can provide information in a comprehensible format for clients and provides a gateway for interaction between the client and server. CGI scripts basically handle the data exchange between and web and GIS servers. The script is launched when the user sends a request. The GIS software is started and runs the analysis requested by the client. It receives output data from GIS software and returns it to the browser for presentation to the client (Plewe 1997, Peng 1999).

Concentrating the workload on the server has several advantages. The most important of these is that it provides for centralized hardware and software set-up that can be easily maintained and updated. This ensures that all users have uniform access to the most recent version of a particular tool. The downside of this arrangement is that "simultaneous oversubscription" of the site (an unexpected number of users flooding the site with requests at the same time) could slow the system and discourage prospective users. In the server-side processing approach, rather than having basic functions carried out at the user end, each request made by the client, irrespective of whether it is a simple pan or zoom function or a more complex analysis, requires the server to run the application and respond with results. This occupies server time and can slow the procedure and, in some cases, the response time.

Client-Side Approach

In the client-side approach, the GIS analysis and models are executed locally on the user's own computer. The client uses the Internet to download data, GIS software, and models from the server onto the local machine. Small, executable applications such as Java applets and ActiveX controls are created that broaden the capabilities of HTML to handle spatial maps and data. These are comparable to CGI scripts in the server-side approach. These applications do not require separate installation processes, can be downloaded at runtime, and are executable within the web server.

The decision whether to utilize a client-side or a server-side approach requires the developers to find a balance or a trade-off that best suits the particular needs of the user. Some of the issues that must be considered are: the target audience and the needs and the requirements of this audience; the capabilities of the providers themselves; the speed of connection available; and the anticipated number of persons accessing the site at a given time. Generally, a client-side approach works best when there are large numbers of users but little demand for advanced GIS-type analysis capabilities. A server-side approach suits a clientele that is not very large and that requires specialized GIS analysis functions (Plewe 1997).

CHAPTER 4:
EXAMPLES OF SOFTWARE DEVELOPMENT PLATFORMS

There are a variety of products available on the market to serve GIS functions and maps on the Internet. By the sheer nature of a rapidly changing and expanding field, there are many varied players and it is impossible to provide a complete overview of all the tools available in the market. To give a sense of some of what is available at the time that this Quick Study was prepared, examples of tools provided by four companies are discussed here: Environmental Systems Research Institute (ESRI, at http://www.esri.com/), Intergraph (http://www.intergraph.com/dynamicdefault.asp), MapInfo (http://www.mapinfo.com), and Autodesk (http://www3.autodesk.com/adsk/). Discussion of a particular tool is not an endorsement of that product.

ESRI

ESRI currently offers four applications that build upon their desktop GIS software.

- **ArcView Internet Map Server** (IMS) (http://www.esri.com/software/arcview/extensions/imsect.html) is an image-based application that can be used in conjunction with the ESRI ArcView GIS software. ArcView IMS publishes any map that can be generated with ArcView. It requires ArcView GIS Version 3.0, or higher, running under Windows 95, Windows NT, or UNIX. It is shipped as an extension of ArcView that is a wizard that can reproduce maps generated within ArcView and publishes them on the web. It can also be used as an ESRI Map web server extension that handles web client requests and as MapCafe, which is a Java applet that resides in the browser and offers basic tools to browse, explore, and query maps on the Internet. This provides the end user with a familiar ArcView-like interface and is relatively fast to set up.
- **MapObjects IMS** (http://www.esri.com/software/mapobjects/ims/index.html) is also an image-based application. The MapObjects Internet Solutions Kit includes three integrated applications: MapObjects IMS, MapObjects Professional, and ArcExplorer. Maps can be served via MapObjects IMS by creating a project in ArcExplorer and executing IMS Catalog, IMS Launch, and IMS administrator. The component MapObjects administrator then serves the map on the web with an ArcExplorer interface. Advanced users can build custom applications by using development environments such as Visual Basic, Delphi, Visual C++, and other object-oriented programming languages.

- **RouteMap IMS** is useful for organizations that need to add map routing capabilities to their web sites. Unique symbols can be created to represent various points of interests for users. This allows users to plot and print route maps to locations within the continental United States. At the time of writing, it is only for use within these geographic limits.
- **Arc IMS** (http://www.esri.com/software/arcims/index.html) is an extension to ArcInfo that allows users to combine data from local computers with data located on remote servers. The user can create HTML and Java client versions through ArcIMS and customize client-side capabilities using object-oriented programming languages such as Java Script and Visual Basic.

Intergraph

- **GeoMedia Web Map** (http://www.intergraph.com/software/geo_map/geo_web_4.asp) reads data from a wide variety of CAD (Computer-Aided Design) and GIS formats. This is particularly useful for organizations that have and use maps in these formats and need to view them simultaneously. In addition to Intergraph formats, GeoMedia Web Map reads ArcInfo, ArcView, Oracle Spatial Cartridge/Spatial Data Option, and other formats directly. Versions to be released promise to be able to receive data from AutoCAD, MapInfo, and Structured Query Language (SQL) server data servers as well. GeoMedia Web Map delivers data to the client in a highly compressed vector format called ActiveCGM. This ensures faster delivery to the browsers. Descriptive information can also be linked to map features through standard relational database techniques to create hyperlinked features that are accessible to clients using a standard web browser. GeoMedia Web Map permits users to combine raster and vector information within the same map.
- **GeoMedia Web Enterprise** (http://www.intergraph.com/gis/) is a tool that gives access to complex spatial analysis tools using raster data. It lets users create dynamic, custom web-mapping applications to analyze and manipulate geographic data. The server software includes several sample applications that can be used for routing, crime analysis, rezoning notification, and site selection. GeoMedia Web Enterprise builds on GeoMedia Web Map to provide an entire series of spatial and network analysis objects and services that assist in the smart distribution of data over the web. GeoMedia Web Enterprise objects are designed to work with industry-standard programming languages such as Visual Basic, Visual C++, PowerBuilder, and Delphi. They can use Java-based scripting as the development environment.

Autodesk

- **MapGuide** (http://www3.autodesk.com/adsk/autoindex/0,,147398,00.html) transfers data from the server to the client as live vector data rather than raster format data. Because of this, the client can perform functions such as querying, buffering, and thematic mapping without generating a large amount of network traffic. Autodesk MapGuide runs as a service under Windows NT. The client—Autodesk MapGuide Viewer—uses Netscape API, ISAPI, and standard CGI interfaces to integrate with Netscape, Microsoft, and other web server products.

MapInfo

MapInfo (http://www.mapxtreme.com/) has two applications that are basic variations of the original MapXtreme.

- **MapXtreme NT** and **MapXtreme Java Edition** are image-based applications that function around MapInfo's MapX. In the MapXtreme Java Edition, a client-side Java Bean provides the GIS functionalities required for vector-based applications. Unlike MapXtreme NT, MapXtreme

Java Edition runs only on platforms that have a Java Virtual Machine. MapInfo's web site for MapXtreme at http://www.mapxtreme.com/software/mapxtreme/nt_vs_java.html provides a detailed comparison of the two applications.

- **MapXsite** (http://www.mapxtreme.com/mapxsite/index.html) is a stripped down version of MapXtreme but provides several of the functions that many users and developers of Internet-based GIS require. The tool allows users to identify particular locations and to generate maps locating various services and functions of interest to the user. The user can query more specific information from this database. These functions, although basic to advanced users of GIS applications, are a relatively easy to use, inexpensive, and quick way of launching a site that covers many of the basic needs of an organization considering launching an Internet-based GIS site.

CHAPTER 5:

SAMPLE IMPLEMENTATION OF AN INTERNET-BASED DECISION-SUPPORT TOOL

Once it has been decided to set up an Internet-based decision-support tool or to provide GIS functions over the Internet, several issues need to be evaluated before actually starting work on launching the Internet tool. Some technical and non-technical issues include:

- which GIS software, data, and model versions to use;
- the site capacity and hardware/software requirements to run the site;
- the core team to be involved in implementing project goals;
- the programming languages to be used;
- which web browser (e.g., Netscape or Internet Explorer) and which version to tailor the application to;
- which target audience to tailor the web site to;
- the Internet access and speed of connectivity; and
- advertising and promoting the use and access to the tool once it is functional.

An effective way to examine the issues and decisions involved in making a GIS decision-support tool/ Internet accessible is through a case study. To illustrate some of the challenges and issues involved in setting up an Internet-accessible GIS tool, we describe the development of a particular site. The reader is encouraged to visit the site, use the tool, and assess the degree to which the tool's objectives have been met (http://www.ecn.purdue.edu/runoff).

The Tool

The Long-Term Hydrological Impact Assessment (L-THIA) model provides estimates of changes in runoff, recharge, and Non-Point Source (NPS) pollution caused by past, present, or future changes in land use. L-THIA was initially developed in response to a need for a site suitability analysis tool for planners and decision-makers that was easy to use and that made use of information readily available from municipal databases (Harbor 1994). L-THIA uses the Curve Number (CN) approach to characterizing the impact that different land uses and soils have on runoff, and combines this with 30 years of local precipitation data to provide relative estimates of changes in long-term average runoff due to land use change. The L-THIA model was selected by the U.S. Environmental Protection Agency (EPA Region 5) as a potential Internet-accessible land use decision-support tool for planners, municipalities, and other professionals and organizations involved in making decisions that affect land use change within watersheds. This model was chosen because it is easy to use, is nondata intensive, and is straightforward.

Originally, L-THIA was developed as a spreadsheet model (Harbor 1994). Although data requirements were modest, they limited the use of L-THIA. To overcome some of the data requirement difficulties associated with L-THIA, Grove (1997) integrated L-THIA with a GIS tool. The L-THIA model was rewritten in the "C" programming language, and an executable program was created to run within the GIS L-THIA system. After L-THIA was run, runoff depth and volume maps were created within the GIS. Although this system simplified its application, it was still difficult for many potential users. Bhaduri (1998) simplified and extended the system by creating a user-friendly interface within ArcView GIS and adding an NPS pollution estimation capability. Lim et al (1999) enhanced this version to consider additional NPS pollutants.

The goal of the project described below was to make L-THIA available as a web-based decision-support tool, both in its simple spreadsheet format and as a GIS tool.

The Team

Assembling a complete team covering all aspects of developing an Internet-based GIS is the first step in creating a user-friendly tool. To make L-THIA Internet accessible, a team was assembled including team leaders, a model developer, and GIS and planning professionals and programmers.

Team Leaders. Team leaders are needed to provide long-term vision for project direction and to co-ordinate efforts of the team. They were essential to keep the project on track, as it is easy for individual team members to lose perspective of overall project goals.

GIS Professionals. These professionals initially converted the spreadsheet version of the model into a GIS version and then extended these capabilities to the Internet version. In the next stage, they worked with GIS software programming to make the WWW version of the model available as a download. This downloadable version is to be used as an extension within ArcView on the user's local machines and then to extend similar capabilities without it being necessary for the client to have GIS software locally or to have prior experience of GIS use.

Land Use Planners. Land use planners were included in the team to ensure that information and tasks that the decision-support tool is designed to perform are always aligned with the needs of the end user and so that the information is explained and presented in a manner that to which the end user can relate. Additionally, the planner provided feedback to the programmers and ensured that the interface being developed for the decision-support tool was intuitive, especially for users without extensive GIS experience.

Programmers. Programmers were brought in to cover the technical aspects of serving the GIS functions, data, the model, and the decision-support tool over the Internet. The programmers were responsible for writing the CGI scripts, Java Script, Java programming, and providing the interface between the server and the GIS software.

Serving the Tool Over the Internet

Programming issues: A variety of programming languages and approaches were used to create the WWW versions of L-THIA. The languages were selected based on their capabilities and strengths. The "spreadsheet" version of the model was created using HTML, Perl script, Java Script, and Java. Java Script and HTML were used to create the user interface. Perl script uses the information provided by the user to query weather data from an Oracle database and to run an executable version of the L-THIA model. Results are presented in tables, bar charts, or pie charts. The graphics are created with Java Script and Java. Care was taken to maintain compatibility between Netscape and Internet Explorer with the WWW spreadsheet version of the model. Some Java Script and Java code function differently in these browsers. To reach the maximum audience, it was desirable that the WWW spreadsheet version of the tool work in both browsers.

The ArcView Internet Map Server tool was selected as the starting point for creating a WWW GIS version of the L-THIA tool due to its ability to be extended and the availability of the existing ArcView L-THIA tool. ArcView IMS was extended using Java to create the WWW GIS L-THIA tool. Java was used to create the interface that the user interacts with and to provide an interface between the user and the ArcView GIS functionality required to run the GIS L-THIA.

For both the WWW spreadsheet and WWW GIS versions of L-THIA, a server-side approach was used in creating the WWW tools. This was used as opposed to the client-side approach because significant interaction with tools on the server was required. In both instances, the weather database is maintained in Oracle on the server. In the case of the WWW GIS tool, capabilities within the ArcView GIS are used. By using the server-side approach, these capabilities can be readily provided to the tool users.

One particularly important issue that came up when making the model available on the Internet was the variable level of familiarity that prospective clients might have with GIS functionalities and with standard GIS software. Not all clients of the site were expected to have access to digital spatial data and it was essential to consider that some users might prefer a spreadsheet version of the model. Therefore, to cater to a wider audience, including some who might not have readily available data in GIS format or may not be comfortable dealing with a GIS, three WWW-based versions of L-THIA with NPS pollution capabilities were developed. The first is a spreadsheet-like version, the second is a set of downloadable Avenue scripts that can be run within ArcView on the user's desktop computer, and the third is a WWW-based GIS version that accesses databases stored at a centralized location.

Spreadsheet Version. In the WWW spreadsheet version of L-THIA (Figure 2), the user interacts with a WWW interface written with HTML, Java Script, and Java to select the location (state and county) of the site being analyzed and to provide information about the area of each land use and hydrological soil group combination within the area of interest. The location data provided by the user are used within a CGI script written in Perl to query an Oracle database on the WWW server to obtain the long-term daily precipitation data needed within L-THIA. Thus, the user only needs to select the location of interest. They do not need to prepare a rainfall data file and other input requirements. Long-term daily rainfall data for approximately 500 locations within the continental U.S. are currently stored within the L-THIA WWW-based systems. A CGI script determines the curve number values from the land use and hydrological soil information provided by the user. Once the CGI scripts have generated the necessary information, L-THIA is run on the WWW server using the rainfall data and curve number values as input. The L-THIA-generated runoff and NPS pollution output are processed with CGI scripts, Java Script, and Java to provide WWW-based tabular and graphical representations of the model outputs.

In the L-THIA/NPS WWW interface (Figure 2), weather data for the appropriate weather station are queried from the database and reformatted for the L-THIA run (Figure 3). The user provides the area of each land use and hydrological soil group for each period of interest. Areas of land use and soil combinations can be provided for one to three time periods. For example, a user may wish to analyze the effects of historical and future land use changes. Areas

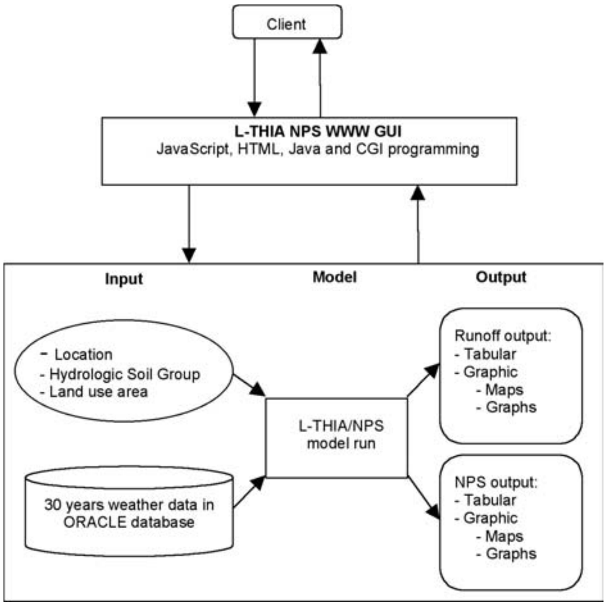

Figure 2. L-THIA/NPS WWW Overview

Figure 3. L-THIA WWW Spreadsheet Version User Interface

of unique land use and soil combinations can be provided for a past time period, as they are at present, or as they might be at some time in the future. Hydrological soil group maps can be requested from the interface for each of the 48 states in the continental U.S. These hydrological maps along with counties and major roads appear in a second WWW browser window. The user can interactively zoom to the location of interest and determine the appropriate hydrological soil group(s) to use in the analysis. The ArcView IMS was used to provide access to the soil maps and supporting data. Once the user has provided the information required by L-THIA, they select the "Run L-THIA" (Figure 2) button to run the model. L-THIA runs on the WWW server and generates a series of tables, bar charts, and pie charts for runoff and NPS pollution.

In the L-THIA/NPS WWW runoff output table, all of the information that the user provided in the input interface is listed in addition to calculated values for curve number, runoff depth, and runoff volume for each time period analyzed. Bar graphs provide runoff depth, runoff volume, total volume, and average runoff depth information. Presentation of the results in this form can often assist the user in quickly understanding model results. Land use and runoff volume for each time of interest are also provided in pie-chart form. Tabular and graphical output is also available for each of the 12 NPS pollutants considered.

GIS Version. The ArcView GIS version of L-THIA was created using a series of Avenue scripts and an executable version of the L-THIA model (Bhaduri 1998, Lim et al. 1999). This version (Figure 4) (Lim et al. 1999) was used as the starting point for the implementation of the WWW-based L-THIA GIS system. ArcView IMS and Java were used to make the core functionality of this system WWW accessible (Figure5).

The user interacts with the Java-based interface in their WWW browser that sends requests to ArcView IMS through the WWW server. ArcView IMS parses the information and executes corresponding Avenue scripts in the L-THIA GIS on the server. Once L-THIA components are run, appropriate maps are passed back to the user's WWW browser. The GIS L-THIA, and supporting data are maintained and run on the WWW server. This has many advantages for the user, but most importantly it means that the user does not need to have a GIS, L-THIA code, or data

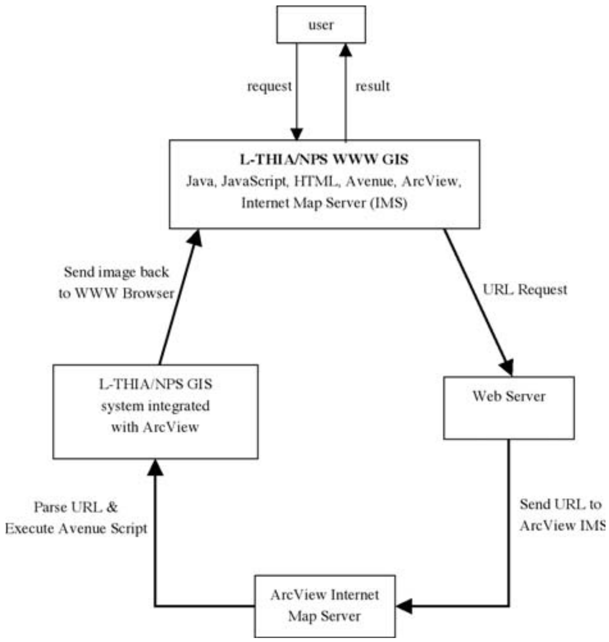

Figure 4. Serving L-THIA/NPS WWW GIS Version

on his/her computer, as this is maintained on the host server.

The ArcView L-THIA GIS application can also be downloaded from the L-THIA WWW site for use locally. To use this version of L-THIA, the user needs ArcView and ArcView Spatial Analyst on their computer. Documentation and sample data sets are also available for download with the ArcView L-THIA/NPS GIS to aid the user in utilizing the tool. Once the L-THIA extension is loaded, a set of buttons appears on the screen within ArcView that can be used to run L-THIA within ArcView (Figure 5).

To run the WWW-based L-THIA GIS version, the user simply needs to have a WWW browser on their computer. The GIS and model components run on the WWW server. The WWW interface (Figure 6) provides buttons to zoom and identify features within the maps presented in the user's WWW browser. The user can also zoom to a location of interest by selecting pull-down menus with county names for each state. The user can zoom in and digitize an area

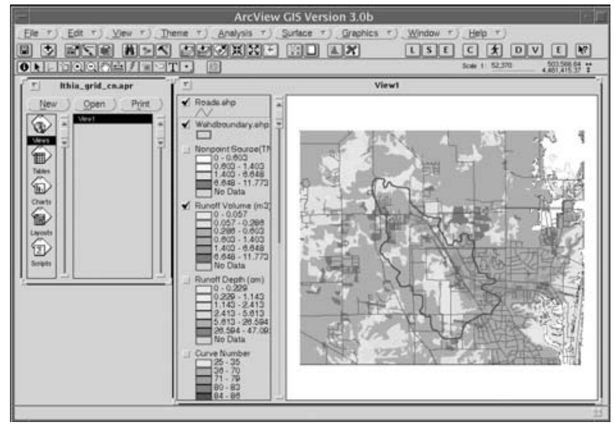

Figure 5. ArcView Interface of the L-THIA/NPS GIS

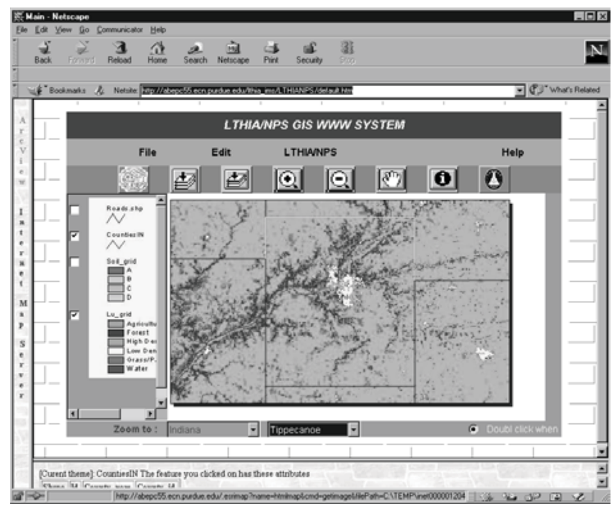

Figure 6. L-THIA WWW GIS Showing Land Use for Tippecanoe County, Indiana

of interest for an L-THIA model run. The L-THIA pull-down menu enables users to run the L-THIA model. The runoff depth function creates a curve number map and runoff depth map using the land use and hydrological soil group data for the area identified by the user. Runoff volume and NPS pollution maps are generated with the other menu selections.

L-THIA is designed for a wide range of users, from land use planners to concerned citizens. The WWW-based L-THIA GIS version has an intuitive GUI. It provides simple, easy-to-use access to the model and features drop-down menus for location, land use, and soil type.

Some prior experience with ArcView is helpful in using the ArcView L-THIA version. Introductory material available at the web site can assist the users in getting started with using the model. Detailed case studies and tutorials for both versions are available on the L-THIA homepage. Write-ups describing how to analyze model results aid users of the web-based tool to evaluate results and the relative impacts of different land use changes within watersheds. The user has the option of forwarding requests and questions to the developers for detailed answers. This helps make the site more attractive to users and integrates the model with the uses that the target audience is likely to make of the model.

The ArcView-based L-THIA tool is available at http://www.ecn.purdue.edu/runoff.

CHAPTER 6:

MAPPING AND USER INTERFACE ISSUES INVOLVED

Developing a user-friendly interface that is intuitive for the end user to obtain information from and use in the manner that the tool was intended requires attention to several factors. In the case of the WWW-based L-THIA GIS tool, the team developed an initial version of the tool. This was then presented to a wide variety of test users ranging from students, professional planners, environmental scientists, and audiences at conferences. The feedback from such interactions was used to improve the site and make it more user friendly. A series of supporting documents in the form of background information and walk-through examples of using the tool were developed to assist the user in simulating L-THIA results.

Although using the Internet and spatial information in the form of maps is intuitive for many persons, the combination of using spatial information and accessing GIS functions through the Internet is initially daunting to most potential users. Presenting GIS functions and capabilities to users who have never previously been faced with such information is a particularly challenging task.

Simply reproducing the interface of a traditional desktop GIS within an Internet browser is the easiest approach and appeals to users already familiar with GIS, but does not necessarily work well for the general public. The majority of the clientele of an Internet-based GIS or decision-support tool do not have prior experience using such software. This makes the task of serving such functions very different. A decision to use the site is based on the usefulness of the tool and the ease with which the user can work out how to use the site. Thus, Internet GIS has several new challenges compared to traditional GIS software, including a lack of prior experience in the users, space and time constraints, and to some extent different requirements for visual appeal. Good designers take these concerns into account when designing user interfaces for the Internet (Lowe 1999).

The GIS novice using the Internet may not be familiar with GIS terms and capabilities. Techniques such as map overlay, buffer analysis, and geocoding need to be simplified and presented in a user-friendly graphical interface (Figure 7).

Users without formal GIS training who access sites providing GIS functions for the first time must be able to easily identify functions and capabilities and to manipulate the spatial data with ease. The clients who are expected to use the web-based tool are the most

Figure 7. Popular Website Used for a Variety of GIS-Based Decision-Making

important factor to be considered when designing a GUI. Decisions such as the familiarity of the likely audience to GIS terminology such as pan, scale, co-ordinates, layer, rectification, or digital terrain model (DTM) are factors in deciding whether to use icons instead of these technical terms. In the case of WWW-based L-THIA/NPS GIS, icons were used to provide GIS functions such as zoom in, zoom out, pan, and go back to the original data layer and the last displayed layer (Figures 8 and 9).

New users often face a steep learning curve when first using spatial data. Analysis techniques common in GIS are significantly different from other types of analysis. Users need to familiarize themselves with the command structure and nomenclature of GIS. When a user accesses an Internet-based GIS, knowledge of data coverage, structure and support systems should not be required. This does not help in attracting new users to web sites that have not looked after and solved such issues.

To assist users in effectively obtaining results from the decision-support tool, links are provided to

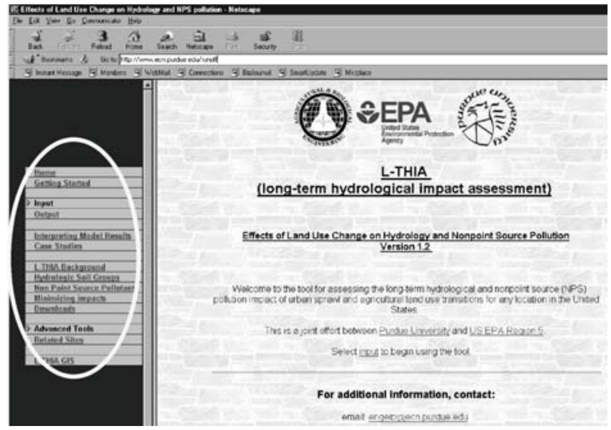

Figure 8. Information to Assist Users

background-related information on using the tool; additionally, case studies have been developed and presented as a series of worked-out examples. This has been further modified based on responses received from users. Giving the user the option of contacting the team that developed the decision-support tool is mutually beneficial. It presents the user with an opportunity to clarify any questions, doubts, or issues, and it provides the developers with beneficial feedback and a view of user requirements.

Web sites that make use of intuitive symbols instead of text to explain GIS functions such as overlay, buffer, pan, and zoom will attract users from a wider section. The EPA has large amounts of spatial data available on its web site (http://www.epa.gov). Users can query the location of environmental interest such as hazardous waste sites, toxic release sites, and superfund sites by simply clicking layers on and off (Figure 9). Users can also locate schools, hospitals, churches, and other facilities by zooming into areas of interest.

User feedback is essential in designing and maintaining a good site. Providing the user with the opportunity to offer feedback helps keep the site attractive and easy to use. Interactive sites are generally perceived to be more attractive (Figure 7). The speed of performance is also valued highly by users of web-based GIS tools (Doyle et al 1998).

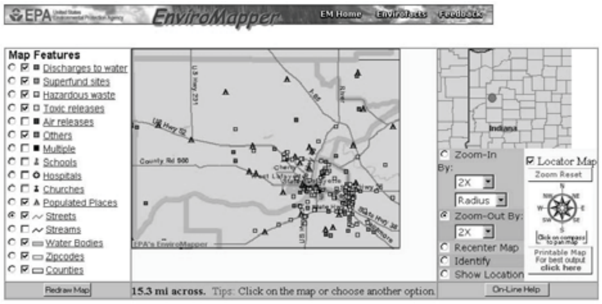

Figure 9. EPA's Website Serving Spatial Data (http://www.epa.gov)

A well-designed web site anticipates errors likely to be made by users, realizes the time it takes to load particular pages, and designs the GUI accordingly. Care needs to be taken regarding the size of displays. Most programmers and GIS professionals who are designing the site work use high-end computers with exceptionally large screens and, therefore, design the GUI accordingly. Most users, particularly for tools that are targeted to home audiences and small organizations, do not have similar facilities at home and scrolling left and right and up and down is not always the most convenient proposition.

CHAPTER 7:
CONCLUSIONS

Making decision-support tool and GIS capabilities Internet accessible has many advantages for the providers and the users of such facilities. These include financial savings for the user and provider, ease of access and learning, and ease of access to information; this encourages participation in the process, creating a more democratic process of decision-making. The advantages of shared knowledge and data have been extensively discussed and their merits well established. The growth in this industry has been phenomenal in the last decade and with more applications being developed in this and related fields there will likely be a phenomenal growth in its use in everyday life by persons who might not already be using Internet-based GIS and decision-support tools.

This Quick Study outlines some of the advantages and the issues involved in developing and implementing an Internet-based spreadsheet and GIS decision-support tool. However, there are rapid increases in technology and growth in this field and this must be kept in mind when designing and implementing GIS and decision-support tools that are Internet-based. Each tool is unique in the manner in which it can be implemented and made operational. Issues such as design of user interface and making the tool intuitive to use and as user friendly as possible are general requirements and are not likely to change significantly with changing technology and facilities available to serve such tools.

LIST OF FIGURES

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TABLE OF INTERNET GIS TERMINOLOGY

This section is provided to the user as a quick reference for words found in the field of Internet technology and Geographic Information Systems.

ActiveX was developed by Microsoft; it allows users to interact with remote computer hard drives and files. Netscape does not support ActiveX at this point and it can be turned off in Microsoft Internet Explorer.

Applet is a small downloadable Java application that runs within a web page and creates special effects.

Bandwidth is the amount of information transferred within a specified period and is dependent on the speed of the modem or Internet connection.

Browser is an application that allows users to use the Internet. The most popularly used browsers are Netscape and Microsoft Internet Explorer.

CGI (Common Gateway Interface) is a World Wide Web programming script that facilitates the interaction between web browsers, servers, and other data and applications such as GIS software.

CORBA (Common Object Request Broker Architecture) allows programs at different locations and developed by different vendors to communicate in a network through an interface broker. CORBA serves as an interface between the client and the background application much like CGI.

DGI (Distributed Geographic Information) as proposed by Plewe (1997) refers to the widespread distribution of geographic information to a larger audience than those who have access to traditional desktop GIS.

DNS (Domain Name Server or Service) is an Internet service that translates the names of computers and the Internet names of businesses and organizations to the Internet Protocol (IP) number that the Internet uses to actually identify each computer.

Domain name is a unique name of a particular Internet site (e.g., www.purdue.edu)

Firewall is a security measure taken by companies to keep out any unwanted intruders. It protects the resources of a private network from users from other networks.

FTP (File Transfer Protocol) is one of the applications that run on the Internet. This allows the user to upload and download files from one computer to another.

Gopher is a menu-oriented hierarchical way of organizing and retrieving information, made somewhat obsolete by the World Wide Web. Gopher client software, graphical or text-based, is used to navigate up, down, and across local and global resource lists.

GUI (Graphical User Interface) refers to a software front-end meant to provide an attractive and easy-to-use interface between a computer user and application.

HTML (Hyper Text Markup Language) is a format that tells a computer how to display a particular web page. The documents themselves are plain text files (ASCII) with special "tags" or codes that a web browser knows how to interpret and display on the screen. It consists of tagged text, which is displayed to the reader. The tags to the text tell the browser how to format the text and provides information regarding page layout, graphics, text fonts, text/background color, and hypertext links.

http (Hyper Text Transfer Protocol) is a protocol for moving hypertext (typically web pages and documents) over the Internet.

hypertext is text that contains "links" to other documents - words or phrases in the document that can be chosen by a reader and which cause another document to be retrieved and displayed.

Internet is a world-wide collection of computers, networks, and client computers, linked by Transmission Control Protocol/Internet Protocol and associated protocols.

Intranet is an organizational network connecting internal users with internal network, computing, and data resources.

IP (Internet Protocol) is the "language" that computers connected to the Internet use to communicate with each other.

IP Number is a 32-bit number used to uniquely identify every computer connected to the Internet. Usually expressed as four groups of numbers, each ranging from 0 to 255 (e.g., 208.4.210.2).

Java is an object-oriented, popularly used, programming language developed by Sun Microsystems. It is platform-independent and can run on UNIX, Windows, or Macintosh; it provides a common interface for all computer platforms.

Java Script was developed by Netscape to provide scripting on web pages. Where a Java applet is compiled, the browser interprets the Java Script at the time of download. Browsers that understand Java Script will perform various dynamic changes to the web pages. Many web sites now require Java- and Java Script-enabled browsers.

Protocol is a specific method of communication or "language" that allows computers or software programs to "talk" to each other to exchange information or data.

Query is a request for information from a database.

SDTS (Spatial Data Transfer Standard) is a standard set by the U.S. government to promote and facilitate the transfer of digital spatial data between dissimilar computer systems, while preserving information meaning and minimizing the need for information external to the transfer.

Server is a computer that provides information to other computers on a network or the Internet (e.g., a web server provides text as graphics files to web browsers running on client computers).

TCP (Transmission Control Protocol) is the major transport protocol in the Internet suite of protocols providing reliable, connection-oriented, full-duplex streams.

TCP/IP (Transmission Control Protocol/Internet Protocol) is a fundamental protocol that carries all Internet traffic for protocols such as File Transfer Protocol, Telnet, Gopher, and Web.

URL (Uniform Resource Locator) is the addressing system used in the World Wide Web and other Internet resources. The URL contains information regarding the method of access, the server to be accessed, and the path of any file to be accessed (e.g., **http://www.ecn.purdue.edu/~runoff** is an URL).

VRML (Virtual Reality Modeling Language) is used to serve three-dimensional information over the Internet using a VRML browser. In recent years, the potential for visualizing urban spaces, elevation information, surface conditions, and other similar applications has found widespread use in planning and community participation processes over the Internet.

Web Browser (World Wide Web browser), which connects over the Intranet or Internet to web servers, retrieves information in the form of home pages and displays ("render") material according to imbedded HTML tags.

Web Hosting is a set of services provided by a company. The company provides space on their computers for businesses and individuals to put their web pages on. Many small companies do not need the expense involved or have the extensive time necessary to host their own web pages and use the services provided by such a company.

Web Server is a program that accepts requests from web browsers and delivers ("serves up") appropriate documents ("home pages") and other files such as images, video, and Java applets.

World Wide Web (WWW) is a networking application that runs on the Internet. It is an easy but powerful global information system, based on a combination of information retrieval and hypertext techniques.

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