Evaluating Conservation Practices Using GIS and Virtual Reality Modeling Language

Troy J. Lively* and George F. Czapar

ABSTRACT

In order for conservation practices to be installed most effectively, watershed planners need to consider numerous factors such as hydrology, topology, and farming practices. Flat maps, however, may not give decision-makers sufficient perspective to determine the best location for a particular conservation practice. Geographic information systems (GIS) and virtual reality modeling language (VRML) can be used to generate a three-dimensional environment for a watershed. This view identifies spatial relationships in the watershed and can help direct the planning, installation, and maintenance of conservation practices. This paper explains the usefulness of VRML in the promotion of properly placed best management practices (BMPs). A three-dimensional environment for the Lake Springfield Watershed, in central Illinois, was created using GIS and VRML. A 30-m resolution digital elevation model (DEM) was utilized as the base for creating the topological layer for the three-dimensional environment. Other spatial points of interest included slope, land use, hydrology, soil type, roads, and cropping type. An additional benefit of viewing an environment in three-dimensions is that it provides watershed groups with a visual inventory of existing BMPs. This can be used to highlight conservation achievements and demonstrate the need for additional efforts.

THE three-dimensional computer environment is an innovative and useful way to look at natural resource conservation. This environment lends itself to viewing the installed practice with the "lay of the land" and potential locations for highly effective best management practices (BMPs). Proper placement of BMPs is important to conserve soil, improve water quality, and reduce unwarranted costs for an ineffective practice. Placing data in a three-dimensional view improves perception to viewers and may aid in demonstrating the need for additional BMPs.

Three-dimensional viewing of real-world phenomenon gives researchers and decision-makers a perspective not seen with flat maps. Virtual reality modeling language (VRML) makes this type of visualization possible. Viewing the location of a grass buffer strip near a stream on a flat map may give the viewer a perception of a properly installed BMP. When viewed in the three-dimensional environment, the grass buffer strip may not be as effective due to the steepness of slope leading to the stream. In this case, the three-dimensional environment aids in determining the suitability of the installed BMP and what other alternatives should be explored.

Virtual reality modeling language is an effective visualization tool for many different types of spatial relationships and features. MacArthur and Olson (2000) studied the application of VRML in a higher education curriculum. They found that students enjoyed learning from this type of visualization and obtained as much information as in traditionally taught courses. Virtual reality modeling language allows the user to explore the virtual environments from different perspectives and help identify spatial relationships. Grunwald et al. (2000) utilized VRML to view soil landscape models and suggested application for environmental assessment studies, water quality simulation modeling, and site-specific management. In addition, Geographical Information System (GIS) may complement VRML with its spatial database and georeferencing capabilities. The presentation of spatial information may be accomplished much more effectively with the use of three-dimensional environments and GIS compared with that of a flat map style (Dickison and Greenwell, 2000; O'Toole et al., 2000). The USEPA has also utilized VRML for interactive exploration of their geographically spatial data sets (Rhyne and Fowler, 1998). The USEPA has developed some examples of the VRML-converted databases at their GIS-Vis Integration website (available at: http://www.epa.gov/gisvis; verified 22 Apr. 2002) (USEPA, 2000).

The Lake Springfield Watershed is an area covering approximately 71 600 ha. southwest of Springfield, IL (City, Water, Light, and Power, 1992). The watershed is predominately cropped in corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] rotations covering approximately 90% of its area. Water quality research has been performed on this watershed for several years, aiding in the identification of main source areas of nonpoint-source pollution. A three-dimensional environment of the watershed was created to highlight BMPs and their benefits, and to promote properly placed BMPs in vulnerable areas.

MATERIALS AND METHODS

The three-dimensional environment for the Lake Springfield Watershed was created using Environmental Systems Research Institute's (ESRI) ARC/INFO 8.01, ARC TIN, ARC GRID, and ArcView with 3D Analyst and Spatial Analyst extensions (ESRI 2000a, 2000b, 2000c, 2000d, 1999a, 1999b, 1997, 1996). Though most of the process of displaying and creating the three-dimensional environment can be done with ArcView and its two extensions (3D Analyst and Spatial Analyst), ARC/INFO, ARC TIN, and GRID are powerful tools that manipulate raw data that may be imported into ArcView. Once created, the three-dimensional world may be exported to VRML and served on the Internet, which enables interested parties with a VRML browser to explore the watershed and

T.J. Lively, Sangamon County Soil and Water Conservation District, 40 Adloff Lane, Suite 7, Springfield, IL 62703; and G.F. Czapar, Univ. of Illinois Extension, Springfield Center, P.O. Box 8199, Springfield, IL 62791. Received 4 Jan. 2001. *Corresponding author (troy@ilspringfi.fsc.usda.gov).

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Abbreviations: BMP, best management practices; CAVE, automatic virtual environment; DEM, digital elevation model; ESRI, Environmental Systems Research Institute; GIS, geographic information system; GPS, global positioning system; HEL, highly erodible land; TIN, triangulated irregular network; VRML, virtual reality modeling language.

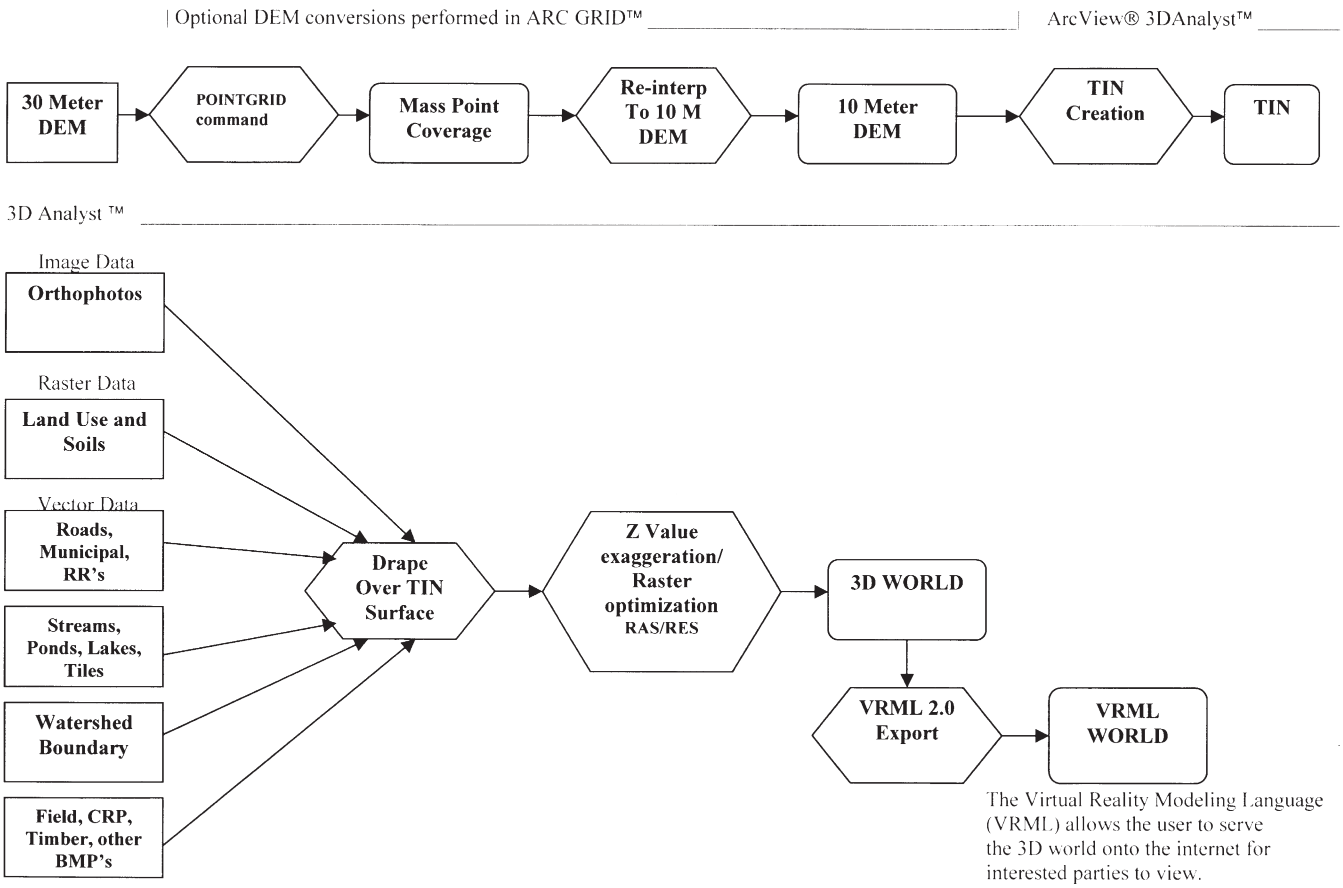

Fig. 1. Flow diagram for the creation of a three-dimensional environment and VRML world.

its points of interest. The process is illustrated by a flow diagram in Fig. 1.

There are a number of freeware and shareware VRML browsers available on the Internet. The Cortona VRML browser from Parallel Graphics (Parallel Graphics, 2000) was utilized for this project, but users may choose the browser that best suits their needs. The VRML Repository hosted by Web3D Consortium (Web3D Consortium, 2000) is an excellent website for VRML information including software, links, and sample worlds.

A 30-m resolution Digital Elevation Model (DEM) (Fig. 2) was utilized as the base for creating the topological layer for the three-dimensional environment. Digital Elevation Models of this standard may be downloaded at no cost from the U.S. Geological Survey website (USGS, 2000). Though the small scale (1:250 000) DEM is a viable option for the creation of topography in a large area, such as a watershed, a point survey of a smaller area from sources such as a global positioning system (GPS) or a total station may prove to be more accurate and usable when working with BMPs in a field-by-field basis. The DEM has the ability to be re-interpolated to a finer resolution using ARC GRID. The DEM may then be used to create a Triangulated Irregular Network (TIN) of the watershed (ESRI, 2000a, 2000b, 2000c, 2000d).

The TIN model (Fig. 3) is a representation of a surface created from a set of mass points from which triangles are formed. The triangles form a continuous surface and store topological information about neighboring triangles (Zeiler, 1999). The triangles form the base from which other data will be draped. Draping layers onto the TIN is similar to draping a sheet onto an object. The sheet covers the object, but the shape of the object is still identifiable.

The TIN may be added to ArcView 3D Analyst in a three-dimensional view. Additional layers may now be created and/or imported into ArcView 3D Analyst and draped onto the TIN (Fig. 4). The layers may need property manipulation to produce the desired effect. A "Z" value exaggeration may be added to increase the relief effect of the phenomenon. (Example: The Lake Springfield Watershed is particularly flat and by adding a vertical exaggeration factor the topographical variations became more obvious.)

Assessing what factors influence BMP effectiveness determines what layers need to be present in the three-dimensional environment. In determining the effectiveness of certain BMPs, the location of each BMP was examined relative to other spatial points of interest: slope, land use, hydrology, soil type, roads, and cropping type. Each of these layers has varying weighted influence on determining if a BMP is properly installed and whether one is needed. Some layers may be highlighted or emphasized in the final three-dimensional world; for example, highly erodible land (HEL) is highlighted in Fig. 5. Once the desired layers have been draped onto the TIN and the legends have been edited, the three-dimensional world may then be exported into a VRML 2.0 format. This option allows the user to serve the three-dimensional world onto the Internet for exploring (Fig. 5).

This newly created three-dimensional environment is navigable by users who have access to a PC with an Internet browser and VRML plug-in, and is accessible to parties interested in the watershed.

RESULTS AND DISCUSSION

Although the 30-m DEM provides a good topographical base layer for the entire watershed, it does not lend itself to large-scale field-size areas (1:3 000 to 1:10 000) due to its resolution (30 m). A mass point file converted to a DEM of a field or small study area would be much more effective for deriving slope and topography. Another concern is the accuracy of source data. The DEM must have the highest possible resolution for the study area of concern, as do the other layers. The other layers should be of the same projection as the DEM and should line up with the features they represent. Digitizing these layers on-screen utilizing a digital orthophotograph as the background is an effective way of lining features up properly.

Some difficulties may be experienced when utilizing the GIS platforms ARC/INFO, ARC TIN, and GRID due to their complexities. An inexperienced GIS user may find it difficult and time consuming to work with the programs' principles and commands. The user may find that ArcView with 3D Analyst performs the data manipulation that is needed. The ArcView program with 3D Analyst and Spatial Analyst extensions is a very user-friendly program with drop-down windows as opposed to command lines used to perform functions. Changing properties in 3D Analyst may be necessary to display the desired relationships in the three-dimensional world. 3D Analyst allows the user to change transparency, vertical exaggeration, background color, sun angle, and other properties. Other difficulties may be encountered when adding more advanced features to the three-dimensional VRML product, such as anchors and links to other sites. Given the cost of Arc View 3D Analyst, each user may not have access to the software. Virtual reality modeling language addresses this by allowing a three-dimensional environment, which only requires that the user have access to a web browser and the Internet.

Another benefit to the three-dimensional environment created by 3D Analyst is the program's ability to export the three-dimensional world into a VRML 2.0 form. This option allows the user to offer the three-dimensional data on the Internet for viewing. This is very CPU-intensive and may require a large amount of storage space depending on the three-dimensional environment size and graphics. A VRML programmer may also add VRML world links or anchors to objects in the three-dimensional environment. These anchors direct the VRML browser to perform actions such as playing sound byte or movie files, displaying a picture, or linking to another VRML world or web page. These can be programmed using a simple text editor (Ames et al., 1997).

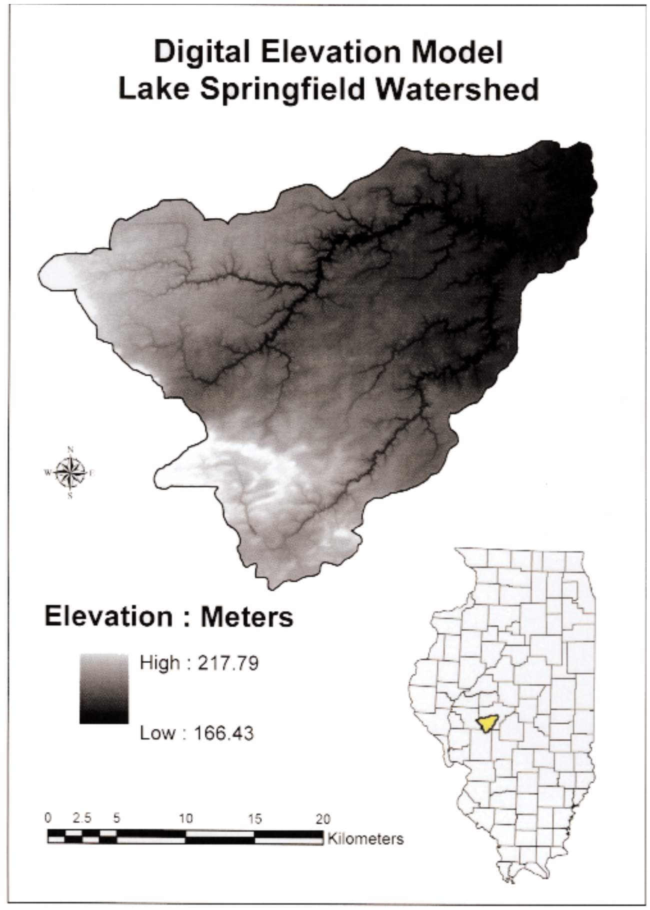

Fig. 2. Digital Elevation Model (DEM) of the Lake Springfield Watershed in Illinois. Elevations are represented by varying shades of black. The approximate center of watershed is 89.7992°W long and 39.6388°N lat.

The VRML world is an appropriate venue to display a three-dimensional environment serving on a kiosk or the Internet for presentations to interested parties. The VRML format environment also works with an Automatic Virtual Environment (CAVE) display (Johnston and Reetz, 2000), which is gaining popularity for display at museums and research facilities. Viewing the virtual world immersed in sound and images gives users exploring the virtual world a more realistic experience. The three-dimensional environment also allows the running of hydrological and other environmental models. Though some of these models may not be linked to ArcView 3D Analyst, their results may be imported into a three-dimensional scene to aid in decision-making and assessment.

One final benefit of this technology is that it provides watershed groups with a visual inventory of BMPs. It can be used to highlight conservation achievements and justify the need for additional efforts.

SUMMARY

This technique for viewing an environment in three-dimension may be a tool for researchers interested in environmental spatial relationships and conservation specialists working with the planning, installation, and maintenance of conservation practices. Watershed groups may also find interest

Fig. 3. Triangulated Irregular Network (TIN) of the Lake Springfield Watershed. Not scalable due to software limitations. The approximate center of watershed is 89.7992°W long, 39.6388°N lat.

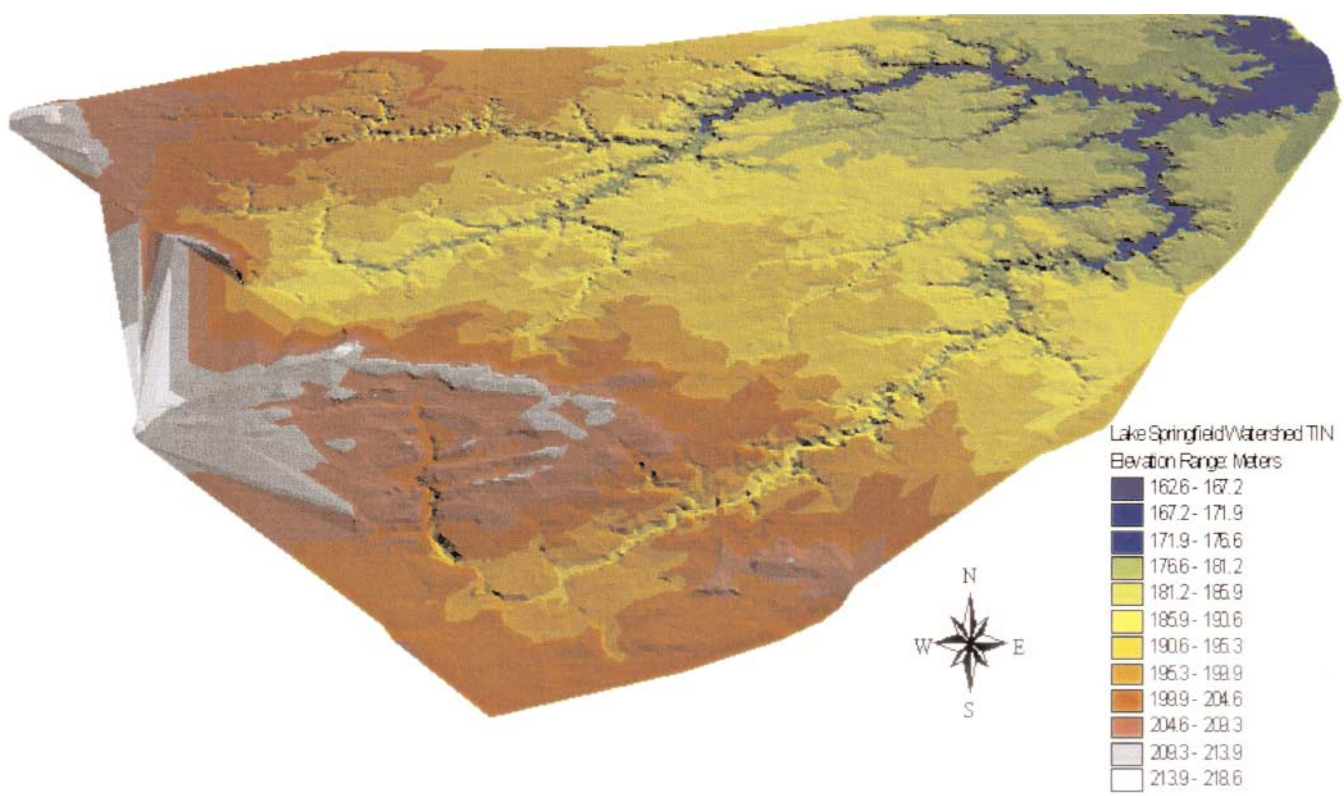

Fig. 4. Surface drape over a triangulated irregular network (TIN) of the Lake Springfield Watershed. Elevations are represented by varying shades. Not scalable due to software limitations. The approximate center of watershed is 89.7992°W long, 39.6388°N lat.

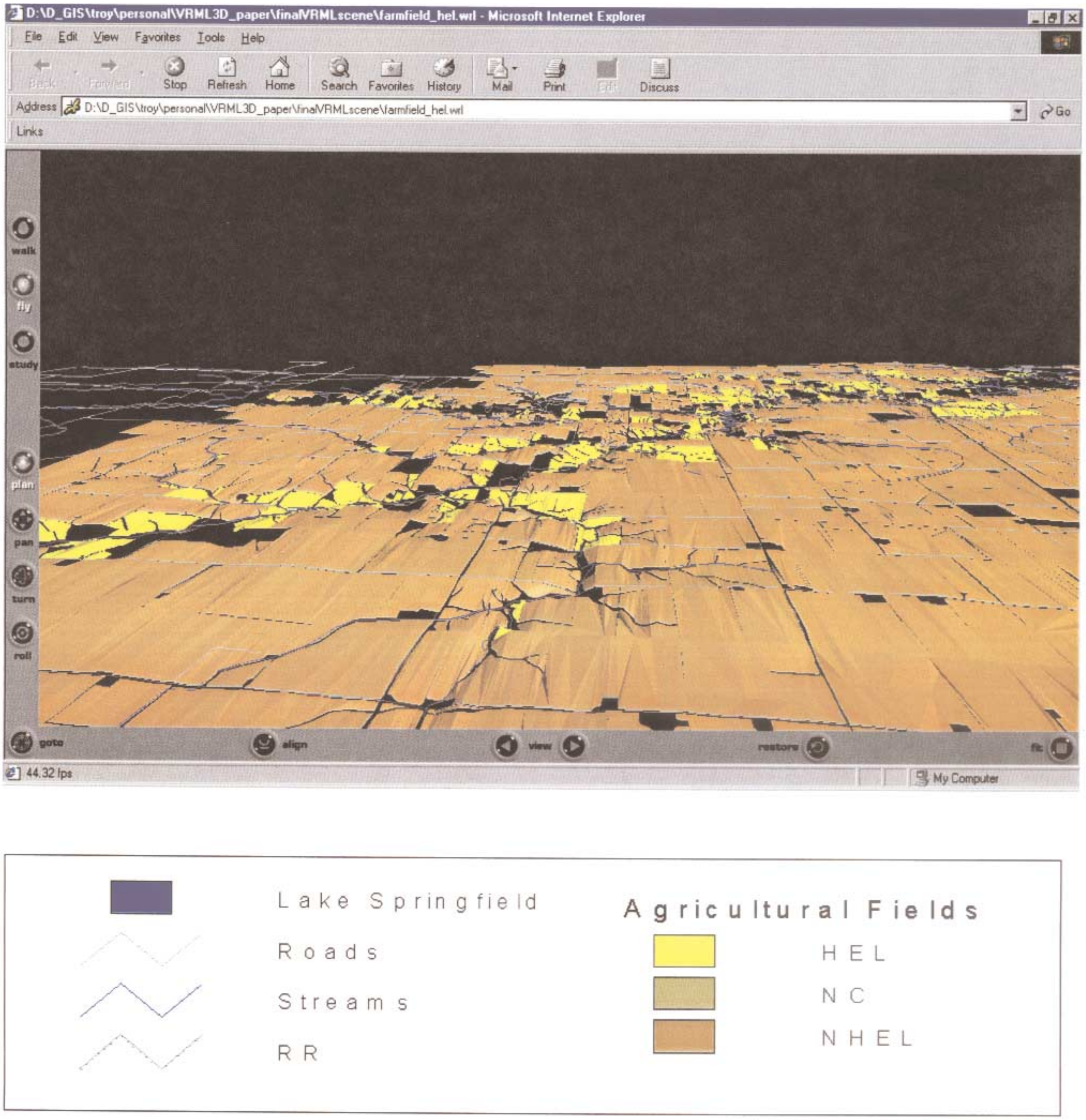

Fig. 5. Virtual reality modeling language browser plug-in with Microsoft Internet Explorer. Highly erodible land, HEL (highlighted in yellow), identified in the Lake Springfield Watershed. Looking Northwest from the Southern Tip of the Watershed. The approximate center of watershed is 89.7992°W long 39.6388°N lat. NC = not cropped and NHEL = nonhighly erodible land.

in this technique for locating and prioritizing areas of concern in a watershed and demonstrating a need for conservation efforts.

Conserving our natural resources is important for our future. By utilizing current technologies such as GIS, VRML, and the Internet, we may be able to further promote natural resource stewardship.

REFERENCES

Ames, A.L., D.R. Nadeau, and J.L. Moreland. 1997. The VRML 2.0 sourcebook. John Wiley & Sons, New York.

City, Water, Light, and Power. 1992. Lake Springfield ecology and management: A Leaseholder and community guide. City of Springfield, Springfield, IL.

Dickison, S.E., and L.T. Greenwell. 2000. The integration of GIS with 3D/animation software for presentations to local government [Online]. [11 p.] Proc. Annu. ESRI Int. User Conf., 20th, San Diego, CA. 26–30 June 2000. Available at http://www.esri.com/ library/userconf/proc00/professional/papers/PAP395/p395.htm (accessed 20 Apr. 2001; verified 26 Feb. 2002). ESRI, Redlands, CA.

Environmental Systems Research Institute. 1996. Using the ArcView Spatial Analyst: Advanced spatial analysis using raster and vector data. ESRI, Redlands, CA.

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Environmental Systems Research Institute. 1997. Understanding GIS: The ARC/INFO method. ESRI, Redlands, CA.

Environmental Systems Research Institute. 1999a. ArcView GIS. Release 3.2. ESRI, Redlands, CA.

Environmental Systems Research Institute. 1999b. Using ArcView 3D Analyst: 3D surface creation, visualization, and analysis. ESRI, Redlands, CA.

Environmental Systems Research Institute. 2000a. ArcDoc. Release 8.02. ESRI, Redlands, CA.

Environmental Systems Research Institute. 2000b. ARC GRID. Release 8.02. ESRI, Redlands, CA.

Environmental Systems Research Institute. 2000c. ARC/INFO. Release 8.02. ESRI, Redlands, CA.

Environmental Systems Research Institute. 2000d. ARC TIN. Release 8.02. ESRI, Redlands, CA.

Grunwald, S., P. Barak, K. McSweeney, and B. Lowery. 2000. Soil landscape models at different scales potratyed in virtual reality modeling language. Soil Sci. 165:598–615.

Johnston, D., and W. Reetz. 2000. 3D visualization of geographic data using the CAVE [Online]. Available at http://www.gis.uiuc.edu/research/hpgis/cave.html (accessed 20 Apr. 2001).

MacArthur, R., and A. Olson. 2000. Building landscape visualizations for instruction [Online]. [10 p.] Proc. Annu. ESRI Int. User Conf., 20th, San Diego, CA. 26–30 June 2000. Available at http://gis.esri.com/library/userconf/proc00/professional/papers/PAP607/p607.htm (verified 22 Apr. 2002).

O'Toole, B.E., M.B. Fletcher, and R. Banks. 2000. The integration of Arc View/3D Analyst and 3D simulation technologies for interactive visualization of urban environments [Online]. [11 p.] Proc. Annu. ESRI Int. User Conf., 20th, San Diego, CA. 26–30 June 2000. Available at http://gis.esri.com/library/userconf/proc00/professional/papers/PAP969/p969.htm (verified 22 Apr. 2002).

Parallel Graphics. 2000. Cortona VRML browser software [Online]. [2 p.] Available at http://www.parallelgraphics.com (accessed 20 Apr. 2001; verified 26 Feb. 2002). Parallel Graphics, New York.

Rhyne, T.M., and T. Fowler. 1998. Geo-VRML visualization: A tool for spatial data mining [Online]. [4 p.] Available at http://www.geovista.psu.edu/icavis/Publications/rhyne98.html (accessed 18 Apr. 2001; verified 26 Feb. 2002). USEPA, Washington, DC.

U.S. Environmental Protection Agency. 2000. Geographical information systems visualization [Online]. [2 p.] Available at http://www.epa.gov/gisvis (accessed 25 Apr. 2001; verified 22 Apr. 2002). USEPA, Washington, DC.

U.S. Geologic Survey. 2000. USGS geographic data download [Online]. [4 p.] Available at http://edc.usgs.gov/doc/edchome/ndcdb/ndcdb.html (accessed 10 Oct. 2000; verified 26 Feb. 2002). USGS, Reston, VA.

Web3D Consortium. 2000. The Web3D Repository? [Online]. [2 p.] Available at http://www.web3d.org/vrml/vrml.htm (accessed 10 Oct. 2000; verified 26 Feb. 2002).

Zeiler, M. 1999. Modeling our world: The ESRI guide to geodatabase design. Environmental Systems Research Inst., Redlands, CA.

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