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Interactive topographic web mapping using scalable vector graphics

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INTERACTIVE TOPOGRAPHIC WEB MAPPING

USING

SCALABLE VECTOR GRAPHICS

A Thesis

Presented to the

Department of Geography-Geology

and the

Faculty of the Graduate College

University of Nebraska

in Partial Fulfillment

of the Requirements for the Degree

Master of Arts

University of Nebraska at Omaha

by

Peter Pavlička

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INTERACTIVE TOPOGRAPHIC WEB MAPPING USING

SCALABLE VECTOR GRAPHICS

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University of Nebraska, 2003

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Abstract

Large scale topographic maps portray detailed information about the landscape. They are used for a wide variety of purposes. USGS large scale topographic maps at 1:24,000 have been traditionally distributed in paper form. With the advent of the Internet, these maps can now be distributed electronically. Instead of common raster format presentation, the solution presented here is based on a vector approach. The vector format provides many advantages compared to the use of a raster-based presentation. This research shows that Scalable Vector Graphics (SVG) is a promising technology for delivering high quality interactive topographic maps via the Internet, both in terms of graphic quality and interactivity. A possible structure for the SVG map document is proposed. Interactive features such as toggling thematic layers on and off, UTM coordinate readout for x, y, and z (elevation) were developed as well. Adding this type of interactivity can help to better extract information from a topographic map. A focus group analysis with the online SVG topographic map shows a high-level of user-acceptance.

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1. Introduction

1.1 Nature of the Problem

The Internet has proven to be a phenomenal communication technology, bringing about new possibilities to distribute, share, and access information. For cartography, the Internet not only offers new tools for the distribution of spatial data but also offers new ways to present spatial data. These "web maps" can be delivered through the Internet in various ways. The most common are static cartographic representations, such as scanned maps; however, interactivity or other multimedia features can be successfully added to improve the communication between the map maker and viewer.

The GIS community also naturally began to utilize the Internet to develop Internet GIS and other Internet-based applications for distributing and interactively processing geographic information. Both cartographers and GIS professionals have learned that the distribution of maps and spatial data over the Internet is not a trivial issue and involves many serious considerations. The graphic quality of the web maps is one such issue.

Many maps currently available via the Web lack the graphic quality of their paper counterparts (Ysakowski and Neumann 2002, Kraak and Brown 2001). In many cases, the lack of quality of maps on the Web is related to the raster format used to present them, as can be seen in the two depictions of a topographic map in Figure 1.1

Raster formats have a number of disadvantages for presenting maps. They are scale dependent and it is not possible to associate multiple attributes with a map object.

The vector format provides an improved graphic quality through scalability and the

potential for extensibility (enhancement with other technologies) that cannot be
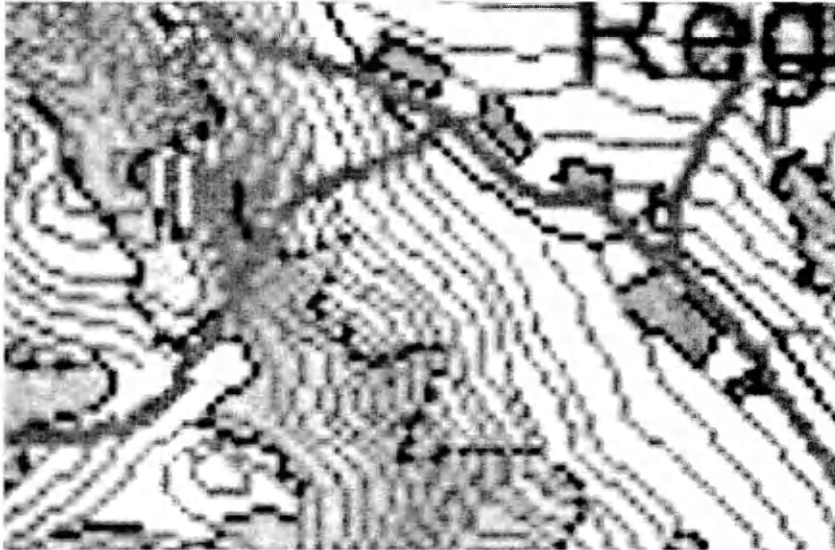
a) topographic map in raster format
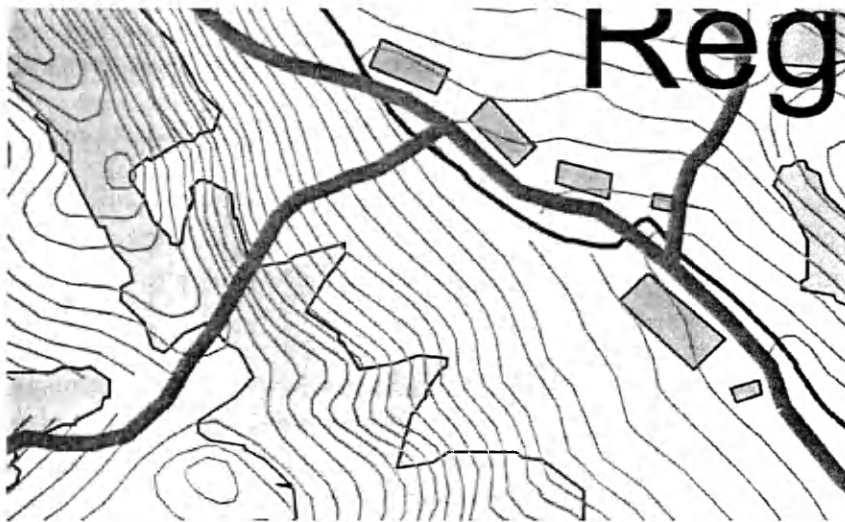
b) topographic map in SVG (vector) format

Figure 1.1: Comparison of a portion of a topographic map in both raster and vector format. The file sizes are the same.

obtained in a raster representation. This is not to suggest that raster maps will not continue to play an important role in the delivery of spatial information, it is just that data-driven components are better delivered using a vector format. Simply stated, vector graphic elements keep their quality and always lead to sharp, crisp displays, and can include more than just their geometric attributes. Not only is the graphical reproduction increased significantly by using vectors, but also the manipulation of spatial data is more enhanced with vector objects like interactivity, analysis, and screen-related functions such as zooming and panning, etc. (Neumann and Winter, 2001).

A new, promising vector format called SVG (Scalable Vector Graphics) was introduced in 1999 and may bring new possibilities for the distribution of maps through the Web (Neumann and Winter, 2001). SVG is a completely open standard recommended and developed by the World Wide Web Consortium (W3C). It is a standardized XML (eXtensible Markup Language) language for describing 2D graphics via vector graphics, text and raster graphics, and it also facilitates interactivity, animation and other multimedia functions.

Most of the maps available through the Web are small general reference maps or thematic maps (Kraak and Brown, 2001). Although there are some implementations for the large scale topographic maps in raster format on the Internet, such as from Topozone.com, the cartographic quality and interactivity leaves much to be desired. SVG may provide the solution to bringing this map type to the Web at an acceptable graphic quality, as in Figure 1.1

1.2 Research Objectives

This thesis has two main objectives: *First*, to explore the possibility to distribute USGS 1:24,000 vector-based topographic web maps through the Internet, considering problems with file size (downloading time) and the overall cartographic quality (graphics, accuracy, etc.). *Second*, to construct an interactive web-based version of a USGS 1:24,000 topographic map that would implement specific functions using SVG and other open standard scripting languages, such as ECMAScript (JavaScript). This online interactive map will be tested with a focus group to determine its usability and how well it can serve as an online topographic map.

1.3 Hypotheses and Rationale

Hypotheses

First, SVG is a suitable format for the distribution of USGS vector-based topographic maps through the Internet in terms of graphic quality and a reasonable file size. A "reasonable" file size in this case refers is defined as a file that downloads and displays quickly, within a matter of seconds.

Second, intuitive embedded interactive elements within the SVG map can be used for analytical purposes to better extract geographic information from a topographic map. The intuitive nature of these tools and the overall cartographic quality of the map will be tested through a focus group analysis.

Rationale

The explanation of the first hypothesis is relatively simple. It has been shown that while the cartographic quality produced by SVG is high (Neumann 2003, see also Figure 1 - raster vs. SVG vector graphics), it can produce large files which may not be suitable for distribution through the Internet. A digital topographic map, which consists of several main categories of map features (layers), contours, hypsometry, land cover, waters, etc., consists of many vectors. The file size of a digital map increases with the increasing number of vectors. Transmission time, depending on the Internet connection speed, for downloading such a map can be very long for the end user. The question is whether the SVG version of a topographic map, or a sub-section of the map, can be a reasonable size for the user.

The most significant difference between paper and web topographic maps lies in interactivity. Although paper maps are superior in several aspects, they do not offer features that web maps can offer – interactive analytical functions. Using programming and editing tools, it is possible to create an interactive topographic map with SVG. Instead of using expensive GIS tools and Server/Java-applets/Plug-in combinations, an interactive topographic map can be based on a standard XML web-technology and open standard scripting languages such as JavaScript. Requiring only a web browser, it will be possible to analyze a topographic web map and find such information, which can otherwise be achieved only by using GIS tools, for example to display coordinates, turn layers on and off, show elevation value, etc. The advantages of an online interactive, vector-based web map will be tested through a focus group analysis.

1.4 Significance of the Research

A USGS topographic map at a scale of 1:24,000 has not yet been presented on the web in a vector format. Such a map, together with some embedded interactive elements, can be very useful from a practical point of view. This research will show the differences and possible limitations as well as suitability for the dissemination of USGS topographic maps over the Internet. Testing of intuitive interactive elements can determine whether such a map can be useful for better extraction of information from a topographic map.

The thesis is organized as follows:

Chapter 1 is an introduction to the thesis and includes the nature of the problem, research objectives, hypotheses and rationale, and the significance of the research.

Chapter 2 provides the literature overview of terminology and basic concepts that are used in this thesis. It also defines the scientific framework and perspective for this research.

Chapter 3 presents data sources and their characteristics that were used in this work. An overview of USGS large scale maps as well as their symbology, digital formats, and distribution is presented.

Chapter 4 introduces the methodology that was used for the creation of the interactive topographic web map. Data preprocessing, code optimization and minimization, the testing of the product as well as qualitative methods used for the product evaluation are described.

Chapter 5 and 6 describe the final results and discuss the advantages or weaknesses of the technologies used here for the distribution of large scale topographic maps through the Internet.

2. Terminology and Concepts

2.1 Web Maps – Definitions and Concepts

The distribution of maps over the Internet is a complex problem that can be seen from various perspectives. Maps can be delivered through the Internet in many ways and digital formats. These new possibilities include innovative features that have been added to digital maps, such as interactivity, animation or other multimedia functions.

The term *web map* itself is derived and developed from the classical map and means that a map is presented or disseminated over the Internet and uses the advantages of the WWW. Cartwright (2003) presents five areas based upon which web maps differ from paper maps: speed, interactivity, commercialization, viable end-user environment, and boundedness (how much a web map is linked to other maps and related services under the control of others).

According to Kraak and Brown (2001), web maps integrate cartography and multimedia: *"The use of maps on the Web implicitly hyperlinks visualizations with other multimedia elements."* They classify web maps into two categories: static and dynamic. These categories are further subdivided into view-only and interactive maps (Figure 2.1).

Peterson gives a similar classification of web maps (Peterson, 1997). He recognizes three types of maps on the Web: static, interactive, and animated. Static web maps are mostly represented as images. Essentially, they can be scanned paper maps presented in a digital raster format (GIF, JPEG). Although these types of maps are the

most common on the Internet (Caquard, 2003), they have not been designed to take

advantages of the capabilities of the Web. They serve best to give the map user an
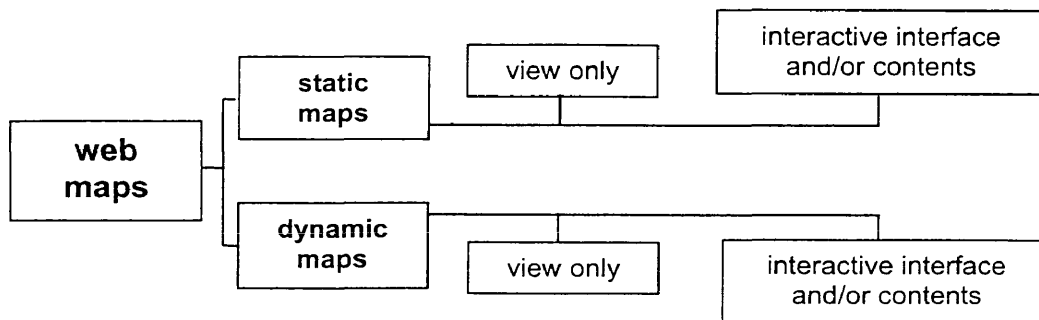
Figure 2.1: Classification of web maps (Kraak and Brown, 2001).

impression of available map products on paper. Animated maps are designed for

depicting temporal trends of dynamic processes in the landscape such as weather,

transportation, etc. They are usually stored in a format for the display of digital movies,

such as AVI, MPEG, or QuickTime (Peterson, 1999).

The dominant emphasis in this work will be placed on the interactive map.

Cartwright explains interactivity as an interrogation on any part of the map image and

then a request for any available complementary information by the user. *"This may be in*

the form of other media (audio, visual, or animation) or database or metadata

information" (Cartwright, 2003). The user can obtain more effective and efficient means

of transferring knowledge using good interactive products. Interactivity also means that

the user can choose among different representations (zoom level, kind of symbols, colors,

etc.) and analytical functions: changing the number of classes, the classification method,

queries, etc. Through these functions, the user is no longer a passive consumer of

information but actively involved in exploring data (Caquard, 2003).

2.2 Distribution of Web Maps over the Internet

2.2.1 Internet GIS

Distribution of maps currently available on the Internet varies from the simple raster presentation to much more sophisticated solutions that incorporate interactivity and/or animation. This chapter introduces and explains basic concepts for digital map distribution to better understand the research question in a broader context.

Since the 1980s, the processing, graphical presentation, and the distribution of maps has been strongly influenced by GIS. As the paradigm of GIS is shifting into a new direction, referred to as *Internet GIS* (Peng and Tsou, 2003), the distribution of maps also acquires new dimensions (interactivity, multimedia features, data interoperability, etc.). It can be said that Internet GIS represents powerful tools for the dissemination of maps via the Internet, since they integrate the potential of GIS and Internet technologies.

Previously, a GIS was individual, private, and independent (but disconnected). The evolution of GIS from its initial to current stage is depicted in Figure 2.2. The current trend in GIS development leads to distributed, shared, holistic, and integrated GIS. This new major direction, termed appropriately *openGIS*, relates to a truly open structure for operations and data. The concept means true freedom from difficult data format conversions and a truly shared and connected infrastructure (Davis, 2001).
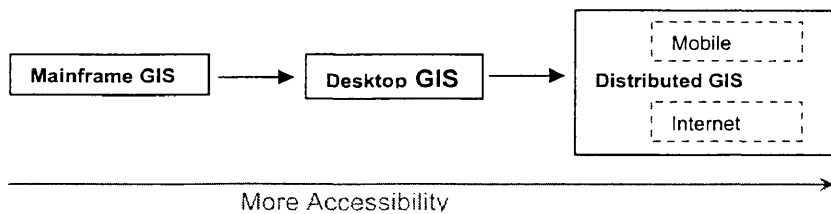
Figure 2.2: A development path of distributed GIS (Peng and Tsou, 2003).

Peng and Tsou in their book "*Internet GIS*" provide an excellent introduction and explanation of all aspects Internet GIS questions. They refer to Internet GIS as a "*research and application area that utilizes the Internet to facilitate the access, processing, and dissemination of geographic information and spatial analysis knowledge*" (Peng and Tsou, 2003).

The idea of Internet GIS starts with the realization that not all information is stored in one single place or in one single format. The ultimate and ideal data access technology is one that can access any information of any data format from anywhere in a uniform way.

The architecture of Internet GIS follows the Client-Server Model with Web browsers as the clients and the Web site serving the application as the server. These two approaches are referred to as: (a) the Client-side; and (b) the Server-side architecture. The following is a general client-server model of basic components in Internet GIS (Figure 2.3).
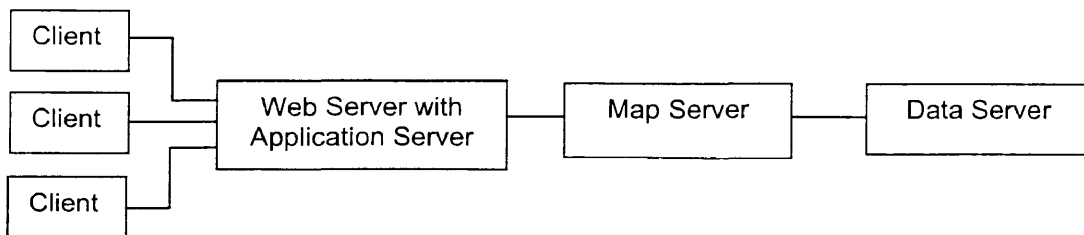
Figure 2.3: Basic components of Internet GIS.

Client-Side model of Internet GIS

The client-side Internet GIS architecture is a highly client-dependent platform

configuration which requires the client machine to take up all the responsibilities of

processing GIS operations. To perform the GIS operations in the client machine, the Web

browser must be assisted with client-side scripting languages, Web-enabled programming

languages such as Java, and Web browser plug-ins whenever necessary (Shea, 2001). An

example of client-side Internet GIS architecture model is depicted in Figure 2.4.
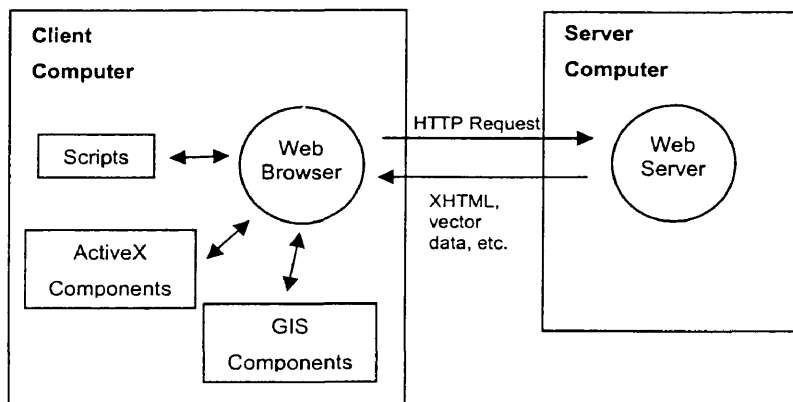
Figure 2.4: An example of client-side architecture.

Server-Side model of Internet GIS

The server-side Internet GIS architecture requires a sophisticated hardware configuration on the server platform to handle the highly process-demanding request from the clients. The Web browser on the client-side plays a passive role in this approach – it only generates an HTTP request and waits for the results from the server and displays immediately on the client computer without taking any responsibility for processing GIS operations. An example of server-side application can be seen in Figure 2.5 where the server-side model is divided into three parts: Data Tier, Middle-Tier, and Client Tier.
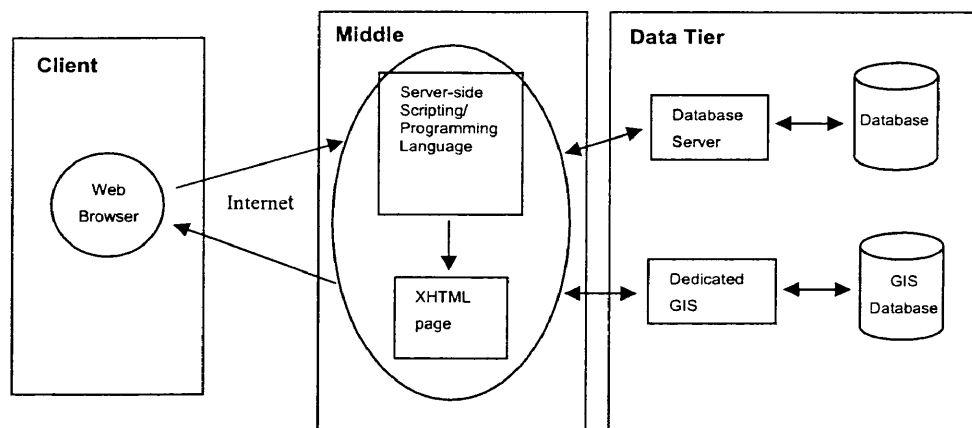
Figure 2.5: An example of server-side architecture.

Both client-side and server-side solutions have some advantages and disadvantages. According to Shea (Shea, 2001) the client-side solutions provide a better working environment combined with powerful analysis functions. He claims that "*This approach is favorable for a smaller group of sophisticated users who are looking for complicated*

GIS functions." On the other hand, the server-side solutions offer a standardized and economical GIS solution to serve a wide group of infrequent users who are not eagerly looking for a highly-responsive GIS server.

Green and Bossomaier (2002) characterize three advantages of Internet GIS. These advantages include:

- *World-wide access* – accessible information from anywhere in the world

- *Standard interface* – a web browser, no need to install GIS software on a client

- *Faster, more cost-effective maintenance* – information can be accessed at its source, so there is less need to collect data at a central location

Since Internet GIS is a current trend in GIS development, there are numerous software/program packages and solutions. They range from open source to highly proprietary technologies. The evaluation of the different possibilities would represent another research project.

Aside from technological problems of Internet GIS, interoperability of geodata is another issue that relates to the context of Internet GIS. The Open GIS Consortium (OGC) has been the leading organization dealing with the full integration of geospatial data and geoprocessing into mainstream information technology, known as *interoperability*. OGC defines interoperability as "*software components operating reciprocally (working with each other) to overcome tedious batch conversion tasks, import/export obstacles, and distributed resource access barriers imposed by heterogeneous processing environments and heterogeneous data*" (Buehler and McKee, 1998).

OGC proposed a comprehensive software architecture called *OpenGIS Specification* that defines a comprehensive software framework for distributed access to geodata and geoprocessing resources. The OpenGIS specification includes an abstract specification and a series of implementation specifications for various Distributed-Computing Platforms (DCP). The main purpose of this specification is to establish communication mechanisms among different communities of geodata producers and users (Buehler and McKee, 1998).

The *Geography Markup Language* (GML) is a product of OGC. GML 2.0 is currently an OGC-endorsed specification. It is an XML application to encode geographic features (Peng and Tsou, 2003). GML is designed to support interoperability by providing metadata through some common basic geometry tags that are supported by all systems and by providing shared context through application schemata. It has to be noted that there is a clear distinction between geographic data (which is encoded in GML) and graphic interpretations of that data as might appear on a map or other form of visualization. Geographic data is concerned with a representation of the world in spatial terms that is independent of any particular visualization of that data. How those data are symbolized on a map, what colors or line weights are used is something quite different. The representation of geographic data content might be accomplished by developing a rendering tool to interpret GML data. To make a map from GML, the GML elements have to be styled into a form which can be interpreted for graphical display in a web browser. Potential graphical display formats include W3C Scalable Vector Graphics

(SVG), the Microsoft Vector Markup Language (VML), and the X3D. Graphical formats for map representation will be discussed later.

2.2.2 Non-GIS Solutions

Internet GIS represents an intelligent way to distribute maps via the Internet. Aside from what technologies are used, whether open source or proprietary software packages, they can offer sophisticated solutions for dissemination of highly interactive and dynamic maps. A database, where geospatial data is stored, plays a central role in this process whether it is a client-side Internet GIS or server-side solution. However, maps may also be distributed a different way, without a geospatial database in the background. Although this approach is much simpler in comparison to Internet GIS solutions, results are not necessarily of lower quality. In many cases such solutions can be more effective and can offer better results, especially for small general reference maps or thematic maps. Basically, this approach uses and relies on different capabilities of both graphical and non-graphical file formats.

Static map images in raster format, even if they are scanned depictions of paper maps or maps exported from GIS to a raster format, represent the simplest form of web maps. They can be embedded either inside an HTML page or disseminated separately as raster images, since a web browser is able to display them. Different raster formats are used for these types of images such as JPEG, GIF, PNG, etc. Clickable raster maps represent more intelligent solution but are still at a low level in terms of possible interactivity, operational possibilities, dynamic features, etc.

An appropriate vector format, alone or combined with some client-side scripting language such as JavaScript (ECMAScript), can offer a much more sophisticated solution. Besides advantages offered by vector graphics, interactivity and other dynamic features (animation, video, etc.) can be easily added to these types of web maps. SVG and JavaScript are such an example. The following sub-section is an overview of currently relevant digital graphic formats that could play a potential role in the process of map distribution.

2.2.3 Digital Formats for Web Map Distribution

As it was already mentioned, a digital format, in which web maps are presented/distributed, plays an important role in the process of web map distribution. However, the emphasis is placed not only on the data structure but also on other properties of the data format. A successful format should fulfill the requirements of cartographers or GIS professionals. Besides being interactive and dynamic, it should also fulfill requirements of interoperability, extensibility, and be an open standard (not proprietary).

2.2.2.1 Raster formats

Although maps distributed in raster formats are being replaced by vector formats, they still have unique properties for presenting some spatial information such as digital elevation models, orthophotomaps, etc. The following is the overview of raster formats

used in web cartography. At present there are three widely used standard graphic formats (GIF, JPEG, and PNG):

GIF (Graphics Interchange Format) – A standard on the Web. However, this format for compressed files is actually owned by Unisys. The GIF compression is "lossless," meaning that after decompression the image looks the same as before compression. It uses a LZW (Lempel Ziv Welch) compression making the file size very small. Later, "interlaced" and the "transparent" features as well as "animation" were added to GIF. GIF compression is best used for images that have solid colors. A weakness of GIF is that it supports only 8-bit color, giving a maximum of 256 different colors for the single image.

JPEG (Joint Photographic Experts Group) – is another raster format developed specifically for photographic images and similar continuous tone images of many colors. JPEG supports millions of colors (24-bit). It is a variable lossy format, which works by analyzing images and discarding that information that the eye is unlikely to notice. The degree of compression is adjustable (JPEG, 2003). JPEG is not a favorable format for the storage of intermediate stages of editing because the associated lossy compression algorithm makes it lose data every time the image is compressed and the quality degradation will be accumulated if it is re-edited, restored and re-saved over the same file (Matthews, 2000). JPEG is a particularly poor choice for maps with linework because the compression algorithm introduces artifacts on either side of the line. However, JPEG offers a much more efficient compression algorithm that can produce a smaller file size with quite minimal loss of quality for photographic images. JPEG has no support at all

for transparency – one of the major graphics features on the Web for stacking multiple images.

PNG (Portable Network Graphics) – The most versatile of the current Web graphic formats, it became the W3C's first recommendation in 1996. PNG is also a lossless format and can compress more efficiently than a GIF or JPEG of the same color depth. The quality is better in most cases and it creates small files that are downloaded more quickly. One of the most common criticisms of PNG is its lack of support for animation.

At the outset of the PNG development, it was targeted as a flexible, portable and royalty-free Web raster format replacing the older and simpler GIF format. The following features clearly show that PNG is suitable for online applications (Roelofs, 1999):

- ❑ Two-dimensional progressive display
- ❑ Multiple layers of transparency
- ❑ Built-in gamma correction
- ❑ Supports true-color, grayscale, and palette-based
- ❑ File integrity checks
- ❑ Metadata for searching and indexing

As mentioned, JPEG is a lossy format and data degradation is unavoidable. It is not the best format for handling spatial data that requires accurate storage and transmission of information. Whereas, PNG is a lossless format and is a good choice for high resolution, true-color images, such as satellite images, which are unsuited to limited color depth of GIF and the lossy compression of JPEG (Shea, 2001).

2.2.2.2 Vector formats

Vector formats offer greater potential for the distribution of maps over the Web. A vector format provides graphic quality, scalability, and extensibility that cannot be obtained with the raster formats. However, unlike raster formats, where standards were established relatively quickly, there still exists no reliable standard for the exchange of vector data. "Standard," in this case, means that a majority of companies accepts or uses a technology, which is actually used by viewers and editors on web sites (Neumann and Winter, 2001). In this part, the overview of currently available vector formats used for web maps distribution is described.

Neumann and Winter (2002) introduce two existing approaches that are "attractive" for vector web maps distribution - WWW vector formats and 2D API's (Application Programming Interface) combined with applets or ActiveX objects.

WWW vector formats are single formats developed either by graphical industries or consortia. Only those formats are introduced that present real potential for further development in web cartography.

DrawML – a format that facilitates depicting and refreshing technical drawings.

DWG (Drawing Web Format) – developed by AutoDesk's corporation, visualized by the WHIP4 plugin, now being replaced by the Volo View plugin. It is compatible with JavaScript, which means that interactivity can be added. However, it does not support animations. Its basic functions are panning, smooth zooming in/out, zooming in window, zooming on pre-defined views, layer in/out, and showing hyperlinks.

SWF (ShockWave File) – proprietary format from Macromedia. Currently, it is the most widely implemented vector format on the Web. It supports interaction and runs as a Macromedia plugin within the browser. It not only shows vector graphics but video and audio clips can be easily integrated or displayed. There is a wide range of functions for animations and integration of special graphic effects. Although it is a widely implemented vector format, it is not really expected that "Flash" will replace other open standard technologies for the Web such as SVG. It is proprietary and binary format, which is also contrary to the idea of open source. Moreover, it is problematic to integrate external data and reedit or create functions based upon the needs of the cartographer.

PDF (Portable Document File) – format developed by Adobe and based on the PostScript file format. These files can be viewed in a browser by using the Adobe Acrobat Reader plug-in. This viewer operates independently from a browser. A PDF file can contain embedded graphic objects (bitmaps and vector images), hypertext links (internal as well as external), links to external files such as sound, QuickTime or AVI movies and links for variable forms data. The PDF is very useful if one wants to print high quality images and graphics. It also provides a good protection because documents may be password protected against reading, printing, or copying.

WebCGM (Web Computer Graphic Metafile) – This is an effort to enable ISO's CGM standard for the Web. The Web version is binary and constitutes a W3C recommendation. It is primarily designed to visualize technical and scientific drawings.

VRML (Virtual Reality Modeling Language) – This language is for describing three-dimensional (3D) space. Even though designed for 3D representations, it is able to

render good 2D drawings as well. VRML files are also ASCII files. A VRML object is scalable and one can zoom in or out, rotate, turn around, pan, etc. A plug-in is necessary. VRML is being restructured at the present time.

SVG (Scalable Vector Graphics) – A completely open standard recommended and developed by the World Wide Web Consortium (W3C). SVG is a purely text-based collection of XML-like commands, generating graphics that require no plug-ins or extra tools to be visible on a website. SVG, for example, offers many of the advantages of Flash, plus the following features: embedded fonts, extensible markup language (XML), style sheets (CSS), interactivity and animations. With the help of DOM (Document Object Model), full HTML compatibility is obtained. A more detailed description about SVG will be provided in the part of SVG (2.3)

2D API's Combined With Applets or ActiveX:

ActiveX - An approach by Microsoft to reach objects coded with Microsoft code, by using Visual Basic, a proprietary scripting language. It can not be used in a very meaningful way, since it depends on a specific browser and operating system. Its documentation is poor. ActiveXs are embedded in other documents and may be recalled through them. This explains how ActiveX may be found in Microsoft Word and PowerPoint documents as well.

Java2D – is a binary program with graphical 2D output that is inserted in web pages. Java2D is flexible and does not depend on a single platform. It runs as a "virtual machine" on the client. Java2D was designed by Sun and Adobe for platform independent, simple and outstanding graphical programming. Basically, it offers the same

graphical possibilities as SVG - in fact, most SVG viewers and plug-ins are written in Java. To attain a similar level of interaction as SVG, higher programming skills are necessary in Java2D. With Java2D it is possible to create extensive and sophisticated libraries in fields of databases, user interfaces, 2D graphics, 3D graphics, multimedia, networking and telecommunication. Java2 applets are able to command SVG plug-ins. With a little effort, stand-alone programs can be generated from the same sources.

2.3 SVG - Open Web-standard for Web Delivered Maps

2.3.1 XML Technology

The W3C (World Wide Web Consortium), which has about 450 member organizations from all over the world, was created in October 1994 to lead the World Wide Web to its full potential by developing common protocols that promote its evolution and ensure its interoperability. W3C is now transforming the architecture of the initial Web, that has been essentially built on HTML, URIs, and HTTP, into one built on XML (see Figure 2.6). HTML has proved to be widely successful. However, members of the W3C realized that a much more extensible alternative to HTML would be necessary to cope with the increasing demands of data-centric Web applications that require more functionality beyond the current HTML.

The reason for this lies in following three fundamental principles that the Web has to fulfill for successful development: interoperability, evolution, and decentralization.

Simply stated, XML (eXtensible Markup Language) is the technology on which the future Web will be based. It is the universal standard for structured web documents, for maximal independence of networks and platforms. The whole concept of XML consists of separating data from presentation.
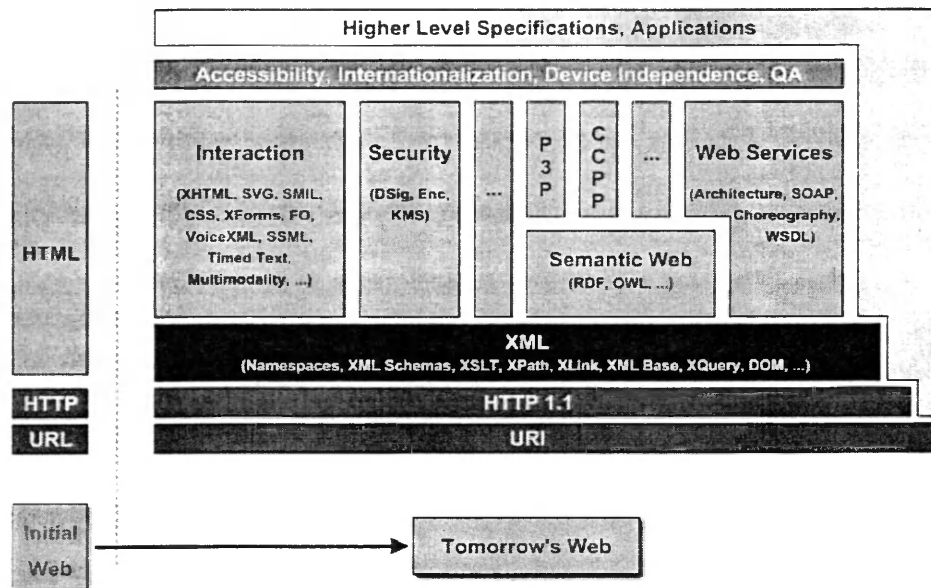
Figure 2.6: Transformation of the architecture of the initial Web.
Source: http://www.w3.org/Consortium

XML uses several technologies for such things as file format translation (XSLT), formatting (XSLFO), syntax description and validation (DTD and Schema), querying data (XQL), and for hyperlinking (XLL and XPOINTER). Based upon these base technologies, the foundation of all further "dialects" (specializations) have been introduced, like SMIL (multimedia), SVG (vector graphics), MathML (special mathematical symbols and formats), X3D (3D graphics), XHTML (successor of HTML),

GML (Geography Markup Language), and so on. All further implementations and dialects are based on the same syntax rules and can share base techniques, such as parsers, validators and editors. This is one of the major advantages of XML technology.

2.3.2 SVG Specification and Characteristics

As already mentioned, SVG is two-dimensional vector graphics based on XML. It is a fully open standard defined by W3C that uses all advantages of XML technology. Scalable Vector Graphics (SVG) Specification 1.1, released in January 14th 2003 by W3C, is the main document which completely defines the whole SVG technology.

The history of SVG is traced to September 2001 when it became an official W3C recommendation (SVG 1.0). The SVG standard has been developed and supported by all major graphics and software companies and organizations that are web relevant such as (in alphabetical order) Adobe; Apple; Autodesk; Corel; HP; IBM; Inso; Macromedia; Microsoft; Netscape; Quark; RAL; Sun; and Visio (W3C, 2003; Neumann and Winter, 2002).

SVG Specification 1.1 specifies the name Scalable Vector Graphics, where "*scalable*" or "*to be scalable*" means to increase or decrease uniformly or not being limited to a single, fixed, pixel size. On the Web, scalable also means that "*a particular technology can grow to a large number of files, a large number of users, and a wide variety of applications*" (W3, 2003). "*Vector graphics*" simply refers to a geometry based on vectors.

SVG is a language that allows for three types of graphic objects: vector graphic shapes, images and text. These objects can be grouped, styled, and composed into higher level objects. Besides static graphics, SVG allows animations and interactivity as well. Because it is based on XML, it can be also combined with other XML standards to extend its own possibilities. In order to confer the standard appearance of graphical objects, CSS (Cascading Style Sheets) can be used as well. SVG can be integrated with existing DOM (Document Object Model) which means that SVG objects can be controlled and modified by the usual JavaScripts/Java interfaces (Neumann and Winter, 2001; see also Figure 2.7).
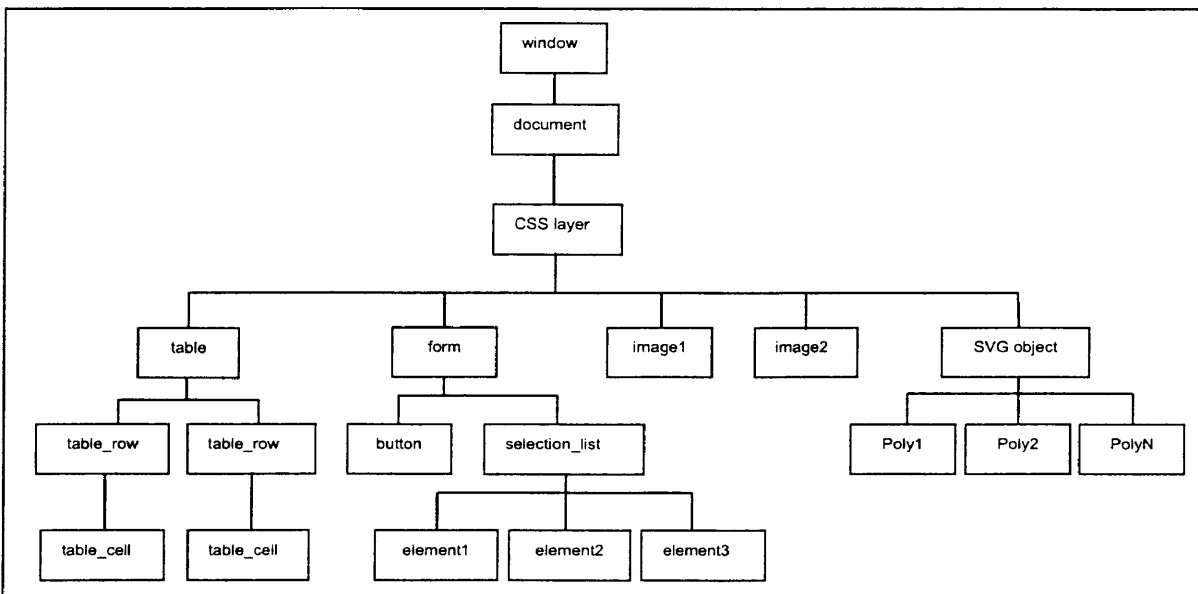
Figure 2.7: Example for a simple DOM object hierarchy (Neumann and Winter, 2001).

A single SVG document/file consists of a header, a root-element (SVG-element) and several "child" elements with attributes. A header includes several system

specifications like SVG Namespace, Public Identifier, and System Identifier for the SVG

Recommendation. The following is an example for a SVG header according to SVG

Specification 1.1 (W3C, 2003):

SVG Namespace:

    http://www.w3.org/2000/svg

Public Identifier for SVG 1.1:

    PUBLIC"-//W3C//DTD SVG 1.1//EN"

System Identifier for the SVG 1.1 Recommendation:

    http://www.w3.org/Graphics/SVG/1.1/DTD/svg11.dtd

Basic elements in SVG like rectangle, circle, ellipse, line, polyline, polygon, and

path make extensive use of attributes. Entities may be, for example, defined and then

used later in the file, or re-used by setting references to the objects' ID. A typical

example is a symbol which can be defined once using several basic elements and then

used later for different objects. This is especially useful in cartographic applications. The

following is the example of a simple SVG document where a symbol is defined using

<def> tag and then later used by <use> and *xlink:href* commands.

```
<?xml version="1.0" encoding="iso-8859-1"?>
    <!DOCTYPE svg PUBLIC "-//W3C//DTD SVG 20001102//EN"
    http://www.w3.org/TR/2000/CR-SVG-20001102/DTD/svg-20001102.dtd>
<svg width="869" height="598" viewBox="248821 -4584462.91 8220 5628">
    <defs>
        <symbol>
            <g id="hp_spotheights_symbol" stroke="brown;stroke-width:2;">
                <line x1="-7.5" y1="-7.5" x2="7.5" y2="7.5"/>
                <line x1="7.5" y1="-7.5" x2="-7.5" y2="7.5"/>
            </g>
        </symbol>
    </defs>
    <g id="hp_spotheights">
```

```
      <use id="hp_points_0" x="255864.14" y="-4579627.08" xlink:href="#hp_spotheights_symbol"/>
   </g>
</svg>
```

SVG uses the Cartesian coordinate system where the XY origin is defined in the left upper corner of the drawing. It also utilizes a variety of geometrical transformations based on 3x3 matrix operations like translation, scale, rotation, or cut which means that there are basically no restrictions for defining cartographic projections. Neumann and Winter provide constructive examples of geometric transformations for cartographic applications (Neumann and Winter, 2001). The equivalent graphical illustrations can be found on their server at www.carto.net. Besides basic vector graphics, objects manipulations, and geometric operations, SVG also offers the potential for manipulation of text, raster, as well as interactivity and animation to drawings.

The purpose of this review is not to provide an exhaustive explanation but just to present a brief introduction from a cartographic perspective to further understand the topic. More examples of SVG applications in cartography can be found in publications by Neumann (2003) and Neumann and Winter (2001). The following chapter explains the overall advantages of SVG for web-cartographic purposes.

2.3.3 Advantages of SVG Technology

Based upon already introduced SVG technology, literature research, and practical implementations, the advantages of SVG for web cartographic purposes can be summarized to the following points:

❏ Vector graphics

❏ SVG is not proprietary; it is an open standard defined by W3C

❏ XML-based technology compatible with other XML standards

❏ Text-based format, easily readable and editable by simple text editors

❏ CSS compatible; determination of presentation attributes

❏ DOM access; customization with JavaScript

❏ Extensibility with other server technologies like Java, ASP, PHP, PEARL etc.

❏ Flexible implementation; different platforms and operating systems

2.4 Qualitative Methods in Cartography

One who produces maps, even digital or paper, always has to take into consideration that a map serves a variety of purposes for users. Qualitative methods are useful when maps are either evaluated or tested in order to find out whether they serve their purposes correctly or, for instance, they require further improvements. Suchan and Brewer (2000) provide an overview of qualitative methods that are used for research on mapmaking and map use. They also describe these methods along with cartographic examples.

A focus group is a qualitative method that is commonly used in cartography to reveal users perceptions, opinions and reactions to evaluate or improve the cartographic product. The significance of this methodology lies in the qualitative evaluation of a product by a group of people who are chosen by a certain criteria. The focus group

methodology is also commonly used in human geography and social sciences. Bedford and Burgess define the focus group as "*a one-off meeting of between four or eight individuals who are brought together to discuss a particular topic chosen by the researcher who moderate or structure the discussion*" (Limb and Dwyer, 2001). Morgan (1997) gives several definitions related to focus group techniques - determination of the type of participants, the level of group structure, the size of groups, and the number of groups. In cartography, the focus group method has been utilized in several studies to improve design, efficiency and readability of maps or map products (e.g., Monnmonier and Gluck, 1994, Suchan and Brewer, 2000, Davies and Medyckyj-Scott, 1994).

3. Data Sources and Characteristics

3.1 Large Scale Topographic Maps

Topographic maps portray detailed information about the landscape for both natural and man-made features. They are an indispensable tool for government, science, industry, and leisure for a wide variety of purposes. The USGS (U.S. Geological Survey) provides topographic maps and updates the standard series maps in different scales for the entire United States. The map coverage is completed for large scale maps (1:24,000), intermediate scale maps (1:50,000 and 1:100,000) as well as small scale maps (1:250,000, 1:500,000, and 1:1,000,000).

Since the large scale topographic maps are the subject of this research, the following sub-chapters describe the large scale topographic maps in a greater detail. A series of government publications (http://topomaps.usgs.gov) provides all relevant information about topographic maps - where they can be found, including standards, data sources, links, etc.

3.1.1 Topographic Mapping

Large scale topographic maps in scale 1:24,000, also known as 7.5-minute quadrangle series, are the most detailed and the best known USGS maps. They divide the United States into quadrangles bounded by two lines of latitude and two lines of longitude. For example, a 7.5-minute map shows an area that spans 7.5 minutes of

latitude and 7.5 minutes of longitude, and it is usually named after the most prominent

feature in the quadrangle. The area portrayed on each sheet ranges from 64 square miles

at latitude 30 degrees north to 49 square miles at latitude 49 degrees north. A scale of

1:24,000 allows considerable detail to be shown in the quadrangle areas. The sheet size is

about 22 x 27 inches north of latitude 31 degrees and 23 x 27 inches south of that latitude

(USGS, 2003a).

Topographic mapping, especially large scale mapping remains a central activity

for the USGS. The 1:24,000-scale topographic map is the only uniform map series that

covers the entire area of the United States in considerable detail. There are more than

55,000 7.5-minutes maps for the 48 contiguous States (USGS, 2003a). This map series,

officially completed in 1992, has been recently replaced by *The National Map* (a new

perspective on geographic base information). However, all maps as well as the other

derived products from this program still remain a valuable source of information and

serve as the base for other mapping applications (including *The National Map*).

The first large scale topographic map was produced in 1879. *Planetable surveying*

was the main mapping technique for producing such maps at that time. This classic

method was replaced by aerial photographs and photogrammetric techniques around the

1940's. Essentially, the whole 7.5-minute map series was created using stereo aerial

photographs (USGS, 2003a), with Kelsh stereoplotters and subsequentially with

computer-aided analytical stereoplotters.

With the advent of computers and related technologies, the demand for mapping

information in computer-compatible form has accelerated very rapidly. To make these

maps more available, the topographic maps were digitized and stored in The National

Digital Cartographic Data Base (NDCDB).
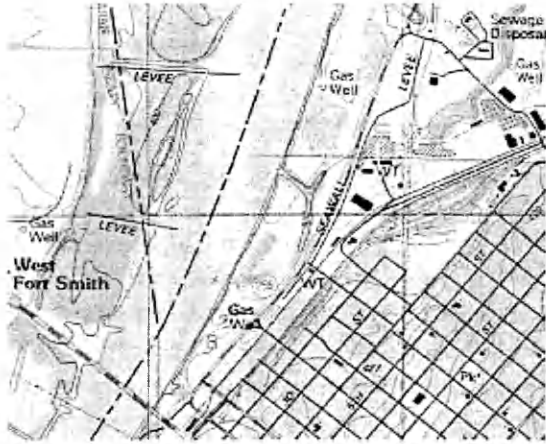
Figure 3.1: Example of 7.5-minute quadrangle; portion of Fort Smith, Arkansas (Source: USGS, 2003).

3.1.2 Standards, Accuracy and Symbology

7.5-minute quadrangle maps are the elementary part of *The National Mapping Program* (NMP) provided by the USGS. These types of maps, as well as the other cartographic products from this program, are created based on standards. Standards specify and establish criteria for how products are made. The USGS defines standards as follows: "*Standards set the criteria and specifications to ensure that all products prepared by the USGS Geography Discipline under the National Mapping Program (NMP) reflect current mapping and data policies and are accurate and consistent in style and content.*" The standards are technical documents that are essential for efficient sharing of products and to provide information about geospatial data. They are

periodically updated to reflect the changes in policy or to define new or improved data and map specifications (USGS, 2003b).

USGS defines three basic types of standards:

Digital Data Standards – standards for geospatial data produced by NMP. They include standards for Digital Elevation Models (DEM), Digital Line Graphics (DLG), Digital Orthophoto (DOQ), Digital Raster Graphics (DRG), National Hydrographic Dataset, and Raster Feature Separate Standards. Some of these standards will be described later in more detail.

Printed Map Standards – standards which define *Primary Series Topographic Maps* which include 1:24,000- or 1:25,000-scale quadrangles of the conterminous United States and Hawaii, 1:63,360-scale quadrangles of Alaska, and 1:20,000-scale quadrangles of Puerto Rico.

Additional Standards – include standards like metadata and accuracy standards, and various technical instructions.

Since large scale topographic maps are used by various of users, organizations, and professionals, the issue of map accuracy is vital. In 1941, USGS developed *The National Map Accuracy Standards* in order to fulfill the high expectations and requirements placed on topographic maps. The map accuracy includes both horizontal and vertical map precision. These were revised in 1947 and are valid today. The online version of *The National Map Accuracy Standards* is available at:

http://rockyweb.cr.usgs.gov/nmpstds/nmas647.html

For *horizontal accuracy*, precision is defined as "*not more than 10 percent of the points tested shall be in error by no more than 1/50 inch, measured on the publication scale.*" Limits of accuracy shall apply in all cases only to positions of well-defined points. Well-defined points are those that are easily visible or recoverable on the ground, such as bench marks, property boundary monuments, etc.

Vertical accuracy, as applied to contour maps on all publication scales, shall be such that not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval. In checking elevations taken from the map, the apparent vertical error may be decreased by assuming a horizontal displacement within the permissible horizontal error for a map of that scale.

It has to be noted that the accuracy standards defined above are for published maps. Digital data like DEM, DLG have their own accuracy which will be described later.

The symbology is also an important part of topographic maps, since it depicts the symbols that are related to real objects on the Earth. Symbols simply perform the abstraction of these objects. Symbols for 1:24,000-scale quadrangle maps are defined in two technical documents, *Publication Symbols Part 5 and 6* (Supplementary Symbol Specification) that are related to Primary Series Quadrangle Standards (USGS, 2003c). They define symbol names, technical parameters like number, size specification, color and remarks how symbols should be used correctly. Figure 3.2 presents an example of a symbol for a primary highway.

100	Class 1—Primary highway, hard surface, four or more lanes........ ────────── ⁿ ⌐ᵃ⌐ᵃ Overall width to scale with minimum .02". Line weight .003". See symbol 5 12 for red fill.
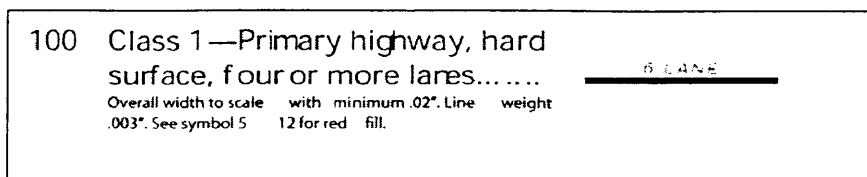
Figure 3.2: Symbol for primary highway as defined by USGS.

3.1.3 Maps Distribution

Paper maps can be found and ordered by contacting USGS Earth Science Information Centers (ESIC). This and other related services are available online at:

http://topomaps.usgs.gov/ordering_maps.html

This research uses USGS digital data products. The following methods can be used for searching, downloading or ordering digital data for 1:24,000-scale topographic maps:

1. EarthExplorer – http://earthexplorer.usgs.gov for searching various kinds of digital geodata including raster and vector formats for large scale topographic maps (DLG, DEM, etc.). See Figure 3.3.

2. ftp://edcftp.cr.usgs.gov/pub/data/DLG/LARGE_SCALE/ - USGS FTP server with DLG files (all currently available layers) for the entire area of the United States. The name of the map needs to determined through EarthExplorer, Global Mapper, or other source.

EarthExplorer: Data Set Selection

New!!! The "USGS Urban Area Photography" collection has been added to EarthExplorer. Find it under "Aerial Photography" in the Data Set Selection list.

Spatial Coverage

Define on Map   Click on a coordinate before pressing the "Edit" button.

Enter Coordinates   41 15 30 N 095 56 15 W

Enter Place Name   *Review/Edit* ⚲ Delete ☐ **Clear Area**   Degree/Minute/Second ▾

Data Set Selection

⊟ **Digital Line Graphs(Related Links)**
   INFO ☐ Digital Line Graph - 1:100,000 scale
   INFO ☑ Digital Line Graph - Large Scale
⊟ **Elevation(Related Links)**
   INFO ☐ Digital Elevation Model - 15 Minute
   INFO ☐ Digital Elevation Model - 30 Minute
   INFO ☑ Digital Elevation Model - 7.5 Minute

➡ **Continue**

Figure 3.3: EarthExplorer for searching and downloading digital geodata.

ftp://edcftp.cr.usgs.gov/pub/data/DLG/LARGE_SCALE/0/omaha_north_NE/ - Micro

File   Edit   View   Favorites   Tools   Help

◉ Back ▾ ◉ ▾ ⤴ ⚲ Search   » Google ▾

Address ftp://edcftp.cr.usgs.gov/pub/data/DLG/LARGE_SCALE/0/omaha_north_NE/

Other Places ⊗

▣ 0
My Documents
Shared Documents
My Network Places

Details ⊗

boundaries
hydrography
hypsography
manmade_features
nonveg_features
public_lands
surface_cover
survey_control
transportation

Figure 3.4: USGS FTP server for large scale topographic maps with thematic layers (in alphabetical order).

3. http://www.globalmapper.com/ - A proprietary server. Some data are available at no cost. This site is especially good for downloading DEM data.

4. http://topowest.com and www.topozone.com – Provide scanned topographic maps in various raster formats for orientation/information purposes. Allows ordering of paper versions for selected areas.

3.2 Characteristics of Digital Data for Large Scale Topographic Maps

3.2.1 Spatial Data Transfer Standard (SDTS)

The need for earth science data standards became apparent as the application of computers in geography and cartography grew within the federal government. USGS along with other academic, industrial, federal, state, and local government and cartographic agencies required a standard data format for transferring and exchanging spatial data. In 1992, after twelve years of developing, reviewing, revising, and testing, the standard-SDTS was approved as Federal Information Processing Standard (FIPS) Publication 173, known as *FIPSPUB 173-1, 1994*. The FIPS version has been superceded by the current version, known as *ANSI NCITS 320-1998* and was ratified by the American National Standards Institute (ANSI) in 1998 (USGSd, 2003).

SDTS is a *"robust way of transferring earth-referenced spatial data between dissimilar computer systems with the potential for no information loss. It is a transfer standard that **embraces** the philosophy of self-contained transfers, i.e. spatial data,*

attribute, georeferencing, data quality report, data dictionary, and other supporting

metadata all included in the transfer (USGS, 1998)."

SDTS consists of the six components: a.) Logical Specifications, b) Spatial

Features, c) ISO 8211 Encoding, d) Topological Vector Profile, e) Raster Profile, and f)

Point Profile. Parts a-c deal with its own piece of the spatial data transfer problem, parts

d-f define specific rules and formats for applying SDTS for the exchange of particular

types of data in SDTS.

There are two USGS cartographic products in the SDTS standard, vector *Digital*

Line Graph (DLG) and digital elevation model (DEM) data.

3.2.1.1 Digital Line Graph (DLG)

Digital Line Graph (DLG) files are digital vector representations of cartographic

information derived from the USGS 1:20,000-, 1:24,000-, and 1:25,000-scale 7.5-minute

topographic quadrangle maps, created by manual or automated digitizing methods. They

are available in nine categories or layers/units (see Table 3.1). DLGs are primarily

projected to the Universal Transverse Mercator (UTM) projection system, but some are

projected to the State Plane coordinate system. They are referenced to either the North

American Datum (NAD) of 1927 (NAD27) or the NAD of 1983 (NAD83).

Layer	Feature Type
Public Land Survey System (PLSS)	Township, range, and section lines
Boundaries	State, county, city, and other national and State lands such as forests and parks
Transportation	Roads and trails, railroads, pipelines and transmission lines
Hydrography	Flowing water, standing water, and wetlands
Hypsography	Contours and supplementary spot elevations
Non-vegetative features	Glacial moraine, lava, sand, and gravel
Survey control and markers	Horizontal and vertical monuments (third order or better)
Manmade features	Cultural features, such as building, not collected in other data categories
Vegetative surface cover	Woods, scrub, orchards, and vineyards

Table 3.1: Categories for 1:24,000-scale DLG files.

The structure of the DLG data follows four subject areas: levels of structuring, topology, topological elements and graph theory. The large-scale DLG data are in the DLG Level-3 (DLG-3) format which means that they have the full range of attribute codes and have a full topological structure. Topological structure is based on graph theory in which a two-dimensional diagram is expressed as a directed graph composed of

a set of nodes (topologically significant points), lines, and areas in a manner that explicitly expresses logical relationships between adjacent elements (USGS, 1999).

A more exact expression of this structure is defined in DLG Standard Part 1 - General. Nodes are defined there as the locators of the endpoints of every line. *A single node* may mark the start or the end of one or more lines; therefore, nodes occur at intersections of linear features and at other places on linear features where the feature is subdivided into separate line segments. A *line* is an ordered set of points (vertices) that describes the position and shape of a linear feature on a map. Each line starts and ends at a node, thus, having an explicit order from start to stop and a left-to-right connotation. Lines may not cross over themselves or any other lines except at a node. An *area* is a continuous unbroken region of a map bounded by lines. Every DLG data file identifies at least two areas (one representing an area covered by the file and the other representing the area outside the coverage of the file).

The DLG data do not carry quantified accuracy statements. However, the following procedures are used prior to data release for distribution:

- ❑ File Fidelity and Completeness - The data are either manually digitized using equipment with a resolution of 0.001 inch and an absolute accuracy of from 0.003 to 0.005 inch or are scanned on an automatic device with a resolution of 0.0013 inch (30 points per millimeter).

- ❑ Attribute Accuracy

- ❑ Topological Fidelity

- ❑ Edge Matching

❑   Quality Control Flags

Attribute codes are used to describe the physical and cultural characteristics of

DLG node, line, and area elements. The codes are based on cartographic features

symbolized on source maps. Each DLG element has one or more attribute codes

composed of a three-digit major code and a four-digit minor code. The attribute scheme

is open-ended so that additional codes may be added as needed. It is not necessary for

each element to have associated attributes. In general, attribute codes are not assigned to

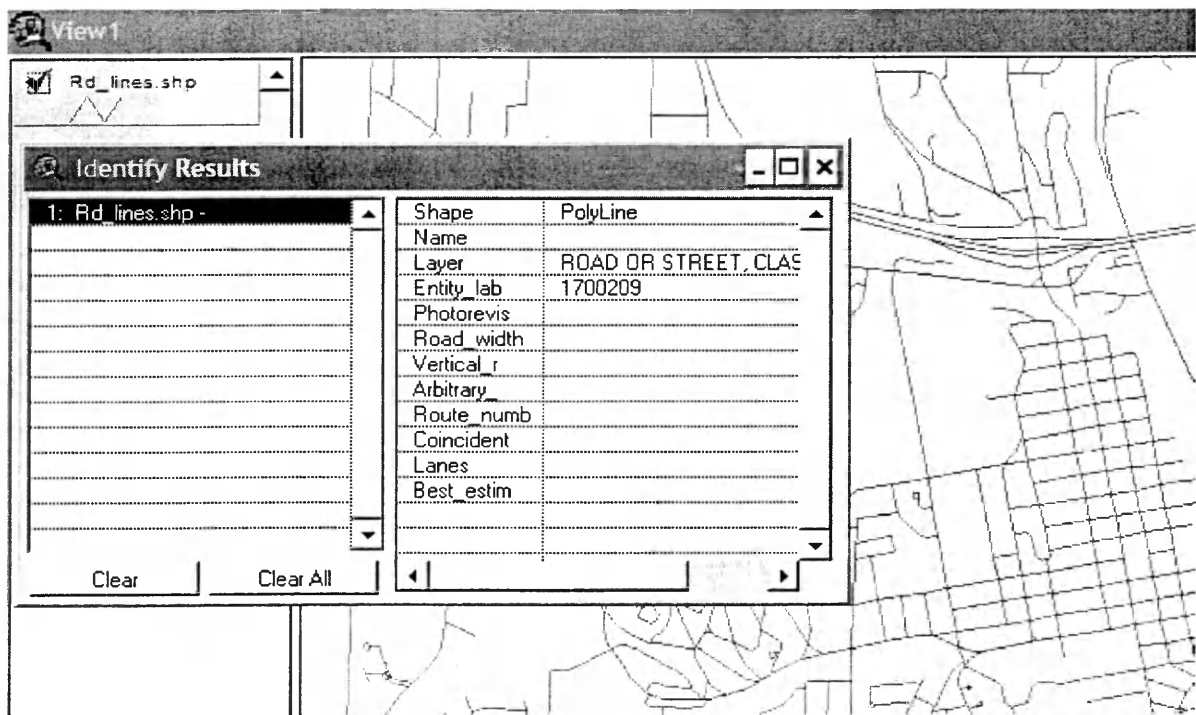an element if the attributes can be derived based on relationships to adjacent elements.

Figure 3.5: DLG file imported to ArcView ShapeFile with all attribute data (Transportaton layer – roads).

3.2.1.2 Digital Elevation Model (DEM)

The USGS Digital Elevation Model (DEM) is a sampled array of elevations for a number of ground positions at regularly spaced intervals (USGSe, 2003). The DEM data for 7.5-minute units correspond to the USGS 1:24,000-scale quadrangle topographic map series. Each 7.5-minute DEM is based on 30 by 30-meter data spacing with the Universal Transverse Mercator (UTM) projection. DEM data were created either from digitized contours or from scanned National Aerial Program Photography Program (NAPP) photographs. DEM accuracy is based on the Root Mean Square Error (RMSE) for linearly interpolated elevations in the DEM and corresponding true elevation from the published maps. The vertical accuracy of 7.5-minute DEMs is equal to or better than 15 meters. In order to check the accuracy, a minimum of 28 points per DEM is required (20 interior points and 8 edge points).

A DEM file is organized into three logical records and three classification levels. Logical records for a DEM file are as follows:

- Type A - contains information defining the general characteristics of the DEM, including DEM name, boundaries, units of measurement, minimum and maximum elevations, projection parameters, and number of type B records.

- Type B - contains the elevation data and associated header information.

- Type C - contains statistics on the accuracy of the data.

A classification level refers to accuracy and systematic errors. All DEM data for 7.5-minute are in classification Level-1, which means that a vertical RMSE of 15m is the maximum permitted and 7m is the desired vertical accuracy. More information about

USGS DEM standards is available through online government publication (USGS, 2003f).

Figure 3.6: Example of 7.5-minute DEM (Sturgis, SD).

3.2.2 Digital Raster Graphics (DRG)

Digital Raster Graphics (DRG) is another digital product of U.S. Geological Survey that is related to large scale topographic maps. DRGs represent scanned images of standard series topographic maps, including all ancillary (map collar) information. The images are georeferenced to the Universal Transverse Mercator projection. The

horizontal positional accuracy and datum of the DRG matches the accuracy and datum of

the source map. All maps were scanned at a minimum resolution of 250 dots per inch

(USGS, 2003g). Digital Raster Graphics are mentioned here only for information

purposes, since all geodata information existing in the DRG should be available in the
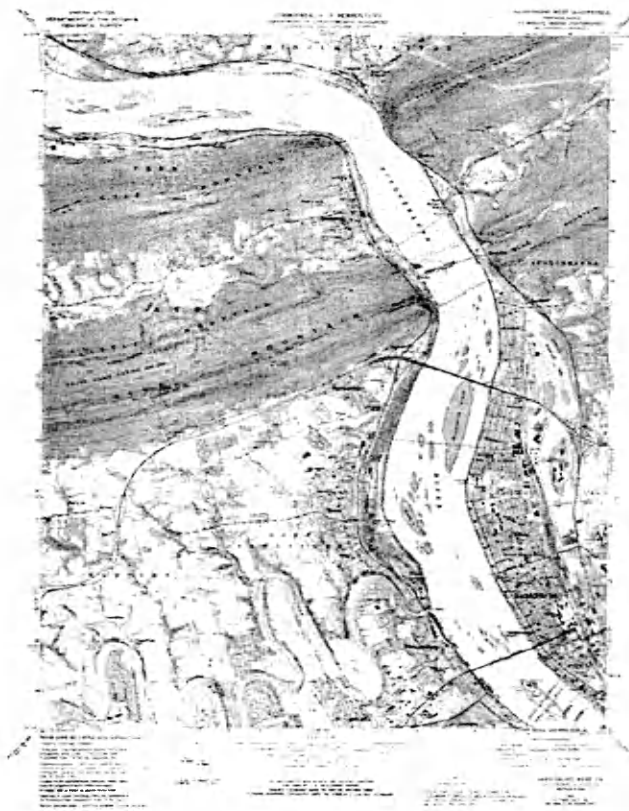
DLG vector format.

Figure 3.7: Example of 7.5-minute DRG.

3.2.3 Digital Orthophoto Quadrangle (DOQ)

Aerial photographs can effectively serve as a valuable source of information for

topographic maps. Since an aerial photograph is not in the orthogonal projection, some

geometrical corrections are required for bringing such images to a map-like form. This method, called rectification, removes the effects of tilt and relief displacement from the aerial photograph. The orthophoto has a uniform scale and can serve as a map for other cartographic purposes.

USGS defines DOQ as "*computer-generated image of an aerial photograph in which image displacement caused by terrain relief and camera tilts has been removed. It combines the image characteristics of a photograph with the geometric qualities of a map.* (USGS, 2003h)"

DOQs produced by USGS are either gray-scale, natural color, or color-infrared (CIR) images with 1-meter ground resolution. The standard DOQ is formatted with an ASCII keyword header followed by a series of 8-bit binary image lines. Color DOQs are 24-bit band-interleaved-by-pixel (BIP) images. The header contains a wide range of data for identifying, displaying, and georeferencing the image. All DOQs are referenced to the North American Datum of 1983 (NAD 83) and cast on the Universal Transverse Mercator (UTM) projection. DOQs can effectively serve as a cartographic base for displaying, generating, and modifying associated digital geodata (USGS, 2003h). They can also be used as a background image to a 7.5-minute quadrangle topographic map.

Figure 3.8: Example of DOQ (Omaha, NE).

3.3 Summary

This chapter has described data sources and their characteristics that relate to 7.5-minute large scale topographic maps in scale 1:24,000. In order to better understand the research questions, a brief introduction to large scale topographic maps and topographic mapping as well as their characteristics has been provided. A focus in this chapter has been placed on digital data sources and their distribution, such as DLG and DEM, that are directly related to this research. Digital vector or raster data stored in these formats are distributed based upon standards defined by the USGS.

4. Methodology

4.1 Data Preprocessing

USGS represents the initial source of digital data for large scale topographic maps provided in the SDTS format. SDTS consists of DLG and DEM components. Because there are no tools available for direct conversion of these file formats to SVG, other methods had to be developed for their conversion. SVG is a relatively new format, so conversion methods are not yet available.

The purpose of the data preprocessing was to process the source data to a required structure (for all map objects) and export the data to SVG format for further use. Both DLG and DEM data can be easily imported/exported in a GIS system. Therefore, a GIS program was used as a primary tool in this initial phase. Because DLG and DEM represent a different data structure, vector vs. raster, different methods had to be used. The whole process of data preprocessing can be divided into three general steps:

❑ import of source data into a GIS

❑ graphical and attribute processing of source data in the GIS program

❑ data export to SVG

4.1.1 Vector Data

4.1.1.1 Import of Source DLG Data into a GIS

Since all graphic and attribute information for the SVG map is in the DLG format, DLG plays a more important role in this project than DEM. The DEM was used to provide a 3D terrain effect through analytical hill-shading and to implement the interactive elevation display.

Most GIS systems import DLG files, including both the image and attribute data. Once imported, data can be processed, analyzed, and converted to various vector formats. Currently, ArcView/ArcGIS from ESRI and MapInfo from MapInfo Corporation offer export possibilities to SVG. DLG can be easily imported, processed, and exported to SVG in both ArcView/ArcGIS and MapInfo. Basically, there are three reasons why DLG has to be processed in a GIS:

1. There are no direct import/export tools from DLG to SVG (using another program is necessary).

2. Processing the source data is necessary in order to separate map objects and eliminate unneeded graphical features (unneeded number of vertices increase the file size). The illustration on left on the Figure 4.1 displays a line from a DLG file as multiple segments. The SVG file on the right combines these segments into a single line.

3. The separation and export of individual map objects (roads, contours, rivers, etc.) in order to assign their graphic attributes (style and symbology).
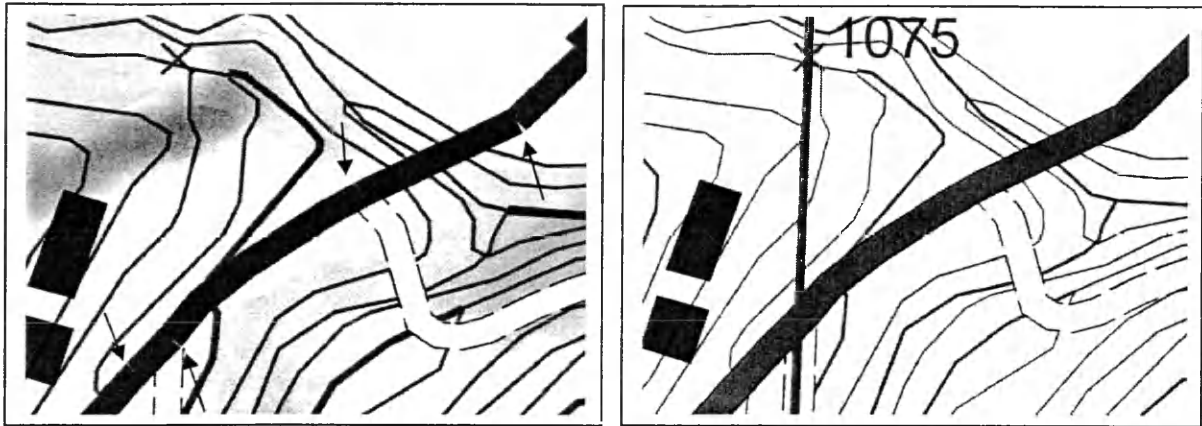
Figure 4.1: Inappropriate properties of DLG objects that have to be eliminated - unneeded number of

vertices (on the left) instead of one solid line (on the right).

In this work, ArcView 3.3 was used as the GIS. The ArcView program offers

good export/import possibilities for both DLG and SVG. The source data can be

downloaded from the USGS server as described in chapter 3.1.2 (see also Figure 3.4).

Downloaded DLG data has to be subsequently imported to ArcView. Kerski proposes a

way for importing DLG files into ArcView using the Avenue script **dlg2shp.ave** (Kerski,

2002). Besides the free **dlg2shp** script, other ways can be used, such as internal USGS

programs/utilities, freeware software (e.g., dlgv32 Pro), or commercial format

viewer/translators, such as GlobalMapper. In general, the import of DLG files to

ArcView is straightforward and it does not require special skills or experience.

DLG files, distributed in nine basic layers, were imported as three feature types -

area, line, and point features - for each thematic layer. For example, spot heights (point

features) and contours (line features) represent the same thematic layer — hypsography.

The number of Shape Files generated by ArcView for each topographic map sheet is the determined by the area it portrays. Theoretically, each thematic layer can consist of area, line, and point features. This creates three separate Shape Files. This separation of each thematic layer to point, line, and area features is determined by ArcView, which strictly stores data only with the same feature types in one layer/file (for example, only point features in one layer/file). Besides geometric features that are converted to the Shape File, attribute features, which are also encoded in DLG, are translated to the Shape File as well. After conversion, all source DLG files are stored in the ArcView Shape File format as separate files.

4.1.1.2 Processing of Source Data and Separation of Objects and Their Attributes from Thematic Layers

Each Shape File, independent of what feature type it contains – area, line or points, can consist of individual objects or groups of objects that relate to the particular thematic layer. For example, point features in one Shape File can be represented by different groups for individual objects in a map like churches, schools, towers, etc. These objects also have their own attributes that are stored in the database file. In the case of ArcView, this file is in the *.dbf* format. These objects are also represented by different symbols in a map. Therefore, they have to be separated from a database and individually exported to SVG as a group of objects. The whole process is depicted in Figure 4.2. SQL queries were used (Figure 4.3) and the results saved as individual files. To make the whole process clearer, file names were assigned in the logical order as depicted in Figure 4.3.

4.1.1.3 Data Export to SVG format

Conversion possibilities from ESRI's Shape File (ArcView) to SVG have been

the subject of previous research (Pavlicko, 2003). According to that investigation, the

conversion possibilities can be divided into two main groups:

❑ *ArcView extensions or Avenue scripts*

❑ *graphical conversions (exporting shapefile to a particular graphic vector format*

and then subsequently to a final SVG file using graphic-based programs such as

Adobe Illustrator, Corel, etc.)

Although *graphical conversions* offer good solutions, they are many times

inefficient, especially because they loose geometrical properties of the map content. For

example, the map could be re-projected to a new unknown projection. This might be

acceptable for small-scale general reference maps where spatial accuracy is less

important. However, this is not appropriate for large scale topographic maps. Therefore,

other solutions had to be sought.

ArcView extensions, or Avenue scripts, that convert Shape Files to SVG

represent more complex solution for publishing maps on the Web than just a pure format

conversion. Using such programs, one can create a fully functional cartographic product.

Besides the map content in SVG, other features can be added to the final map such as

scale, legend, interactive features, etc. Currently, there are four programs available for

ArcView that are able to make conversions from Shape File to SVG - SVGMapper,

shp2svg, Neten'Map LT, MapViewSVG.

In this work, only the conversion tools for the map content to SVG were used.

This conversion consisted of a geometric translation of map features/objects only.

Although these tools offer good solutions, they still have a lot of limitations. For example,

they cannot convert more complex features such as multi-lines (a line that consists of

more than one line), and symbols, that is so necessary for the creation of a large scale

topographic map according to the standard symbology (see USGS, 2003c). That's why

the converted map features to SVG served only as a basis for their further development

(symbology, interactive features). Figure 4.3 is the example of conversion program -
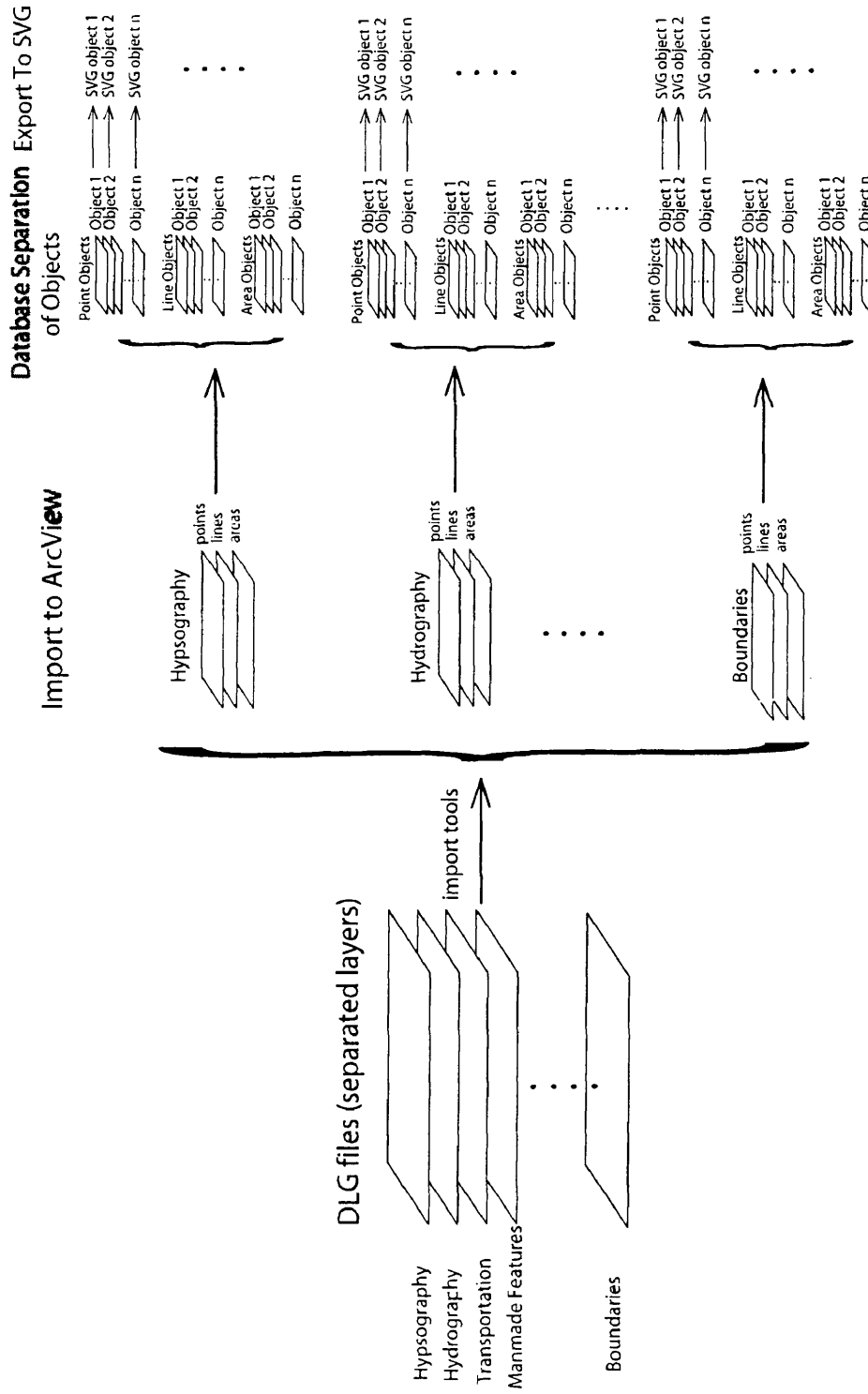
SVGMapper.

Figure 4.2: The process of importing, processing, and exporting source data from DLG to SVG
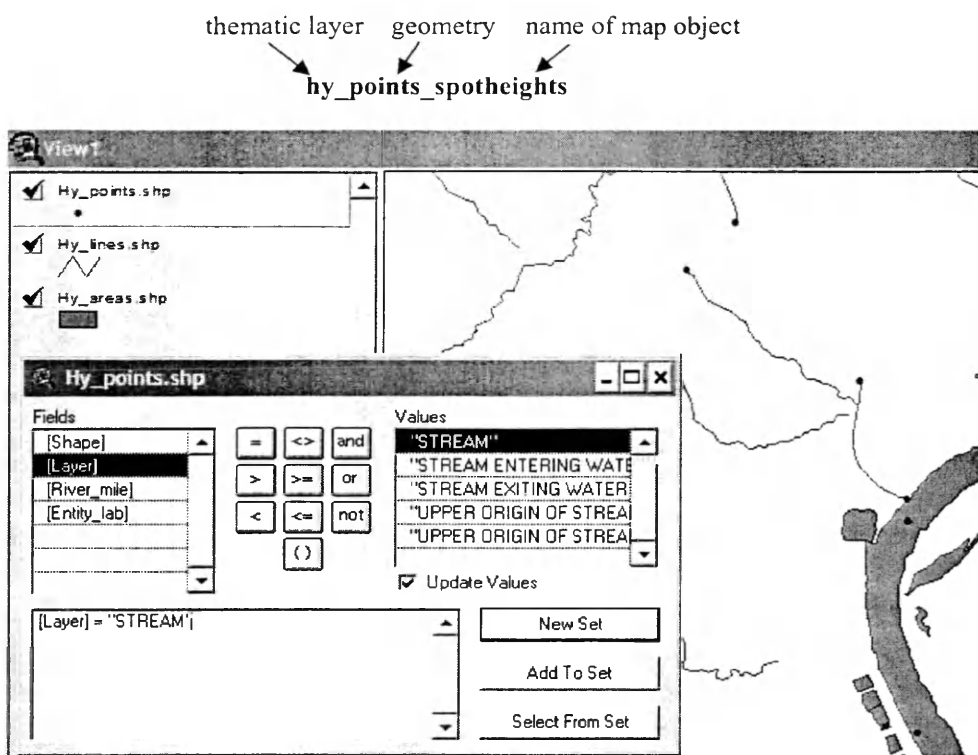
thematic layer   geometry   name of map object

hy_points_spotheights

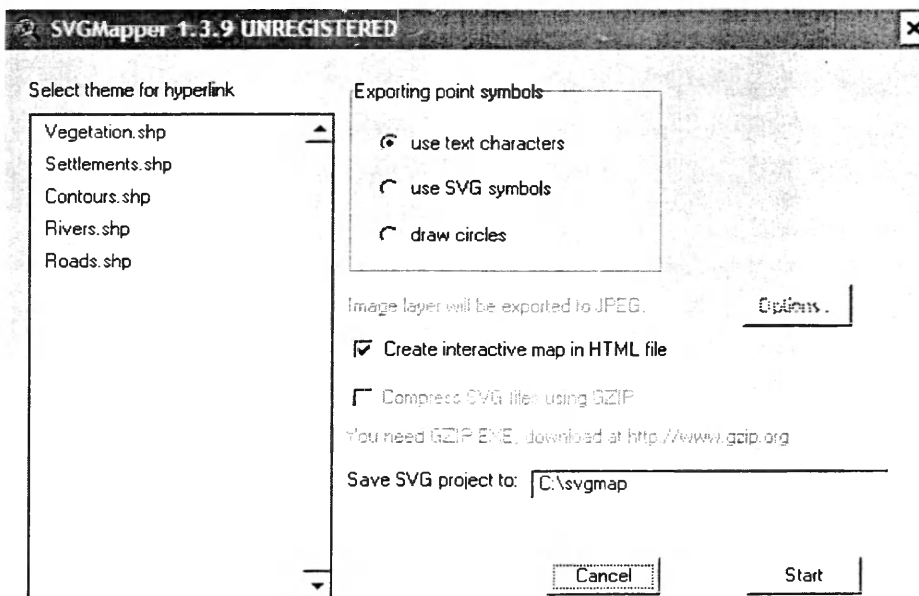*Figure 4.3:* File names and database separation of objects using SQL queries.

Figure 4.4 Example of conversion program SVGMapper.

4.1.2 Raster Data

Digital Elevation Model (DEM) data was used in this project for adding more

information content to the interactive topographic web map, specifically:

- ❑ 3D terrain effect through an analytical hill-shading

- ❑ an elevation readout function (implemented through JavaScript)

Another GIS program called GRASS (Geographic Resource Analysis Support System)

was used to import, process, and export the DEM to the required format/structure.

GRASS is open source software that offers powerful tools for the manipulation of DEMs.

USGS DEM files can be imported to GRASS using the command *r.in.dem*. After setting

up the projection and region, DEM data can be processed and exported to various raster

formats.

The 2D shaded relief can be created using certain raster oriented graphics

programs such as Adobe Photoshop, Paint Shop Pro or others. It serves only for

visualization purposes to reach the 3D effect of relief (see Figure 4.5).

In this work, a DEM raster image was exported from GRASS to the TIFF raster

format as a 256-level grayscale image. The TIFF image was imported into Adobe

Photoshop. Using the alpha channel and filter technique *Lightning effects* it is possible to

create the 3D effect of the relief. Such a technique was described by Patterson (Patterson,

2003). The resultant image can then be used as a background image in the final

topographic map. This relief shading was integrated with the final SVG map and

represents a way in which the resultant map can contain more information than is
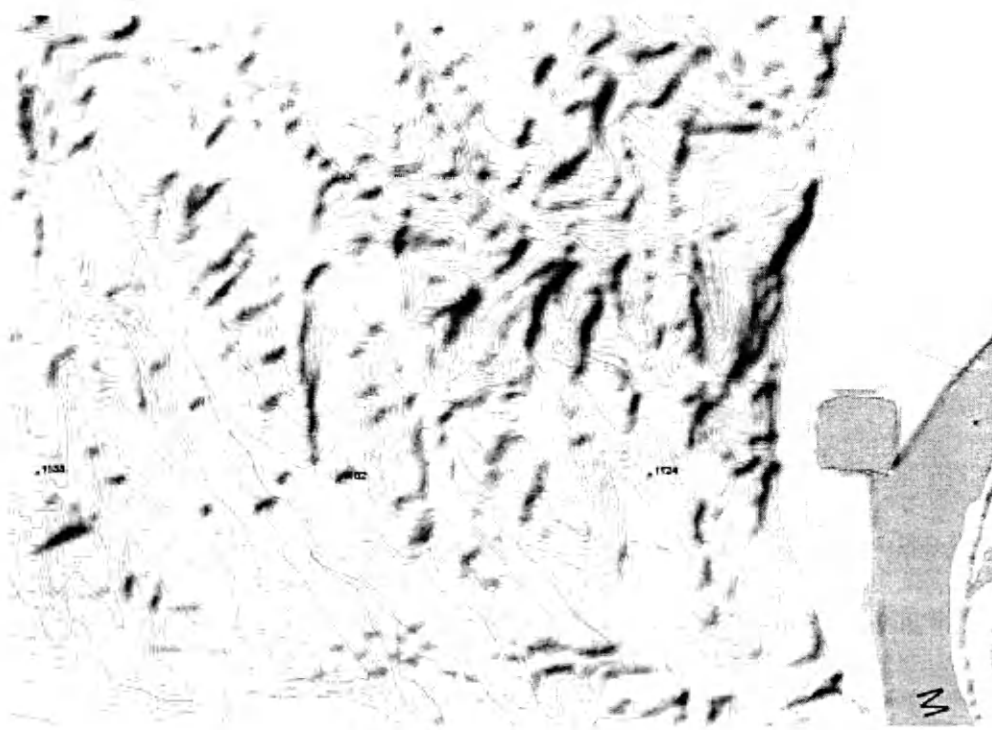
available through the USGS map.

Figure 4.5: Relief shading using raster image in the background.

The feature that most distinguishes topographic maps from maps of other types is that they provide information about shape and elevation of the land. Instead of contours, the DEM can serve this purpose very effectively. The elevation value is represented as a pixel value. Isakowski and Neumann (2002) present a solution for how to create an interactive function and use the DEM to determine the z-value (elevation value) for the topographic map. They store DEM data in a JavaScript array and, by calculating the real-world coordinates, the elevation value can be displayed. For this purpose, DEM data has to be exported to a JavaScript array proposed by Isakowski and Neumann. Using the *r.out.ascii* GRASS command, DEM data can be processed and exported to the required structure and then adjusted in a text-based editor such as Notepad, WordPad, etc. The

following is the example of a JavaScript array in which DEM values are stored. Each array contains values for one row in the raster file. The number of created arrays is equal to the number of rows in DEM.

var dem1 = [371,367,362,358,353,354,356,360,362,362,361,358,353,347,341,338,337,336,335,337,339, 341,342,343,343,344,346,350,352,352,355,359,354,355,359,365,371,370,366,359,350,346,343,340,338,33 5,332,329,327,327,325,323,321,316,316,316,318,326,334,338,336,327, ...,n];

4.2 SVG Code Optimization and Minimization

Once all map objects are encoded in separate SVG files, the process of compacting and creating one solid file can now begin. For the creation of the SVG topographic map, the structure of the SVG document has to be defined. The following sub-section discusses the SVG document structure that could serve the purpose of large scale topographic maps. Since the SVG topographic map will be distributed via the Internet, the size of the resultant file should be as small as possible. Therefore, the structure of the code is important as it directly determines the file size.

Each topographic map consists of a series of map objects that are represented by symbols. Symbols are defined by the USGS standards. Therefore, the topographic web map has to follow the standard USGS symbology. The process of SVG code optimization and minimization is divided into two parts. First, the structure of the SVG document is proposed. The second part discusses the cartographic symbols that have to be created in order to create the final map with the standard symbology.

4.2.1 Structure of the SVG Document

Many things need to be considered to create a completely vector topographic map in SVG. For example, how map objects will be grouped together, what is the rendering order of the SVG document and how effectively these objects are encoded in SVG need to be given careful consideration. The topographic map contains several thematic layers including of area, line, point, and text features. To avoid unnecessary overlap when objects are rendered, the order of area, line, and point objects among all thematic layers has to be established. According to SVG Specification 1.1, elements in a SVG document fragment have an implicit drawing order with the first elements in the SVG document fragment getting "painted" first. Subsequent elements are painted on top of previously painted elements. Grouping elements such as the 'g' tag have the effect of producing a temporary separate canvas initialized to transparent black onto which child elements are painted (SVG, 2003).

The proposed SVG structure goes out from the assumption that area features have to be rendered first, which means that they also have to be defined first in the document. Line features are then as second, followed by point and text features. Moreover, the area, line, point, as well as text features that relate to the same thematic layer have to be organized in order to provide the proper rendering. The following is the list of objects (symbols) specified by their thematic and geometric affiliation that were used here.

	Point Features	*Line Features*	*Area Features*
Hypsography	Spot elevation	Index contour Intermediate contour Carrying contour	
Hydrography	Stream mileage	Perennial stream Intermittent stream Shoreline	Lake, pond
Transportation		Class1 – Primary Highway Class2 – Secondary Highway Class3 – Lt. duty, hard or impr. Class4 – Unimproved dirt Railroad – single track	
Boundaries		State or territory County, parish, municipio Incorporated city, village	
Public Lands Survey System	Section corner	Section line	
Manmade Features	Small building Church Tower School Tank		Buildup area
Surface Cover			Woods, brushwood
Survey Control	Vertical control station Horizontal contr. station		

The structure of the SVG document has to fulfill certain hierarchical object order (rules) and rendering order to avoid problems with display. It has been proposed as follows:

❑ All objects that represent the same map object are grouped and create the lowest hierarchical level of the SVG document (e.g., all churches as map objects are grouped to create a group "church")

❑ All objects that relate to the same category (thematic layer) are grouped together based upon their geometry and create the higher hierarchical level. For example, all area objects that relate to hydrography are grouped together, or all point features for manmade features are also grouped together.

❑ Groups (objects) that represent all categories and relate to the same geometry are grouped to the highest hierarchical level (e.g., all thematic layers with area features are grouped together)

❑ The rendering order for the groups with highest hierarchical order is as follows: areas are defined first, followed by lines, points and text

❑ The rendering order for the different thematic categories with the same geometry is established according to their affiliation to the real surface (e.g., contours should be rendered first in relation to roads or railroads because they represent the surface, and roads are built on surface; etc.).

According to the previous rules, the SVG document would look like the following code:

```
<g id="areas">
        <g id="surface_cover_areas">
                <g id="forest"></g>
        </g>
        <g id="hydrography_areas">
                <g id="hydrography_areas_stream></g>
                <g id="hydrography_areas_industrial></g>
        </g>
</g>
<g id="lines">
```

```
        <g id="hypsography_lines">
                <g id="hypsography_lines_intermediate></g>
        </g>
        <g id="hydrography_lines">
                <g id="hydrography_lines_intermitterstream"></g>
        </g>
</g>
<g id="points">
        <g id="hypsography_points">
                <g id="hypsography_points_spotheights"> </g>
        </g>
        <g id="hydrography_points">
                <g id="streammileage"></g>
        </g>
</g>
< g id="text">
        <g id="hypsography_text"></g>
        <g id="hydrography_text"></g>
</g>
```

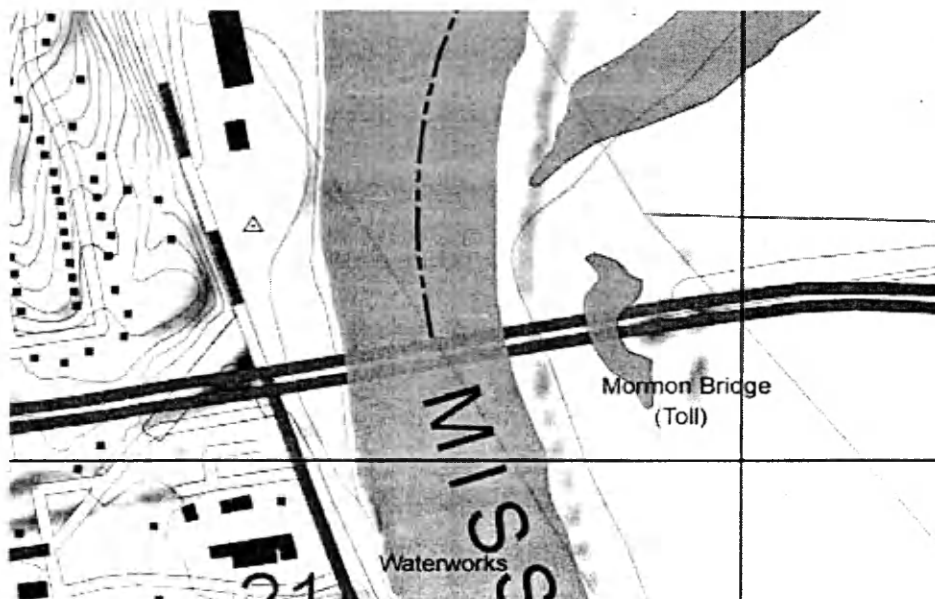Figure 4.6 and 4.7 show what can happen if the rendering and hierarchical object order is

disrupted.

Figure 4.6: Overlapping problem caused by an incorrect hierarchical rendering object order.
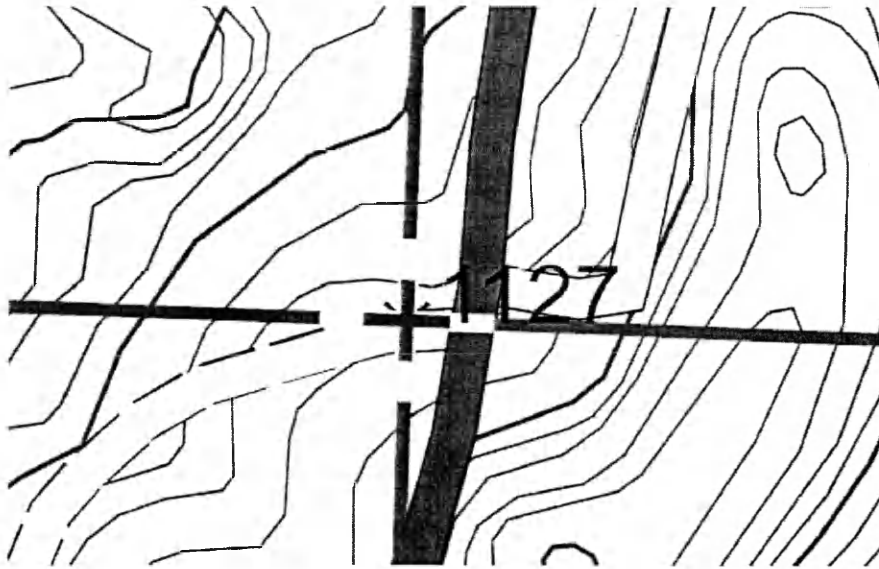
Figure 4.7: Spot elevation (brown cross) as a point feature is overlapped by line features (section line).

4.2.2 Cartographic Symbols for Large Scale Topographic Map in SVG

Cartographic symbols on 7.5-minute quadrangle maps are defined by USGS

Standards (USGS, 2003c). Each symbol is defined by its size, color, placement, and name

(see Figure 3.2). Based upon these standards, it is possible to create the same symbology

for map objects that are found in the paper version of topographic maps.

SVG offers many advantages for the creation of symbology for 1:24,000-scale

topographic maps. The application of the SVG "style" to map objects as SVG elements is

not a very complicated process, and there are a variety of ways to handle such definitions.

SVG offers four methods of applying style to elements (Laaker, 2002):

- ☐ XML presentation attributes

- ☐ Inline CSS (Cascading Style Sheets) properties

- ☐ Internal CSS style sheet references

❑ External CSS style sheet references

Style can be applied directly to objects (using the first two methods listed) or defined in a style sheet (internal or external). Direct application of style allows for the quickest method to test the results of style application, whereas style sheets allow for cleaner, more organized documents (Laaker, 2002). Since this effort is directed towards smaller file sizes for the SVG document, CSS styles provide a better solution. They make the document clearer and reduce the amount of code.

One of the most useful features in SVG is the ability to establish an object (or group of objects) as a symbolic group. By doing so, this "symbol" can be referenced multiple times throughout the document. This is useful especially for point features. For example, a point feature like a church or spot height is defined as a symbol and then it can be later referenced as many times as needed.

For complex map features, such as multi-lines which consist of several different lines with different styles, a method suggested by Neumann and Winter leads to a very effective solution. To create a multi-line, they propose to re-use the geometry of a single line. This is useful in case of roads (class1 and class2) where lines consist of two or three styles. Figure 4.8 displays the code and corresponding graphic example:

```
<?xml version="1.0" encoding="utf-8"?>
<!DOCTYPE svg PUBLIC "-//W3C//DTD SVG 1.0//EN" "http://www.w3.org/TR/2001/REC-SVG-
20010904/DTD/svg10.dtd" [
        <!ENTITY roadBelow "fill:none;stroke:black;stroke-width:10;">
        <!ENTITY roadAbove "fill:none;stroke:yellow;stroke-width:5;">
        <!ENTITY roadAboveSmall "fill:none;stroke:black;stroke-width:1;">
]>
<svg width="310" height="390">
        <g id="roads" style="&roadBelow;" >
                <path id="road1" d="M0.485,379.5c0,0,60.274-249.315,308.219-286.302"/>
```
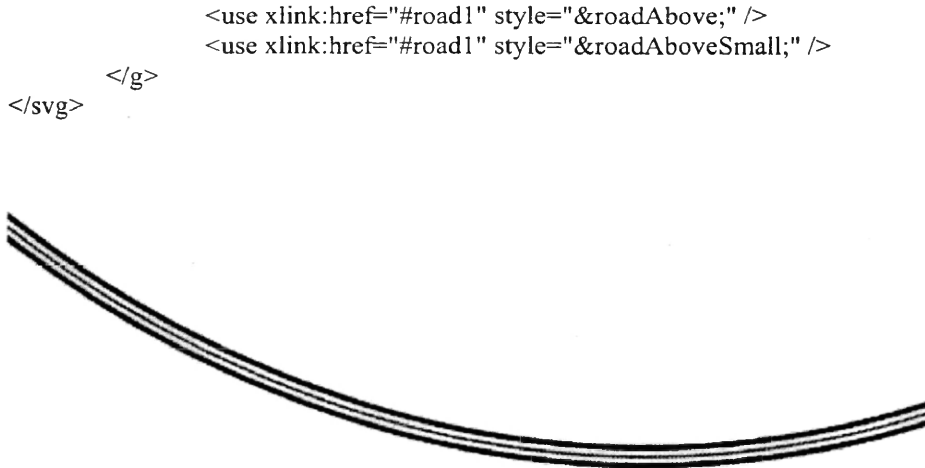
```
            <use xlink:href="#road1" style="&roadAbove;" />
            <use xlink:href="#road1" style="&roadAboveSmall;" />
        </g>
</svg>
```


Figure 4.8: Multi-line composed of three styles.

4.3 Interactivity with the SVG Topographic Map

Basic interactivity with the SVG map, such as zooming, panning, and resetting

(returning to the original view) are implemented through the SVG Viewer. Another three

interactive features were created for this SVG topographic map:

- ❑ toggle layers on and off

- ❑ display of UTM coordinates

- ❑ elevation (z-value) display

Neumann and Winter (2002) provide a list of features that can be useful for an interactive

topographic web map. Besides basic functions that serve navigational purposes

(coordinates, zooming, layers on/off, etc.), they propose other functions that would allow

analyzing a topographic map through the use of ECMAScript (JavaScript) as a client-side

scripting language. With ECMAScript, one is able to fully access SVG's and every browser feature's DOM. In next section, scripts for coordinate readouts and toggling layers are described.

The coordinate-readout problem can be divided into two parts: a) coordinates X and Y (UTM projection) b) Z-coordinate (elevation). The ideas for these mouse-over events are borrowed from the carto.net server (Neumann and Winter, 2003a) and Kevin Lindsey (Lindsey, 2003). After initializing values for coordinate calculation and getting references to SVG object, the function *showCoords* does the actual coordinate calculation and data display in the html document in which the SVG document is embedded. The function *resetCoords()* does the reset offset and pixelSizes for the coordinate calculation. The function *resetCoords()* is also called when a zoom and scroll event occurs. The whole procedure is described in detail by Neumann and Winter (2003a). The script below was adapted for this project.

```
function init(evt) {
            _svgMapObj = evt.getTarget().getOwnerDocument();
var directTarget = evt.getTarget();
if( directTarget.getNodeType() != 9 ){ // if not DOCUMENT_NODE
  svgDoc = directTarget.getOwnerDocument();
}
else {
  svgDoc = directTarget;
}
            svgSVGObj = svgDoc.getDocumentElement();
            var viewbox = new String(svgSVGObj.getAttribute("viewBox"));
var viewboxes = viewbox.split(' ');
_mapX     = viewboxes[0];
_mapY     = viewboxes[1];
_mapW     = viewboxes[2];
_mapH     = viewboxes[3];
_rectW    = svgSVGObj.getAttribute("width");
_rectH    = svgSVGObj.getAttribute("height");
            _xOrigRatio    = parseFloat(_mapW / _rectW);
            _yOrigRatio    = parseFloat(_mapH / _rectH);
            resetCoords();
      }
```

```
function _showCoords(evt) {
        var _x    = evt.getClientX();
        var _y    = evt.getClientY();
        var _newX      = _offsetX + parseFloat(_x * _xRatio);
        var _newY      = - _offsetY - _y * _yRatio;
        _showX.value   = Math.round(_newX);
        _showY.value   = Math.round(_newY);
}
function resetCoords() {
  var scale = svgSVGObj.getCurrentScale();
  var trans = svgSVGObj.getCurrentTranslate();
  var transx = trans.getX();
  var transy = trans.getY();
  _xRatio      = _xOrigRatio / scale;
  _yRatio      = _yOrigRatio / scale;
  _offsetX     = _mapX - transx * _xRatio;
  _offsetY     = parseFloat(_mapY + _rectH * _yRatio) - transy * _yRatio;
}
```

To show z-value (elevation), a different method had to be used since SVG

currently does not allow reading raster values at a current mouse position. The method

was proposed by Isakowski and Neumann (2002). DEM data are stored in ECMAScript

array. When the position of mouse is known (x and y coordinate), the z-value for that

position is taken from the ECMAScript array. The following is the script for the z-value

calculation:

```
function _getZval(_x, _y) {
        var _zRatio       = _rectW / dem1.length;
        var _zRatioMid    = _zRatio / 2;

        var _xCol         = _x / _zRatio;
        var _yCol         = _y / _zRatio;

        var _xx = _xCol % _zRatio;
        var _yy = _yCol % _zRatio;

        if(_xx < _zRatioMid)       _xc = Math.floor(_xCol);
        else                       _xc = Math.ceil(_xCol);

        if(_yy < _zRatioMid)       _yc = Math.floor(_yCol);
        else                       _yc = Math.ceil(_yCol);

        if(_yc < 1)       _yc = 1;
```

```
        var _z    = eval("dem" + _yc)[_xc];
return _z;
}
```

4.4 Qualitative Methods for the Evaluation of an Interactive Topographic Web Map

A *Focus Group* analysis was performed to determine the usability of the SVG

interactive topographic web map and how well such a map can serve as an online

topographic map. Methodology for this type of research was explained by Monmonier

and Gluck (1994). Monmonier and Gluck assert that focus groups are low-cost, efficient

qualitative method for investigation and design improvement. They applied focus groups

for design improvement in dynamic cartography. The 26 information, cartographic, and

computer specialists who participated in the interviews provided a range of opinions on

graphic scripts and the dynamic integration of maps and statistical graphs. Respondents

in each session first viewed a graphic script designed to explore the correlation between

two spatial distributions and then discussed the script's informativeness, coherence, merit,

and deficiencies. Respondents next viewed and discussed a two-part demonstration of

portions of a time-series script and of a user-control enhancement for the correlation

script (Monmonier and Gluck, 1994).

The focus group analysis was performed here in order to determine the usability

of online topographic map using the vector approach (SVG), such as the graphic quality

in comparison to raster counterparts, informativeness, and whether is it possible to better

extract geographic information from such a map in comparison to online raster

topographic web maps. The 15 students from a 300-level university cartography class

were chosen as a focus group. They served as a representative sample. A short oral introduction to the problem was given so that they would be familiar with the topic. Then, six tasks were given to them obtain some familiarity with the SVG topographic map. Tasks were focused on graphics quality, information content extraction, symbology, and the level usefulness of interactive features. A map from Topozone.com served as an example of online topographic map in a raster format. The same map was also available in SVG and students could switch back and forth between these maps.

The following is the list of tasks that were given to the focus group:

Tasks for Focus Group:

Note: Complete the following six tasks. As first, start with the Topozone map, then with the SVG map. If you can't complete the task within a short amount of time try to do it with the SVG map. You shouldn't spend more than 3 minutes on each question.

1. Find the Mormon bridge (Road 680 and the Missouri river). The complex of 11 large buildings is located approximately 1 mile (2 inches) west of the bridge. What is the elevation of largest building (roughly)?

2. On the SVG map you can see the yellow spot. This spot represents the place where the creek rises. Find the same location on the Topozone map. Can you tell how many roads the creek crosses till it reaches the Missouri river? Go back to the SVG map and do the same. Which way is more comfortable (practical)?

3. On each topographic map you can find Public Land Survey System grid. Each map has its own number. Of squares 17 and 20, which has a higher forest density? Which of them has a higher road density?

Now, work with the SVG map only.

4. Can you tell what object relates to these coordinates:

$x = 250,717; \ y = 4,582,877$

5. How many road classes can be found on the SVG map (considering the symbology, legend and the use of zoom in/out)

6. Can you find the boundary between Iowa and Nebraska?

These tasks served for getting students more familiar with the SVG map. They could obtain the general impression about both the SVG and Topozone map as well as specific detail information related to symbology and interactive features. After that, the group proceeded to another room for further discussion. Questions for the discussion concerned specific problems related to graphics quality, information content extraction, symbology, and the level usefulness of interactive features. The student answers were recorded and analyzed.

Questions for focus group:

1. According to the previous tasks, do you think that the graphic quality is better in SVG (vector) maps or in raster maps? Why?
2. What advantages do you think such SVG maps can offer? (in general)
3. What do you think are the biggest disadvantages of the presented SVG map? Why?

4. Did you find the vector map more informative in comparison to the raster map?
5. From what map, raster or vector, can you better extract geographic information? Why?
6. Do you think that turning layers on/off helps to better extract geographic information from the map?
7. Based upon coordinate readout, can you locate objects on a map? Do you think that this type of coordinate readout could be more improved? How?

8. Did you notice some differences in symbology between SVG map and the original USGS map (represented by the Topozone map in our case)? If yes, how big were those differences?
9. Do you think that SVG maps can be useful and can serve well as online topographic maps?

5. Results and Discussion

5.1 Interactive Topographic Web Map Project Description

Except ArcView 3.3, the final SVG map presentation was created using only open standard and open source tools – GRASS GIS, SVG, XHTML, and ECMAScript. The architecture of the project web page with the embedded SVG map, project titles and names, and navigational bar is based on HTML. The ECMAScripts (JavaScripts), which provide the interactivity and store some additional data, are in two separate files. Style information for both the SVG map and HTML are stored in CSS files. All files are linked together to create the solid and fully functional web page (see Figure 5.1).
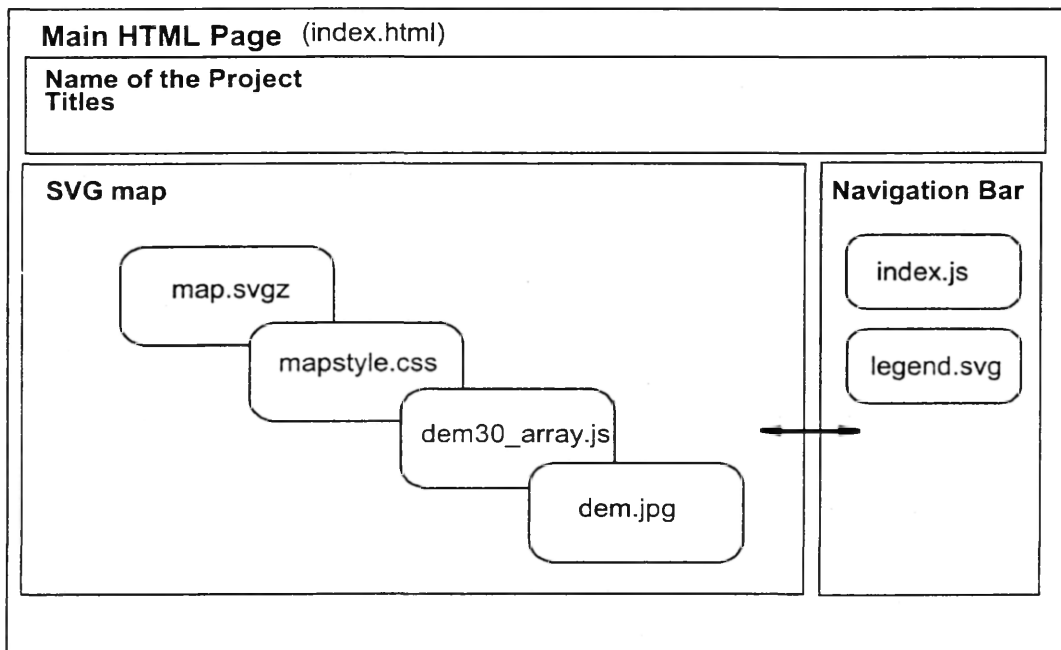
Figure 5.1: Architecture of the interactive map with the linked files
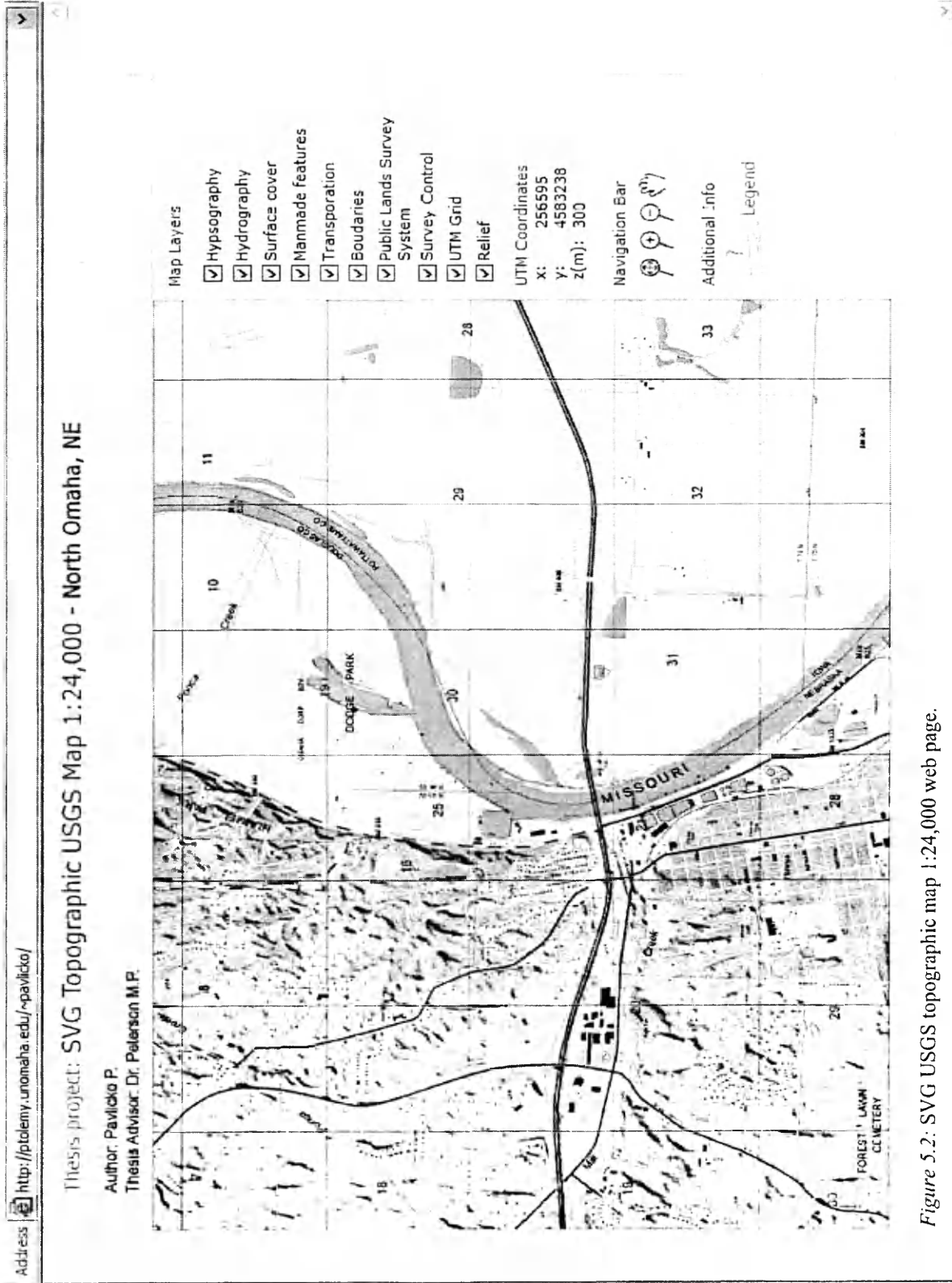
Figure 5.2: SVG USGS topographic map 1:24,000 web page.
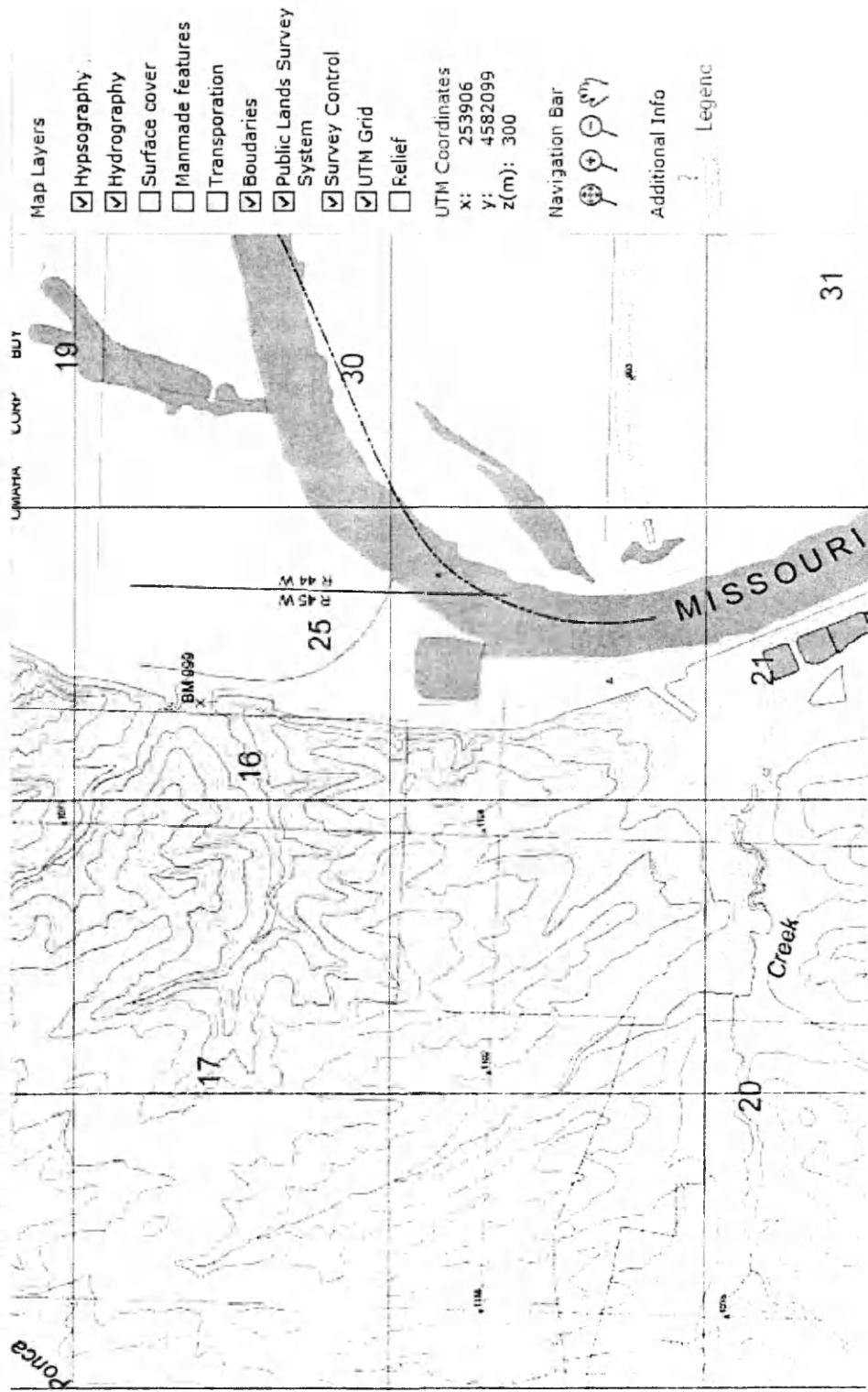
Figure 5.3: SVG presentation with some layer removed.
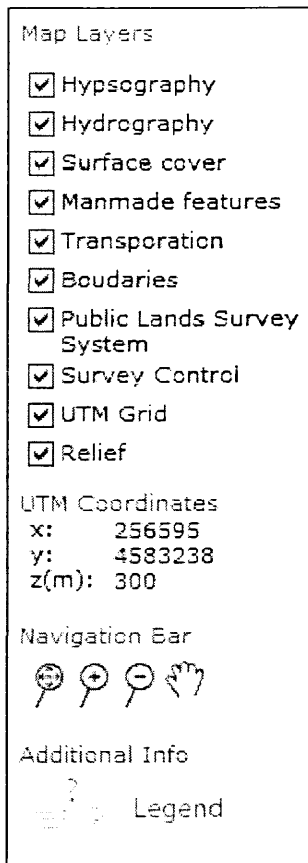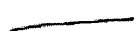
Figure 5.4: Navigation Bar

The navigation bar consists of checkboxes that represent all thematic vector layers and raster shaded relief. The layers can be separately turned on/off according to user needs (Figure 5.3). *UTM Coordinates* display plane X and Y coordinates in the UTM projection. The Z-coordinate depicts the actual elevation in meters. Zooming, panning, and resetting to the original view are controlled through Adobe SVG Viewer functions. Small icons which are enlarged on mouse-over provide the instructions on how to use zoom in, zoom out and pan functions in Adobe SVG Viewer, and how to get to the original view. Under *Additional Info*, a user can find the link to the SVG legend (Figure 5.5). In the legend, all symbols that are used in the SVG map are explained and classified into the thematic layers.

Hypsography

contour

intermediate contour

$\times^{1152}$ spot elevation

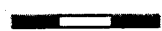## Hydrography

river; creek

lake; pond
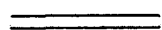
Surface Cover

forest

Manmade Features

■ small building

church

large building

buildup area

Transportation

road - class1

road - class2

road - class3

road - class4

Boundaries

state boundary

Public Lands Survey System

section line

+ section corner

17 section number

Survey Control

$\times^{1152}$ vertical control station

△ horizontal control station

Figure 5.5: Legend of SVG topographic web map.
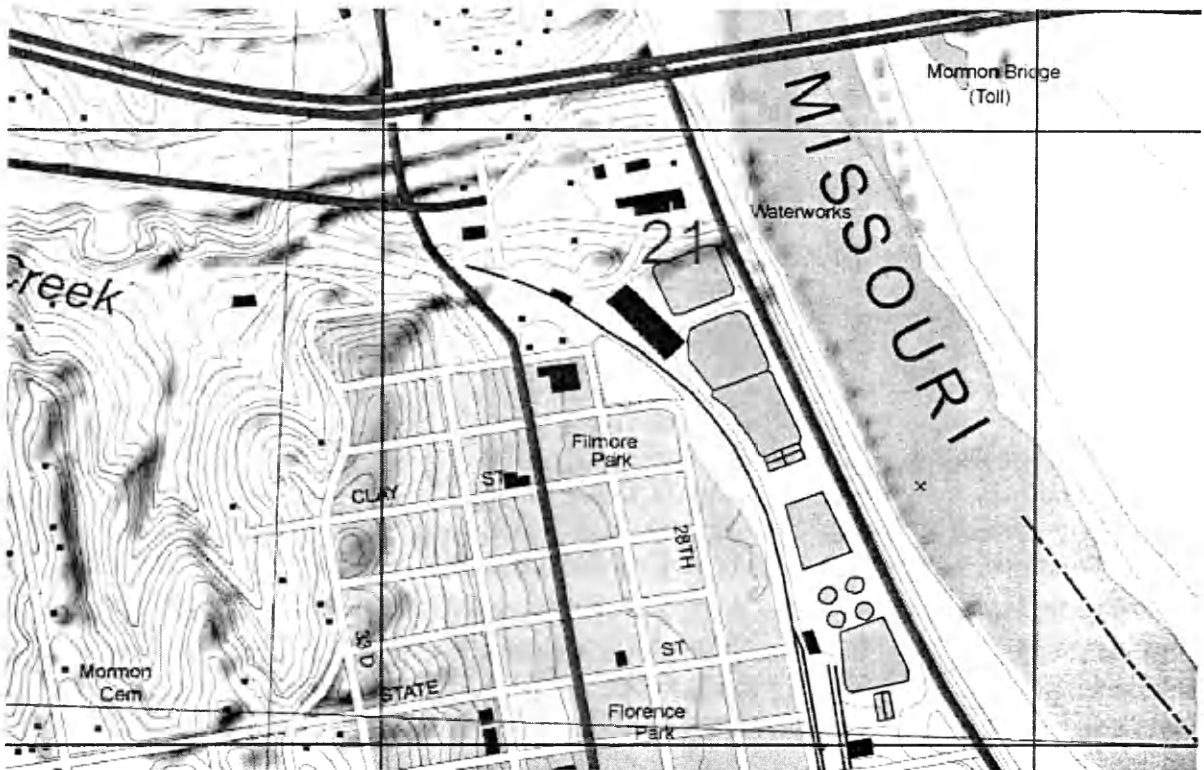
Figure 5.6: SVG provides considerable quality of graphics (detail associated with SVG).

One purpose of this project was to determine if SVG produces acceptable file sizes for use through the Web. The size of only a small portion of a 1:24,000 topographic map (approximately 30%), including the SVG map and JavaScript files, is 1,140KB. If the SVG map is compressed into the *.svgz* format, a standard compression technique for SVG files, the size is reduced 515KB, a difference of 625KB. These file sizes are acceptable sizes for use with the Internet, and would be downloaded in a matter of seconds with most configurations.

5.2 Online Distribution of Topographic Maps with SVG

5.2.1 Assets/Limitations

The advantages to SVG were explained in section 2.3. SVG represents a major improvement for web cartography and web GIS. Besides vector graphics, SVG can be linked with other XML languages and scripting languages to extend its possibilities. Although there are many positive aspects that make SVG a progressive technology, it still struggles with several limitations. The problem of a file size is one such a limitation. The SVG map in this project represents just a portion of the whole 7.5-minute quadrangle (see Figure 5.7). However, the size of that SVG file, not including JavaScript coding, is 940kB in uncompressed form or approximately 300kB in compressed form (gzip). Depending on the connection speed, such a file in compressed form would be downloaded in approximately 10 seconds with the slowest modem connection (28.8kB/s). File sizes for whole topo-sheets in SVG (all thematic layers) would vary, depending on the information content of the map. In order to investigate SVG file sizes, research was conducting on several 1:24,000-scale topographic maps from Wyoming, Montana, and Nebraska. These SVG files were all between 3 to 4 MB. Such big files are not appropriate for the web at this time. It is difficult to manipulate such files; they can easily "crash" the plug-in, and stress bandwidth. In addition, the maps that present so much detail would be unreadable without zooming. Therefore other solutions that are based on database approach are necessary. Methods for delivering larger geographic datasets for large scale topographic maps are proposed by Neumann (Neumann, 2003b).
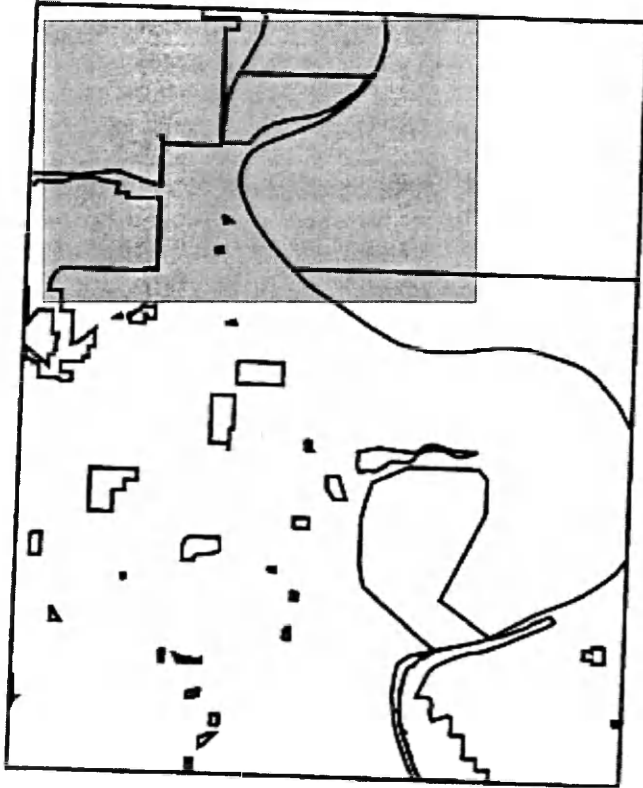
Figure 5.7: The area of the SVG map project (grey color) on the 7.5-minute quadrangle map (North Omaha, NE). The area represents about 1/3 of the map.

5.2.2 User Findings/Recommendations Based on Focus Group Analysis

The underlying purpose of the focus group analysis was to provide some initial feedback on how well SVG can serve as an effective technology for the delivery of online interactive topographic maps. Though more rigorous evaluation methods could have been employed given more time and resources, this focus group consisted of just 15 students in an upper division undergraduate cartography class. They completed six specifically designed tasks to acquaint the students with both the vector-based SVG

topographic map and raster-based topographic maps as available on Topozone.com.

Immediately thereafter, the focus group was taken to a conference room and asked a

series of questions (see chapter 4.4). A summary of their perceptions/reactions goes as

follows:

Graphic Quality:

- There was a general agreement that the SVG map provides better graphic quality in comparison to Topozone map

- The focus group commented that the SVG always provides a clear and sharp image after zooming or panning and there is no waiting for the server to respond with an updated map, as occurs with Topozone.com

- There were no misinterpretations related to graphics (e.g, unrecognizable objects)

- They generally preferred the SVG solution

Information extraction

- SVG represented a faster way of obtaining thematic information. The toggling of the layers was especially useful. For example, if someone is looking for information related to roads, all other thematic layers can be turned off except for the transportation layer, and information can then be easily extracted.

- SVG provides a better way of obtaining information in comparison to the raster Topozone map.

Interactive features and symbology

- ❏ The toggling of layers in SVG was a very useful feature

- ❏ Interpretation of the z-value (elevation) was confusing. They did not understand that z refers to elevation)

- ❏ The symbology was adequate in comparison to USGS. They did not notice any differences between the original USGS map and SVG version.

- ❏ The legend was easy to read

Advantages

- ❏ Graphic quality

- ❏ Faster download and re-draw in comparison to Topozone.com

- ❏ Easy manipulation of the map (zooming and panning)

- ❏ Information extraction was facilitated by the layer view

Disadvantages

- ❏ Problems with some interactive features (z-coordinate, locating the objects based on given coordinates)

- ❏ More interactive features needed

6. Conclusion

6.1 Overview of Thesis

This work comprised of six chapters. In chapter one, the nature of the problem, research objectives, hypothesis, rationale, as well as the significance of the research were explained. Chapter two examined the terminology and major concepts that were used in this work, including qualitative methods that are used in cartography such as the focus group. Chapter three describes and explains data sources and characteristics for large scale topographic maps that are distributed in digital formats and the related standards defined by USGS for DLG and DEM. Chapter four discusses the methodology that was used in the creation of a fully functional interactive topographic web map, including the conversion of source data to a compact SVG file, the symbolization process as well as the addition of the interactive features JavaScript. An important consideration in Web cartography is the size of the file. Methods for reducing the size of the SVG document were proposed as well. This chapter also examined the focus group methodology that was used in the evaluation of the final SVG map. Finally, chapter five presents the major findings (assets and limitations) for the SVG large scale topographic map, including user comments and recommendations based on focus group analysis. In this final chapter, the conclusions of this thesis are presented.

6.2 Major Findings and Future Work

This research has shown that Scalable Vector Graphics is a promising technology for delivering high quality interactive topographic maps via the Internet. Vector formats, in comparison to their raster counterparts, provide many advantages such as the quality of the graphical representation, maintenance and actualization, interactivity, and extensibility through other web programming languages. Large scale topographic maps have not yet been presented on the Web in vector form, using either open-standard or proprietary technology. Although there are some implementations for the distribution of such large scale topographic maps in raster form, the graphic quality as well as interactivity leaves much to be desired.

This research has confirmed that USGS 7.5-minute quadrangle maps can be successfully implemented and disseminated through the SVG. This work has shown that SVG offers many advantages. The graphic quality and manipulation with such SVG topographic maps is superior to the raster implementations. This research has also proposed the possible structure of the SVG map document. Interactive features like toggling layers on and off, UTM coordinate readout for x, y, and z (elevation) was developed as well. Such a map can help to better extract the information from a topographic map as it was indicated by the focus group analysis.

However, there are still some limitations to SVG that have to be taken into the consideration. The size of SVG files for the distribution of large scale topographic maps remains one of the biggest disadvantages not only for SVG but for the vector approach in general. This is why the online presentation of entire topographic map sheets is still

problematic. The file sizes are too big and therefore, not appropriate for the distribution on the Web at this time. According to the results, only portions (subsets) of 1:24,000-scale topographic map sheet can be distributed, with some interactive elements. To distribute topographic maps for a large area encompassing many map sheets using SVG, it would be necessary to create a database that could distribute small parts of an individual topographic map on demand.

This work has laid the foundation for the distribution of USGS topographic web maps through SVG. The online analysis of topographic maps can be provided through interactive features using client-side scripting languages like JavaScript. The number of such features that could be implemented is basically unlimited and can be developed to serve specific applications. This represents the future challenge and an interesting subject of future research.

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