

EPA Drinking Water Mapping Application: Client Focus and Architecture Design

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Abstract

EPA's Office of Ground Water and Drinking Water has developed a special Drinking Water Mapping Application (DWMA) to serve the program needs of its staff and other carefully targeted clients. This secure Web-based application uses ESRI ArcIMS and ESRI SDE as core system components. The system design approach is geared to make the maximum possible use of existing Web and database services within EPA to provide missing critical information products for its target audiences. The design architecture will be explored along with an overview of the types of mapping and data products available through the application.

1.0 Introduction

The U.S. Environmental Protection Agency (EPA) Office of Ground Water and Drinking Water (OGWDW) Drinking Water Mapping Application (DWMA) is a Web-based geospatial application that enables queries of the Safe Drinking Water Information System (SDWIS/FED) and the identification of contaminant risks to surface water and groundwater used for public drinking water supplies. The primary goal of the DWMA is to provide a secure application that EPA staff can easily use to obtain reports and maps that help manage programs under the Safe Drinking Water Act. This document describes the data sources, Web interface, functionality, and system architecture of the DWMA.

2.0 Data Sources

The DWMA uses the U.S. Geological Survey (USGS) National Hydrography Dataset (NHD) to represent surface waters. Other national-level data sources integrated in the application are

- SDWIS/FED
- Permit Compliance System (PCS)
- Resource Conservation and Recovery Act Information (RCRAInfo)
- Comprehensive Environmental Response Compensation & Liability Information System (CERCLIS)
- USGS nitrogen fertilizer use estimates
- USGS herbicide use estimates
- U.S. Department of Agriculture (USDA) land application estimates for animal waste
- USGS Proposed National Atlas Karst Map
- USGS Ground-water Regions of the Conterminous United States with Unconsolidated Watercourses
- USGS Principal Aquifers of the 48 Contiguous United States
- USGS Surficial Geology of the Conterminous United States.

The application also uses data from EPA's Reach Address Database (RAD), which is a repository of water quality data submitted by states to EPA. Data in the RAD are also based on the NHD,

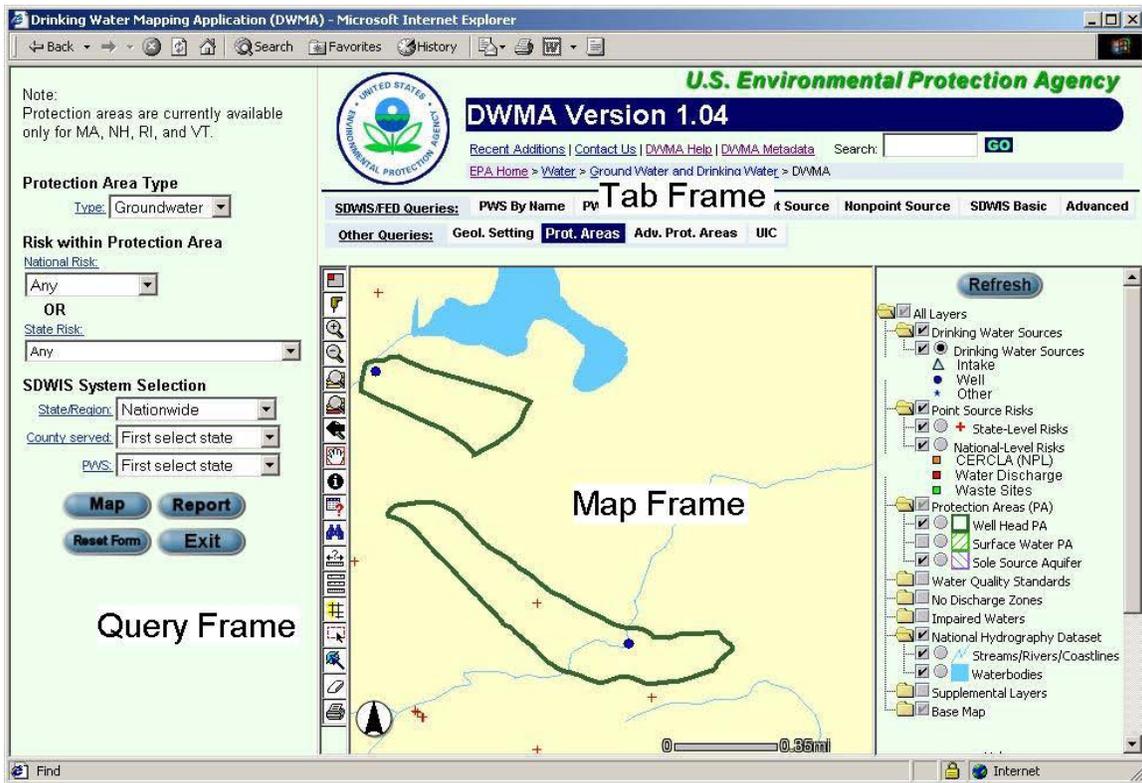
which maintains consistency when used for creating maps in the DWMA. State-level information (only available for certain states) in the application include

- Wellhead protection areas
- Source water protection areas
- Sole-source aquifer designations
- State supplied hydrogeologic settings.

3.0 Web Interface

The DWMA Web interface is divided into multiple frames as seen in Figure 1 below. The top “Tab Frame” consists of the EPA standard header and the query “tabs.” The query “tabs” control the query options, which appear in the “Query Frame” on the left. The “Map Frame” in the center and its sub-frames contain the map and associated tools and legends.

Figure 1. DWMA Web Interface



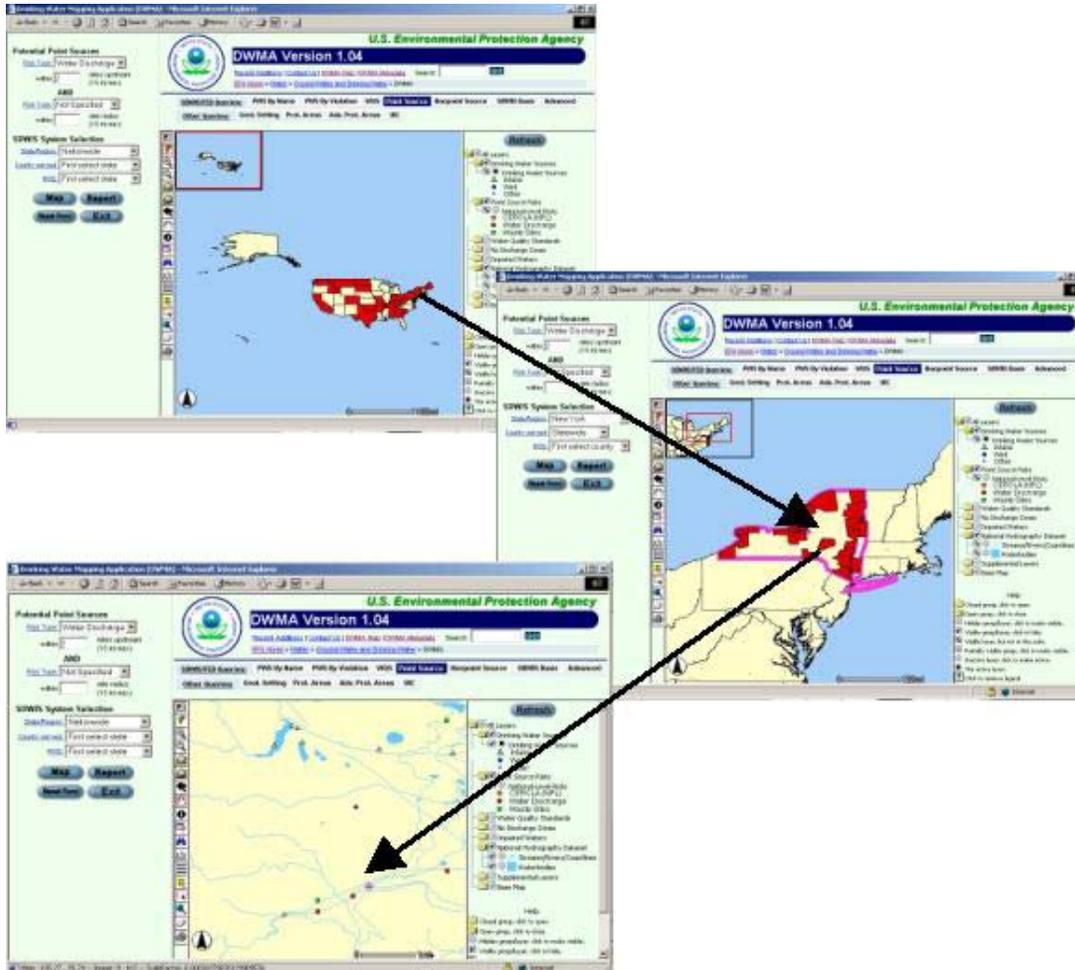
To operate the DWMA, the user simply performs the following steps:

- Select a query tab of interest
- Select query parameters of interest
- Click on the map or report button to generate either a map or report.

The output of a DWMA query varies with the current scale of analysis (national, state, or county). A nationwide query returns the states containing water systems that satisfy the query definition. A state query returns counties, and a county query returns actual water systems. A map query highlights the result set in red on the map, while a report query generates a table in a pop-up window.

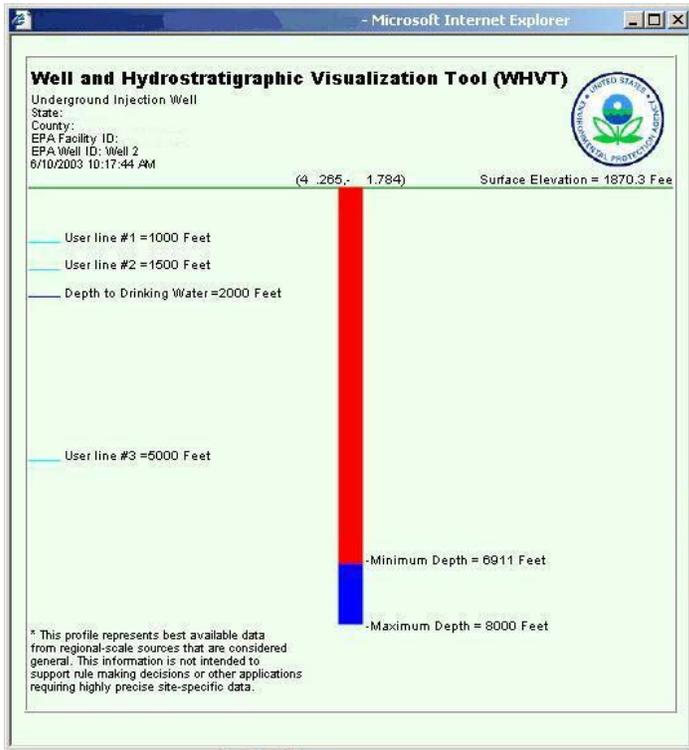
At any time, the user can use any of the map tools in the map toolbar that appears just to the left of the map. RTI has created two custom map tools, the “drill-down” tool  and the “well visualization” tool . The drill-down tool allows the user to move from national, state, and county level map results to their corresponding more detailed maps simply by clicking on the map itself. Selecting this tool and then clicking on a state or county of interest automatically populates the appropriate query drop-down and initiates the map request. Figure 2 demonstrates a sequence of drill-down requests resulting in ever increasing resolution on the candidate set of results.

Figure 2. Drill Down Output



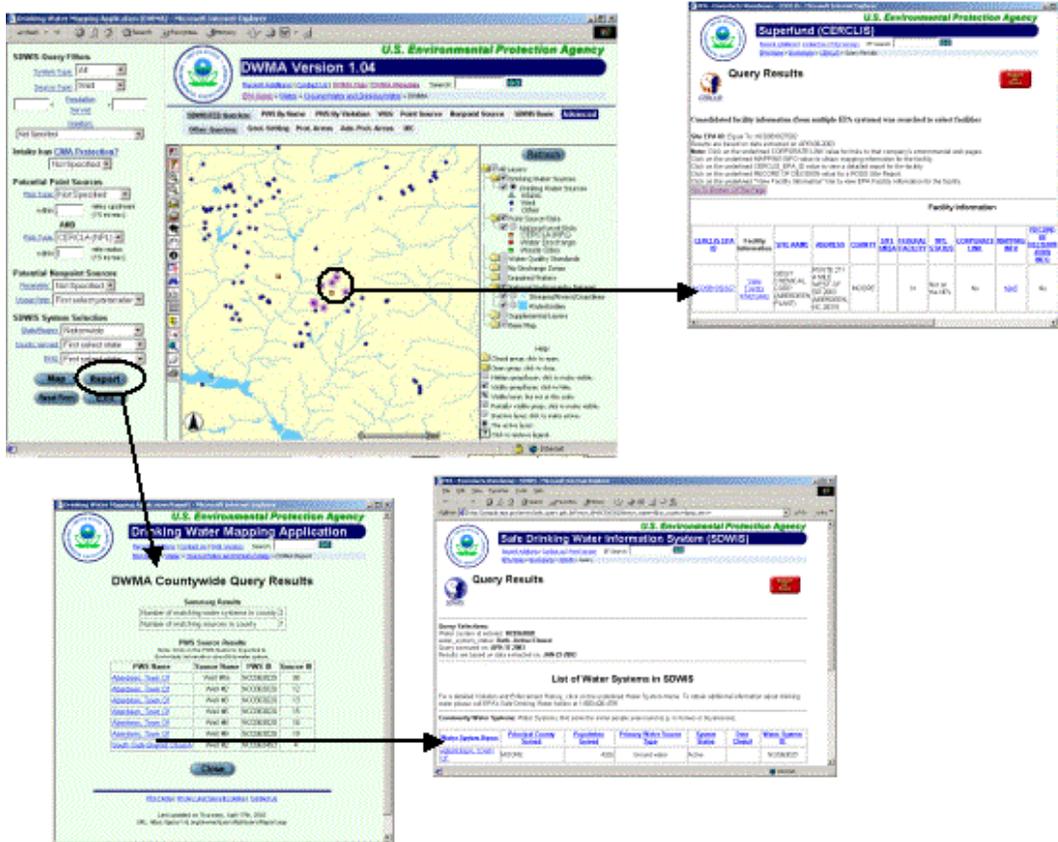
The well visualization tool allows a user to generate a customized well profile graphic for any UIC well point as shown in Figure 3.

Figure 3. Well Visualization Tool Output



Many of the DWMA reports and the output obtained when a user identifies on a map feature are hot-linked to existing EPA Web reports. This allows the user to move seamlessly from results sets generated by the DWMA into the more detailed information offered by these existing EPA web reports as seen in Figure 4. All query parameters and layer legend names are hot-linked to appropriate metadata.

Figure 4. Tapping into Existing EPA Reports



4.0 Functionality

The DWMA currently offers seven query tabs based on SDWIS/FED and other national data sources. These queries are all based on data that are available in national-scale databases, such as SDWIS/FED, NHD-RAD, PCS, RCRIS, CERCLIS, and other national-scale data sources from EPA, USGS, and USDA. The DWMA also offers four query tabs based on state supplied data and other data sources, including surface water and well-head protection areas, state lists of contaminant risks, well geologic setting attributes, and underground injection control wells. All queries can be performed at multiple spatial levels, including national, EPA Regional, state, county, and PWS queries.

4.1 SDWIS/FED Queries

PWS By Name: The PWS by name query tab allows the user to find particular public water systems (PWS) by name or to summarize PWS counts nationwide, in an EPA Region, state, or county. These data are derived from the Envirofacts copy of SDWIS/FED.

PWS By Violation: The PWS by violation query tab allows the user to find states or counties containing PWS with violations for a specified analyte type and/or to locate the particular water systems with violations. These data are derived from the Envirofacts copy of SDWIS/FED.

WQS: The WQS query tab allows the user to identify water systems that have PWS with or without documented Clean Water Act protection and determine the number and location of these PWS. These data are derived from NHD-RAD.

Point Source: The point source query tab allows the user to find the location and number of water intakes affected by water discharges within 15 miles upstream of a given PWS. The user can also search for waste sites and CERCLA (NPL) sites within a 15-mile radius of a given PWS. These data are derived from PCS, RCRIS, and CERCLIS.

Nonpoint Source: The nonpoint source query tab allows the user to find water systems where the usage rate of the specified parameter (atrazine, nitrogen, or animal waste/manure) meets the specified rate in the usage rate drop-down box. These data are derived from USGS and USDA data sources.

SDWIS Basic: SDWIS Basic is the default selected query tab when the application opens. Using this tab, the user can search for locations with community water systems (CWS), non-transient non-community water systems (NTNCWS), or transient non-community water systems (TNCWS) that consist of intakes, wells, reservoirs, or springs. The user can also filter the query by the population served or by a violation. These data are derived from the Envirofacts copy of SDWIS/FED.

Advanced: The advanced query tab combines the functionality of the tabs described above in Section 4.1 and allows the user to perform simultaneous queries across multiple data sources. These data are derived from all of the sources listed above.

4.2 Other Queries

Geological Setting: The geological setting tab allows the user to identify wells based on whether a well is unconfined, semiconfined, or confined and whether a well taps fractured bedrock or a nonfractured porous medium such as stratified drift.

Protection Areas: The protection areas tab allows the user to identify groundwater or surface water protection areas that may be impacted by nationally or state defined contaminant risks.

Advanced Protection Areas: The advanced protection area tab combines the functionality of the tabs described above in Section 4.2, allowing the user to identify wells with higher risk potential for specific contaminants.

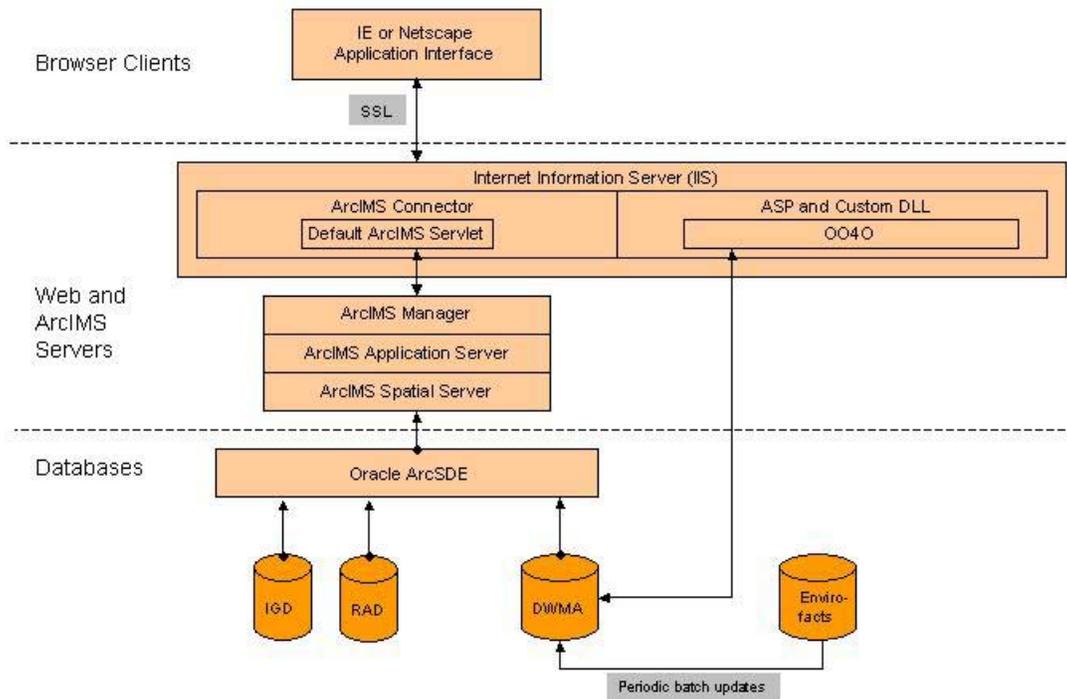
UIC: The underground injection control (UIC) class I tab currently does not provide query functionality. Instead, the known locations and approximate locations of UIC class I wells are identified on the map. The custom well visualization tool on this tab provides a graphical view of geologic characteristics (e.g., confining layers and major aquifers) for a given UIC. These data are derived from EPA and USGS data sources.

5.0 System Architecture

The DWMA is a read-only Web application for use by EPA OGWDW and other designated EPA staff. The underlying mapping application within the DWMA is a customized version of the HTML viewer supplied with the ArcIMS software produced by the Environmental Systems Research Institute (ESRI). This mapping application is implemented utilizing frames and JavaScript. Other computing technologies used in the DWMA include Active Server Pages (ASP), Visual Basic (VB)

Dynamic Link Libraries (DLLs), Oracle PL/SQL procedures, and Oracle Objects for Object Linking and Embedding (OO4O). The application uses an Oracle database. The database consists of a number of Oracle database tables and an Oracle package of PL/SQL procedures. The database tables store relationships between drinking water sources and various potential point and nonpoint sources of contamination. The DWMA leverages existing EPA database infrastructure by connecting directly to the RAD for NHD and event data and directly to EPA's Integrated GeoDatabase (IGD) for other contextual data. While Oracle Spatial is not required to run the DWMA, it was used by RTI to build and periodically update some of the database tables used by the DWMA. Figure 5 provides a high-level view of the DWMA system architecture.

Figure 5. DWMA System Architecture



5.1 Client

The DWMA client is an Internet-enabled device running one of the following Web browsers:

- Internet Explorer, version 5.0 or later
- Netscape Navigator, version 6.2 or later.

The well visualization tool requires the user to install Adobe SVG Viewer, a free plug-in available at <http://www.adobe.com/svg/viewer/install/main.html>.

5.2 Middleware

The DWMA middleware consists of a mapping/Web server. This server (or servers) requires the following software:

- ESRI's ArcIMS 4.0

- Microsoft's Internet Information Services (IIS) Web Server with the Active Server Pages (ASP) capability enabled
- Oracle NET 8
- Oracle Objects for Object Linking and Embedding (OO4O)
- Microsoft Access open database connectivity (ODBC) driver.

The mapping application design is based on a customized version of the standard ArcIMS HTML viewer and uses the default connector. The HTML viewer model relies on the use of HTML frames and JavaScript. The basic HTML viewer application was customized to meet the application requirements. Out-of-the-box functionality inherent in ArcIMS was leveraged whenever possible. Two additional tools were added to the interface to provide

- "Drill down" functionality to allow graphical specification of state and county drop-down box values.
- Well visualization tool to generate a customized well profile graphic.

The default ArcIMS HTML viewer requires the user to toggle between the layer list and symbology views. The DWMA uses a customized version of dbGroupToc (version 1.4), a legend enhancement to the HTML viewer developed by David Bollinger. The DWMA legend allows the user to control the display of layers and set the active layer in the same view that shows the layer symbology.

As described in Section 5.3, all DWMA spatial layers are stored in an ArcSDE-based geodatabase. The DWMA's customized ArcIMS HTML viewer connects to these spatial layers via ArcSDE. The application connects to the DWMA procedures using ASP, Visual Basic custom DLLs, and OO4O. A custom DLL references OO4O for communication with the DWMA database's stored procedures. OO4O is an Oracle middleware component that allows native access to Oracle databases from client applications using Microsoft's Object Linking and Embedding (OLE) standard. OO4O was chosen over Active Data Objects (ADO) and ODBC for performance and compatibility reasons. Appropriate Oracle Transport Network Substrate (TNS) entries are required on the server to connect to the Oracle databases.

5.3 Database

The DWMA connects to two separate Oracle database servers running Oracle Enterprise Edition 8.1.7 and ArcSDE 8.1.2. One of these database servers hosts the DWMA and RAD geodatabases. The second server hosts the IGD geodatabase. The DWMA database contains the Oracle PL/SQL stored procedures, an extract of data warehouse tables from EPA's Envirofacts SDWIS/FED, and all other application data tables that did not already exist in the RAD and IGD. The RAD contains the underlying NHD and associated data and the IGD contains a number of background or "wallpaper" layers. All spatial data are stored in ESRI's binary SDE format in all three geodatabases.

5.4 Security

The application runs in a typical Web browser window. Communication with the Web server uses a Secure Socket Layer (SSL) server certificate for data encryption. The application requires users to login and authenticates users and passwords against data tables stored in the Oracle database. Once the application authenticates an individual user, a separate, single Oracle database user and password is used within the application to execute the DWMA's Oracle procedures. All users also share accounts that connect ArcIMS to the ArcSDE data stored in the DWMA, RAD, and IGD geodatabases. All database access is read-only and all map services are secured through a servlet access control list.

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References

Cooter, William S. (presenter-RTI), Sinnott, James (RTI), Lowry, Michael (RTI), Lloyd, Jennifer (RTI), Sullivan, Elizabeth (RTI) and Anzzolin, Roger (EPA), July 2002, *A WEB-based Application Supporting Major Safe Drinking Water Act Goals*, 22nd Annual ESRI International User Conference, San Diego, CA (Internet Address: <http://gis.esri.com/library/userconf/proc02/index.html>).

Cooter, William S. (RTI), Sinnott, James (RTI), Lowry, Michael (RTI) and Anzzolin, Roger (EPA), May 2002, *A Web-based GIS Application With a Focus on Source Water Protection Goals of the Safe Drinking Water Act*, Proceedings of the 2002 National Monitoring Conference, Madison, WI, USGS National Water Quality Monitoring Council, Reston, VA.

EPA OW, October 2001, *Geospatial Application, Prototype Display, and Analytical Data Development – Drinking Water Information Requirements Document*, Prepared by RTI International for EPA OW/OGWDW.

EPA OW, January 2003, *Drinking Water Mapping Application (DWMA) Preliminary Design Document*, Prepared by RTI International for EPA OW/OGWDW.

EPA OW, April 2003, *Introduction to the Drinking Water Mapping Application (DWMA) version 1.03*, Prepared by RTI International for EPA OW/OGWDW.

EPA OW, May 2003, *Drinking Water Mapping Application (DWMA) Version 1.04 Physical Design Document*, Prepared by RTI International for EPA OW/OGWDW.

Plastino, Michael, July 2000, *EPA Office of Water Georeferencing Plan: Toward a More Integrated EPA Information Framework*, 20th Annual ESRI International User Conference, San Diego, CA (Internet Address: http://gis.esri.com/library/userconf/proc00/professional/professional_content.html).

United States Geological Survey, 1992 (Segments through 1999). *Ground Water Atlas of the United States: Hydrologic Investigations Atlas 730*, Office of Ground Water, U.S. Geological Survey, 12201 Sunrise Valley Dr., Reston, VA, 20192, Chapters A through N. (Internet address: <http://capp.water.usgs.gov/gwa/index.html>).

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