INTERACTIVE DISPLAY AND QUERY OF NEAR REAL-TIME DATA FROM A HYDROLOGIC ALERT NETWORK

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REFERENCE: Proceedings of the 1993 Georgia Water Resources Conference, held April 20 and 21, 1993, at The University of Georgia, Kathryn J. Hatcher, Editor, Institute of Natural Resources, The University of Georgia, Athens, Georgia.

INTRODUCTION

Within the U.S. Geological Survey (USGS), an extensive hydrologic network exists to record and transmit currently sensed data to the Automated Data Processing System (ADAPS; Dempster 1990). Data values are recorded at field sampling sites on electronic data-collection platforms (DCP). These values are transmitted by satellite to a ground station and by telecommunications lines to a USGS District office. There they are processed within ADAPS on a Prime minicomputer. Data that exceed predefined thresholds are identified as alert values. These data help alert water-resource specialists that hydrologic events are occurring. Knowledge of the current alert status at sampling sites within a State is of critical importance during floods, hurricanes, and other extreme hydrologic events. This report describes a system of computer programs designed to display current information from a hydrologic alert network.

BACKGROUND

Within the U.S. Geological Survey, an extensive hydrologic network is used to record and transmit currently sensed data to the Automated Data Processing System (ADAPS). Hydrologic data from each sampling site are referenced by parameter codes corresponding to stage, streamflow, precipitation, specific conductance, and other characteristics. Values that exceed predefined thresholds are flagged as alert values. Knowledge of the current alert status at sampling sites within a State is of critical importance during floods, hurricanes, and other extreme hydrologic events.

A system of computer programs for real-time mapping (RTMAP), written in Arc Macro Language (AML1) and Fortran, provides interactive graphics display and query of hydrologic data from the network in a map-based, menu--driven environment. Data are processed within a range of 15 minutes to 4 hours after being recorded, resulting in a near real-time data base. Site-header information and unit values data are retrieved automatically from ADAPS and processed into an ARC/INFO point coverage and related data files. The macro RTMAP.AML controls the menu-driven display and query of the data. Hydrologic sites are displayed on a State map and flagged according to their alert status. If a site and associated parameter code are selected, a time-series graph of the current value, and values from the previous 5-day period, can be drawn to the graphics screen. Plot files of the current map, graph, or entire graphics screen can be sent directly to a PostScript printer. Extensive additional functions are incorporated into the RTMAP graphics system to give the user a wide range of options for investigating the available data.

HYDROLOGIC ALERT NETWORK

The components of a hydrologic alert network include field sampling sites; their associated hydrologic conditions; and the hardware and software necessary to record, transmit, and process the values of current hydrologic conditions at those sites. The computer programs described improve the ability of the user to investigate the information and to make conclusions about the status of hydrologic conditions within a State.

In this report, the term "site" will refer to a hydrologic sampling site that transmits data from a DCP to the ADAPS data base. Some sites record river stage, also called gage height. For these sites, unit (instantaneous) values of stage are converted to streamflow, or discharge, using rating curves stored within ADAPS. Some sites record the intensity of precipitation with tipping-bucket rain gages. Full descriptions of sites are published annually in the USGS water-data reports for each State.

A parameter code is an index number assigned to a particular hydrologic condition, or type of data. The U.S. Environmental Protection Agency and USGS use a 5-digit numbering system (Hutchinson 1975). For example, the parameter code 00010 denotes water temperature, in degrees Celsius, and 00400 denotes pH, in standard units. For a given site, unit values of hydrologic data are recorded, by parameter code, within ADAPS and also are aggregated into daily values.

Within ADAPS, a hydrologist may define threshold values for a given parameter code at a given site. These thresholds define five categories of alert status: extreme high alert, high alert, normal, low alert, and extreme low alert. A high-alert condition may occur, for example, for streamflow or precipitation during floods or for toxic levels of a dissolved constituent. A low-alert condition may occur, for example, for streamflow during drought, for dissolved oxygen concentration during conditions of oxygen depletion, or for pH during strongly acidic conditions.

During major hydrologic events, water-resource specialists and managers need up-to-date information on the alert status at sites within the area of their concern. This current, or real-time, information is important for making operational decisions and directing work crews. The real-time mapping (RTMAP) system of computer programs was developed to provide the user with interactive display and query of current data from a hydrologic alert network, using a map-based, menu-driven graphics environment. The USGS is now (April 1992) using the RTMAP system in pilot studies to monitor hydrologic networks in South Carolina and Puerto Rico.

REAL-TIME MAPPING

The RTMAP system consists of two main components. One interacts with ADAPS on the Prime minicomputer system and is described in the next section. The other, described in the subsequent section, uses ARC/INFO to display data from the alert network on a UNIX-based workstation.

Processing of Near Real-time Data

The first component of the RTMAP system is a retrieval program that extracts unit-values data from ADAPS on the Prime minicomputer. The program retrieves the data at fixed intervals using the job-timer utility. Two data files are created. The file "mapdat" contains the most-current data for sites and parameter codes for which threshold values have been defined. As many as six parameter codes may be retrieved for each site. The file "mapdat5" contains the hour values for the previous 5-day period. The two files are transferred to the UNIX-based workstation for further processing. at longer intervals, a site-description file is retrieved from ADAPS and transferred as well. It includes latitude-longitude coordinates and the list of parameter codes for each site.

Time lags may occur between sensing and transmission at the DCP site, between storage and processing within ADAPS, and between retrievals using the job timer. Because of these lags, data values are usually transferred to the workstation within a range of 15 minutes to 4 hours after being recorded. This results in a near real-time data base of hydrologic data.

Interactive Display And Query

The second main component of the RTMAP system operates on a UNIX-based workstation and uses ARC/INFO geographic information system (GIS) software. This component processes data within ARC/INFO and provides the user with interactive display and query of current data from the hydrologic network.

This UNIX-based component is modular and consists of about 30 ARC Macro Language (AML) programs. The programs were written during 1991-92 using revision 5.0.1 of the ARC/INFO software. Two primary pull-down menus and three form menus provide the interactive interface with the user. The principles of design for these menus are similar to those described by Lanfear (1991). Five Fortran programs are used. These programs are written in ANSI-standard Fortran 77 and have been tested extensively for errors. They are self-contained and do not require the addition of other program libraries during creation of the executable code.

Three main AML programs initiate all activities on the workstation. The first two generally process data into ARC/INFO format; the third initiates the interactive graphics interface. Data-processing functions begin with the program GEN_RTSITE.AML. This program reads the site-description file and creates a spatial data base, or coverage, containing one point for each site in the hydrologic alert network. This program should be executed whenever the list of sites or associated parameter codes is changed. A second program, PROC_RTSITE.AML, processes the data files "mapdat" and "mapdat5," which contain the values of current data and the previous 5-day period, respectively. The program produces summary files, creates INFO files from the current data, and relates these files to the point coverage. This program should be executed whenever new data have been retrieved from ADAPS. Both programs may be initiated by a system administrator or may be executed at regular intervals using a job-timer utility.

The third main program, RTMAP.AML, is the entry point to the interactive display and query of the real-time data. It invokes the primary menu, which controls an extensive set of AML programs, other menus, and Fortran programs. It can be executed whenever a user, for example a water-resource specialist or emergency planner, wants to examine the alert data.

Description of an Interactive Graphics Session

At the beginning of the interactive graphics session, an initial popup display describes the RTMAP system. Then the default graphics screen is displayed. Figure 1 shows an example of this default display. County boundaries, hydrographic features, and sampling sites are drawn for the State. The current data values are shown for each site, using a special set of symbols that provide a quick summary of major hydrologic data. A cluster of four small boxes at each site represent four predefined major param-

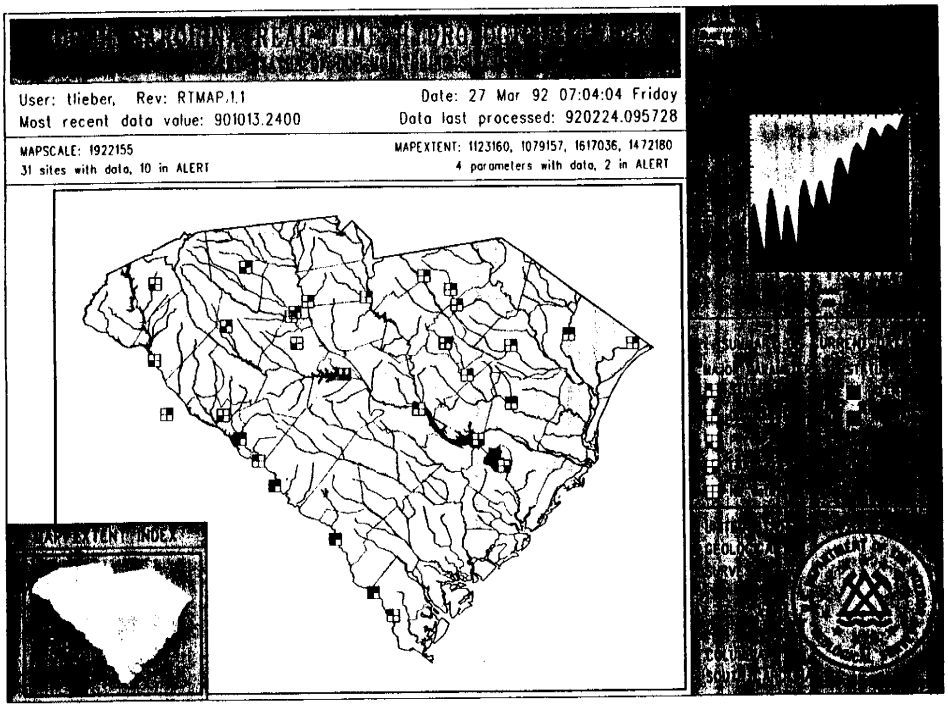


Figure 1. RTMAP graphics screen display showing alert status for set of four major hydrologic parameter codes. This is the default display. Graph at upper right shows 5-day unit values record for selected sampling site and parameter.

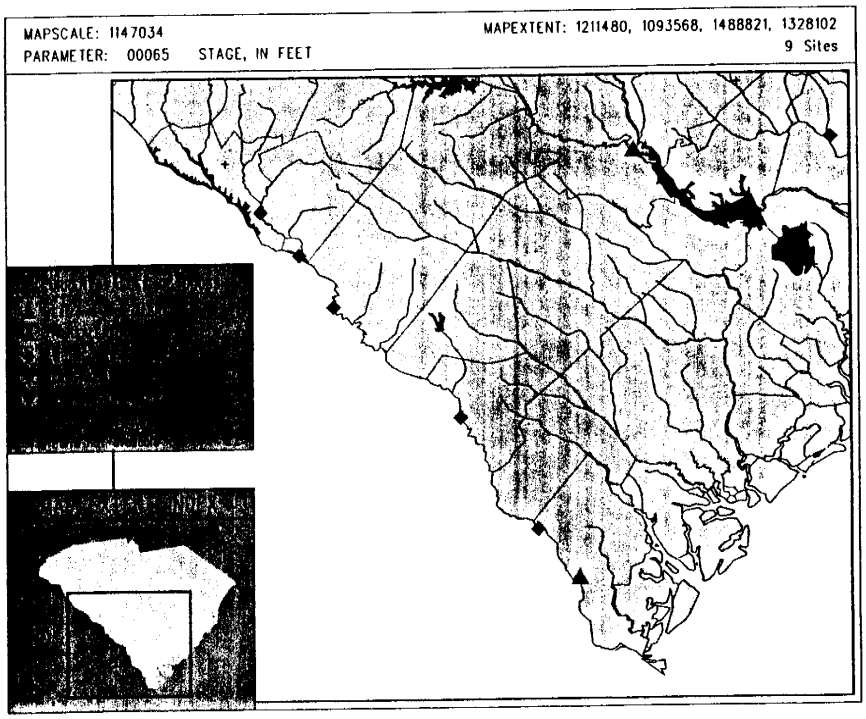
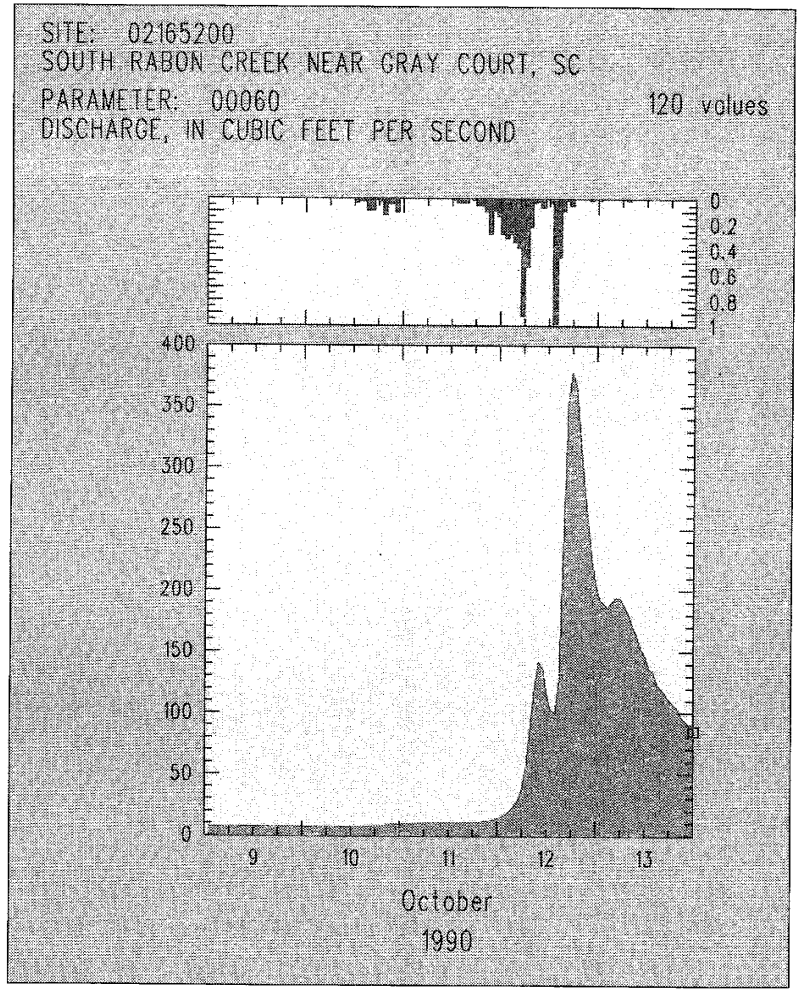


Figure 2. Map component of an RTMP graphics screen display, showing alert status for single hydrographic parameter code within user-defined map extent. Explanation on map summarizes number of sampling sites in network for each alert-status category. Extent of map is shown as an outline box on State map index.



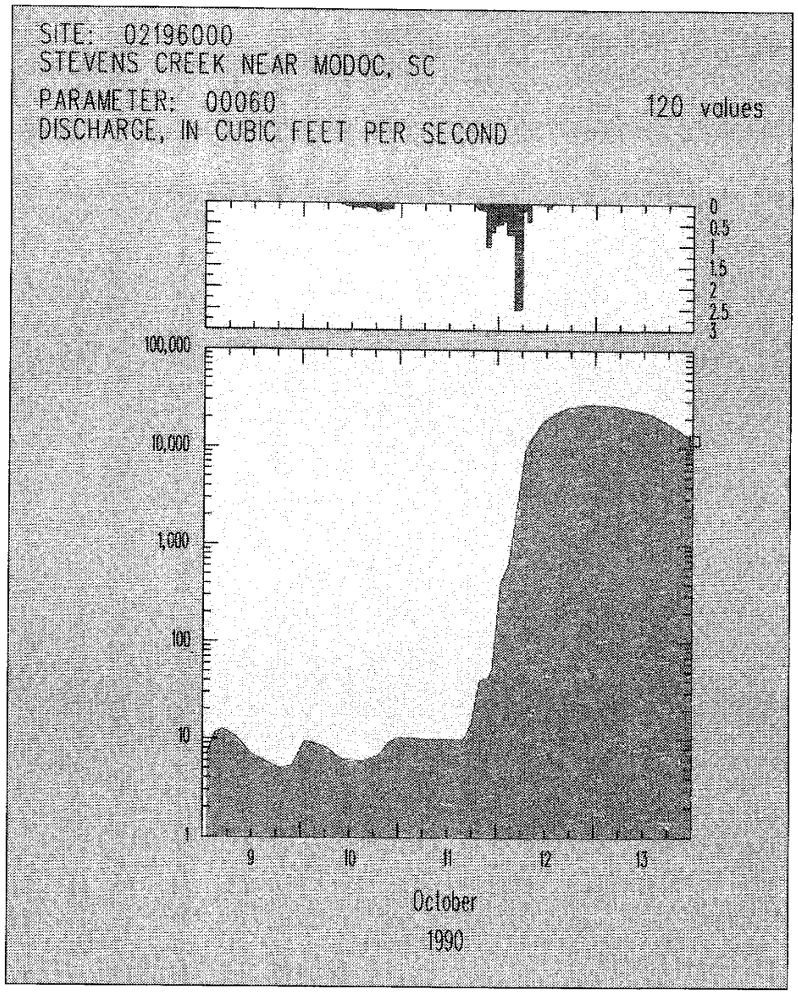


Figure 3.--Time-series graphs of the 5-day unit-values record. Site on left has drainage area of 29.9 square miles; site on right has drainage area of 545 square miles. Concurrent precipitation at each site shown as icicle bar graph above main graph. The RTMAP system contains generic programming code for producing time-series or X-Y graphs within ARC/INFO plotting environment. Y-axes were scaled automatically.

eter codes, as set by the system administrator. A red box, dark on the black-and-white figure, indicates that the current value is in alert status. An orange box (medium gray) indicates that the current value is in the normal rang, or non-alert status, as defined by the thresholds from ADAPS. An empty box indicates that no current data value exists for the parameter code at that site.

The user can choose from a wide range of menu options to change the display or to access information. In general, the user make choices by a point-and-click operation, and information is listed in popup displays. Two typical operations are selecting a single parameter code for display and zooming in on a smaller section of the State map. Figure 2 shows an example of the map after these operations. With a single parameter code, more information can be displayed, such as whether alert values are high or low, extreme or not. The inset that shows the alert symbols also summarizes the number of sites for each category of alert status. The extent of the current map display is shown as an outline box on the State map index.

The ability to draw a graph of data for the previous 5-day period was a major design requirement. After a specific site and parameter code have been selected, using point-and-click operations, a time-series graph may be created. By default, the graph is placed in the upper-right corner of the graphics screen. Figure 1 shows stage at a site influenced by tidal fluctuations. Figure 3 illustrates a major hydrologic event at two sites. Concurrent precipitation values are drawn above the main graph. The programming code that produces the time-series graph is flexible; it contains generic subroutines and functions for producing a wide variety of graphs within the ARC/INFO plotting environment.

The user can choose at any time to save graphics displays to plot files or map compositions. The current map, graph, or entire graphics screen can be written to a plot file. At the user's choice, the plot file is converted to a file in PostScript format and sent to an on-line printer. This procedure is relatively efficient and rapid because all graphics displayed are saved automatically to map compositions.

The interactive menus were designed with the goal of presenting a simple, intuitive set of choices that still provide great flexibility and power to the user. The RTMAP graphics system is largely self-documenting. A complete set of on-line documentation can be displayed interactively or printed. Each pull-down sub-menu contains a help option that explains the options in the sub-menu. Extensive additional menu functions are incorporated into the RTMAP graphics system to give the user a wide range of options for investigating the available data. These include extensive capability to select and display sets of features from coverages, both within the default workspace and a user-defined workspace; a comprehensive set of options for creating and manipulating map compositions; and the identification of coverage features and their attributes. The RTMAP graphics system is robust and effective, and has exceeded al design specifications. RTMAP provides a satisfactory method for interested persons, both professional and lay, to monitor the status of a hydrologic alert network.

SUMMARY

Within the U.S. Geological Survey, an extensive hydrologic network is used to record and transmit currently sensed data for processing in District offices. Data values that exceed predefined thresholds are flagged as being in alert status. Knowledge of the alert status at sampling sites is of critical importance during major hydrologic events.

A system of computer programs called RTMAP (real--time mapping) is a useful tool for displaying information from a hydrologic alert network. One component retrieves near real-time data at regular intervals. The second component provides the graphics interface, and is written using AML, ARC/INFO menus, and Fortran. The RTMAP graphics system is an interactive, map-based, menu-driven application. Hydrologic sites are displayed on a State map and flagged according to their alert status. Time-series graphs can be generated. The RTMAP graphics system gives the interactive user a wide range of options for display and query of the available data.

NOTES

1. Any use of trade, product, or firm names in this publication is for identification purposes only and does not imply endorsement by the U.S. Government.
2. This paper first appeared in the Proceedings of the Twelfth Annual ESRI User Conference, Palm Springs, California, May 1992. It is reprinted here with permission of Environmental Systems Research Institute (ESRI), Redland, California.

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