Title
Improving water quality reporting in California with the Geo Waterbody system

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Publication Date
1998-02-01

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IMPROVING WATER QUALITY REPORTING IN CALIFORNIA WITH THE GEO WATERBODY SYSTEM

ABSTRACT

In California, water quality assessment information is currently reported via a FoxPro (DOS) system known as the WaterBody System (WBS). WBS does not have a spatial component, and therefore users typically enter information for large named water courses. Several states, including California, have developed links from WBS waterbodies to EPA River Reach File (RF3-alpha) features, spatially referencing WBS to an existing nationwide hydrography layer. This spatial referencing step, however, has typically occurred after local scientists and resource managers entered assessment information into the WBS.

In order to improve water quality reporting, the University of California, Davis (UCD) Information Center for the Environment (ICE) has developed GeoWBS, a customized graphical user interface using ArcView and the Dialog Designer Extension that allows users entering water quality assessment information to better spatially define waterbodies. This system links the assessment information to RF3-alpha, permits direct SQL connectivity to the underlying WBS architecture, and helps standardize user input. Starting in 1998, the California Regional Water Quality Control Board (RWQCB) scientists will be trained to use the system and will report their assessments on more spatially refined waterbodies. Consequently, the water quality assessment information reported to EPA will be more spatially precise, queriable through a graphical interface, and will likely result in improved water quality monitoring, reporting, and policy-setting.

Prepared for presentation at the 1998 ESRI ARC/INFO Users Conference, San Diego, California.

INTRODUCTION

The University of California, Davis (UCD) Information Center for the Environment (ICE) has been collaborating for several years with the U.S. Environmental Protection Agency (USEPA) and the State Water Resources Control Board (SWRCB) to improve reporting and management of water quality data for California. Due to an increased interest in presenting water quality information with a higher degree of spatial refinement, USEPA has funded ICE to georeference the water quality assessment data stored in the Waterbody System (WBS). WBS is a DOS level, FoxPro database used by Regional Water Quality Control Boards and the SWRCB to store all water quality information used for Clean Water Act Section 305(b) and 303(d) TMDL (Total Maximum Daily Load) reporting requirements. The purpose of the assessments is to document the extent to which the beneficial uses (for example, fisheries, water supplies, recreational activities) expected of a river or watershed are actually supported by the current waterways, and, if they are impaired with respect to a particular beneficial use, whether the condition is improving or getting worse.

After georeferencing and linking the existing WBS database for 1994 and 1996 reporting years to RF3-alpha (USEPA, 1993), ICE developed the Geo WaterBody System (GeoWBS) ArcView interface. GeoWBS allows the Regional Water Quality Control Board (RWQCB) staff to spatially identify new water body entries into the system as they are entering the assessment information, while also permitting them to refine the existing, often very coarse water body extents. The resultant data set provides a much clearer geographical indication of where impairment is occurring. The customized program allows WBS users at the Regional Boards to view on screen a map of the assessment area, interactively select sequential reaches for aggregation, and then enter an assessment on these aggregated portions of the water body. Assessments may also be reported on individual RF3-alpha reaches. The total length of each water body is calculated automatically by ArcView, so estimates of waterbody size by the user are no longer necessary. The RWQCBs provide the SWRCB with their new annual assessments (estimated to cover 20% of the total Region per year), and then the SWRCB summarizes the information and reports to the EPA.

The Clean Water Act

In 1972, Congress enacted the first comprehensive national clean water legislation in response to growing public concern for serious and widespread water pollution. The Clean Water Act is the primary federal law that protects our nation's waters, including lakes, rivers, aquifers and coastal areas. As a result of a cooperative effort by federal, state, tribal and local governments to implement the pollution control programs established in 1972 by the Clean Water Act, the quality of our waters has improved over the past 25 years.

The Clean Water Act's primary objective is to restore and maintain the integrity of the nation's waters. This objective translates into two fundamental national goals:

- eliminate the discharge of pollutants into the nation's waters, and
- achieve water quality levels that are fishable and swimmable. (USEPA, 1991)

The Clean Water Act focuses on improving the quality of the nation's waters. It provides a comprehensive framework of standards, technical tools, environmental monitoring and financial assistance to address the many causes of pollution and poor water quality, including municipal and industrial wastewater discharges, polluted runoff from urban and rural areas, and habitat destruction.

Total Maximum Daily Load (TMDL) Guidelines

While water quality on a national basis has improved markedly since the passage of the Clean Water Act, many waterbodies in the United States still do not meet water quality standards of "fishable, swimmable" even though point sources are regulated to the level of technology currently required by law. Under the Clean Water Act section 303 (d), states must submit a prioritized list of waterbodies which do not meet water quality standards to the USEPA. States are also required to establish Total Maximum Daily Loads (TMDLs) for these waterbodies. A TMDL is a written, quantitative assessment of water quality problems and contributing pollutant sources. It specifies the amount of a pollutant or other stressor that needs to be reduced to meet water quality standards, allocates pollution control responsibilities among pollution sources in a watershed, and provides a basis for taking actions needed to restore a waterbody (Clifford et. al, 1994) .

The GeoWBS program enables users to enter detailed information about TMDL waterbodies. Unlike the existing DOS FoxPro WBS, in which analysts simply type assessment data into a large table, GeoWBS walks users through all steps for entering required information, including TMDL causes and sources of pollution. GeoWBS provides analysts with an ArcView interface for viewing and selecting geographic extents of the assessments, and choosing beneficial uses, types and sources of impairment, management practices, and related assessment elements from pre-established vocabularies (as "pick lists.")

METHODS

System Description

As discussed earlier, the USEPA Waterbody System is a FoxPro 2.6 DOS application created by Research Triangle Institute (RTI), a USEPA contractor. When requested by EPA to develop GeoWBS, ICE was required to maintain the original WBS application while using ArcView to create a spatial interface that would "talk" to WBS. GeoWBS was created in ArcView 3.0a using Avenue and the Dialog Designer Extension. The GeoWBS ArcView project is highly customized using over 160 different Avenue scripts. However, the user never sees these scripts within GeoWBS and consequently cannot modify the scripts in any way. The GeoWBS project simply contains a startup script that reads a table (The Sed Table) containing the names of all the scripts needed to run the project. The startup script then loads all the scripts named within the Sed Table into the application and embeds them. The startup script also builds three views, then loads, renames, and sets the legend for over fifteen data layers. Once the startup script is done, GeoWBS contains three views and the Main Control Dialog (Figure 1).

Each view serves the user in a different way. The Main View is where all the spatial Waterbody data is held and where all the processing of that data is done. In this View, the user selects the spatial extent of river reaches, lakes, wetlands, groundwater basins, estuaries, bays, shorelines, and oceans that they wish to assess. Not all of the waterbody types listed above (esp., estuaries, bays, oceans and wetlands) have completed statewide spatial coverages. To enable the user to report on the waterbody types without statewide coverages, we allow the users to make their own spatial data layers within the GeoWBS program. The user can create a polygon, of any size and shape, in the Main View to represent a waterbody. Once the user is satisfied with the new "waterbody", a script is run to identify the waterbody, give it a unique code (Waterbody-ID), calculate the area or length of the Waterbody (WBSize), and add the waterbody to the appropriate shapefile in the Main View. For a more detailed description of how users generate their own waterbodies, please read see Appendix A. For the waterbody types that do have a statewide spatial coverage, the user simply picks a waterbody from that coverage and enters an assessment. For all of the statewide coverages, unique codes were generated and crosswalk tables were built to connect the waterbody-ID (generated in GeoWBS) with the unique key for the spatial feature in the proper waterbody type coverage. This allows the assessment to be attached to a spatial entity without losing unique identifiers. For additional information on these crosswalks and unique identifiers, please see Appendix B. The Navigation and Tracking views help the user navigate within the region without getting "lost" when zooming in on the data. The Navigation View contains layers such as counties, roads, the geographic names index, and the 1:24,000 and 1:100,000 scale quad boundaries. A user can locate an area of interest using these layers and then zoom in. The user can then set the Main View Extent to their current extent in the Navigation View and locate the desired waterbody. An additional feature, the Tracking View, allows the user to see the current extent (in either the Main View or Navigation View) drawn as a red box over the current working SWRCB Region.

The Main Control Dialog (Figure 2) is the point from which the user can find waterbodies, create and assess a new waterbody, edit previous waterbody assessments or spatial properties, create a report, and map an existing waterbody and its assessment. Overall, the Main Control Dialog sets off over 20 dialogs from the five buttons for Find, Make, Edit, Report and Map Waterbody (Figure 2). Each button sends the user into a different interface of dialog boxes of which the first is the Find Interface.

Finding a waterbody within a region may be very difficult due to the density of the waterbody spatial data. The Find Interface (Figure 3) allows the user to search all the spatial data layers in the Main View and Navigation View. Several different dialogs are used within the Find Interface, most of which are generated on-the-fly based on the layers available in the different views and based on the attribute data associated with a chosen data layer. Depending on the data layer chosen, the user picks a data field of interest and a list of the unique values in that field is generated as a pick list (Figure 4). That spatial feature is then selected, labeled, and zoomed to in the Main View.

Depending on the spatial selection, the user can either make a new waterbody or edit an existing waterbody. Both Interfaces guide the user through data entry screens using a series of the ArcView Dialog Designer CheckBoxes on the Main Control Dialog (Figure 5). The CheckBoxes are enabled once the user clicks the "Make" or "Edit" buttons. Each CheckBox sets off at least one new dialog, and often a series of dialogs in which data are entered. Decision rules are used to enable and disable CheckBoxes based on the data entered. All controls on the Main Control Dialog (except CheckBoxes) are disabled until the user confirms their data entry.

Data Entry

Once a waterbody is defined with spatial locations and a unique value, the user moves on to assess the Waterbody using the Make Waterbody Interface. The Make Interface includes the primary assessment, TMDL assessment, causes and sources of impairment, non-point source pollutants, and management measures. Each assessment uses one or more dialogs to allow data entry. To describe the data entry process, the Primary Assessment will serve as an example (Figure 6). This Dialog contains default data in every data entry field, and uses drop-down ComboBoxes and ListBoxes where possible. This helps to reduce gaps in the database, prevent typos, and standardize data entry. The Add/Remove ListBoxes allow the user to select from a list of assessment types in the Left ListBox and add those selections to the Right ListBox. It is the list in the right ListBox that gets written into the Waterbody System database. Once satisfied with the assessment, the user clicks the Done Button. This starts another script that writes the data from the Primary Assessment directly into the Waterbody System using ODBC 32 and SQL.

The Edit Waterbody Interface is used once a waterbody has a previous assessment and the user wants to edit the assessment for that waterbody. The user is shown through the Status Checkboxes (Figure 5) which assessments have been completed on the waterbody. The Update Checkboxes are now enabled and are used to edit each assessment. If the user clicks the Primary Assessment Checkbox, the Dialog appears with all the data from the past assessment as the default data. This allows the user to see the past assessment and to modify it accordingly. As in the Make Interface, the data from each assessment is written directly in the Waterbody System database. However, with "Edit" the old waterbody data must first be removed before the new data is written to WBS tables. This is done using SQL and a FoxPro Executable. For more information on problems encountered while using SQL for deleting data and how we worked around those problems, please refer to Appendix C.

In both the Make and Edit Interfaces the user cannot exit the Assessment Cycle without hitting the Waterbody Confirmation button. The confirmation is completed by using SQL to check if there is data in the proper tables in the Waterbody System. The user is shown in the Status Checkboxes what assessments are completed and told in the Main Control Dialog ListBox (Figure 1) whether certain requirements have been met. If a waterbody checks out to be complete, then the unique code for that waterbody is written to a table. This table is used for determining which waterbodies are complete and can be used to generate the 305(b) reports for Congress.

The last two Interfaces are "Report" and "Map" waterbody. These two functions allow the user to generate a report on the selected waterbody in either a table or text format. Input from the SWRCB indicated that this function would be useful in disseminating data to the public, other agencies, and SWRCB staff. The format is generated automatically so that the user simply hits a few buttons and has an electronic version of a report that can be printed. The "Map" interface was developed for similar reasons and creates a close-up map of the waterbody, a map of the waterbody location within the region, and a list of certain assessment data in text format. This information can be printed out or passed on electronically, and is used by the SWRCB and EPA to prepare the reports on waterbody conditions and success toward recovery required by the Clean Water Act.

BENEFITS

Improved spatial refinement of waterbodies and enhanced data standards are two of the many advantages to the new Geo WaterBody System. Permitting users to report on a river segment as small as a couple hundred meters or assess a wetland as small as a vernal pool allows refined data to conserved. With the original Waterbody System users could only assess entire rivers, or the lower or upper stretch of a river. Where that lower and upper stretch ended was unclear. Yet even more ambiguous were the assessments these entire rivers received. One river could be 150 miles long with 20 miles assessed as Partially Supporting for a Beneificial Use and 130 miles assessed as Fully Supporting. Due to the data reporting system (the Waterbody System), it was impossible to know which 20 miles along the 150 mile stretch were partially supporting. It was even unknown whether the 20 miles of Partiailly Supporting assessments are contiguous, or whether sections impaired for different uses overlapped. This is one of the most important problems that the GeoWBS System solved. Users can now select river segments down to roughly a mile or so in length, and that segment only receives one assessment for each Benificial Use. Therefore the 305(b) reports generated to Congress now tell exactly what piece of the river is Not Attainable for Drinking Water, or for Swimming. The State of California can now start to generate reports to Congress that depict the water quality problems of the state more accurately, which in turn can help to determine what problem ares should be funded for improvement.

Data standardization is a problem inherent with any large data set. GeoWBS helps to improve this problem also. Data entry errors are decreased through the use of picklists within ListBoxes and Drop-Down Combo Boxes in Dialog Designer. Data checks scripted in Avenue help to insure data entry in areas often overlooked in the current Waterbody System.

Other advantages of the GeoWBS reporting system include single waterbody reports and maps. The public often wants information on certain areas from the SWRCB and EPA. Now it is easier to give the public those reports and even generate maps depicting certain water quality impairments. Visual representation of water quality issues enables decision-makers and the public to better understand the situation and work toward cooperative solutions to water quality problems.

FUTURE DIRECTIONS

Defining the spatial extent of a waterbody and giving that spatial selection an assessment is a useful tool that can be applied to other classes of environmental problems. One example involves mining mine data in the state of California. There are over 200,000 active and inactive mines within the state. More detailed assessments of water quality could be entered for watersheds and groundwater basins affected by mines. Often these more detailed samples are done, but have no spatial representation. If entered into a system like GeoWBS, the data could show the known and potential effects of mining on water quality. Downstream impacts may be modelled to include making use of information on how certain pollutants travel through the soil and aquifers, rates of transport and degradation in the river systems, and how particular pollutants affect wildlife and the ecosystem. Areas of concern could be identified in soils, rivers, streams, groundwater, or any other spatially-defined feature. An effort to perform this kind of analysis for potential contaminants of drinking water supplies (the Source Water Assessment Program (SWAP)) is underway. A parallel example could apply to analyzing potential effects pesticide use. Approximate locations, quantities, and dates of commercial applications may be assessed from permit records. With spatially defined waterways, potential runoff may be estimated from proximity to waterbodies and site characteristics, and then may be compared with existing monitoring records (e.g., STORET) where field monitoring records exist. Under classes of conditions where effects of applications can be detected in adjacent waterbodies, potential impacts can be investigated or inferred at comparable sites when insufficient data exists. ICE has begun this kind of assessment in the Salton Sea drainage and in parts of the Sacramento Valley. Many of the same spatial issues apply to pesticides that would apply to a mine site. Similarly, the GeoWBS dataset and spatial structure are being used in a pilot study, in cooperation with Caltrans, to assess the relative impact of roadbuilding, vs. land use effects, such as forestry practices, in siltation of coastal rivers. Yet another example involves forestry issues. Knowledge of vegetation patterns, soils, and topology within watersheds could be compared spatially with siltation and other water quality issues within the same watersheds. This could lead to spatial modeling predicting water quality outcomes due to different practices within a watershed. This could be a powerful tool for managers who make important decisions regarding California's Forests.

CONCLUSION

GeoWBS will facilitate update of the assemssment data in the WBS database at each RWQCB in California. Better spatial specificity on the extent of use impairment will in turn improve the RWQCB and SWRCB Clean Water Act Sections 305(b) and 303(d) reports and provide greater clarity in discussions related to TMDL development. Water quality mapping will be used extensively in future 305(b) reports for effective presentation of water quality issues.

Although not itself a monitorning and assessment program, GeoWBS serves as a tool to enhance and improve water quality monitoring and assessment for the State of California. Through extensive testing and effective training methods, cooperators from ICE, EPA and SWRCB expect the quality of assessment information to improve dramatically over the next several years. In the future, analysts will be able to combine water quality information with other environmental data sets and more effectively determine potential causes and effects of environmental pollutants.

Water and intelligent management of rivers has always been central to both the economy and the quality of life in California and the nation as a whole. The Clean Water Act provides a powerful mandate to improve the condition of waterways. However there has never been a data system for compiing the locations, methods, and success of these efforts that provides for easy and standardized entry of expert knowledge, or that permits policy makers, researchers, and the interested public to gain a geographic overview of where rivers are in trouble, and where and how they are recovering. Without this kind of tool, limited resources for protection and restoration are frequently not allocated where they are most needed, and not used in ways that have proven most effective elsewhere. GeoWBS represents a cooperative state-federal-university partnership to make better tools available, and thus to better protect the waterways valuable to all Americans.

Appendix A

Having the User Generate Spatial Waterbody Coverages

Allowing the user to generate polygons to use as a spatial reference for wetlands, estuaries, bays, and oceans enables a very general spatial location to be stored for a waterbody. This was done because statewide coverages for these waterbody types were not available. For reporting purposes, this spatial definition of waterbodies will allow an acreage (generated automatically by ArcView) to be reported through the 305(b) reports. Once statewide coverages are available for this data, it will be easier for the user to connect waterbody assessments to those coverages. The user can create the polygon in the Main View using three dialogs placed within the View itself. One dialog allows the user to draw a polygon, another allows the user to grab and move the vertices of the polygon and add new vertices if needed. The third dialog adds the polygon to the appropriate shapefile through some Avenue scripting. ArcView automatically generates and area for the polygon once it is integrated into the shapefile. This area is converted into acres and used for the Waterbody Size throughout the WBS data.

Appendix B

Unique Codes and Data Crosswalks

Riverine and Coastline Waterbodies are created by spatially selecting part of the River Reach File. The unique identifier in RF3-alpha (tdckey) is crosswalked to the unique identifier in the WBS data (wbid). As mentioned in the Introduction, the crosswalk between the 1994 and 1996 WBS data and RF3-alpha was created due to an increased interest in presenting water quality data spatially. Overall, this took about six months to complete. Now GeoWBS does this automatically, insuring the spatial connection in water quality data for the State of California. GeoWBS also creates this spatial connection to groundwater basins and lakes. The California Department of Water Resources defined the groundwater basin layer, and we generated a unique identifier for each polygon within this coverage to crosswalk the WBS data. The Lakes layer comes from Teal Data Center, and once again, we generated a unique identifier to crosswalk with the WBS data.

Appendix C

Problems using SQL between ArcView and FoxPro

As indicated earlier, ICE was required to leave the FoxPro 2.6 DOS Waterbody System intact and to use the data tables as they were. In order to enable data entry in ArcView using a simplified Dialog Interface, we need a way to "talk" to the original Waterbody. This is done using ODBC and SQL. Once the user has entered all the data in a dialog we use SQL to enter that data directly into the Waterbody System. This became a bit problematic when we needed to delete Waterbody System data for the Edit Interface. The SQL Delete command only marks files for deletion in the FoxPro 2.6 DOS system. In order to remove these marked files, a FoxPro executable is run from ArcView and then the new data is inserted using SQL. Another problem occurred with FoxPro's Memo fields. We are able to use SQL to write to memo fields in the FoxPro Waterbody System tables, but we are not able to retrieve information out of the memo fields using SQL. The memo fields have unlimited length and store comments produced by the user. Therefore, we are unable to bring back past comments through SQL. This problem was solved using another FoxPro executable. This executable takes the comments in the Waterbody Memo field and writes them to a temporary text file. The text file is read by ArcView, through some scripting, and made available to the user through a dialog. Once the user makes their own comments in the data entry dialogs, their new comments are appended to the end of the old comments and written back into the Waterbody System.

ACKNOWLEDGEMENTS

Terry Fleming from US EPA Region IX and Nancy Richard of the SWRCB have worked closely with ICE from the onset of the project in 1994. Bruce Gwynne of the RWQCB in Santa Rosa (region 1) served as the pilot recipient of GeoWBS, and provided much-needed feedback in order for the program to move ahead. Paul Veisze and Mike Byrne of the California Dept. of Fish and Game continue to provide valuable assistance and insight regarding water-related issues in California. We thank all of these individuals for their continued support and enthusiasm for the project.

Within ICE, we wish to acknowledge the many participants who have spent countless hours working to make GeoWBS a success: Derek Masaki, David Hudson, Chad Shook, Jim Mullins, Eric Lehmer, Rob Coman, and Mike McCoy. We also thank other individuals who worked on earlier portions of the project, including Isaac Oshima and Anitra Pawley.

The work described here was supported by the California Resources Agency and the U.S. EPA (R819658) Center for Ecological Health Research at UC Davis. Although the information in this document has been funded in part by the United States Environmental Protection Agency, it may not necessarily reflect the views of these Agencies and no official endorsement should be inferred.

REFERENCES

Clifford, J.J., W.D. Wheaton and R.J. Curry, 1994. *EPA's Reach Indexing Project -- Using GIS to Improve Water Quality Assessment* U.S. Environmental Protection Agency.

US Environmental Protection Agency, 1991. *Guidance for Water Quality-Based Decisions: The TMDL Process*, US EPA.

US Environmental Protection Agency. 1993. *Technical Description of the Reach File.* US EPA Draft, Horizon Systems Corporation, February 1993.

US Environmental Protection Agency (USEPA), 1997. *Guidelines for Preparation of the Comprehensive State Water Quality Assessments (305 (b)Reports) and Electronic Updates: Supplement.*

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