

SJRWMD Arc Hydro: GIS for Better Water Resources Management

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Abstract: Following the successful use of Arc Hydro to develop a series of Web-based Watershed and Water Quality Fact Pages (<http://www.sjrwmd.com/archydro/>), the St. Johns River Water Management District (SJRWMD) has embarked on the development of additional water resources applications to meet its mission to ensure the sustainable use and protection of water resources for the benefit of the people of the District and the state of Florida. New applications include the update, modification and automation of a pollution load screening model (utilizing the Arc Hydro-based accumulate attributes function), development of disconnected editing and multi-purpose file inventory tools for project area applications, and expansion beyond the standard Arc Hydro schema to accommodate coastal/tidal function in order to better assess water quality. As the SJRWMD community continues to embrace Arc Hydro as its base water resources information system, new opportunities are revealed each day illustrating the value of a GIS-based approach to managing water resources.

Introduction In 2003, the Surface Water Quality Monitoring (SWQM) program of the St. Johns River Water Management District (SJRWMD) (figure 1) adopted Arc Hydro as a tool for District-wide water quality and quantity assessment. Arc Hydro is an ArcGIS data model for hydrologic information developed by the Center for Research in Water Resources (CRWR) at the University of Texas and ESRI (Maidment, 2002). Initially developed for improved determination of drainage areas for the SWQM program's 73 water quality monitoring sites, Arc Hydro and the concurrent development of a customized spatial data summary tool (Fox, 2006), made possible the development of a series of web-based fact pages that have proven to be useful to the public as well as

water resources professionals interested in the status of watersheds and water quality in northeast Florida (<http://www.sjrwmd.com/archydro/>). The fact page project is currently in revision with plans to include more SJRWMD water quality monitoring sites as well as additional summaries of watershed data such as wetlands and restoration areas.



Figure 1. Map of the St. Johns River Water Management District in northeast Florida. The Surface Water Quality Monitoring (SWQM) program is a District-wide program, with water quality monitoring sites throughout the area.

Realizing that the Districtwide Arc Hydro geodatabase presents opportunities for development of additional water resources applications (Bourne et al., 2006), and that the geodatabase would be in need of special maintenance beyond that required for

standard GIS data due the complex nature of the Arc Hydro schema, the SWQM program developed several customization projects based on the following aspects:

- The Arc Hydro geometric network and “accumulate attributes” function are well suited to the enhancement of a pollution load screening model that has been in use at the SJRWMD since the mid-1990s.
- Project area modeling efforts would likely be hindered by the overhead of the entire Districtwide geodatabase; however, the geometric network complicates taking data subsets from an Arc Hydro geodatabase.
- Additionally, an efficient data editing workflow would work well with geodatabase subsets and necessitates a mechanism to ensure the maintenance of geodatabase integrity.
- By extending the relationship class concept from feature classes to files of various kinds external to the Arc Hydro geodatabase, a unique inventory system could be developed.
- The use of Arc Hydro by the SWQM program for improved drainage area determination in coastal and estuarine areas was less successful than for its inland water quality monitoring sites.

Pollution Load Screening Model Update and Enhancements in Arc Hydro

The Adamus / Bergman Pollution Load Screening Model (PLSM) was developed during the mid-90's to assist in the production of a District Water Management Plan (Adamus & Bergman, 1995; Mundy and Bergman, 1998). The PLSM has been a useful tool at the District and has been modified and adapted by a number of District project groups. The PLSM was originally designed to produce annual load estimates for total nitrogen, total phosphorus, total suspended solids, biological oxygen demand (BOD), lead and zinc based on land use, soil and rain data; potential problem areas were identified based on comparisons made within regions (major basins) based on a basin-specific ranking system. The original PLSM model was run for each of the “QuadBasins” (smallest unit of drainage area, comparable to the catchment feature class in the Arc Hydro data model)¹ within each major basin; the loading results for each QuadBasin were then compared to the collection of QuadBasins only within the major basin. The original PLSM, and a recent update for ArcGIS (Martinez, 2005) base calculations on rasterized versions

¹ The term QuadBasin has been coined by the SJRWMD for its Arc Hydro geodatabase to reflect the source of unit drainage area delineation, the 6.5 minute USGS Quad maps.

of vector landscape data (land use / land cover, soil hydrogroup). Although raster calculations within GIS are faster than the comparable calculations made with vector data, whenever vector data is converted to raster, a generalization occurs and the question of appropriate grid size for the vector-to-raster conversion becomes important. Additionally, no method for calculating the accumulated loading based on surface water flow was included in the original version of the PLSM.

The “backbone” of the SWQM program’s districtwide Arc Hydro geodatabase is a geometric network that represents hydrologic connectivity throughout the District. The network is comprised of lines representing flow (HydroEdges) primarily through surface rivers, streams, and channels, along with “points of interest” (HydroJunctions) for creating links within the GIS to features that drain to the network (“catchment”; SJRWMD “QuadBasin”), waterbodies, and monitoring points, etc (Maidment, 2002; Fox, et al., 2006a and 2006b). Thus, features not normally included in a standard ArcGIS geometric network can participate in network-based functions.. For example, the Arc Hydro “Trace Feature By NextDownID Attribute” tool selects all the features (point, polygon) upstream and/or downstream of a location that are linked to the geometric network based on relationship classes involving the Arc Hydro feature class “HydroJunction”. The SWQM program used this functionality to generate unique drainage areas for each of program’s 73 water quality monitoring sites. In a similar fashion, the accumulation of attribute values along the direction of surface water flow, such as the parameters calculated for each QuadBasin by the PLSM, is accomplished by the geometric network and the Arc Hydro toolbar; thus each QuadBasin can possess attribution reflecting its local loadings, as well as additional attribution reflecting the accumulation of all of the loadings from upstream.

The SWQM program has developed a customized tool to automate the PLSM calculations. Considering that the SJRWMD is currently divided into 1,439 individual local drainage units (catchments; SJRWMD QuadBasins), automation of the PLSM provides consistent reproducibility of results and ease of model modification by virtue of simplified data input. Features of the automated PLSM tool include:

- Input data sources (land use, soils hydrogroup) are not converted to raster
- Categorization/grouping of land use and soil data for model input is based on data symbolization in the ArcMap table of contents
- The underlying technology for tool development is Visual Studio.NET (VS.NET), ArcObjects, and Custom Libraries for VS.NET
- Custom controls such as the 2007 ribbon interface provide an enhanced user interface

- Model settings (coefficient and concentration tables, etc.) can be saved and loaded for subsequent model runs
- Every result table, shapefile, and folder is time stamped.
- Summary tables are automatically added to the current ArcMap document
- Every summary and result table can be joined to the QuadBasin feature class for interconnectivity with ArcHydro by HydroID

At the top of Figure 2, a sample workflow for the PLSM is displayed. A subset of the Arc Hydro geodatabase is checked-out from the SDE geodatabase (process described in detail in the next section). The subset geodatabase is ready for the PLSM run once it is brought into the ArcMap interface. The four figures A – D displayed in figure 2 represent different ways to display model results, in this case for total Nitrogen over an annual period. The values mapped in A are the ranked absolute values, the darker the color the greater the estimated Nitrogen load. In B, the results are normalized by QuadBasin area, also displayed by ranking. In C, the accumulated annual Nitrogen estimated loading value is displayed for each QuadBasin and in D, the value is normalized by total upstream area. Note that in both B and D, an area located just to the left and below center appears to be the highest ranked for estimated Nitrogen loadings. A more detailed description of the PLSM tool can be found in Fox et al., 1997.

Disconnected Editing (Check – out / Check – in Tool)

The SWQM program is concerned with assessing water quality at the scale of the entire District; most projects within the Department of Water Resources at SJRWMD are focused on more localized areas such as planning units. In order to utilize the functionality of Arc Hydro without being hindered by the inclusion of features outside a project area's functional boundaries, a means by which a working subset of the SDE Districtwide Arc Hydro geodatabase can be exported as a personal geodatabase is necessary. Further, in order to provide District staff with the most current and correct information about the hydrologic features represented in Arc Hydro, a means by which features can be edited and then returned to the SDE Districtwide geodatabase replacing the existing (incorrect) features, but maintaining the crucial JunctionIDs, NextDownIDs and relationship classes, is also needed. To meet these needs, the SWQM contracted with PBS&J to develop a customized disconnected editing tool. With this tool, the user can select a planning unit and then check out a personal geodatabase version of the enterprise SJRWMD Arc Hydro

St. Johns River Water Management District Pollution Load Screening Model Tool

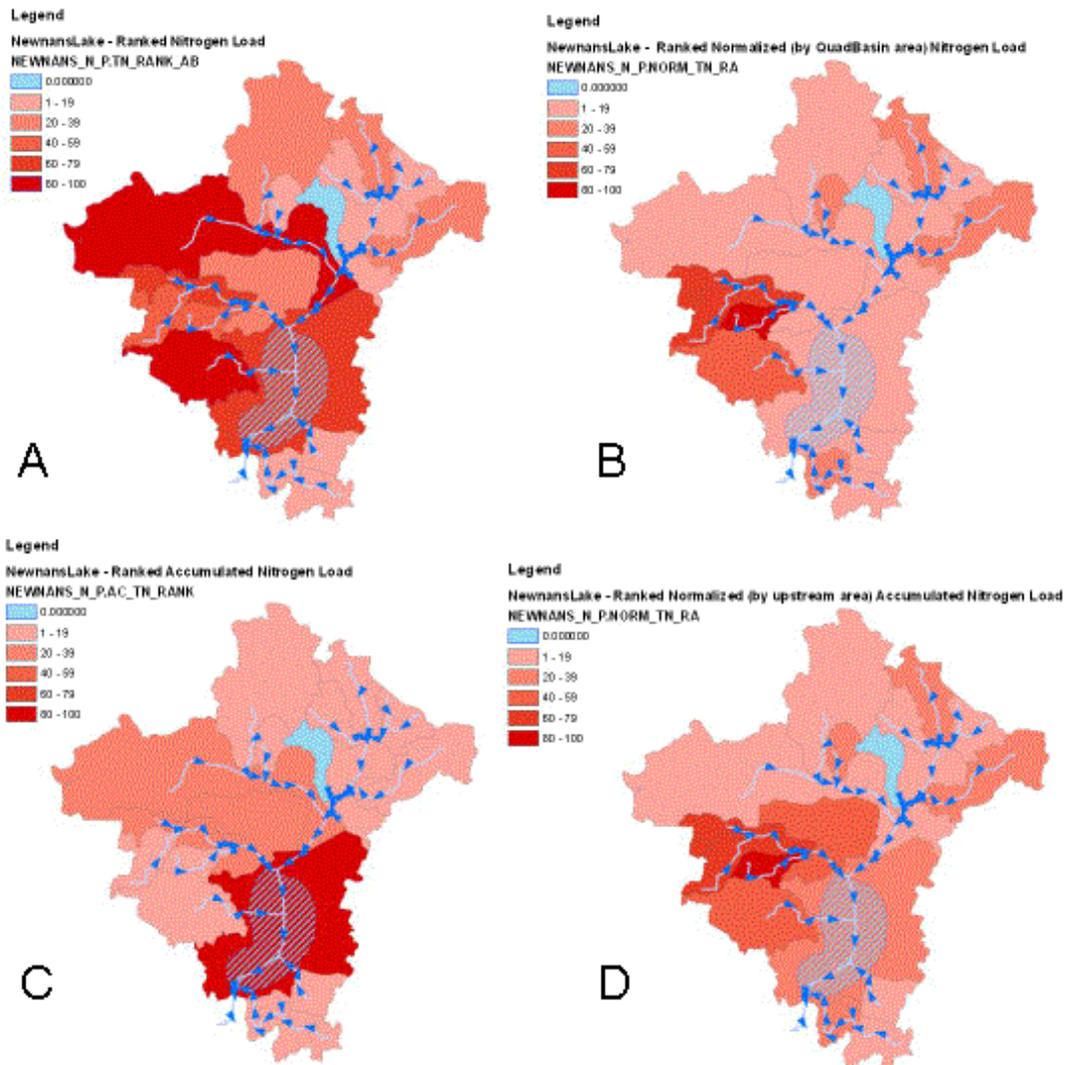
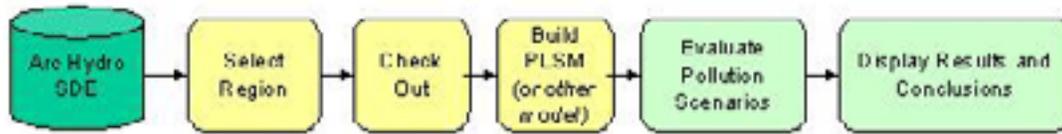


Figure 2. Sample application of the SWQM program's Pollution Load Screening Model (PLSM) tool. The workflow is shown at the top, in which a subset of the Districtwide Arc Hydro geodatabase is checked out from the SDE database (see next section for details). Features from the subset Arc Hydro geodatabase are shown in figures A – D reflecting different ways to display model results.

geodatabase with spatial extent within that planning unit. The check out process ensures that the checked out geodatabase is a working Arc Hydro geodatabase capable of being used by the Arc Hydro Toolset (Maidment, 2002). The hydrologic fidelity of the database is ensured because it is related to the District defined planning units, which are conglomerations of District QuadBasins. A requirements and specifications document provides a workflow for this process and explains the steps necessary to ensure hydrologic fidelity (PBS&J, 2006). Additionally, statistics of disconnected editing usage are kept by the tool and can be plotted on a district-wide scale to understand check out frequency and current check out state. The checked-out geodatabase can be used for two distinct purposes as shown in figure 3. As described in the above section on the PLSM, a project group may be interested in a subset of the Arc Hydro geodatabase for

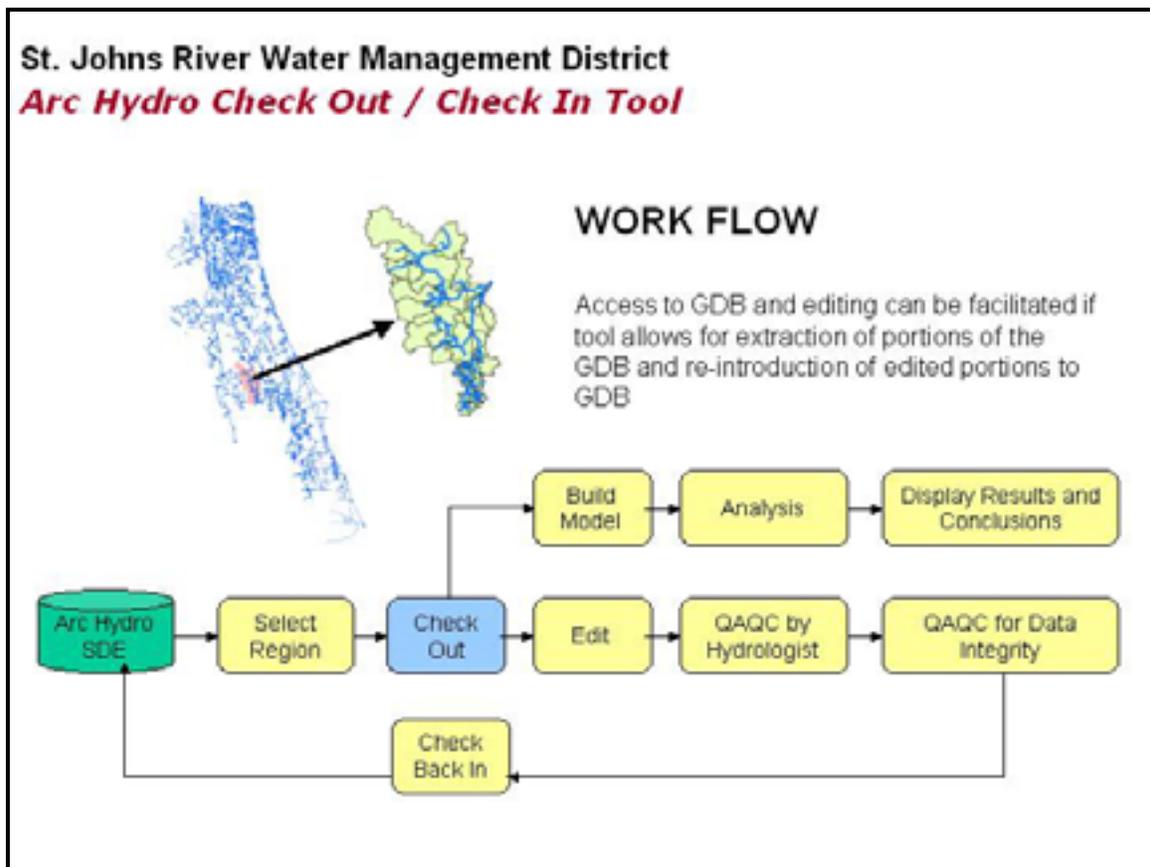


Figure 3. The workflow associated with the Arc Hydro geodatabase Check – Out / Check – In tool. A representation of the Districtwide geodatabase is shown with an area highlighted for check out. Two pathways in the workflow demonstrate that the subset Arc Hydro geodatabase can be intended for development of a model or for editing purposes, in which case the editing process includes at least two levels of QAQC before the data can be checked back in to the Districtwide SDE Arc Hydro geodatabase, maintained by Information Resources at SJRWMD.

the purpose of developing a model. Alternatively, the purpose of the check out may be for editing existing features, adding new features or deleting features from the existing Districtwide database. Both workflows are diagrammed in figure 3.

Features of the Arc Hydro check – out / check – in tool include:

- The tool is located in a tab added to the Table of Contents within the Arc Map interface, instead of the more commonly used toolbar system.
- Within the tool's interface are "sub-tabs" for Set-up, Data Management, Models (described in next section) and Reports.
- Upon selection for check out, a database tree is created within the user interface, providing the user an opportunity to verify that the correct features have been selected.
- The enterprise SJRWMD Arc Hydro database must be versioned
- Following an editing session in which new HydroIDs have been created, a check in process can be initiated without adding the edited data to the Arc Map session; the tool allows for navigation to the location of the edited geodatabase.
- All edited features are assigned new HydroIDs upon check in; the tool automatically checks for and updates all instances of HydroIDs as JunctionID for features participating in relationship classes with HydroJunction features.
- The tool does not replace either standard ArcMap editing functions or Arc Hydro related editing (i.e. flow direction must be set during the editing session with the Arc Hydro toolbar)

The tool was rigorously tested for both check - out and check - in functions following installation at SJRWMD and has been proven to be a valuable addition to the SWQM program's Arc Hydro related projects.

Inventory Tool

An inventory tool function is another Arc Hydro customization. This tool was based on the Gwinnett Arc Hydro Tools, an ArcMap-based extension which contains an inventory of hydraulic and hydrologic models (Bourne, 2005). The SWQM program extended that concept to create an inventory tool that can link to any type of file related to SJRWMD interests. Embedded in the same table of contents tab described above for the disconnected editing function, the inventory functionality is accessed through the tab that is entitled "Models". The inventory tool allows the user to:

- Build the model or file inventory,
- Explore the models or files while operating within the ArcMap system,
- Update the SJRWMD Arc Hydro district-wide database with Model Results²,
and
- Open select models or files in their modeling or native software environments

The technology behind the inventory tool functionality is the “many-to-many” relationship function inherent in ArcGIS (Bourne et al., 2006; PBS&J, 2006). Figure 4 shows examples of the types of files that were linked to the SWQM Arc Hydro geodatabase over the course of the project. Conceivably, any type of file for which the executable file can

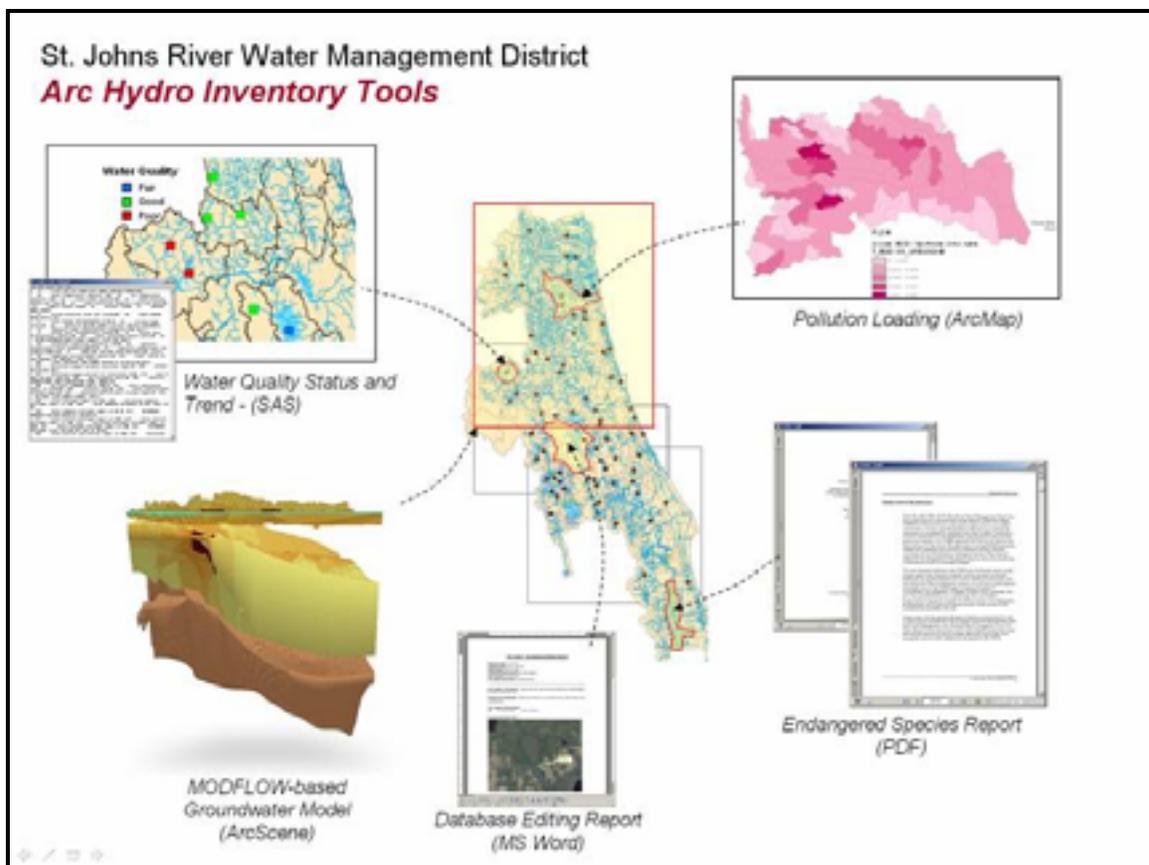


Figure 4. Examples of file types that can be linked to an Arc Hydro geodatabase using the Inventory tool.

² Specifically for the development project, a SAS model for water quality status and trends was used.

be directly accessed (i.e. a PDF file requires Acrobat reader) can be included in the inventory. District staff have expressed interest in seeing this functionality extended to provide a means by which District reports can be catalogued and accessed by geographic / hydrologic feature rather than by keyword, title, author methods common to file cataloguing methods.

ACES: Analytical Framework for Coastal and Estuarine Study

The limitation of Arc Hydro functionality for coastal areas was encountered during the development of the SWQM Arc Hydro geodatabase. In coastal areas flow from multiple directions can occur; in addition to the surface water flow from inland areas, the incoming tide and flow from lateral directions such as the Intracoastal Waterway, must be considered. In some coastal areas, it may be necessary to consider groundwater flow as well. Figure 5 displays the multiple sources of pollutants that can influence water quality at an estuarine water quality monitoring site. The Arc Hydro geometric network requires

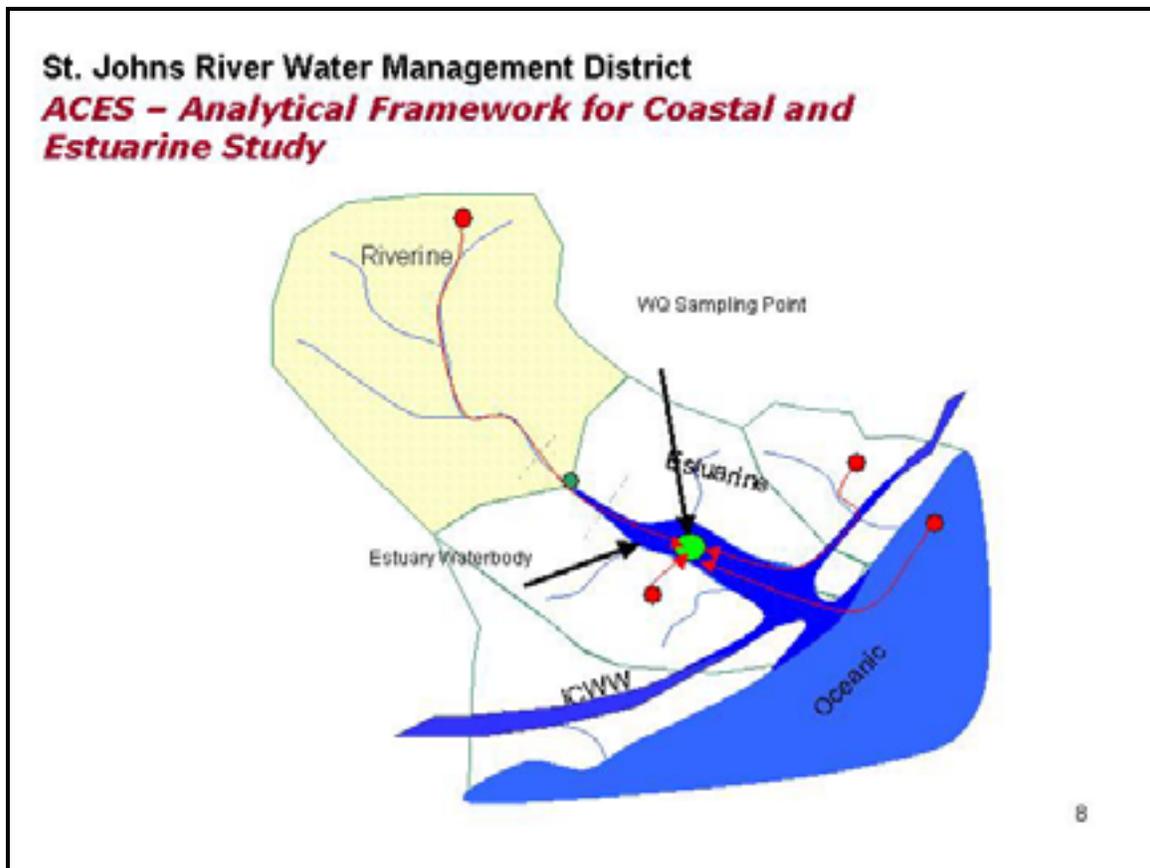


Figure 5. A representation of the water quality assessment problem being addressed by the SWQM program's 2007 Arc Hydro customization project: ACES, the Analytical Framework for Coastal and Estuarine Study.

flow to be limited to a single direction, which meets the needs of most of the SWQM program and SJRWMD area, but does not work well along the coast. A “work around” was created for the SWQM project by establishing somewhat artificial “Tidal Null Points” along the Intracoastal Waterway at the approximate location of the diverging outgoing tide to enforce the Arc Hydro one-way flow (Fox et al., 2006).

In order to assess water quality at estuarine sites, the current (2007) SWQM Arc Hydro customization project is focused on using GIS to better understand the processes that influence water quality along the coast. Recognizing the potential value of a solution that uses GIS to study estuaries, the SWQM program in cooperation with PBS&J have established a new effort called ACES. ACES is the analytical framework for coastal and estuarine study. ACES is intended to be a desktop workbench for study of estuaries and coasts in GIS. A committee of academics, industry experts, and agency scientists has been convened to advise on the development of ACES. The seminal development of ACES is being driven by the current SWQM project – assessing water quality in SJRWMD estuaries. The project is currently in progress and a prototype solution will be developed for the Guana Tolomato Matanzas estuary.

Conclusions

Functionality provided by the Arc Hydro geodatabase, schema and standard toolbar has proven to be a valuable asset to the SWQM program at SJRWMD. Customizations developed by the SWQM program have enhanced Arc Hydro functionality with the development of an automated pollution load screening model tool, a disconnected editing (“Check – out / Check – in”) tool, and a versatile file inventory tool function. Current Arc Hydro related customization is focused on developing a method to better understand coastal / estuarine processes in order to better assess water quality. Staff in other project groups at SJRWMD have expressed interest in utilizing Arc Hydro; a new geodatabase based on the 1:24,000 National Hydrography Dataset is in development.

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