

Benchmark Evaluation Tool (BET) Extension for ArcGIS

by

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Abstract

The Soil and Groundwater Closure Projects (SGCP) Division is responsible for the restoration of the environment at the Savannah River Site (SRS). One critical need in restoration efforts is the ability to evaluate and map analyte data against user-defined benchmarks for human health and ecological risks. Environmental & Geographic Information Systems (E&GIS) developed the Benchmark Evaluation Tool (BET) as an Environmental Systems Research Institute (ESRI) ArcGIS™ 8x extension. BET is designed to allow the user to interactively query and extract data stored in an Oracle™ database or customized data sheet, which are compared to benchmarks through a user-friendly interface. The results are presented according to three categories: exceedances, non-exceedances, and non-detects. BET also provides basic statistics on the sample data, and allows the user to send the map view to a layout for production of an analog map, or export the map view to a graphic file.

Introduction

The Savannah River Site's (SRS) SGCP Department is tasked with evaluating large amounts of geo-chemical contaminant sample data for the purpose of environmental restoration. In order to flag contaminant problem areas, one of the first phases of using geo-chemical samples is to screen it against a variety of human health and ecological benchmarks, such as the EPA primary drinking water standards. This helps the site characterization personnel identify contaminated areas and determine data collection needs for future sampling plans. Savannah River Site warehouses geo-chemical sample data for a variety of media, including soil, sediment, ground water, surface water, soil gas and biota.

History of Development

The first use of GIS to do risk screening on geo-chemical data at Savannah River Site was developed in ArcView 3x in the spring of 1999. The Integrator Operable Unit (IOU) program in the SGCP Department wanted to evaluate soil, sediment, surface water, seepage water, fish and game data for the streams, floodplains and contiguous wetlands, in order analyze data on a watershed basis.

By September of 1999, a GIS project was developed to display and evaluate the vast amount of environmental, geographic, and hydrogeologic data available for the SRS IOU program. The project assembled the graphic and tabular data in a user-friendly format, which enables analysis of every aspect of the conceptual site model. The most significant feature of the IOU GIS project was a customized utility application, which allowed users to perform real-time human health and ecological risk evaluations, obtain statistical summaries, and create time-trend scatter plots of the environmental data of interest. Unlike previous hard copy deliverables, a fully-automated compact disc effectively communicates the maps, tables and hundreds of thousands of analytical records from a relational database. This enabled users to select and manipulate the graphic and/or tabular data of interest and customize it to their specific needs. Since that

time, the IOU program has continued to use the IOU GIS tools to screen, analyze and summarize data for regulatory workplans, and also includes a CDROM containing the data and tools for EPA Region IV and the South Carolina Department of Health and Environmental Control (SC DHEC) to use with their copies of ArcView.

In the spring of 2002, a request came from the Reactors Team in the SGCP Department for the SRS Environmental & Geographic Information Systems (E&GIS) group to develop a similar GIS tool for the Environmental Restoration Data Management System (ERDMS), a modified version of the Commercial Off The Shelf (COTS) BEIDMS database system. It was also requested that the contaminants be plotted on a map display according to three categories: exceedances, non-exceedances, and non-detects, along with the display of basic statistics for each contaminant including benchmark value, number analyses, number of exceedances, number of non-detects, maximum detects, frequency detect, and number plotted. The resulting map layout could then be exported out of ArcMap as a graphic or sent to a plotter for analog output. These graphics would allow the team to identify "hot spots" in the study area and concentrate further investigation in these areas.

E&GIS accepted the challenge to build the BET custom GIS application in May of 2002, and began assembling a team of information technology professionals from within the organization. The team was composed of GIS programmers/analysts, project managers, and database systems experts. Due to the timing of the development, it was decided to develop the tool in ArcGIS versus the ArcView 3x product, as SRS would be rolling over to that product by the time of the BET tool's completion.

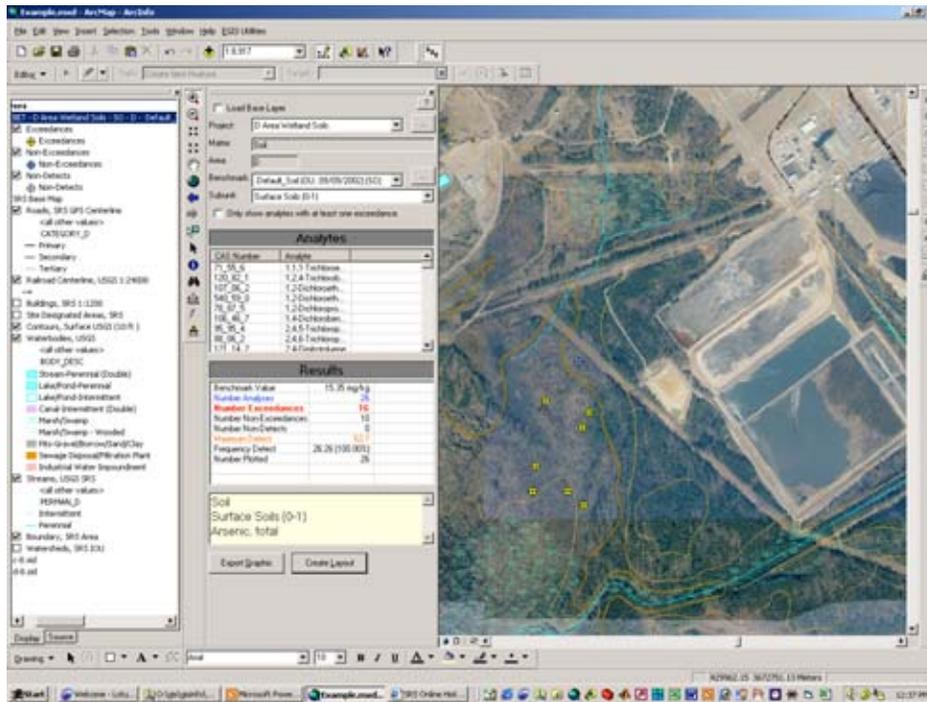
For the application design, the waterfall approach of software development was adopted. The waterfall model provides a systematic process that allows a development team to create software products that are thoroughly designed and tested prior to release to the customer. Requirements for the BET Tool were gathered from the customer in a series of meetings that resulted in approval in late-May. The E&GIS development team began design of the product in early June and the implementation or coding phase beginning in late-June.

The alpha release of BET was completed on September 30, 2002 and was tested by independent quality assurance personnel until mid-October. After some software fixes and adjustments, the beta version of BET was released in late-October. The customer completed beta testing early-November, and the first production version of BET was released on December 30, 2002.

Since the release of BET, several SGCP groups have been interested in the capabilities of the tool. The E&GIS development team has received several requests for modifications to the software to meet the specific needs of individual teams. Modifications to the software are easily incorporated because BET was designed to be scalable and customizable.

Application Description

The graphic user interface (GUI) of the BET application is displayed and described in the following text.



The user can use the BET tool in an existing ArcGIS project or create one on-the-fly by clicking the *Load Base Layers* box at the top of the GUI. The user selects a matrix, project area, benchmark, and subunit choice from the pull-down menus, and the BET retrieves those contaminants that have exceedances for the selected benchmark criteria. When the user selects an individual contaminant from the list, the BET tool dynamically generates exceedances, non-exceedances and unusable data as three distinct data layers. BET also calculates and displays statistics on the displayed contaminant samples, which is described below:

Benchmark Value

The limit value and units of the benchmark used for screening

Total Number of Analyses:

The total number of sample taken for a given media and analyze, throwing out reject qualifiers

Total Number of Benchmark Exceedances:

The total number of sample for a given media and analyte that exceed the given human health or ecological benchmark value

Total Number of Non-Estimated Detected Values:

The total number of samples where results are greater than the detection limit.

Total Number of Estimated Detected Values:

The total number of samples where analyte results are estimated and qualified with “J”

Total Number of Undetected Values:

The total number of samples where results have a “U” qualifier

Total Number of Unusable Data:

The total number of samples where results could not be screened due to unit, qualifier and other types of problem data

Lastly, the user has the option to export the map as an image or to create a map layout with a title, scale bar, etc.

Software System Design

Schematically the design of the BET tool consists of two major components: the *Database Component* which includes the ERDMS Oracle database and a local BET Project database (in Microsoft Access), and the *Software System* which includes the BETDataAccess and BETArcMapExtention components operating within the ArcMap environment, and interacting with the Database Component. This allows the system to query and extract data, analyze the imported data, and output results within the ArcMap environment.

Figure 1 provides a synoptic view of the system design. The BETArcMapExtension provides the interface through which the user can access the ERDMS database. This allows well sample data to be queried and extracted from ERDMS to create a desired project. User can query the data based on specific site areas, environmental matrix types, and a number of sampling parameters such as site ids, sampling events, stations, sampling ids, or even graphically defining an aerial extent. Additionally, sample data can also be imported through a pre-defined Microsoft Excel spreadsheet.

Once the data have been imported, they are saved in the local BET project database, which is also accessible for future analyses. The data query and analyses operations are provided by the two components of the Software System:

BETDataAccess Component

The BETDataAccess component is developed and compiled into a Dynamic Linked Library (DLL) to provide an interface to central ERDMS database and the local project database. The library exposes a number of modules and classes for use by the calling program. Table 1 provides a list of the modules and classes with a description of each. Primarily, these modules and classes provide data access support to the calling programs located in the BETArcMapExtension (see below) component. The modules are developed to optimize the Oracle SQL through the IEIS interface.

The BETDataAccess component also provides the procedures to communicate with individual local BET Project database (in Microsoft Access format). In addition to writing imported data to user-specified project files, it also access the analyte and benchmark data, also stored in the local database. This allows the user to update the analyte and benchmark data, thus increasing the vasatility of the software system.

Table 1. The BETDataAccess DLL is designed to expose modules and classes for access to the central database (i.e. ERDMS) and local project database.

BETDataAccess.dll	
List of Modules and Descriptions	
Module Name	Description
frmProgress	Provides a form that can be used to indicate the progress of long running operations to the user. Shared with BETArcMapExtension.
BETDebug	Contains code for handling exceptions within the program. Such exceptions are displayed to the user and logged to the project database (if possible). Shared with BETArcMapExtension.dll
mdeArrayToolbox	Contains toolbox code for working with arrays.
mdeDatabaseToolbox	Contains toolbox code for working with database connections.
mdeGlobalConstants	Contains the global constant definitions for the entire project. Shared with BETArcMapExtension.
mdeGlobalVariables	Contains the definitions of the variables shared throughout the code.
mdeStringToolbox	Contains toolbox code for working with strings.
clsAnalyteBenchValue	Represents the benchmark value for a single analyte. Can be created by

	clsBenchmarkGroup, or by the user code.
clsAverageTimer	Code for timing portions of the code in order to find the fastest method. Shared with BETArcMapExtension.
clsBenchmarkGroup	Represents the list of all benchmark groups contained in the project database. Created by clsBenchmarkGroupList.
clsBenchmarkGroupList	Provides with a list of the clsBenchmarkGroups defined for the project database. Created by clsBETData
clsBETData	The main interface to the data access DLL. Created by user code.
clsDataPoint	Represents an individual data point. Contains the fields for that datapoint. Created by clsDataPointSet or by user code.
clsDataPointSet	A collection of datapoints. Created by clsProjectData or user code.
clsDataQuery	A class to help with running async queries on either the project or main databases. Raises events to let the calling class know when data is ready. Created by clsBETData
clsErrorTypes	Exports an ENUM containing the error types defined by the DLL.
clsMatrix	Represents an individual matrix type - gives you the various representations of that matrix type. Created by clsMatrixList
clsMatrixList	A list of all possible matrix types. Created by clsBETData
clsProject	Contains all of the information about a specific project in the project database. Created by clsBETData.
clsProjectData	Contains all of the data points defined for the project. Created by clsProject.
clsProjectList	Provides a list of all projects defined in the project database. Created by clsBETData
clsSiteGroup	Represents an individual site group. Created by clsSiteGroupList
clsSiteGroupList	Provides a list of all site groups defined. Created by clsBETData
clsSubUnitList	Provides a list of all subunits defined for a given project. Created by clsProject
clsWasteUnit	Represents the information about an individual waste unit as defined. Created by clsWasteUnitList
clsWasteUnitList	Provides a list of all of the waste units defined. Created by clsBETData

BETArcMapExtension Component

The BETArcMapExtension component is designed to provide an interface to ArcMap. The component contains modules and classes compiled into a DLL that can be registered as an extension to the user interface in ArcMap. When the DLL has been registered in the user's computer system, the extension will be listed among the other available ArcMap extensions (Figure 2).

The ArcObject component implemented by the BETArcMapExtension components includes **MX Commands**, **MX Dockable Windows**, **MX Extensions**, and the **MX CommandBars** categories. The MX Command exposes the ICommand interface which provides the main ArcMap command interface for initializing the BET extension. From the MX Dockable Windows categories, the IDockableWindow and iDockableWindowDef interfaces were used to provide the dockable display container for the tool in ArcMap. The IExtension and IExtensionConfig interfaces available through the implementation of the MX Extensions category in the code allows the DLL to be created as an ArcMap extension, and with the help of the IToolBarDef interface from the MX CommandBars category, a customized toolbar is created on which the tool button resides.

Table 2 provides a list of all the forms, modules, and classes with the corresponding description of each, developed for the BETArcMapExtension DLL. In addition to the main (dockable) interface (frmBTBenchmarkingTool) the forms essentially provides the graphic interface for interaction with the

users for required input information. The modules together with the classes provide procedures and functions for data query, evaluation, and graphical display/output.

Table 2. The BETArcMapExtension component contains forms, modules, and classes for interacting with the user.

BETArcMapExtension.dll	
List of Modules and Descriptions	
Module Name	Description
frmAbout	Form to provide the user with information about the tool and its version.
frmBGAddAnalyte	Provides the interface to add an analyte to a benchmark group.
frmBGAddGroup	Provides the interface to add a benchmark group to the project database.
frmBGBenchmarkGroups	Provides the list of benchmark groups defined in the project database.
frmBGEEditGroup	Allows the user to edit a benchmark group.
frmBTBenchmarkingTool	The main interface to the benchmarking extension. This sits in the docking window.
frmBTLayOutSpecs	When creating a layout, this allows the user to choose which paper size.
frmDDAddRemoveDataPrompt	Shown in the data definition stage; prompts the user for how to remove or add data (by site id, sample id, etc)
frmDDGenericDataSelection	A general purpose form for allowing the user to select which data items to add to a list.
frmDDGroupData	Allows the user to group already selected data into groups (subunits)
frmDDImportFromExcel	Interface for importing data into the project from excel.
frmDDProjectDataDefinition	Main form for adding and removing data from a project as defined in the project database.
frmDDProjectSelection	Interface for selecting which project to edit
frmDDRRemoveData	Interface for selecting what items the user wishes to remove from his project. Has the ability to group a column based on unique values and then present the user with a list of selected values.
frmDDSelectByCoordinates	Form to provide a help hint to the user while selecting an area of the map.
frmImages	Form to hold the images for the command buttons and cursors.
frmProgress	Provides a form that can be used to indicate the progress of long running operations to the user. Shared with BETDataAccess
BETDebug	Contains code for handling exceptions within the program. Such exceptions are displayed to the user and logged to the project database (if possible). Shared with BETDataAccess.dll
mdeArcObjectsToolbox	Contains toolbox code for working with ArcObjects.
mdeArrayToolbox	Contains toolbox code for working with arrays.
mdeBaseLayers	Provides code for loading the standard base layers and adding them to a map.
mdeComboBoxToolBox	Contains toolbox code for working with comboboxes.
mdeDatabaseToolbox	Contains toolbox code for working with database connections.
mdeGlobalConstants	Contains the global constant definitions for the entire project. Shared with BETArcMapExtension.
mdeGlobalVariables	Contains definitions for variables used throughout the code.
mdeInitialize	Code needed to initialize global variables

mdeLayoutElements	Code for setting up layouts
mdeLayoutUtils	Code for setting up layouts
mdeListViewToolbox	Contains toolbox code for working the listviews.
mdeStringToolbox	Contains toolbox code for working with strings.
clsAverageTimer	A class to use for timing portions of the code in order to find the fastest method. Shared with BETDataAccess.dll
clsBenchmarkToolCmd	Provides the interface to ArcMap to create an ICommand
clsBenchmarkToolDock	Provides the interface to ArcMap to create an IDockableWindow
clsExcelImporter	Contains code to read in data from an excel document.
clsExtention	Provides the interface to ArcMap to create an IExtension
clsFormDisabler	Provides code to disable a form for the scope of a function.
clsLayoutSpec	Code for setting up layouts
clsLayoutSpecCol	Code for setting up layouts
clsSelectCoordinates	Provides the interface to ArcMap to create an ITool/ICommand. Used to allow the user to select an area of the map.
clsToolbar	Provides an interface to ArcMap to create an ICommandBar
uctlDataListView	A custom control for displaying data points to the user.

Figure 1. A schematic view of the BET system design

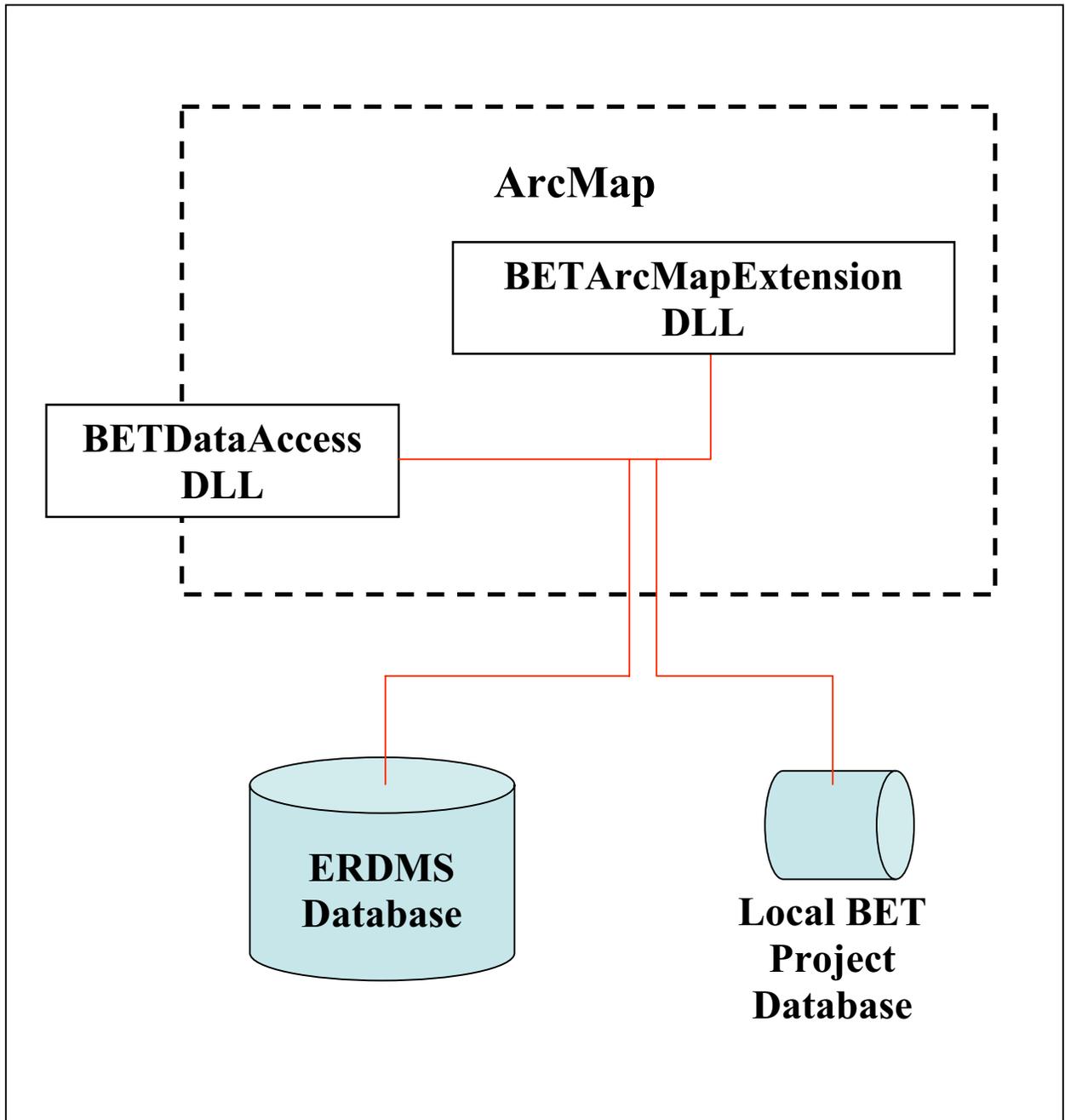
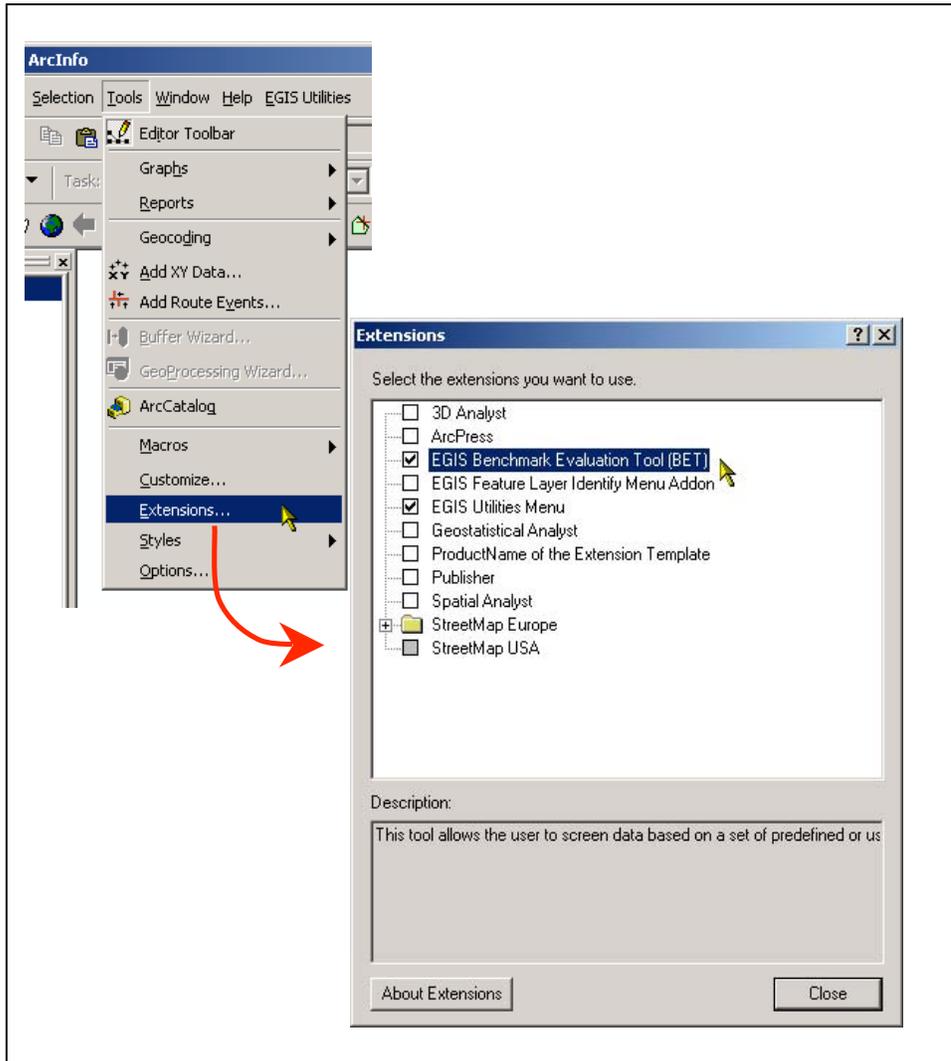


Figure 2. The Benchmark Evaluation Tool is designed as an Extension to ArcMap.



Future Developments

The EGIS department plans to integrate the IOU ArcView 3x tools into the ArcGIS product, so that BET and other ArcGIS environmental risk tools will run off both the ERDMS and IOU databases. Currently, the development of an Automated Risk Assessment Tool (ARAT), which allows users to model risk to ecological receptors for each subunit and/or operable unit, is being migrated to the ArcGIS platform and will be released in the near future.

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