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HydroDesktop User Guide

A free and open source GIS enabled desktop application that enables you to discover, download, visualize, and analyze hydrologic and climate data registered with the CUAHSI Hydrologic Information System.

December 2012

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Distribution

HydroDesktop and all associated source code and documentation are available at the following URL:

http://www.HydroDesktop.org

HydroDesktop, source code, and documentation are provided free of charge under the Berkeley Software Distribution (BSD) license. Please see the following license information:

Disclaimer

Although much effort has been expended in the development and testing of the HydroDesktop, errors and inadequacies may still occur. Users must make the final evaluation as to the usefulness of HydroDesktop for his or her application. HydroDesktop, CUAHSI HIS, and this software manual are based upon work supported by the National Science Foundation.

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

Acknowledgements

HydroDesktop is in development at Brigham Young University and led by Dr. Daniel P. Ames (dan.ames@byu.edu). Development is supported by the Consortium of Universities for the Advancement of Hydrologic Sciences, Inc. (CUAHSI) under NSF Grant Nos. 03-26064 and 07-53521.

If you use HydroDesktop in your research, please consider citing both the HydroDesktop web site (www.hydrodesktop.org) and the paper that describes the software:

Ames, D.P., Horsburgh, J.S., Cao, Y., Kadlec, J., Whiteaker, T., and Valentine, D., 2012. *HydroDesktop: Web Services-Based Software for Hydrologic Data Discovery, Download, Visualization, and Analysis*. Environmental Modeling & Software. Vol 37, pp 146-156.http://dx.doi.org/10.1016/j.envsoft.2012.03.013

The CUAHSI HIS was originally developed through a research project supported by the National Science Foundation (NSF) under Grant Nos. 04-12975, 041-3265, and 06-22374. The leadership of the project team consisted of:

- **David Maidment** (University of Texas at Austin Center for Research in Water Resources), Project Leader and Principal Investigator
- **David G. Tarboton** (Utah State University Department of Civil and Environmental Engineering; Utah Water Research Laboratory), Project Deputy Leader and Co-PI
- **Ilya Zaslavsky** (San Diego Super Computer Center Spatial Information Systems Lab), Co-PI
- **Daniel P. Ames** (Idaho State University Department of Geosciences), Co-PI
- **Jon Goodall** (University of South Carolina Department of Civil and Environmental Engineering), Co-PI

Technical Support

Ongoing support for HydroDesktop is coordinated through CUAHSI and is supported by NSF Grant Nos. 03-26064 and 07-53521. For questions, comments, or if additional information is required, please contact:

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About HydroDesktop

HydroDesktop is a free and open source desktop application developed in C# .NET that serves as a client for CUAHSI HIS WaterOneFlow Web services data and includes data discovery, download, visualization, editing, and integration with other analysis and modeling tools. By communicating with WaterOneFlow, HydroDesktop gives the user access to rich hydrologic datasets that have been published using this Web service standard.

The HydroDesktop source code is hosted on Codeplex. For more information about CUAHSI HIS, see the HIS Website.

General Concepts

WaterOneFlow Web Service

Web services are like programs that you access on the Internet, which typically have one distinct "service" that they provide to you. WaterOneFlow is a Web service whereby you provide a location, a variable of interest (e.g., streamflow), and a time period, and it returns a time series of data. The output format from WaterOneFlow is an XML language called WaterML that includes both the time series data and also the metadata to fully describe the data. This is a standard design that dozens of agencies and universities now use to publish their data.

HydroDesktop knows how to request data from a WaterOneFlow Web service and translate the WaterML response into your local database so that you can get on with your analysis. It handles this details of communicating with Web services so that you don't have to.

Data Management

HydroDesktop works with both spatial and temporal data. Spatial data tend to be in the form of shapefiles, and some shapefiles such as basemap data are distributed with HydroDesktop. Extensions can enable HydroDesktop to work with additional spatial data types such as online map services.

Temporal data are stored in a relational database called the Data Repository. By default, SQLite is used as the database format. Tools in HydroDesktop know how to read this database and present information from it to the user. A default database is included with HydroDesktop, but you can and are encouraged to create and use your own project-specific databases. These databases are filled with temporal data that you acquire through data searches, data import, or data generation using models and analytical tools.

HydroDesktop also has the ability to query a given data service to figure out what data are available through the service. It stores this catalog of available data in another database called the Metadata Cache. To keep things clean, this database is kept separate from the Data Repository. Think of the Metadata Cache as a description of all data from all remote data sources that your installation of HydroDesktop knows about, and the Data Repository as a collection of data that you've actually downloaded from data sources and saved.

The Map

HydroDesktop displays spatial data in the map. For more information on working with the map see Working with the Map on page 8.

Search

HydroDesktop can search for hydrologic time series data, download it, and save it to your local Data Repository database. When searching for data, you can specify the following filters: region of interest, parameter, time range, and data source. When the search results are returned, you can further filter the results and then choose which data you want to actually download.

Projects

You save elements of a HydroDesktop session in a project file. The project file keeps track of which Data Repository database you were using, what layers you had in your map, how those layers were symbolized, etc.

Getting Help

There are a variety ways of getting help with HydroDesktop:

- Click buttons on the Help tab of the ribbon. The Help tab has buttons for opening the help system, leaving a comment, etc.
- Click help buttons on the specific HydroDesktop tools that you are using, if available.
- Add to discussions and issues on the HydroDesktop Website.

Working with the Map

Working with Map Layers

The spatial data in HydroDesktop is organized in map layers. The list of all map layers is shown in the legend. Checking or unchecking a layer checkbox shows or hides the layer in the map. There are five main types of layers:

- Point Layer (for example, cities)
- Line Layer (for example, rivers)
- Polygon Layer (for example, lakes)
- Raster Layer (for example, elevation)
- Background Map Layer (for example, satellite images)

Each layer has a data set storing the associated spatial data. The data set can be a file on the local computer or it can be an online dataset (web map service). Some spatial data are shipped with HydroDesktop. These include the 'World' and 'North America' templates and the 'jacobs_well_spring' and 'elbe' sample projects.

To add a new layer to the map, click the Add button in the main toolbar;
to change the color scheme or symbol of a layer, right-click on the layer in the legend and select Properties;
to add labels to the layer, right-click on the layer in the legend and select Labeling - Label Setup.

SELECTION

You can highlight features in a map layer by using Selection. To enable selection, use the Select tool in the main toolbar. Click on a feature in the map to select it. The selected feature is highlighted in light blue color. Hold the CTRL button to select more features. To deselect all features, click the Deselect All button in the main toolbar.

ATTRIBUTE TABLE

Each point, line or polygon layer has an Attribute table associated with it. This table shows additional information describing the layer. For example, the attribute table of the Countries layer has fields describing the country names, areas and populations.

There are two ways to view or edit the attribute table:

- Click the View Attribute Table button in the main toolbar.
- Right-click on layer in the legend and select Attribute Table Editor

If some features in the layer are selected, then the corresponding rows in the attribute table are also selected. You can also use the Query tool in the selection menu of the attribute table editor to filter the data using a custom query expression.

LAYOUT

To print or export a map, set up the map layout by going to the File menu in the main toolbar and selecting Print Layout. This displays the Print Layout window.

To add a map to the layout, click on the Insert Map button and drag-drop it to the layout. You can change the scale of the map by changing the Scale value in the map properties

of the layout.

To add a legend to the layout, click on the Insert Legend button and drag-drop it to the layout

You can also add a scale bar, north arrow, text or picture to the layout.

Searching for Data

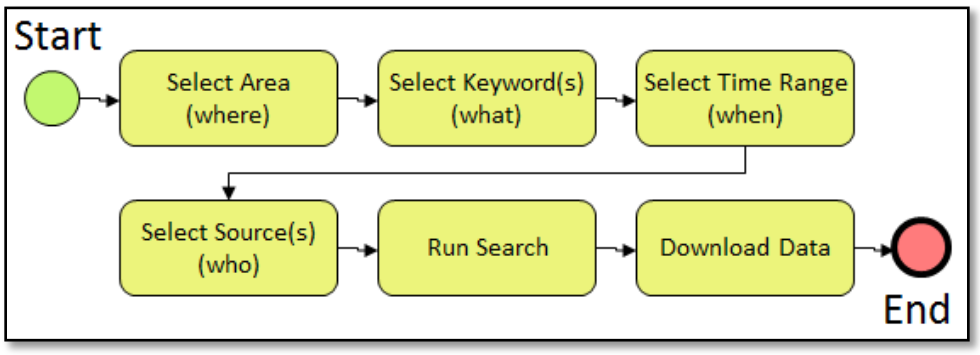
Searching for Time Series Data

When searching for data in HydroDesktop, you can specify the following filters:

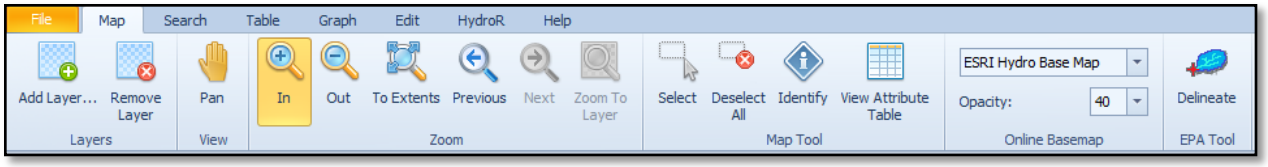
- Area of interest
- Keywords (e.g., Precipitation)
- Time range
- Data sources

Once you initiate a search, HydroDesktop queries the CUAHSI-HIS national catalog of known time series data to find locations of time series that match your search. Search results are presented in the map and include information that HydroDesktop can use to connect to each individual data provider for data access.

You can then further filter the results and choose which data you want to actually download.



The tools for running a search are located on the Search tab of the HydroDesktop ribbon. The panels in this tab represent the steps in the workflow above.



The HydroDesktop Ribbon

Specifying Area of Interest

There are two ways of specifying an area of interest for the search: drawing a box or selecting a polygon.

Drawing a Box

If you are very familiar with the location of your study area, then drawing a box may be the easiest option.

To draw a box around your area of interest:

1. Use the tools on the Map tab to locate and zoom in to your area of interest.
2. On the Search tab, click the Draw Rectangle tool.
3. With the left mouse button, click and drag in the map to draw a box around your study area.

Once a box is drawn, it is highlighted in the map

Selecting a Polygon

If a polygon feature in the map represents your area of interest, you can select that polygon to be used in the search. For example, the polygon could represent a county as found in the U.S. Counties dataset included with HydroDesktop, or the polygon could come from a shapefile that you created and added to the map.

You can either select polygons by location or by attributes of the polygon feature.

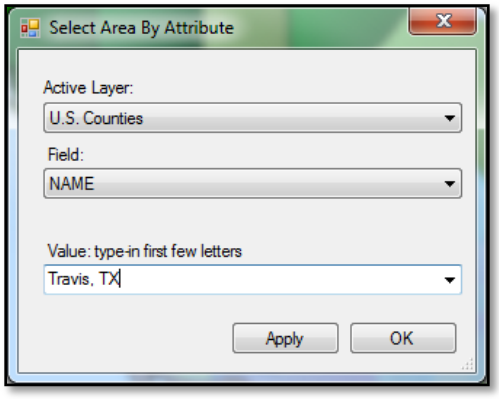
To select polygons by location:

1. In the Legend, left-click to select the map layer that you want to use. Note that you must select a polygon layer. The search will not work with online basemap data, point layers, or line layers.
2. In the Legend, make sure the desired map layer is visible by placing a check in the box next to the layer's name.
3. On the Search tab, click the Select Features tool. This tool works like the Select tool on the Map tab, and either tool can be used to select features.
4. With the left mouse button, click a polygon in the map or draw a box that intersects one or more polygons to select those features.

A selected polygon is highlighted in the map

Alternately, you can select polygons using attributes of polygon features.

To select polygons by attributes:



1. In the Legend, make sure the desired map layer is visible by placing a check in the box next to the layer's name.
2. On the Search tab, click the Select by Attribute button.

3. In the dialog that opens, choose the layer of interest, an attribute of that layer, and then the value of the attribute that will be used to identify the polygon of interest. To choose the value, you can either select it from the list or type in the desired value.
4. With the attribute value highlighted, click OK to close the dialog and select the feature.

CHOOSING KEYWORDS

To facilitate searching across a variety of data sources, each with their own naming conventions for hydrologic parameters, CUAHSI maintains an ontology of hydrologic keywords to which a given data source's parameters are mapped. This means a search for the keyword Precipitation will return results even if a data source calls that parameter "rainfall" or "precip" instead.

You can choose from one or more of these keywords when conducting a search.
To quickly choose a single keyword:

1. In the Keyword panel on the Search tab, locate the drop down box where you can type a keyword.
2. Start typing the keyword, e.g., streamflow, in the box. The box autocompletes to a valid keyword based on what you type. Or, you can click the drop down arrow to choose a keyword from the list.

To select multiple keywords:

1. In the Search tab, click the Add More Keywords button.
2. In the dialog that opens, choose a keyword by either typing it in the text box at the top or by browsing the keywords and selecting a desired keyword.
3. With a keyword highlighted, click the green plus sign to add it to the list of selected keywords.
4. Repeat steps 2 and 3 to add more keywords.
5. Click OK when all desired keywords have been added.

Note: If you are interested in all variables, then use the search term *All*.

SETTING A TIME RANGE

Search results will only be returned if the period of record for a time series intersects the time range that you specify.
To quickly set the time range, enter the start and end dates into the boxes in the Time Range panel of the Search tab. Default values are provided as a guide.

For more advanced options regarding time ranges, click the Select Time button. This button opens a dialog in which you can manually set the start and end dates or quickly select a recent period such as the last month.

CHOOSING DATA SOURCES

Dozens of data sources publish data using WaterOneFlow services, making them accessible in HydroDesktop. These data sources register with CUAHSI's HIS Central, where a catalog of all data sources and what parameters those data sources publish is maintained.

By default, when HydroDesktop performs a search, it sends the request to HIS Central. HIS Central searches its catalog to see what sites exist that match the search criteria, and search results are returned to HydroDesktop.

In many cases, this default behavior is fine and there is no need to modify this aspect of search. However, you do have a couple of advanced options available to you.

One of these options is to restrict the search to specific data sources. You might do this when you know you only want to work with USGS data.

To restrict the option to particular data sources:

1. On the Search tab, click the Select Data Sources button.
2. In the dialog that opens, place a check next to services that you want to include for the search, and click OK.

Another option available is to search the local metadata cache instead of HIS Central. The metadata cache is a database, much like the one at HIS Central, which catalogs what parameters are available from certain data sources. However, the metadata cache is created by you and managed by you. It has no ties to HIS Central. Creating a metadata cache is useful if you are aware of services that are not registered at HIS Central. These services wouldn't be returned in HIS Central search results, but may still be useful to you. For more information on creating a metadata cache, see Metadata Fetcher.

To search the metadata cache instead of HIS Central:

1. On the Search tab, click the Select Data Sources button.
2. In the dialog that opens, check the Local Data Source radio-button and click OK.

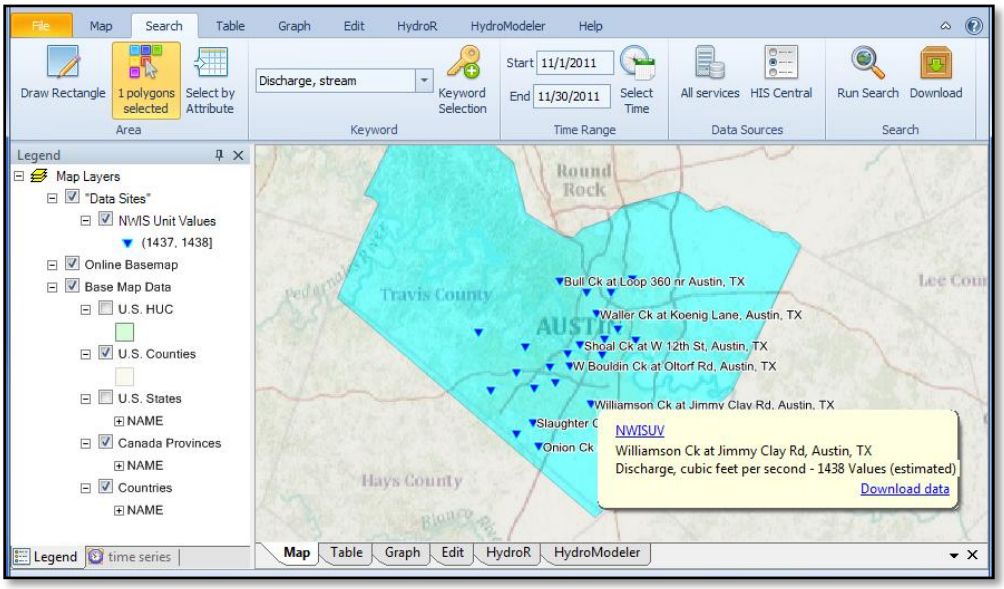
Note: You must have already harvested data into the metadata cache before attempting to search it.

Running a Search

With search parameters set, follow these steps to run a search:

1. In the Search tab, click the Run Search button.
2. When the dialog indicates the search has finished, click to Hide the dialog.

Locations of time series that match your search criteria are displayed in the map and symbolized by data source and number of data values available. You can hover your mouse over one of the symbols in the map to see more about that location.

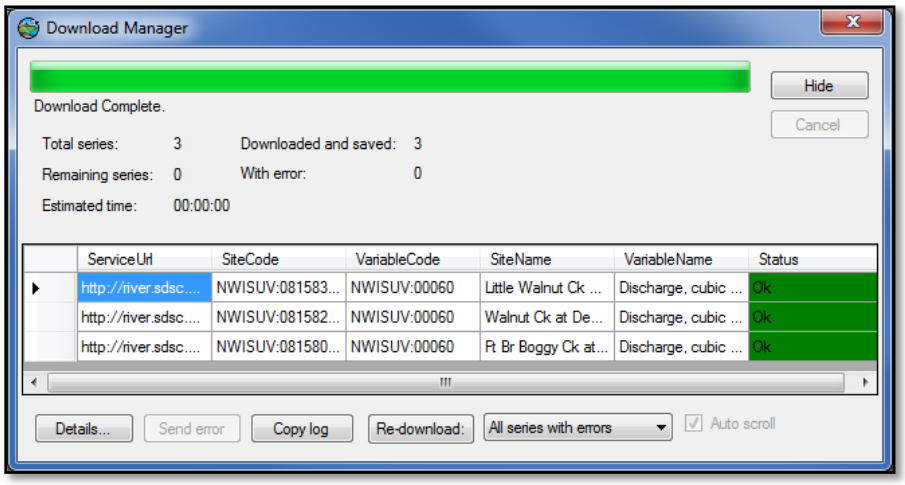


Downloading Data

There are a couple of ways to download data from search results. The easiest is to hover the mouse over the location of a desired time series in the map, and in the pop-up window that opens, click the Download button.

If you would like to download multiple time series, then you can select them and click the Download button on the Search tab. You select series the same way you select other features in the map. For example, you can use the Select tool on the Map tab to click on or draw a box around the time series you want to download.

When the download begins, the Download Manager shows detailed progress of each download.



When the download completes, click to Hide the dialog. If any errors occur during the download, you can click to view the details of the download attempt or attempt to re-download the series with errors. You can also copy the error log so that you can post it to the HydroDesktop issue tracker, thereby alerting the development team to potential issues with the system.

With the download complete, you can now visualize, analyze, and export the data using HydroDesktop's other capabilities.

The Metadata Fetcher

HIS Central maintains a catalog of time series metadata, i.e., where time series variables are measured and from which Web services they may be obtained. HydroDesktop queries HIS Central's catalog when searching for data. But what happens when a service isn't registered with HIS Central? This may happen when a service is developmental or if the service is private. HydroDesktop can still search for data from such services, but instead of searching HIS Central, the search is performed on a local metadata cache database.

The local metadata cache database is similar to the HIS Central catalog. Like the HIS Central catalog, the local metadata cache database doesn't store time series values; it stores information about where time series variables are measured and from which Web services they may be obtained. One difference is that the variables in the local metadata cache database are not mapped to the CUAHSI hydrologic variable ontology, because the ontology and

mappings are maintained by HIS Central. Another difference is that the local metadata cache database only stores metadata from the services that you choose to harvest into it.

The Metadata Fetcher is the tool that you use to harvest metadata into the local metadata cache database. You'll find it under the Data Sources Metadata panel added to the Search tab. The panel has buttons for working with the metadata cache.

The general workflow for harvesting metadata into your local cache is:

- Use the Add Data Source button to add WaterOneFlow services to the list of services that the metadata cache will harvest. This just adds services to a list and doesn't actually perform any harvesting.
- Use the Manage button to harvest metadata for selected services.
  Once metadata has been harvested, you can search the local metadata cache database by using the Search tab. For more information on search see Searching for Data.

MANAGING SERVICES

When you click the Manage button, the Metadata Fetcher window opens showing a list of WaterOneFlow Web services that can be harvested. The title of the service, its URL, and a timestamp indicating when the service was last harvested are displayed.

Note: If you see a timestamp for the year 0001, this indicates that metadata has not yet been harvested for the given service.

To update the local metadata cache database, place a check next to the service(s) that you want to harvest and click Download Metadata. The database will be updated with the latest metadata available from the service. Remember that you are not downloading time series values here. You are simply downloading metadata about where time series are measured to enable efficient searching for data later on.

In the Service Management menu, you'll find options for adding services and removing checked services from the local metadata cache database. You can also refresh the service list if you suspect that the list of services displayed in the Metadata Fetcher window is not current.

Adding Services

The Add WaterOneFlow Service Info window is used to add WaterOneFlow Web services to the list of services for which metadata can be harvested into the local metadata cache database. You can open the Add WaterOneFlow Service Info window either by clicking Add in the Metadata panel of the Table tab in HydroDesktop, or by accessing the Service Management menu in the Metadata Fetcher window.

In the Add WaterOneFlow Service Info window, you can add information for one service at a time or for multiple services. Before updating the local metadata cache database with information about the services you want to add, you can check for any identical services already in the database by clicking the Check Existing button. This helps to avoid duplicate entries in the database. Click Update Database to add information about the services to the database.

Adding a Single Service

To add information about a single WaterOneFlow Web service:

1. In the Add WaterOneFlow Service Info window, activate the Add Single Service tab.
2. Fill out the information for a single service.
3. Optionally, click to check if the service already exists in the database.
4. Click to update the database.

Adding Multiple Services

To add information about multiple WaterOneFlow Web services, you have three options:

1. In the Add WaterOneFlow Service Info window, activate the Add Multiple Services tab and complete the information for each service to add.
2. In the Import menu, choose From HydroServer and input the URL to a HydroServer's Capabilities service.
3. In the Import menu, choose From File and input the path to a comma delimited file containing information about the services to add. The names of the columns in the file must match the names in the Add Multiple Services tab.

For any of the options above, the result is a list of services in the Add Multiple Services tab. Once the list is complete, you can optionally click to check if the service already exists in the database. Then, click to update the database.

Note: A HydroServer is a Web server hosting one or more WaterOneFlow services. HydroServers also publish a Capabilities service which enables clients to automatically determine what services the HydroServer has to offer.

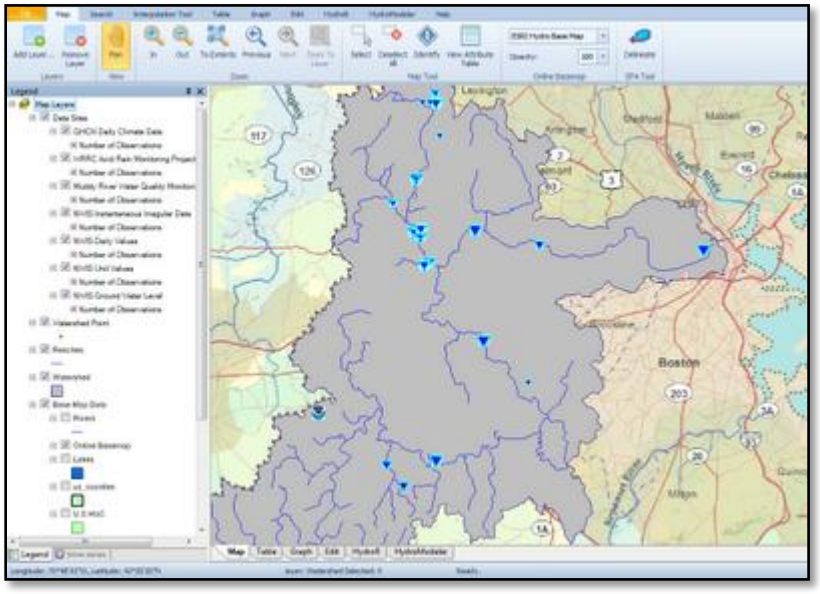
OPTIONS

In the Add WaterOneFlow Service Info window, from the Options menu, you can choose whether or not each service in the list should be checked to see if it matches the WaterOneFlow service signature before adding the service to the database. Checking the service requires following the given URL to see if a Web service is present, and if so, whether or not it has the same methods as defined by WaterOneFlow. This checking requires additional processing time, but helps to insure that only operational WaterOneFlow services are added to the metadata cache database.

EPA DELINEATE WATERSHED TOOL

The EPA Tools in HydroDesktop provide access to EPA's WATERS Web and Database Services. Users can use these tools to get the watershed and the flowlines that are delineated from the specified point on the map. Both the watershed and flowlines are based on NHD (National Hydrography Dataset) system.

Contact information for EPA's WATERS Web and Database Services can be found at the following URL: http://www.epa.gov/waters/comments.html



A search for sites in the Charles River watershed using the EPA Watershed Delineation Tool.

DELINEATING YOUR WATERSHED

Using the EPA Delineation tool to create a watershed shapefile makes it possible to search for hydrological data within particular watersheds. To do this:

1. Click the Delineate button in the EPA Delineation Panel in the Home Tab.
2. Specify the names of Watershed Point, Watershed and Streamline for the files that you want to save.
3. Click OK. You will find the cursor turns to a cross shape.
4. Click at one point that you want to use as the outlet on the map.
5. The Delineation tool is now starting to collect the coordinate information of the point you clicked and send it to the EPA Web Services to get responses.
6. Wait until you see the message "Drawing Features on the Map...". The message box will close automatically after all procedures are complete.
7. You will find three shapefiles with the names you specified shown on the top of the map. They are temporarily saved in *UsersApplication DataHydroDesktopDelineation* folder in your system.
8. You can export the features as shapefiles to other locations by right clicking on the name and selecting Data –> Export Data.
9. You can also check the attributes of these shapefiles by right clicking on the name and selecting View Attributes, or directly click the Attribute button in the ribbon tab.

Now you have a pretty hydrological view of all the upstream of your particular point.

WORKING WITH DATA

HYDRODESKTOP DATABASES

Temporal data are stored in a relational database called the Data Repository. Catalogs of available data, which may not yet have been downloaded into the Data Repository, are maintained in another database called the Metadata Cache database.

Tools in HydroDesktop know how to read these databases and present information from them to the user, and they also know how to properly save information to these databases. Therefore, it's generally a good idea to use HydroDesktop to work with these databases. However, some users may want to open the databases directly. This page describes how to locate and open HydroDesktop databases outside of HydroDesktop.

LOCATING THE HYDRODESKTOP DATABASES

The Data Repository and Metadata Cache databases are linked to the current project opened in HydroDesktop. To locate the Data Repository database:

In the Ribbon, in the Table tab, in the Database panel, click Change. The location of the current database is shown in the dialog that opens.

The Metadata Cache database has the name ending with "_cache.sqlite". To locate the Metadata cache database:

In the Ribbon, in the Table tab, in the Database panel, click Change. The location of the current metadata cache database is shown in the dialog that opens.

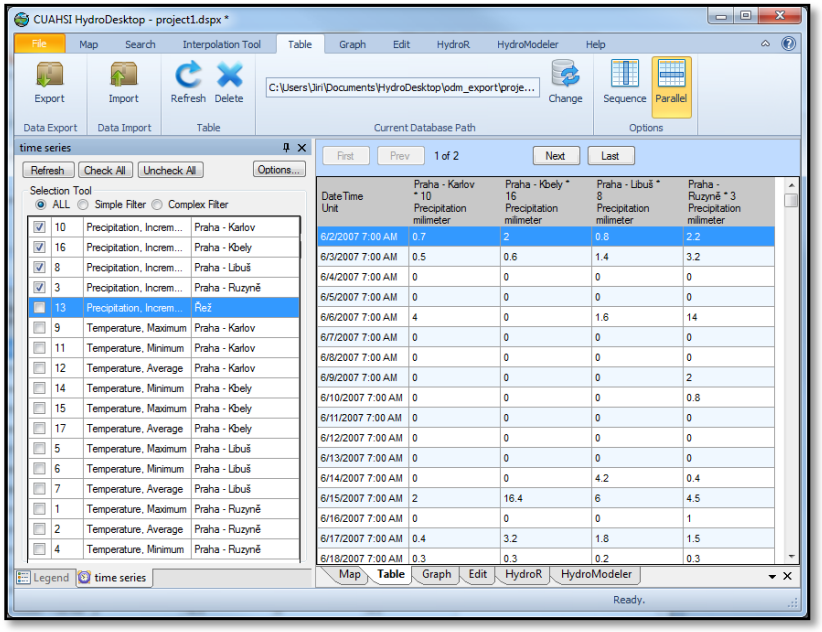
Viewing the HydroDesktop Databases

HydroDesktop attempts to provide simplified and useful views into its databases through its user interface. However, it is also possible to open and peruse the database contents directly. By default, HydroDesktop uses SQLite as its database format. You can view the contents of a SQLite database using the following free viewers:

SQLite Database Browser
Firefox SQLite Manager Add-on (requires Firefox)

The Table Tab

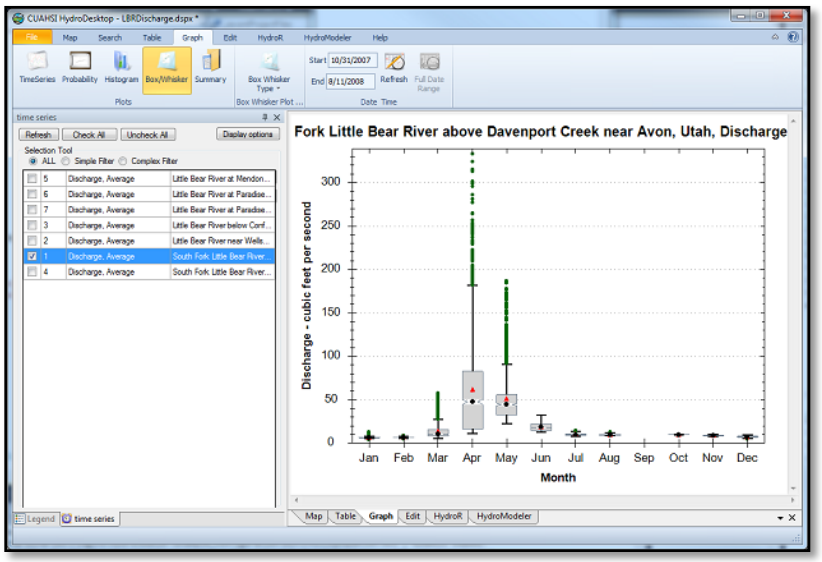
The Table Tab in HydroDesktop provides functions to view and export time series data. You can also change the current database and build your own local metadata cache using the tools on this tab.



The Table Tab

The Graph Tab

The Graph View is a HydroDesktop extension that provides functionality for visualizing data that have been downloaded and stored in the HydroDesktop data repository database. The Graph View enables you to generate a variety of plot types for time series data as well as simple summary statistics that can be used for exploratory data analysis. A variety of plot customization options are available for changing the look and feel of the plots generated by the Graph View extension.

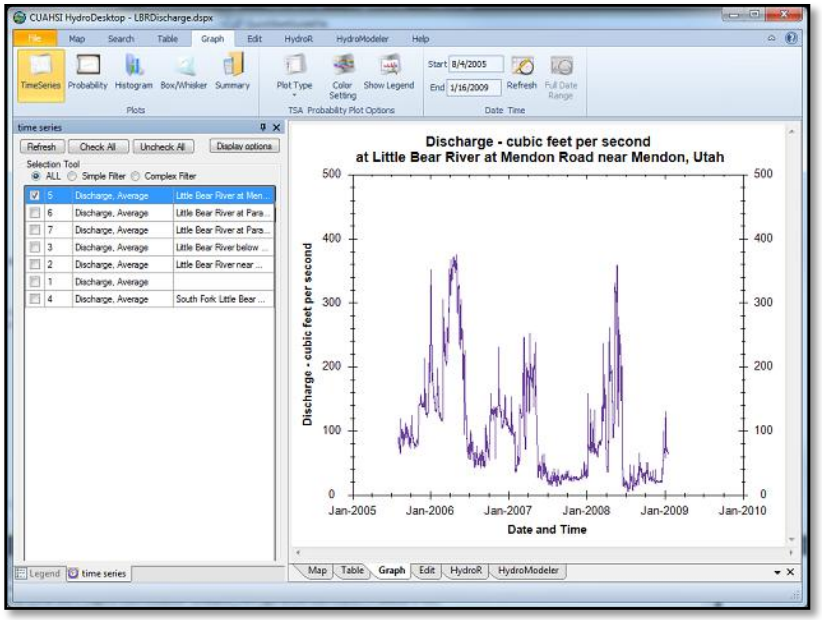


Visualizing Data in the Graph View

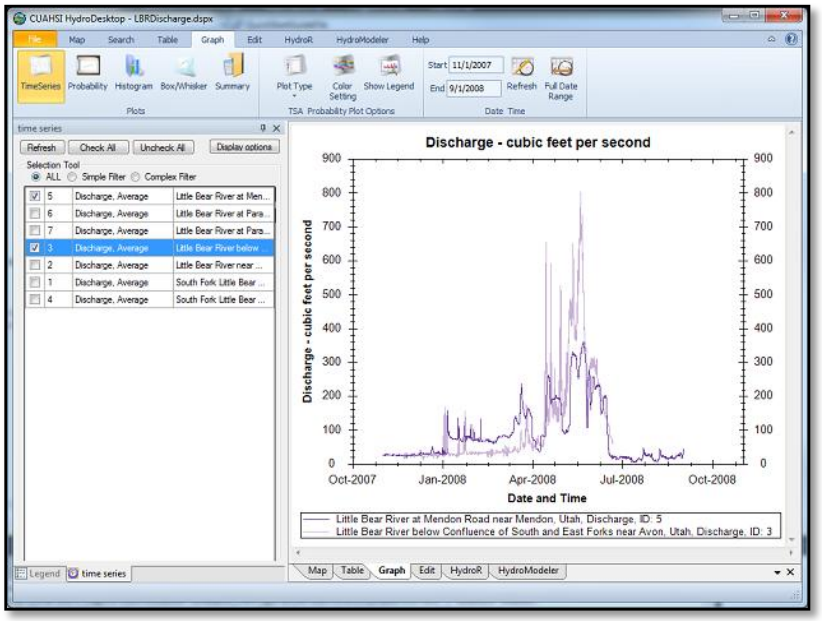
Once you have discovered and downloaded some time series data into HydroDesktop, you can use the following steps to begin visualizing those data using the Graph View extension:

1. Make sure the Graph View is active by clicking on the “Graph” tab at the top of the HydroDesktop window.

2. Select a data series by clicking on the check box to the left of any of the data series in the HydroDesktop Series Selection Tool. You will notice that the Graph View creates a plot of the selected series.



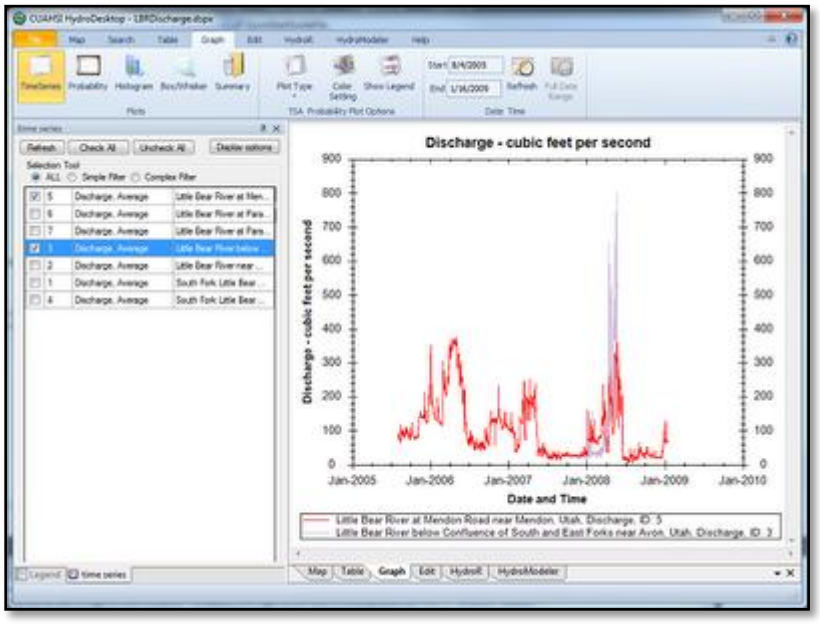
3. You can visualize multiple series at once by selecting multiple series on the series selection tool. You will notice that a legend appears at the bottom of the plot when more than one series is selected.



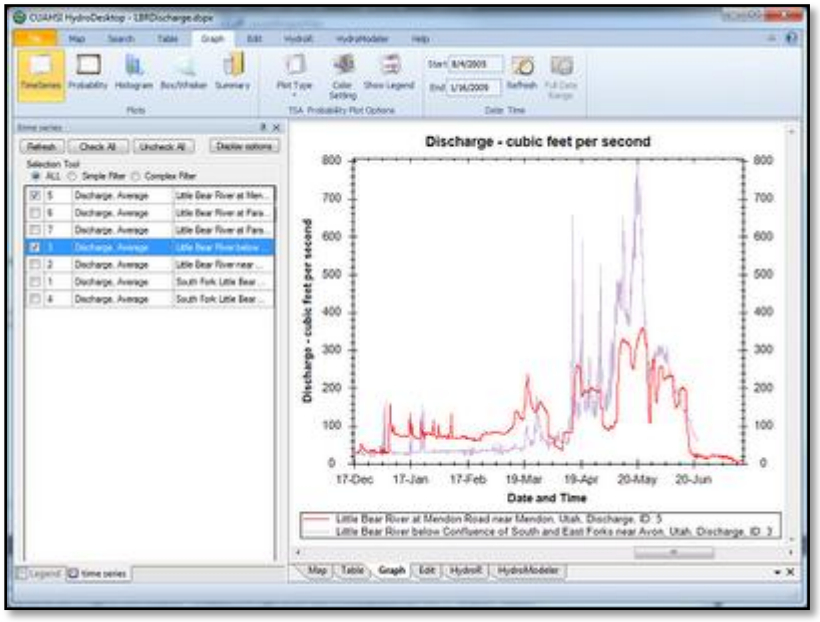
ZOOMING IN AND OUT OF PLOTS

You can easily zoom in and out on a plot within Graph View using the following steps:

1. Create a time series plot by selecting one or more data series in the Series Selection Tool.

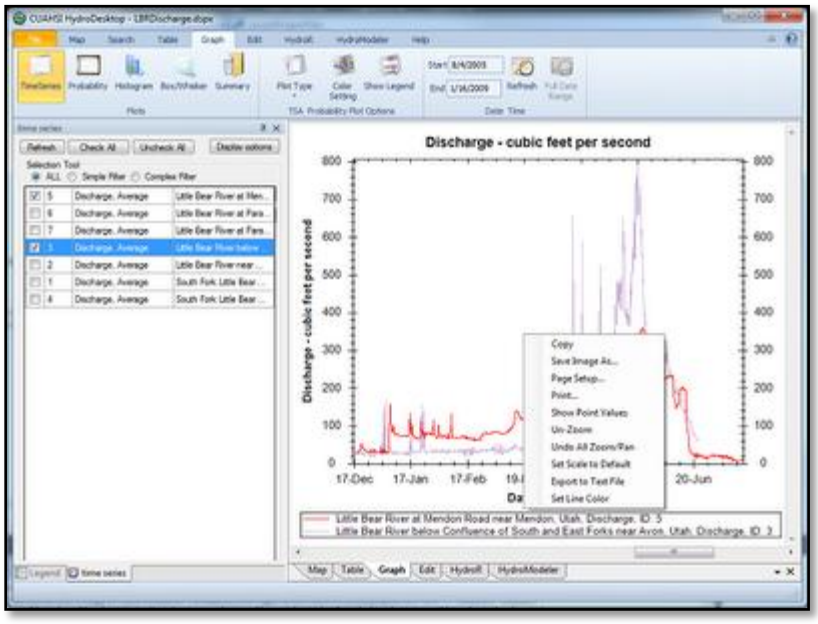


2. Click and drag a rectangle on the plot to define a zoom area. You will notice that when you hover over the plot the cursor changes to a cross, enabling you to select a zoom area.



3. While you are zoomed in, you will notice that scroll bars appear at the bottom and on the right of the plot window. You can zoom in on a time series plot and then scroll through time using the scroll bars.

4. To zoom out, you can right click on the plot and select “Un-zoom,” “Undo All Zoom/Pan,” or “Set Scale to Default.”

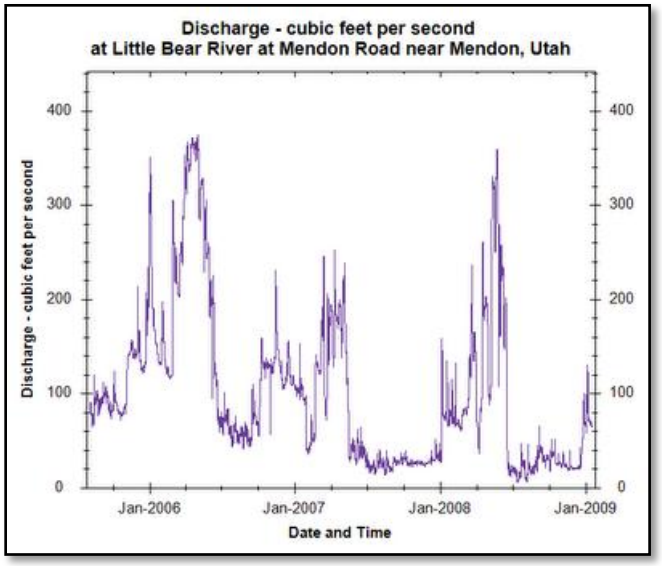


CHANGING THE PLOT TYPE AND DISPLAYING SUMMARY STATISTICS

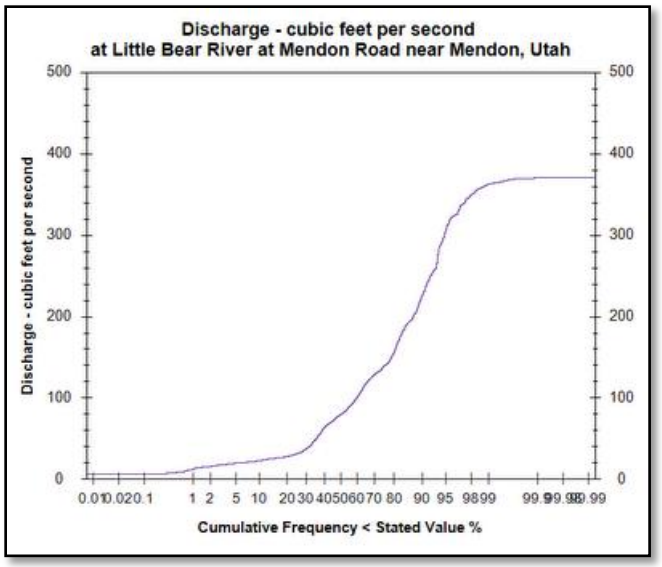
Graph View offers several different types of plots for visualizing your time series data. Use the following steps to change the plot type in Graph View:

1. Select one or more data series to be plotted in the Series Selection Tool.

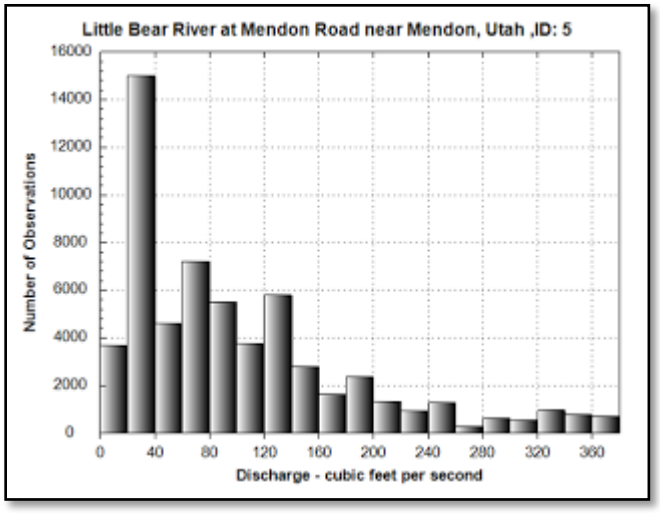
2. On the Graph View ribbon, select the type of plot to be displayed by clicking on the appropriate icon. Available plot types are shown below:



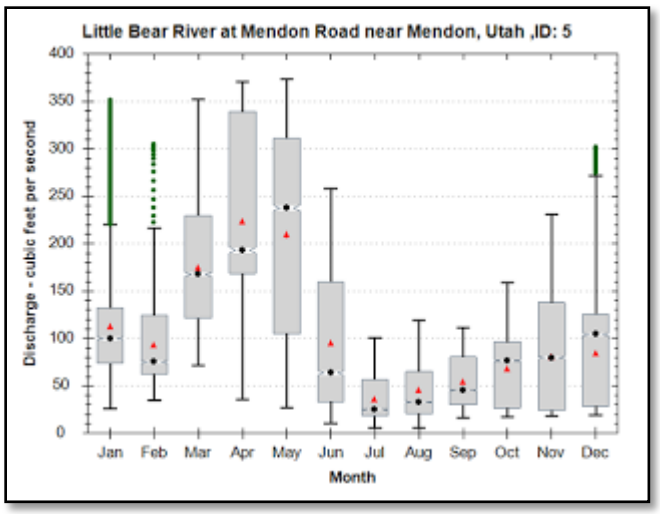
Time Series Plot



Probability Plot

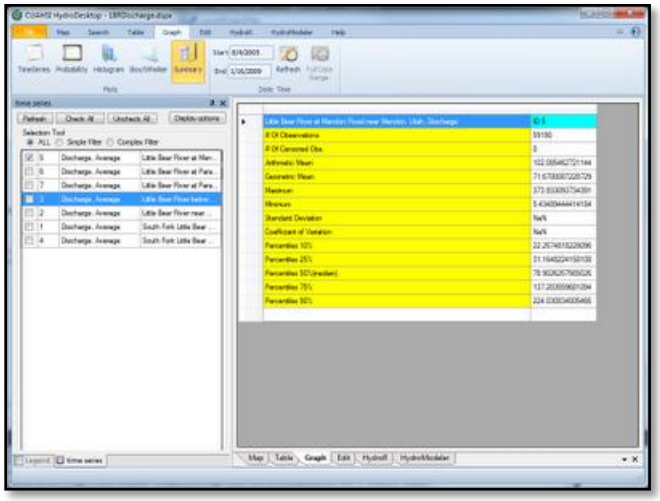


Histogram Plot



Box/Whisker Plot

To display summary statistics for one or more selected time series, click on the “Summary” icon on the Graph View ribbon.



Summary statistics for the currently selected time series will be displayed.

GRAPH OPTIONS

Some of the plot types within the Graph View have some options for customizing the look and feel of the plot that is displayed. Use the following steps to explore the options for each plot type:

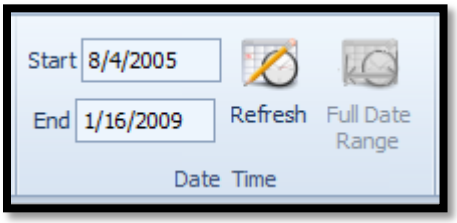
1. Select one or more time series from the Series Selection Tool to create a plot in the Graph View.
2. Select the desired plot type from the Graph View Ribbon at the top of the Graph View. You will notice that a set of options for the selected plot type appears in the Graph View ribbon.
3. Select options to customize the plot. The following describes the options available for each plot type:

- Time Series and Probability Plots - Using the “Plot Type” button you can set the plot type to show the line, the data points, or both. Using the “Color Setting” button you can set the colors used to symbolize the lines and points on the plots. Using the “Close Legend” button you can control whether the legend is shown on the plot or not.
- Histograms - Using the “Histogram Type” button you can control the type of histogram that is shown. Using the “Binning Algorithms” button you can choose the algorithm used to calculate the histogram bins.
- Box/Whisker Plots - Using the “Box Whisker Type” button you can choose the time scale for the box/whisker plots (e.g., monthly, seasonal, yearly, or overall).

SETTING THE PLOT DATE RANGE

You can restrict the date range of the data shown in the Graph View plot using the following steps. The plot is drawn for the selected date range, and the summary statistics are calculated only for data that fall within the selected range.

1. Select one or more time series from the Series Selection Tool to create a plot in the Graph View. You will notice that the start date and end date for the selected time series are shown in the Graph View ribbon.
2. Change the start date and the end date for the plot in the graph view ribbon. When you have selected an appropriate date range, click the “Refresh” button.

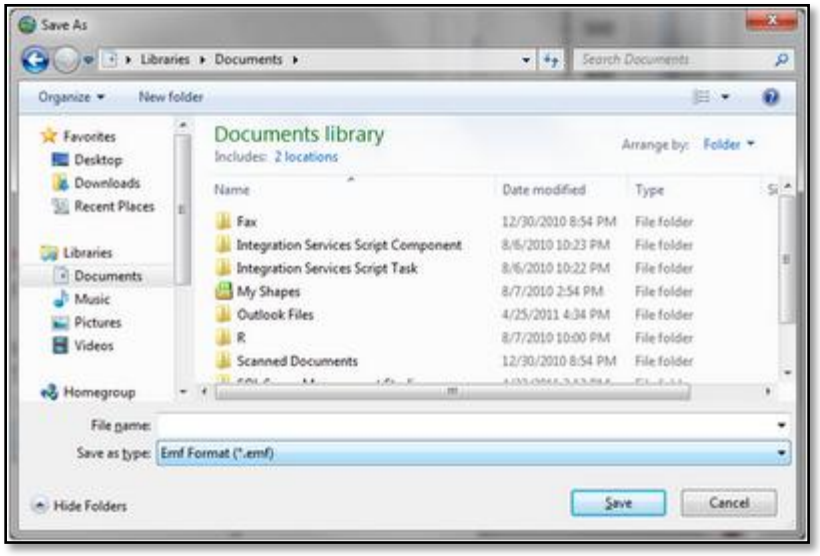


You will notice that the plot has been restricted to the selected date range.
You can easily reset the plot to the full date range by clicking the “Full Date Range” option on the Graph View ribbon.

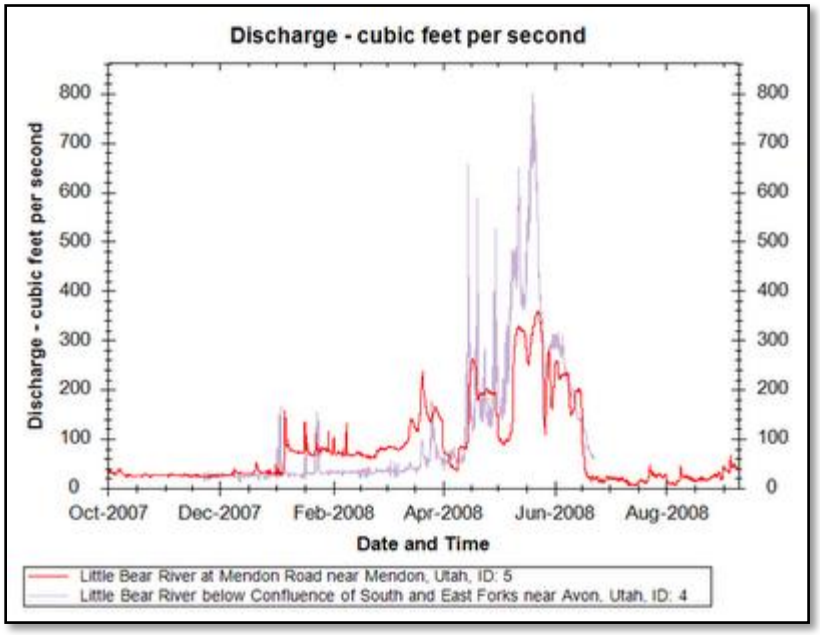
EXPORTING THE PLOT IMAGE

Use the following steps to export the plot image that is shown in the Graph View:

1. Create a plot that you want to export by selecting a number of data series from the Series Selection Tool and the desired plot type from the Graph View Ribbon.
2. To copy the plot image to the clipboard, right click on the plot window and select “Copy” from the context menu. The image can then be pasted into a document or other software program
3. To save a copy of the image to disk, right click on the plot window and select “Save Image As.” A file dialog will open asking you where you want to store the image. Select a location to which you want to save the image, select a desired file type, give your image file a name, and then click the “Save” button to save it to disk.



4. The image that you export will look something like the following (depending on the data series that you have selected).



TIME SERIES DATA IMPORT

HydroDesktop can import time series data from delimited text files and from Microsoft Excel files. This is useful when some of the data for your analysis is not available online and when you want to use HydroDesktop to compare the online downloaded data with your own data.

How To Import Data

Time series can be imported using the data import tool. In addition, users familiar with SQLite can modify the time series database directly. The database is located in the same directory where you saved your project.

Importing using the Data Import Tool

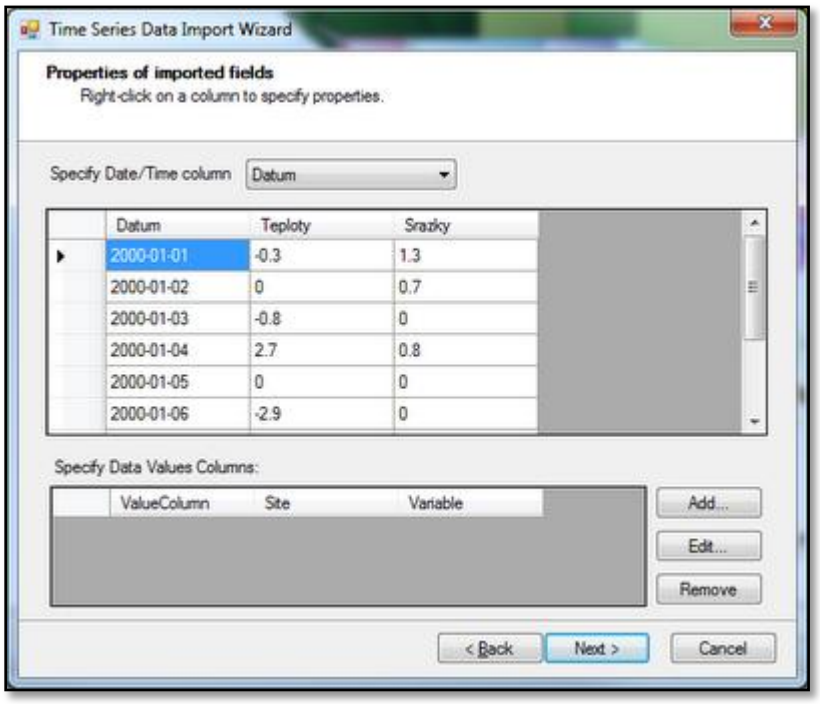
On the Table tab of the ribbon, click the Import button to invoke the data import dialog. In the first step, select the file to import. The file must be an Excel, CSV, WaterML or text file with at least two columns: Time and Value. The file can contain a single time series (one variable at one site) or multiple time series (several variables and / or several sites).

Format Options

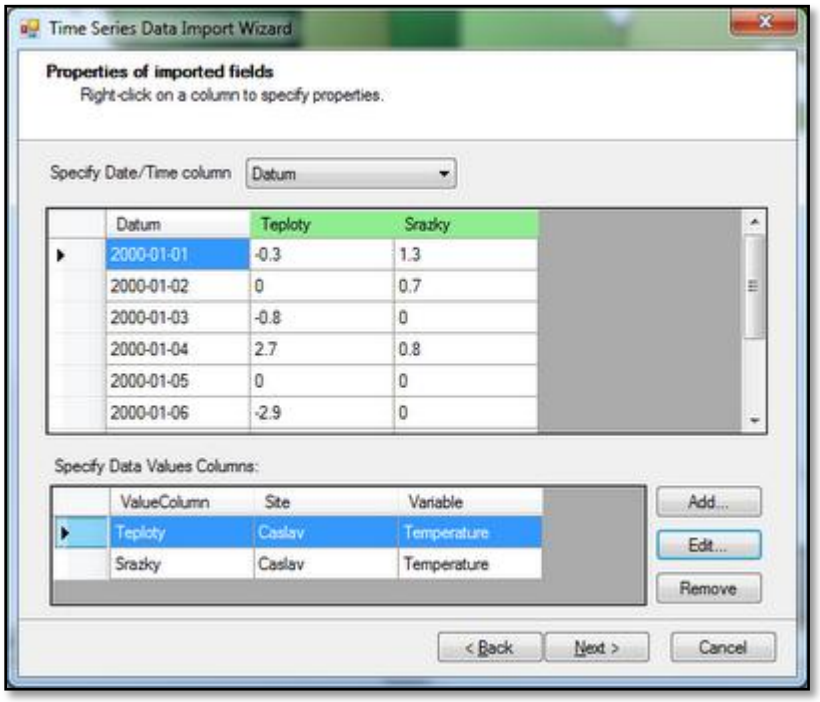
For correct data import of text files, it is necessary to set up the format options. Typically the text files use the delimited format options with one of the following separators: Comma, Tab, Space, Pipe or Semicolon.

Properties of Imported Fields

The imported file must contain one Date/Time column. The system will try to select this column automatically. For all other columns that you wish to import, the properties must be specified. These properties are: Site, Variable, Source, Method, Quality Control and Offset. The Site and Variable properties are required. If your current Hydrodesktop project already contains data, you may select an existing site or an existing variable. Otherwise, use the Create new... button to specify a new site.



Time Series Import Dialogue



Time Series Properties of Imported Columns

Time Series Data Export

HydroDesktop can export your time series data to delimited text files for use in other programs. This is useful when HydroDesktop does not include all of the analysis capabilities needed, or when the user prefers to work with downloaded data in another program.

How To Export Data

Time series can be exported using a number of workflows. In addition, users familiar with SQLite can access the time series database directly. The database is typically located in the same directory where you saved your project.

Exporting using the Data Export Tool

On the Table tab of the ribbon, click the Export button to invoke the data export dialog.

Exporting from the Series Selector

In views such as table view or graph view, a series selector shows a list of time series on the left side of the display. To export a time series, right-click the time series in the series selector and click Export Series.

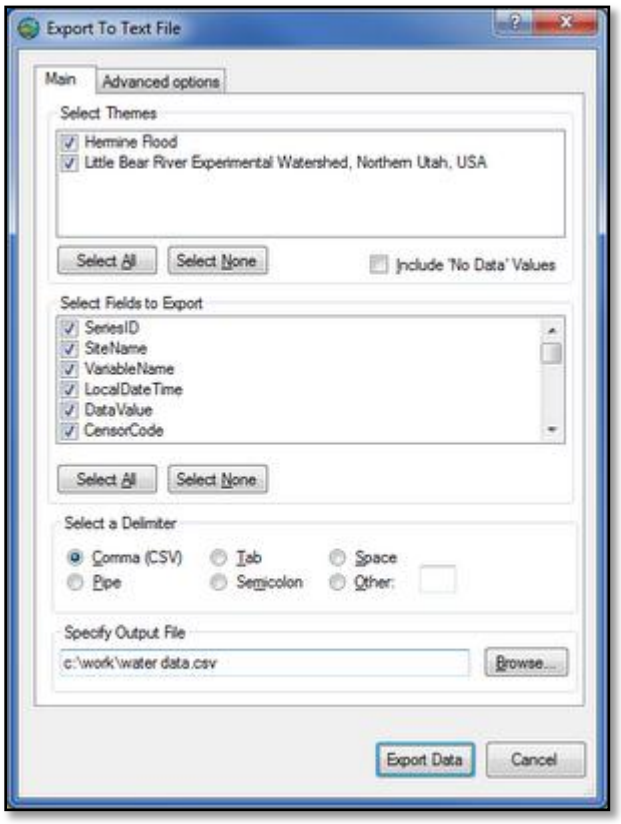
Exporting from the Map Legend

In views such as map view, a legend shows a list of map layers on the left side of the display. If a data search or download has been performed, a group layer called Data Sites will be included in the legend, with each layer in this group symbolized by data source. Layers with downloaded data will include a box drawn around the site symbol.

To export downloaded data for a given data source, right-click the layer name for that data source, point to Data, and click Export Time Series Data.

Export Options

When exporting time series data, a dialog like the one below provides options for the data export.



Time Series Export Dialog

This dialog allows the user to set the following options:

- Which themes will be included
- Whether or not 'No Data' values will be included.
- Which fields will be included to describe each time series value
- Which delimiter will be used to separate field values
- Output file name and location

Note: When exporting individual time series using the series selector, not all export options may be available.

After clicking Export Data in the dialog, the time series data are exported to a text file. You can close the dialog once the export is complete.

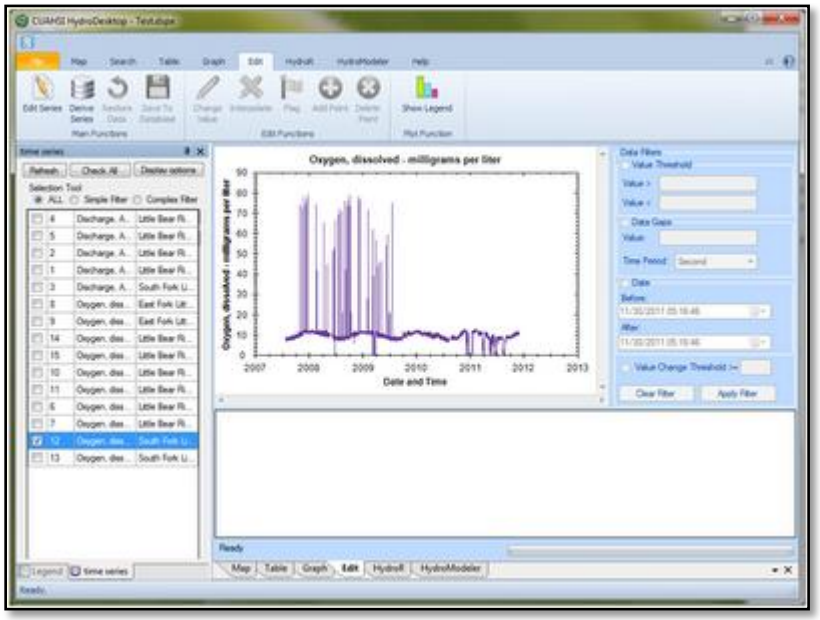
THE EDIT TAB

The Edit View is a HydroDesktop extension that provides functionality for editing time series data that have been downloaded and stored in the HydroDesktop data repository database. The Edit View enables you to perform a number of data editing functions that can be very useful in doing simple data quality assurance and quality control as well as in preparing time series data that may have some anomalous data values for input to an analysis or model.

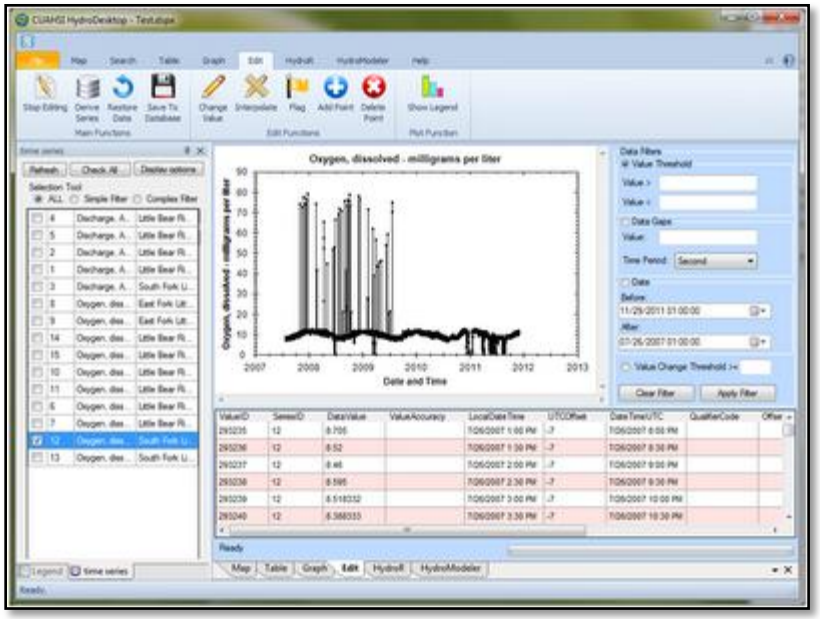
SELECTING DATA SERIES TO EDIT

Edit View was designed to enable editing of one data series at a time. Use the following steps to select a data series for editing:

1. Select a data series in the HydroDesktop Series Selection tool by clicking the check box next to it. This will create a plot of the data series in the plot portion of the Edit View tab.



2. Once a series is selected, click the “Edit Series” button on the Edit View ribbon. You will notice that the plot changes and shows the points associated with the selected series. The data values of the series are also loaded into the tabular view at the bottom of the Edit View tab, and the data filters at the right of the plot are enabled. The series you have selected is now ready for editing.



SELECTING DATA VALUES TO EDIT

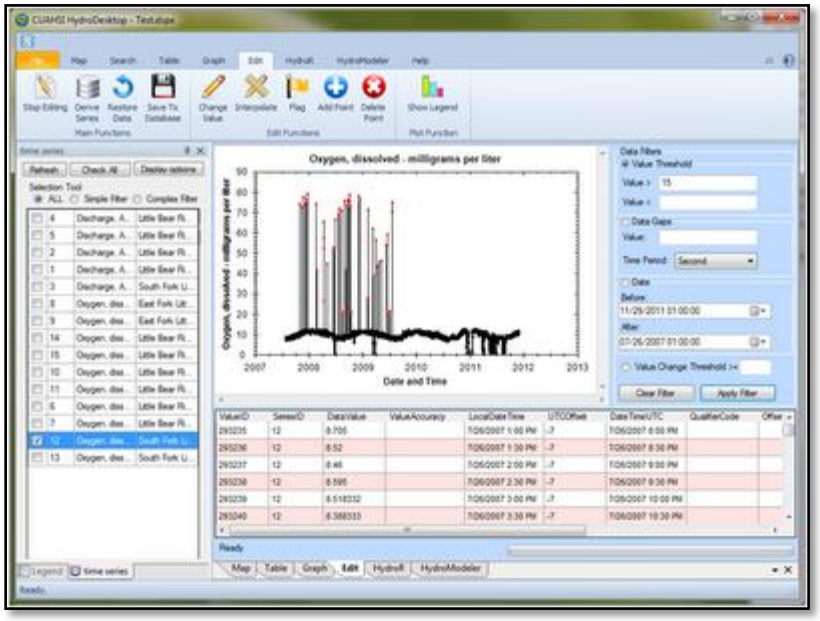
Before data values within a data series can be edited, they must first be selected. You can select individual data values by clicking on their associated record in the tabular view at the bottom of the Edit View tab. When you do so, you will notice that the corresponding point on the plot changes color from black to red. Additionally, the Edit View extension provides several filters that can be used for selecting multiple data values that you would like to edit. These include the following:

- Value Threshold Filter - use this filter to select all data values greater than or less than a given threshold or between two threshold values. Useful for selecting out of range values for interpolation.
- Data Gaps Filter - use this filter to select data values where the time gap between two values is greater than a threshold. Useful for finding data gaps.
- Date Filter - use this filter to select all data values greater than or less than a given date or between two dates. Useful for selecting blocks of data for deletion.
- Value Change Threshold Filter - use this filter to select all data values where the change from one value to the next is greater than some threshold value. Useful for detecting anomalies in time series.

The following is an example of how to apply a value threshold data filter:

1. If you have not already, select a data series for editing and click the “Start Editing” button on the Edit View ribbon.

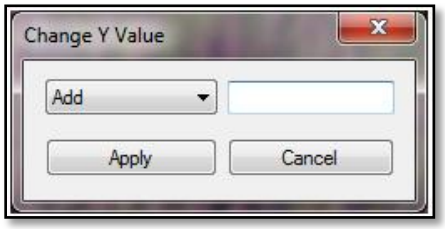
2. Type a value into one of the threshold value boxes and then click the “Apply Filter” button. In the example below, a filter has been applied to select dissolved oxygen data values greater than 15 mg/L, which are obvious out of range values that need to be edited.



CHANGING THE VALUE OF SELECTED DATA VALUES

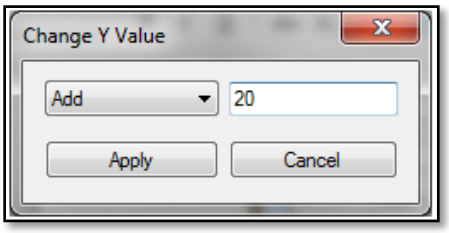
The Edit View extension provides functions for changing the value of selected data values. An example of when this functionality could be useful might be when an improper offset has been used in a datalogger program and the values of a data series need to be adjusted. Use the following steps to change the value of selected data values:

1. If you have not already, select a data series for editing and click the “Start Editing” button on the Edit View ribbon.
2. Use the data filters or click on records in the Edit View table to select the data values that you would like to modify.
3. Click the “Change Value” button on the Edit View ribbon. The following window will open:



4. Select the operation that you would like to perform to the selected data values (e.g., add, subtract, multiply, or set value to).

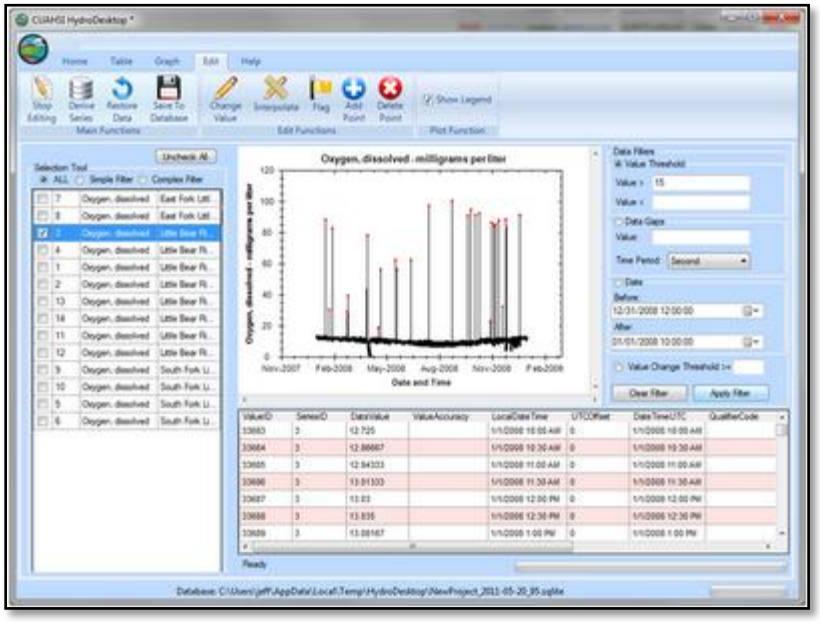
5. Type a numeric value into the text box and then click OK. In the following example, the Edit View extension will add a value of 20 to the selected data values.



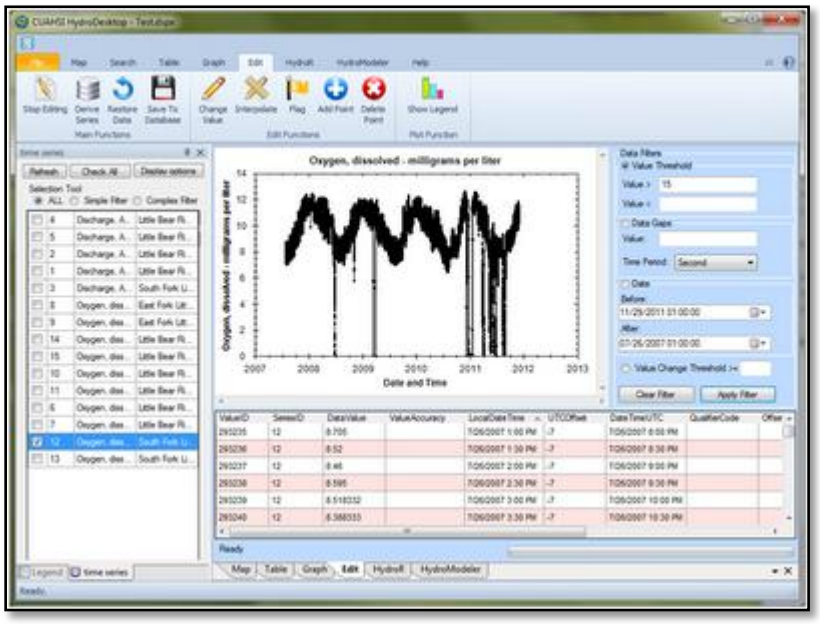
INTERPOLATING SELECTED DATA VALUES

The Edit View extension provides a function for linearly interpolating data values based on the numeric values of the data values that come before and after the selected data values in time. This can be useful for correcting anomalies and obvious out of range values within a dataset. Use the following steps to interpolate selected data values:

1. If you have not already, select a data series for editing and click the "Start Editing" button on the Edit View ribbon.
2. Use the data filters or click on records in the Edit View table to select the data values that you would like to modify. In the following example, all dissolved oxygen data values greater than 15 mg/L have been selected using a value threshold filter as it is known that these are obvious out of range data values that need to be corrected.



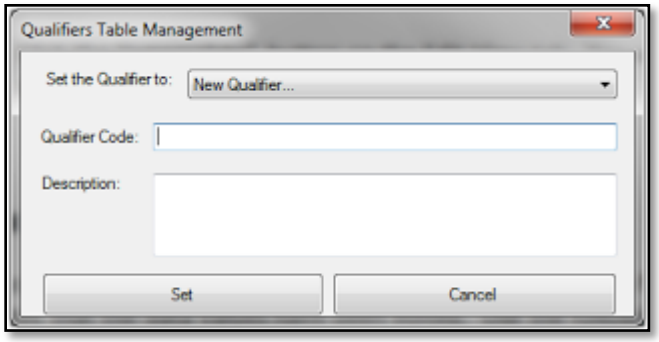
3. Click the “Interpolate” button on the Edit View tab. A window will pop up asking you if you are sure that you want to Interpolate. Click the “Yes” button. After a moment you will notice that the data values you selected have now been linearly interpolated and that the scale of your plot has been changed to reflect the new extents of your data.



FLAGGING SELECTED DATA VALUES WITH QUALIFIERS

When you edit data values within a data series, you may want to flag them with a qualifying comment that states that the data values have been edited. Use the following steps to flag selected data values with a qualifying comment:

1. If you have not already, select a data series for editing and click the “Start Editing” button on the Edit View ribbon.
2. Use the data filters or click on records in the Edit View table to select the data values that you would like to add a qualifying comment to.
3. Click on the “Flag” button on the Edit View ribbon. The following window will open.



4. In this form you can either select a data qualifying comment from the drop down list at the top of the form (in the case that it already exists in the HydroDesktop database), or you can create a new qualifying comment by selecting "New Qualifier" from the drop down list.

5. If you selected "New Qualifier," you need to create a code for your qualifier and a description, which is the text of your qualifying comment.

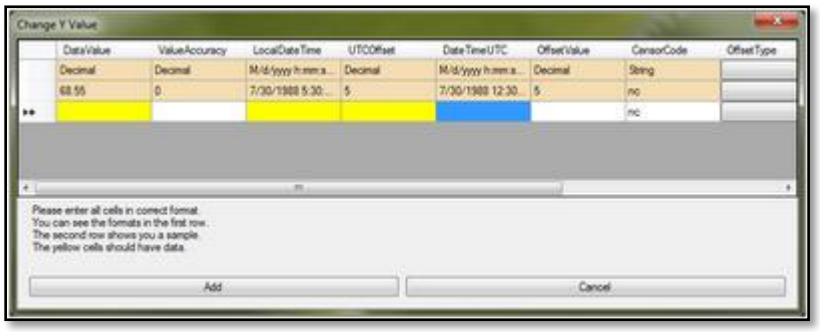
6. Once you have completed the form by either selecting an existing comment or creating a new one, click the "Set" button to apply the qualifying comment to the selected data values.

INSERTING DATA VALUES

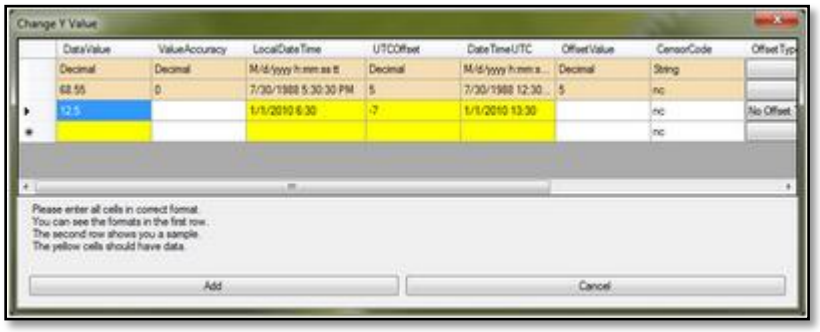
In some cases, you may want to insert one or more data values into an existing data series. This functionality is useful in filling small data gaps with missing values. Use the following steps to insert data values into an existing data series:

1. If you have not already, select a data series for editing and click the "Start Editing" button on the Edit View ribbon.

2. Click the "Add Point" on the Edit View ribbon. The following window will open.



3. On the third row of the table on this form you can type in the data value that you wish to add and the additional metadata that describe it. The minimum required fields are DataValue, LocalDateTime, UTCOffset, and DateTimeUTC, which are all highlighted in yellow.



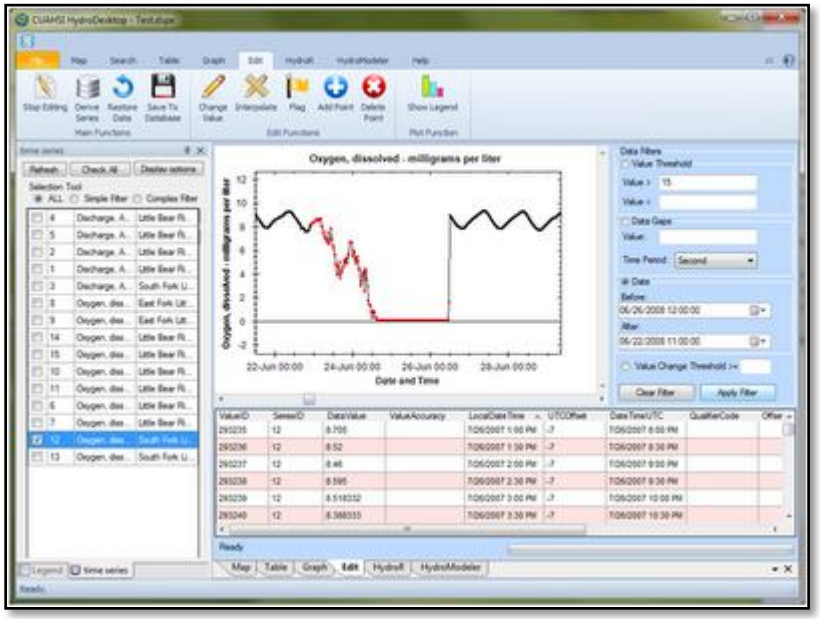
4. You can continue adding new values in the final row in the table until your edits are complete. When you have finished inserting new data values, click the "Add" button to add the new data to your data series.

DELETING DATA VALUES

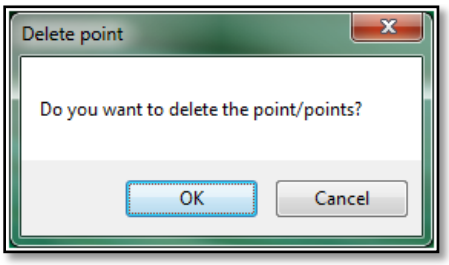
In many cases you will need to delete erroneous data from data series that you are working with. This can be useful for example when you have a sensor data stream within which the sensor has failed and you need to delete the period of data during which the sensor failure occurred. Use the following steps to delete values from a data series:

1. If you have not already, select a data series for editing and click the "Start Editing" button on the Edit View ribbon.

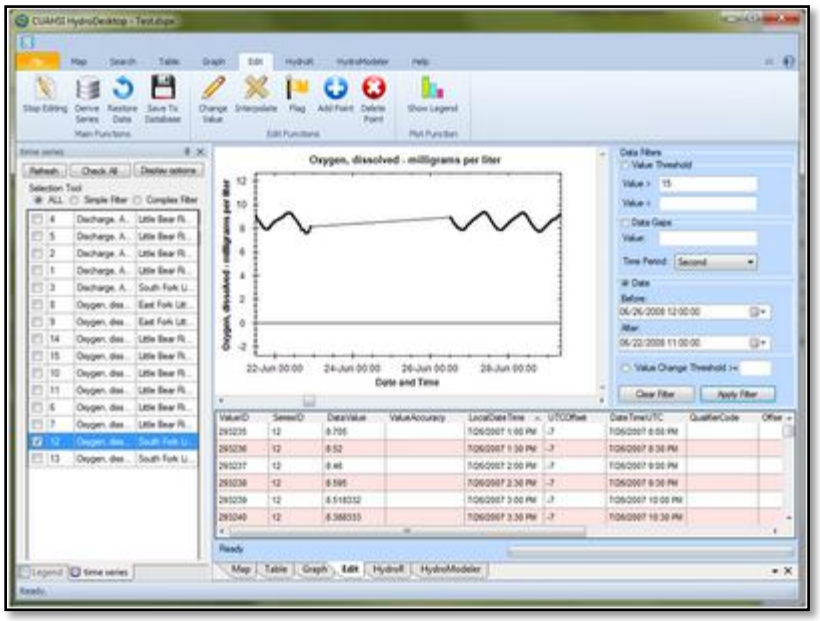
2. Use the data filters or click on records in the Edit View table to select the data values that you would like to modify. In the following example, all dissolved oxygen data during a period of sensor failure have been selected for deletion using the date filter.



3. Click the “Delete Point” button on the Edit View ribbon. The following window will appear. Click the “OK” button to delete the selected data values.



You will notice that the selected data values have been deleted from the data series.



RESTORING DATA SERIES VALUES

During your editing session, the Edit View extension maintains a copy of the data in memory. Any editing functions that you perform are made on the memory copy of the data. The changes that you make to the data will not be saved to the database until you decide to do so. If you make a mistake and would like to undo your edits, you can click the “Restore Data” button on the Edit View ribbon. This button will reload the original data series from the HydroDesktop database and will discard any changes that you have made since your last save.

Saving Data Series Edits to the HydroDesktop Database

To save the edits you have made to a selected data series to the HydroDesktop database, click the "Save to Database" button on the Edit View ribbon. Any changes that you have made to the data series will be saved to the database, overwriting the original data series.

HydroR Plugin

HydroR is a HydroDesktop extension that provides an interface between HydroDesktop and the R statistical computing environment. In a nutshell, R is a language and environment for statistical computing and graphics. R provides a wide variety of statistical and graphical techniques and is highly extensible. R is available as free software, and can be downloaded from http://www.r-project.org/.

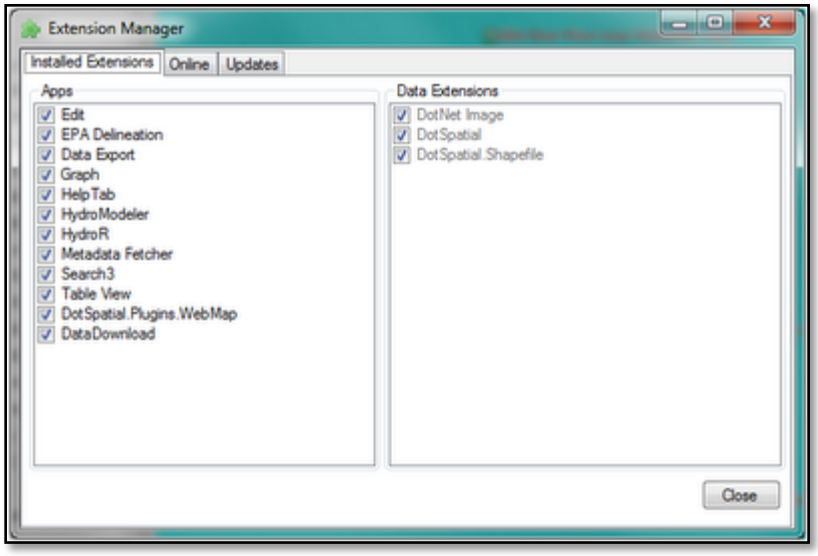
HydroR provides a scripting interface within which R commands can be written and then sent to the R Console for execution. HydroR provides functionality for automatically generating the R code needed to retrieve any of the hydrologic time series data that have been downloaded and stored within HydroDesktop's data repository database into an R List object. The R list object contains all of the metadata for a time series and a Data Frame object that contains the time series data values. Once the data have been transferred from the HydroDesktop database into an R List object, they can be manipulated using any of the graphical or statistical tools that R, or any extended R packages, provide.

Opening the HydroR Extension

Follow the steps below to open the HydroR extension within HydroDesktop:

1. If you don't have HydroDesktop open already, open it by clicking on Start / All Programs / CUAHSI HIS / HydroDesktop / HydroDesktop

2. The HydroR extension is loaded by default, but if you do not see a HydroR tab at the top of your HydroDesktop window, click on the "File" tab at the top of the HydroDesktop window and then click on "Extension Manager" to show the list of available HydroDesktop Extensions.



3. Make sure that the box next to the HydroR extension is checked and then click the "Close" button. You will notice that a new tab called "HydroR" has been added to the HydroDesktop Window.

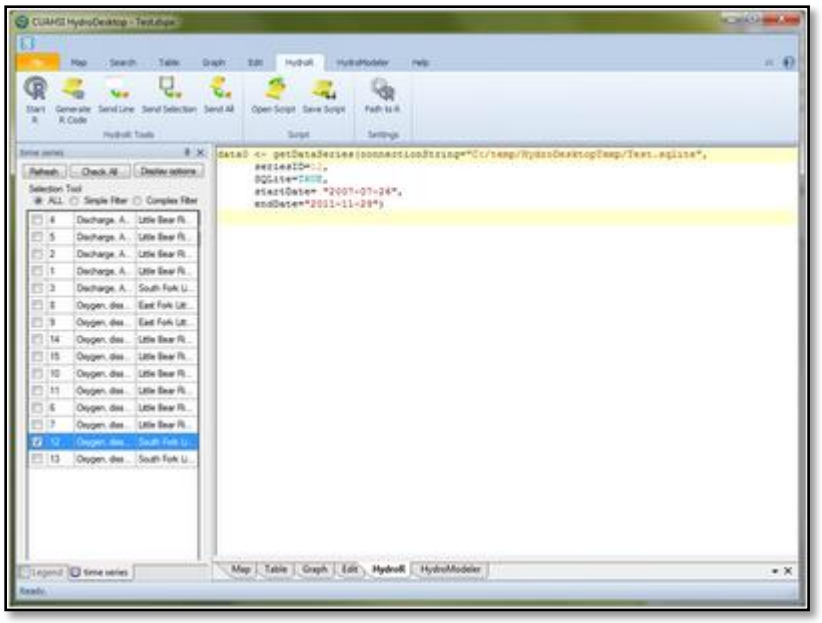
4. Click on the "HydroR" tab to access its functionality. The following window shows the HydroR tab.

LOADING DATA SERIES INTO R FROM HYDRODESKTOP

Once you have discovered and downloaded some time series data into HydroDesktop, you can use the following steps to begin loading any of those time series into R for analysis:

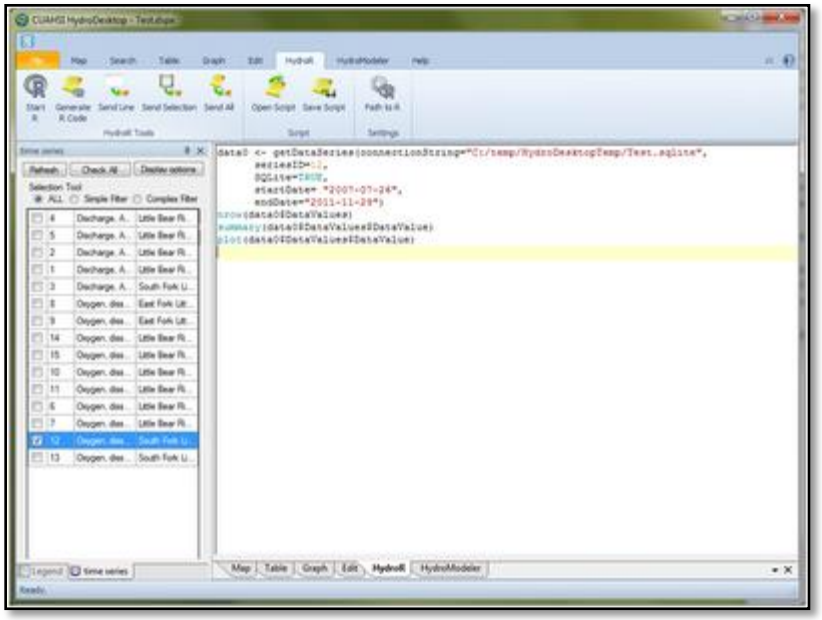
1. Select any of the data series shown in the HydroDesktop Series Selection tool by clicking on the check box to the left of the data series.

2. Click the “Generate R Code” button on the HydroR ribbon. You will notice that new lines of R code have been added to the HydroR script window. These lines of code can be executed by the R console to load the selected data series from the HydroDesktop data repository database into R as an R List object. In the following example, a single data series has been selected and will be loaded into an R List object called “data0.”



CREATING R COMMANDS IN THE HYDROR SCRIPT EDITOR

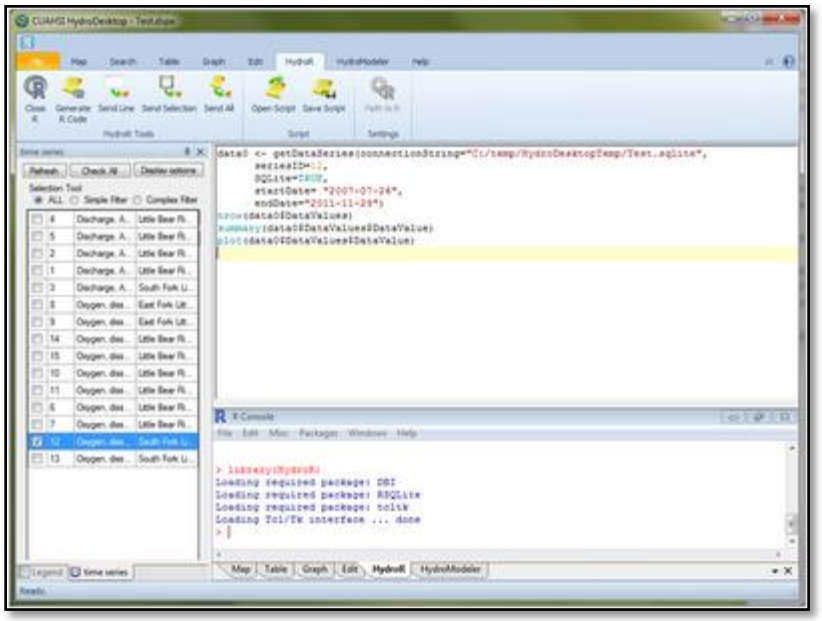
Any command that can be executed within R can be typed into the HydroR script editor. The following figure shows an R script that first loads a data series into an R List object and then determines the number of data values within the data series and some simple descriptive statistics of the data values.



EXECUTING R CODE FROM THE HYDROR SCRIPT EDITOR

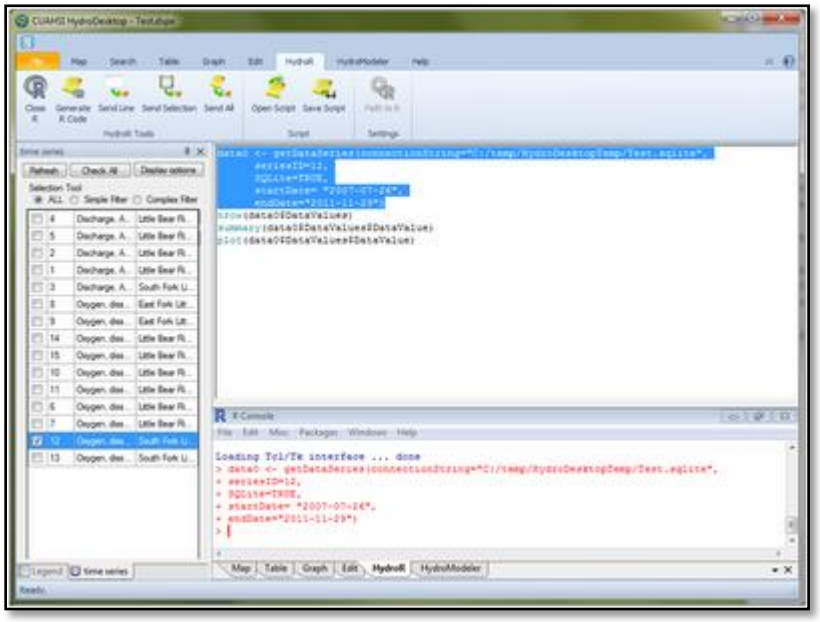
Use the following steps to execute R commands from the HydroR script editor:

1. Open the R Console within HydroR by clicking on the “Start R” button on the HydroR ribbon. You will notice that the R Console opens within the HydroR tab.



Note: The first time you start the R console, you may get a pop-up dialog that asks you to navigate to the location of your R installation. Follow the instructions on the form. You may also have to choose a R CRAN Mirror site from which the HydroR extension will download a number of R packages to complete the installation. Choose a CRAN mirror site that is near you and then click "OK."

2. On the HydroR ribbon, you will notice that there are three buttons for sending code from the HydroR script editor to the R console for execution: 1) Send Line, 2) Send Selection, and 3) Send All. Send Line sends the currently selected line to the R Console, Send Selection sends all of the selected lines to the R Console, and Send All sends everything within the HydroR script editor to the R Console. Select a number of lines by clicking and dragging in the script editor and then click the "Send Selection" button to send them to the R console.

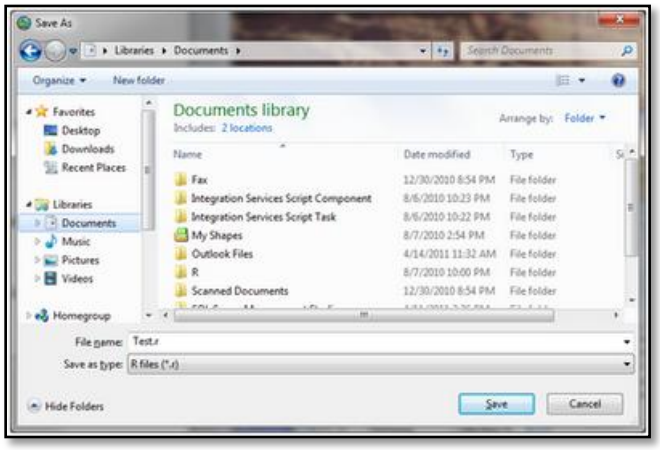


3. You will notice that the lines from the script editor are sent to the R console and executed.

Saving R Scripts and Opening Them Later

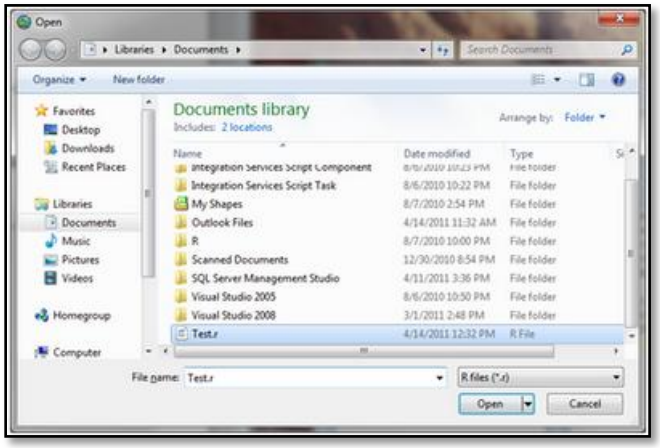
Follow the steps below to save a script that you have written in the HydroR script editor to your hard disk for later use:

1. Click on the “Save Script” button on the HydroR ribbon. A file dialog window will open asking you where you want to save your script.



2. Select a location on disk to save your file and then provide a file name. The file will be stored as a text file with a ”.r” extension. Click the “Save” button.

3. To open a script that you have saved to your hard disk, click the “Open Script” button on the HydroR ribbon. The file dialog window will open asking you where your R script is located on your hard disk.



4. Navigate to your R script that you have saved and select it in the file dialog box. Then click the “Open” button. Your saved script will be loaded into the HydroR script editor.

R Commands Included in the HydroR Package for R

The HydroR package for R, which is used by the HydroR extension for HydroDesktop, includes a number of useful functions for interacting with hydrologic time series data stored within the HydroDesktop data repository database. The following table describes the included functions and shows examples of the included commands.

HydroR Package Functions

Function: plotDataSeries - Creates a time series plot of a selected data series.

Example:

```
plotDataSeries(data0, "DataValues")
```

saveDataSeries - Saves a selected data series to the HydroDesktop data repository database.

Example:

```
data1<-saveDataSeries(connectionString="C:/Program Files/CUAHSI
HIS/HydroDesktop/databases/DataRepository.sqlite",
      newSeries=data0,
      SQLite=TRUE,
      overwrite=FALSE)
```

getDataWithSQL - Executes a SQL query against the HydroDesktop data repository database and returns the result in a R Data Frame object.

Example:

```
Sites <-getDataWithSQL(connectionString="C:/Program Files/CUAHSI
HIS/HydroDesktop/databases/DataRepository.sqlite", SQLString="SELECT * FROM
SITES")
```

getDataSeries - Gets a data series and all of its metadata from the HydroDesktop Data repository database and returns the result in a R List object.

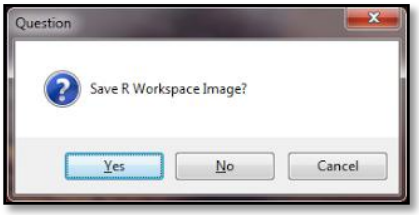
Example:

```
data0 <- getDataSeries(connectionString="C:/Program Files/CUAHSI
HIS/HydroDesktop/databases/DataRepository.sqlite",
   seriesID=4,
   SQLite=TRUE,
   startDate= "2009-10-01",
   endDate="2009-12-03")
```

Closing the R Console

When you are done using the R Console, you can close it using the following steps:

1. Click the "Close R" button on the HydroDesktop ribbon. The following window will appear asking if you want to save the R Workspace Image.

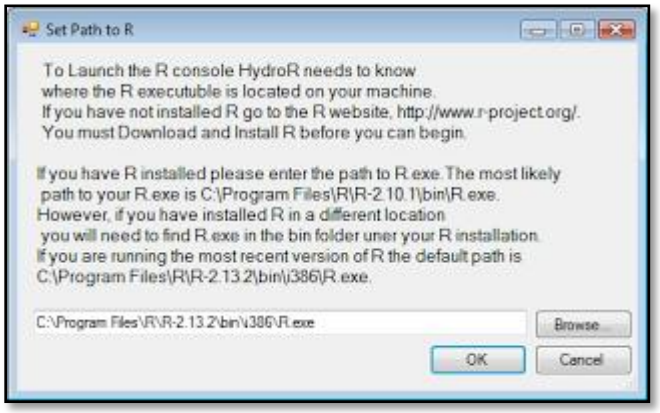


2. Choose whether you want to save your R workspace image containing any R objects that you have loaded.

CHANGING THE R VERSION

When you have multiple versions of R, you can check and change the version of R that is used by HydroR with the following steps:

1. Click the “Path to R” button on the HydroDesktop ribbon. The following window will appear asking if you want to change the path to R.



2. Use the Browse button to locate a different version of R on your computer.

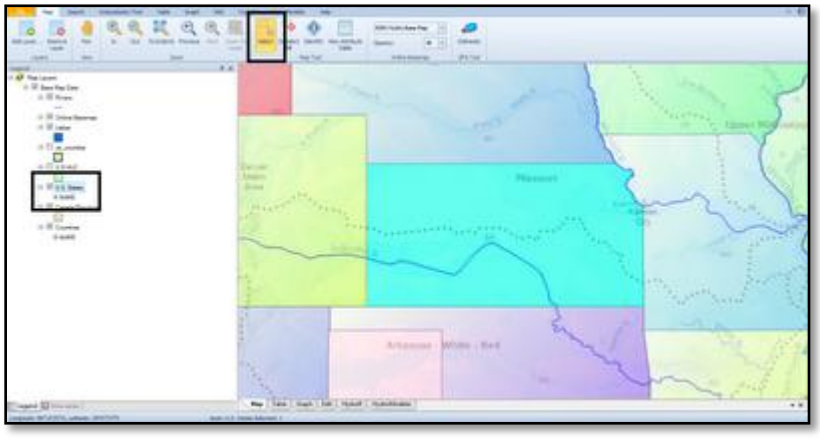
TUTORIALS

FINDING PRECIPITATION AND DISCHARGE DATA IN TOPEKA, KANSAS

A quintessential benefit of using HIS is the ability to access water data from multiple sources from a single search. HydroDesktop provides tools to discover, download, and examine data from any data source registered in CUAHSI HIS. And, what you will see in the following exercise, is that HydroDesktop can be used to examine multiple variables from multiple sources to enable a better understanding of a site or watershed. In this example, we will look at precipitation and discharge near Topeka, Kansas from 1990 to 2010.

Data Sources: Kansas State University Daily Weather Data; USGS NWIS Daily Values
Variables: Precipitation; Discharge
Area of Interest: North Topeka, Kansas

The first step we must take is to limit our search by geography. To do this, lets first look at the state of Kansas as a whole. Select the state of Kansas either by using the *Select by Attribute Tool* on the *Search Ribbon* or highlighting the states layer in the *Legend* and, using the *Select Tool* (located on both the *Map* and *Search* ribbons), clicking on the state of Kansas.

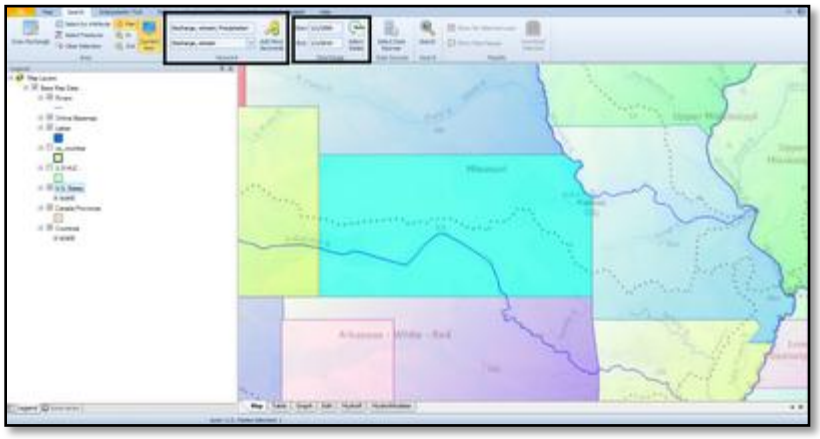


When selecting a feature in HydroDesktop, the corresponding layer must be highlighted in the Legend

Next, we can limit the search for specific variables during a specific time period. This can be done under the *Search Ribbon*. There are three ways to search for multiple keywords. The first is to type the keywords into the upper search box separated by semicolons. You should use this only if you know the exact search terms, otherwise you

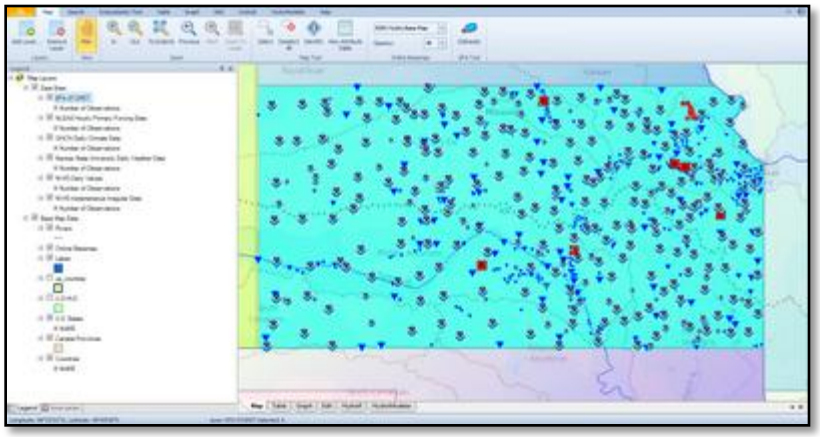
may not get any search results. The second way is to begin typing in the bottom search box, which uses autofill. Identify keywords then enter them into the upper search box by pressing enter. Lastly, you can add keywords by opening up the hierarchy of keywords under the *Add More Keywords* button. In this example, we will be searching for "Precipitation; Discharge, stream"

To define the search temporally, simply add start and end dates in the applicable boxes to the right of the keyword search boxes. In this example we will search from the 1/1/1990 to 1/1/2010.



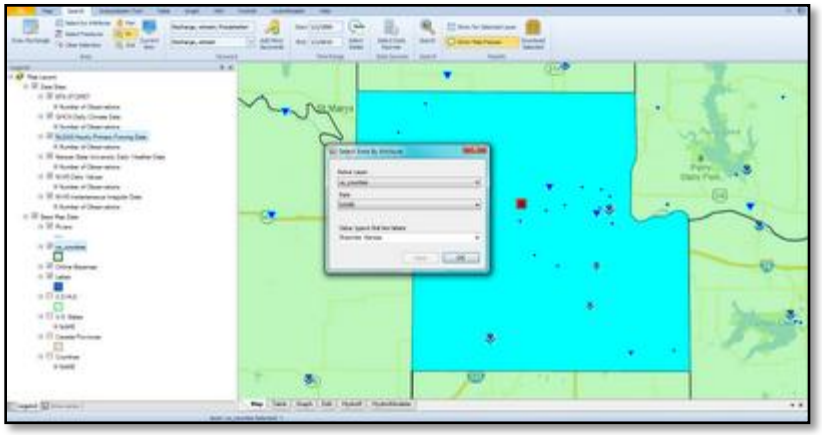
The keyword date search boxes are located next to each other on the Search Tab.

Once you have entered the search criteria, click the Search Button. The search will take a few moments as HydroDesktop searches the metadata catalog for sites that match our search criteria.



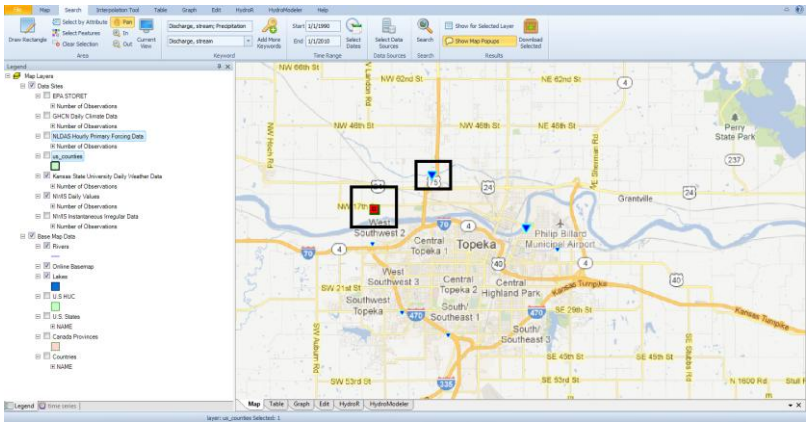
There are sites throughout the state of Kansas with observed precipitation and discharge values.

The search result yields a plethora of sites in the state from a number of data sources including the USGS, EPA, Kansas State University, and is a bit overwhelming to examine all at once. Let's take a closer look at Shawnee County, where Topeka is located. To do this, open the Select by Attribute tool, select the US Counties layer, and type "Shawnee, Kansas" (autofill will complete your entry as it is typed).

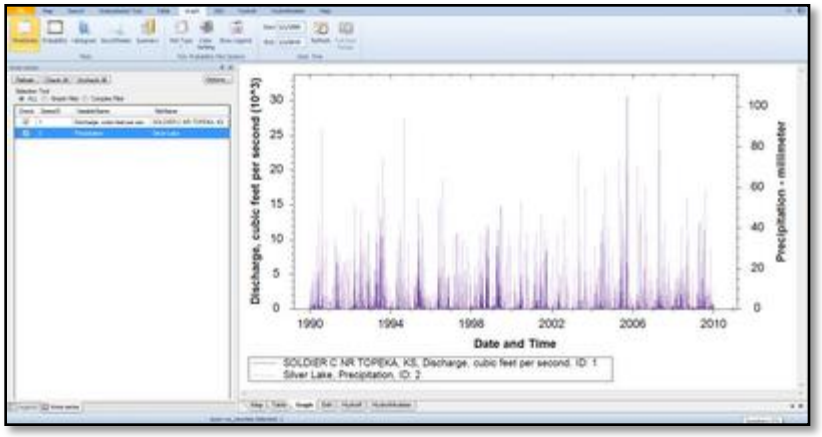


You can use any GIS polygon layer, like the U.S. counties layer that is included with the HydroDesktop installation package, to search for data.

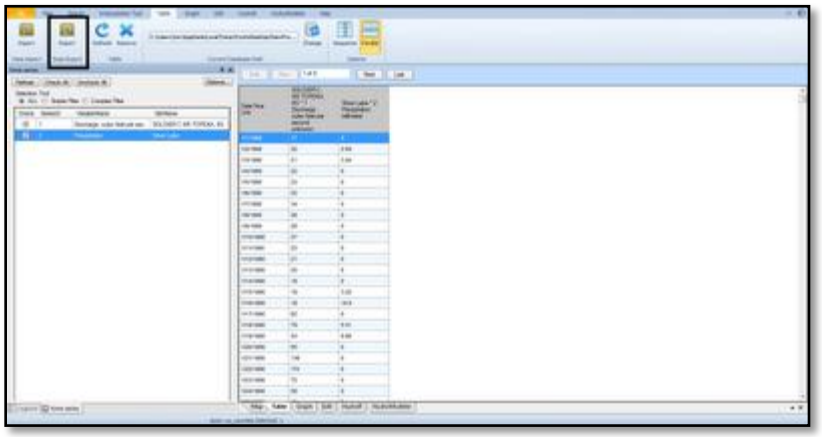
When we zoom into Shawnee County, we can see the search results are much more manageable and we can distinguish between sites that have precipitation observations and those that have discharge observations. To identify the stations with data I want to download, I have zoomed in further on Topeka (see screenshot below), turned the counties layer off, and turned the Google basemap on. After surveying the available sites, I've decided to examine sites in North Topeka. One has precipitation data from Kansas State University Daily Weather Data while the other has discharge data from the USGS NWIS Daily Values.



The data to be downloaded are from two sites in North Topeka (seen above). Finally, I can download the data from these sites by selecting them and clicking the *Download* button or hovering over them with *Map Popups* enabled (on the *Search Ribbon*) and clicking *Download Data*. With the download complete, I can examine the data in the *Graph Ribbon*.



This graph shows precipitation and discharge data observed in North Topeka, Kansas from 1990 to 2010.The data can also be exported using the *Export* button on the *Table Ribbon*.



The option to export data is available on the Table Ribbon.

COMPARING TEMPERATURE IN WATER BODIES NEAR LOGAN, UTAH

Data Sources: Logan River Observations, Northern Utah, USA; Little Bear River Experimental Watershed, Northern Utah, USA; Mud Lake, Idaho, USA

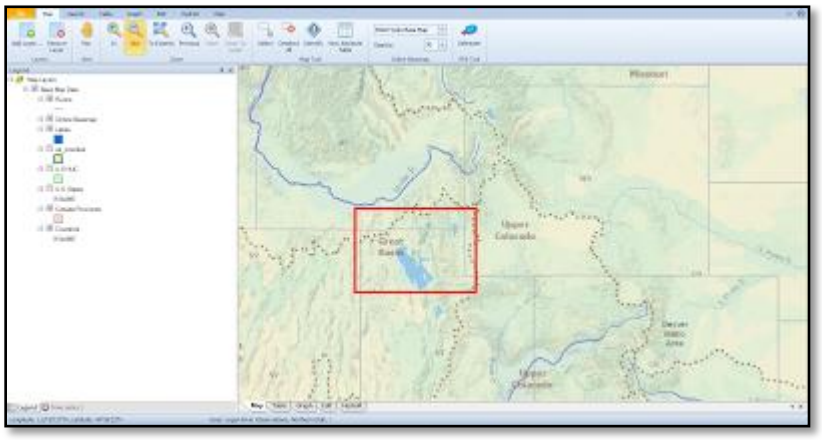
Variable: Water Temperature

Area of Interest: Northern Utah/Southwest Idaho

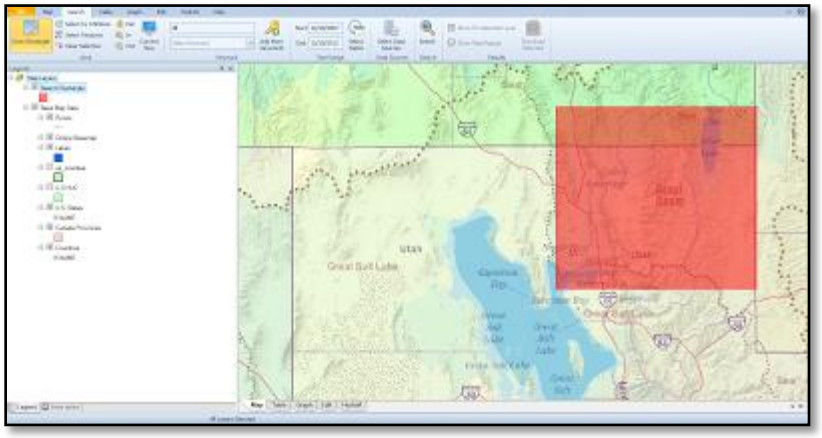
This exercise will walk you through how to download water temperature data from multiple sites to compare conditions in different water bodies throughout a region. In this case, the data are observations from research conducted at Utah State University. The sites are located along the Logan River, Little Bear River, and Mud Lake, all

of which are near Logan, Utah were USU is located.

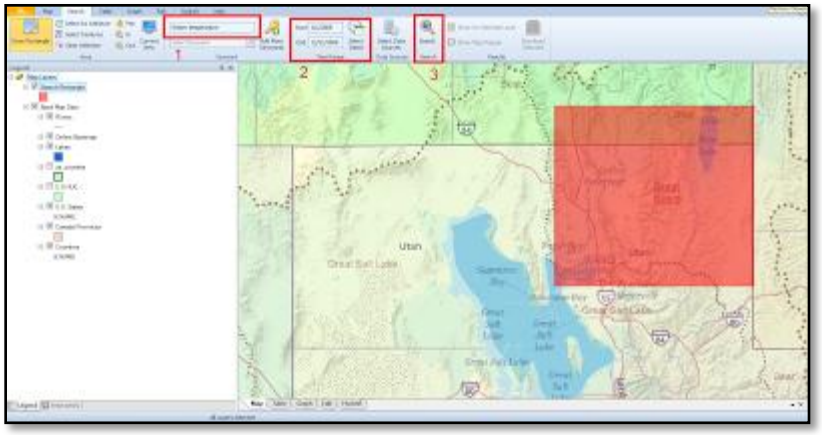
First, let's zoom to northern Utah.



From here, I can use the *Draw Rectangle* tool to define a search region. For this exercise, the search region spans from the Great Salt Lake in the Southwest corner of the search rectangle to include all of Bear Lake and Mud Lake in the Northeast corner.

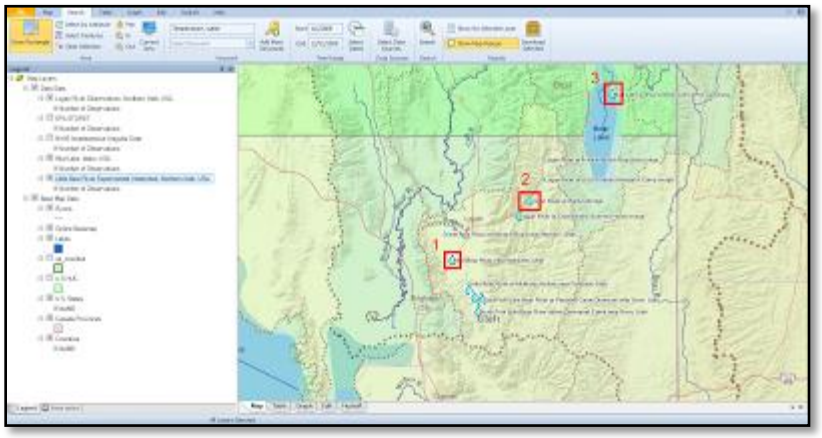


Next, I will want to (1) define the variable I'm looking for (water temperature), (2) define the time period to search over (1/1/2008 - 12/31/2008) and (3) click *Search* to find the sites that match my search criteria.



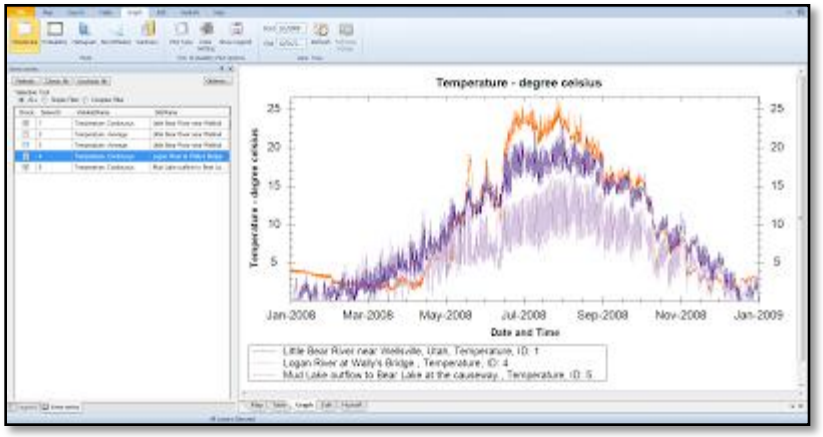
The search will likely return sites from other data sources in addition to the USU sites which I am interested in. I can remove the additional sites from the map by deselecting them in the *Legend*. Once the sites from only the Little Bear River, Logan River, and Mud Lake are being displayed, I can select and download the data that I want. I've chosen to download data from the following sites:

1. Little Bear River near Wellsville, Utah (Little Bear River Experimental Watershed, Northern Utah, USA)
2. Logan River at Wally's Bridge (Logan River Observations, Northern Utah, USA)
3. Mud Lake Outflow to Bear Lake at the causeway (Mud Lake, Idaho, USA)



To download the data, roll over a site and click the *Download data* link or select the site (using the Select Tool) and click the *Download Selected* button on the *Search Ribbon*.

Next I can visualize the data on the Graph tab or look at data values on the Table tab. I can also export the time series data on the Table Ribbon if I want to use the data in another program such as Microsoft Excel.



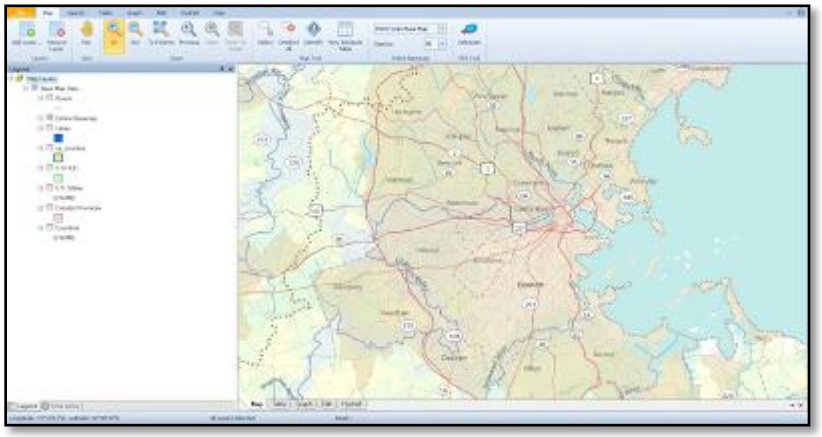
Note: The sites from the Little Bear River include average temperature in addition to continuous temperature (all three have continuous temperature data). You can remove these time series by right clicking and selecting *Delete Series* or you can just leave them unchecked.

USING THE EPA WATERSHED DELINEATION TOOL TO FIND DATA IN THE CHARLES RIVER WATERSHED

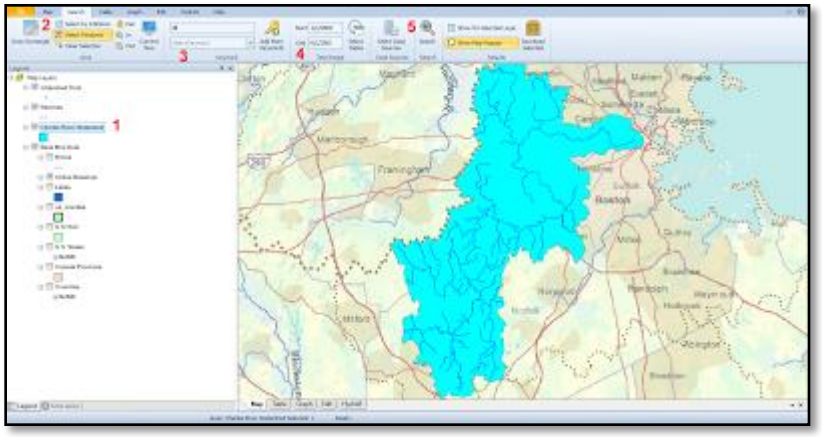
The first two exercises have demonstrated how to search for data using a U.S. counties shapefile and the Draw Rectangle tool, respectively. Another method of searching available in HydroDesktop is to search for data within a specific watershed, which can be done using the *EPA Watershed Delineation Tool* located on the *Map Ribbon*. This tool uses EPA web services to create a watershed polygon on the fly from any point a user clicks in the United States (**Note:** This tool only works for the Contiguous United States). The following example will walk you through how to use this tool to search for data in the Charles River Watershed.

Data Sources: All available
Variables: All available
Area of Interest: Charles River Watershed, Massachusetts

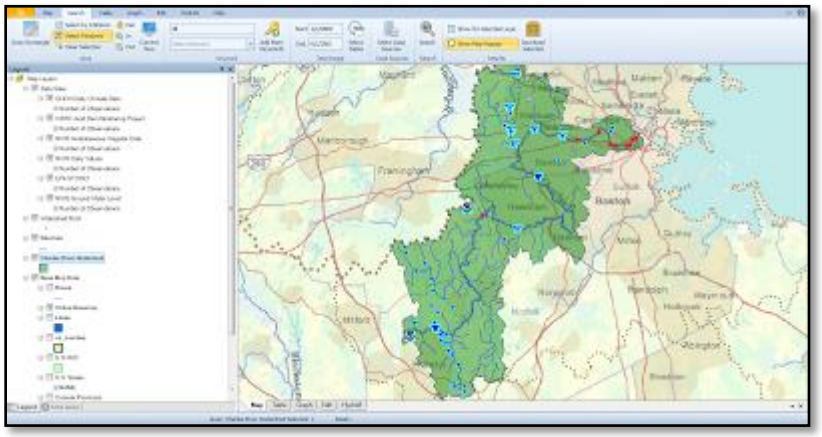
To start, let's zoom to the Boston Metro Area. Here, using the ESRI Hydro Basemap, we can identify a point along the Charles River.



To activate the *EPA Delineate Watershed Tool*, click the *Delineate* button on the *Map Ribbon*. Upon clicking, a new dialogue box will open that enables you to name the resulting shapefiles: a point (your initial point), a line (the reaches of the watershed), and a polygon (the coverage of the watershed).
Next, click a point along the river to delineate a polygon for that watershed and that river's watershed will be delineated upstream from this point.
To activate the watershed polygon for use in searching for data, (1) simply click to highlight the layer in the *Legend* and (2) use the *Select Features* tool to select the watershed polygon. Finally, (3) define the keyword(s) and (4) time period, and (5) click search to return sites with data that match your search criteria. In the example shown below, I have searched for "All" over the time period 1/1/2000 to 6/1/2001.



To download the data from any of the sites returned in the search, simply roll over the site and click *Download data* on the popup window, or select a site and click on the *Download Selected* button located on the *Search tab*.



Data Discovery and Analysis: The Hydrology of Jacob's Well Spring

This exercise demonstrates how to use HydroDesktop to find and analyze water data for Jacob's Well Spring in Texas. With some simple analysis, you will compare characteristics of this groundwater-dominated system with those of a nearby river. During the exercise, you will learn about some of the most commonly-used tools in HydroDesktop.

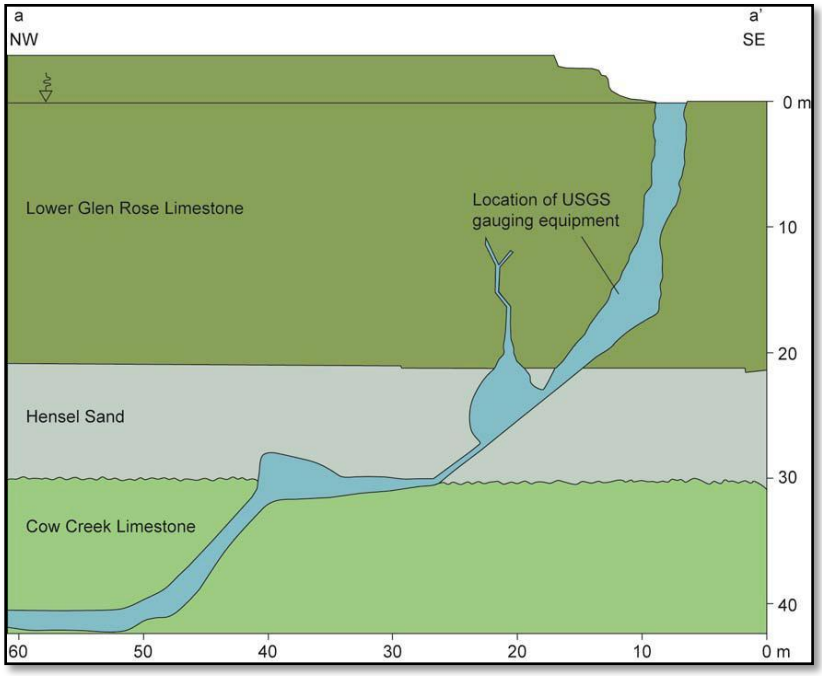
Credit: This exercise was developed by Tim Whiteaker (University of Texas at Austin) and David Tarboton (Utah State University).

About Jacob's Well Spring

The underwater cave known as Jacob's Well emerges in Hays County, Texas, at Jacob's Well Spring where it serves as one of the primary sources of water for Cypress Creek, which later flows into the Blanco River. The clear, crisp water cools down many Texans as it moves through the Blue Hole swimming area near Wimberley, Texas. This karst spring has been impacted in recent years by development in Hays County and increasing demands on the Middle Trinity Aquifer (Davidson, 2008).

Jacob's Well Spring (San Marcos Local News, 2009)

In 2005, a monitoring station was installed at Jacob's Well Spring 18 meters below the ground surface, reporting flow and temperature conditions at 15-minute intervals. The data for this station are accessible via the US Geological Survey's National Water Information System (USGS NWIS).



Cross-sectional diagram of Jacob's Well (Davidson, 2008)

Jacob's Well Spring Monitoring Station (United States Geological Survey, 2007)

For more information about the spring, please read the 2008 Masters thesis of Sarah Cain Davidson from The University of Texas at Austin.

GOALS AND OBJECTIVES

The goal of this exercise is to introduce you to the tools and functions available in HydroDesktop that allow you to search for and synthesize hydrologic time series data in an area of interest. This exercise will teach you how to find and obtain data for Jacob's Well Spring in Texas and compare data characteristics using the analysis capabilities of HydroDesktop.

Objectives for this exercise include:

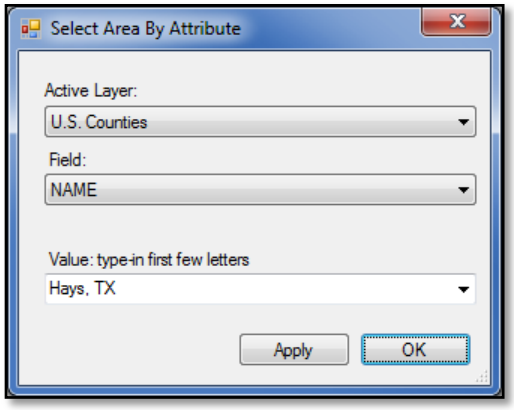
- Find streamflow and temperature data for Jacob's Well Spring in Texas.
- Identify useful time series and download them.
- Visualize time series data in graphs.
- Export time series data for use in other programs.

EXERCISE PROCEDURE

Suppose you live in Hays County in Texas, and for years you have enjoyed taking a dip in the Blue Hole swimming area along Cypress Creek during hot Texas summers. As population growth and increased groundwater pumping threaten Jacob's Well Spring, the primary source of water for Cypress Creek, you decide to learn more about this valuable resource. In this exercise, you'll use HydroDesktop to find temperature data and see how it compares to a nearby river.
The county boundary for Hays County is included in the U.S. Counties layer that is already in the map. You'll use this boundary to restrict the area being searched.

To search for streamflow in Hays County:

1. Set the context with an online basemap.
    a. On the **Map** tab, in the **Online Basemap** panel, choose a basemap such as **ESRI World Topo**.
    b. In the **Online Basemap** panel, set the **Opacity** of the basemap to **50**.
    c. In the **Legend**, uncheck the **U.S. States** layer to hide that layer.
2. In the ribbon, click the **Search** tab.
3. Select Hays County as the area of interest.
    a. In the **Area** panel on the ribbon, click **Select by Attribute**.
    b. Select **U.S. Counties** as the active layer. The default field of NAME will suffice.
    c. Select **Hays, TX**, from the list of county names. You can click in the list and start typing "Hays" to quickly find the item you're looking for.
    d. Click **OK**.



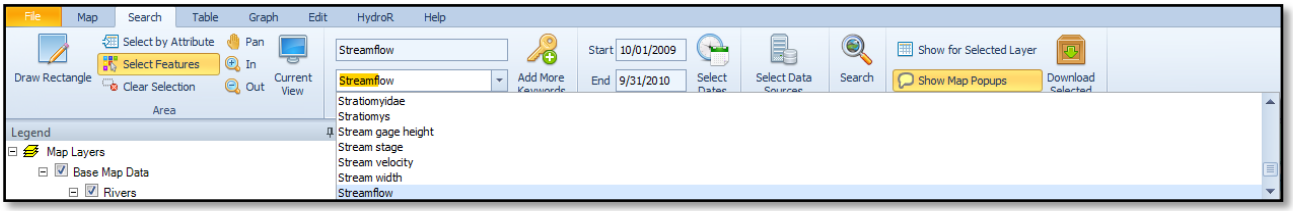
Choosing a Search Area

Next you will tell HydroDesktop what hydrologic variables you want. To help you in this regard, HydroDesktop employs a list of official CUAHSI-HIS keywords for hydrologic variables. Data providers use this list when registering with CUAHSI-HIS. This is a lot easier than typing whatever term the data provider may be using internally (e.g.,
00060 for USGS streamflow).

4. In the box within the **Keyword** panel on the ribbon, type **Streamflow**. The box bottom box autocompletes to a valid search term from the list of parameter keywords that CUAHSI maintains while the top box allows freeform entries.

Next you will tell HydroDesktop the date range of time series that you want. For this exercise, search for data available in the 2010 water year, i.e., 10/1/2009 to 9/30/2010.

5. In the **Time Range** panel, change the start date and end date to **10/1/2009** and **9/30/2010**, respectively.

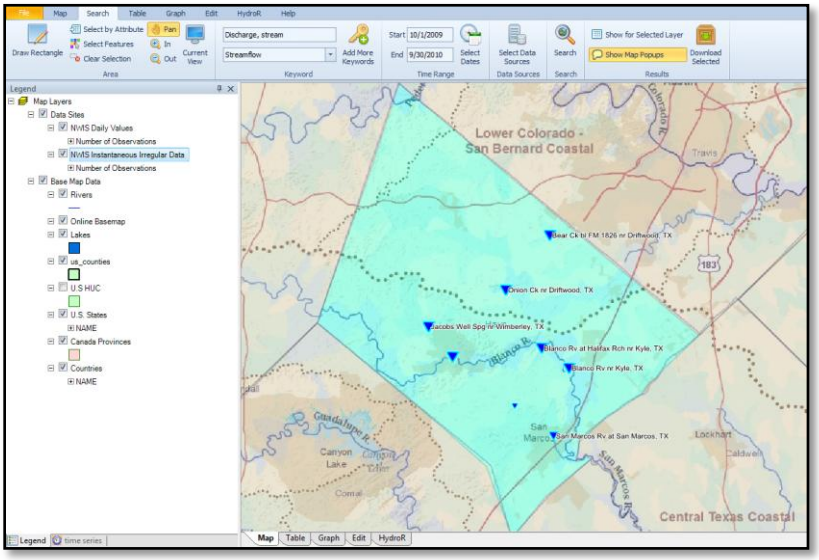


The Search tab displays your search criteria as you enter them

At this point you could click in the Data Sources panel to restrict the search to specific data sources, but for this portion of the exercise you will search all data sources, which is the default setting. With search parameters set, you will now tell HydroDesktop to run the search for data.

6. In the **Search** panel, click **Run Search**.
7. Once the search has completed, close the progress dialog.

When you run a search, HydroDesktop asks the CUAHSI-HIS national catalog for descriptions of time series that match your search criteria. At this point, your software is using a remote online resource and bringing back information to display in your map. After HydroDesktop has finished searching for time series, it displays the locations of time series that fit your search criteria in a map layer called Data Sites. Different symbols for the sites indicate different data sources. You can see a label for the Jacob's Well Spring site in the map.



Locations of Streamflow in Hays County

While the search may have seemed fast, remember that your map is only showing where time series of interest are located, and that you haven't actually downloaded any time series values yet. Now you can begin to refine these search results to locate time series that you actually want to download and save to your database.

DOWNLOADING DATA

For this exercise, you will work with streamflow at the following two sites:

- Jacobs Well Spg nr Wimberley, TX
- Blanco Rv nr Kyle, TX (a site near Jacob's Well Spring for comparison)

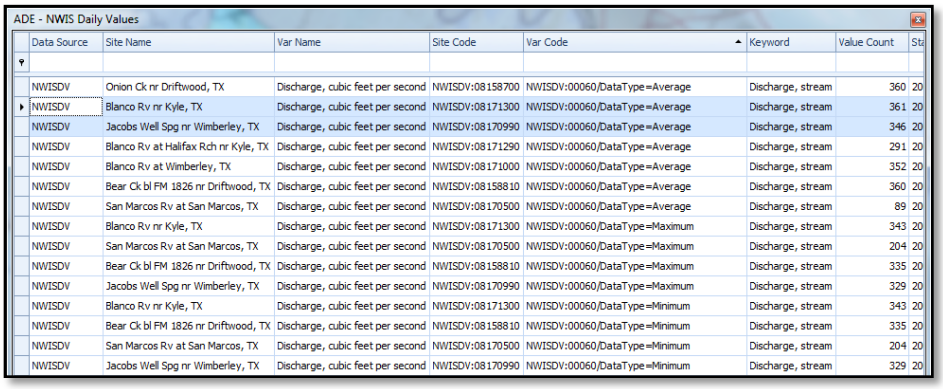
You will select the features that represent these time series so that HydroDesktop knows which time series you want to download. While several data sources were returned from the search, in this exercise you will only download streamflow from the USGS National Water Information System Daily Statistics archive (NWIS Daily Values).

To select time series for download:

1. In the **Legend** on the left, **uncheck all layers except for the NWIS Daily Values** to hide those layers. The only layer you will work with is the NWIS Daily Values layer.
2. Right-click the **NWIS Daily Values** layer name and click **Attribute Table Editor**.

The Attribute Table Editor opens showing you descriptions of time series in this layer. You can scroll through the table and resize columns to see the information.

3. In the **Attribute Table Editor**, use the values in the **SiteName** and **VarCode** columns to identify time series of **average** streamflow values for the two sites listed above. While holding down the CTRL key, left-click on these rows to select them.

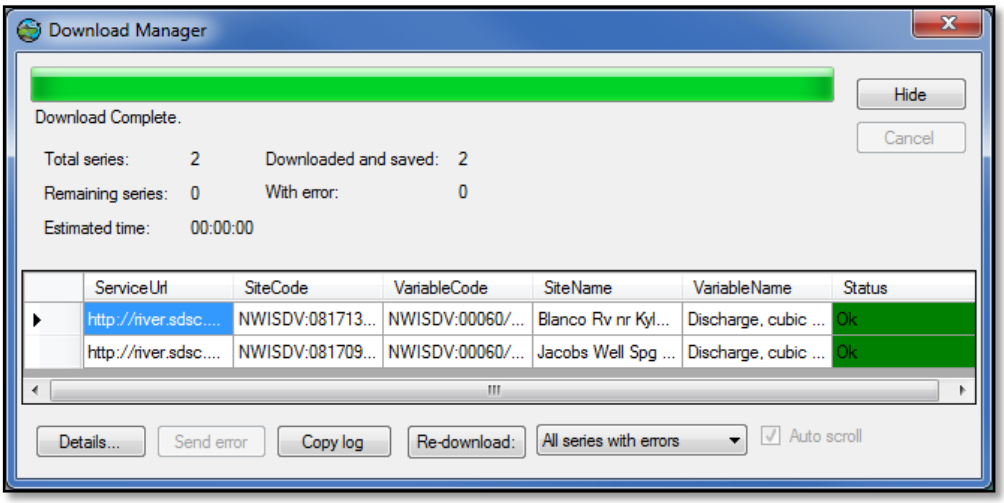


Selecting Time Series for Download

4. Close the Attribute Table Editor.

With these rows selected, you are ready to download the data.

5. In the ribbon, in the **Search** panel, click **Download**. The Download Manager opens to show progress of the download.



6. Hide the Download Manager when the download is complete.

Tip: If a download fails, you can right-click the failed row in the Download Manager to attempt the download again.

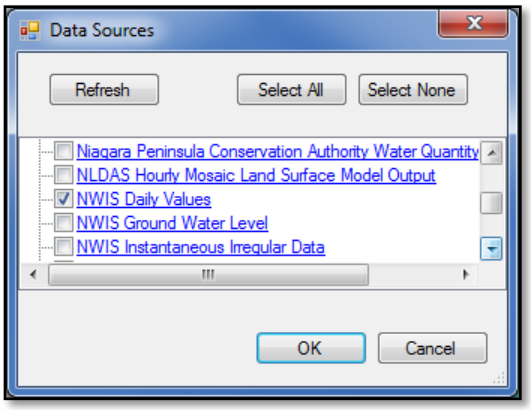
Downloading Additional Data

You might be excited about viewing your downloaded data, but before you do, let's retrieve some water temperature data for Jacob's Well Spring. Since you retrieved data from NWIS Daily Values in the previous search, you will learn how to restrict a search so that NWIS Daily Values is the only data source that is queried.

To search for and download water temperature data:

1. In the ribbon, in the **Keyword** panel, enter **Water temperature** in the bottom (autocomplete) box.
2. Restrict the search to NWIS Daily Values.
   a. In the **Data Sources** panel, click **All Data Sources**.
   b. In the Data Sources dialog, click **Select None**.
   c. In the list of data sources, find and place a check next to **NWIS Daily Values**.
   d. Click **OK** to close the Data Sources dialog.

Tip
You can click the name of a data source in the Data Sources dialog to open a Web page with more information about that source.



Choosing Data Sources

Notice how the icon for All Data Sources has changed to reflect the chosen data source.

3. In the **Search** panel, click **Run Search**.
4. Once the search has completed, close the progress dialog.

An NWIS Daily Values (2) layer is added to the map legend to show results from this second search.

5. In the **Legend** on the left, right-click the **NWIS Daily Values (2)** layer name and click **Attribute Table Editor**.
6. In the **Attribute Table Editor**, use the values in the **SiteName** and **VarCode** columns to identify time series of **average** temperature values for these two sites:
    a. Jacobs Well Spg nr Wimberley, TX
    b. Blanco Rv at Halifax Rch nr Kyle, TX
7. While holding down the CTRL key, left-click on these rows to select them.
8. Close the Attribute Table Editor.
9. In the ribbon, in the **Search** panel, click **Download**.
10. Hide the Download Manager when the download is complete.

Now that you've downloaded the data, you can view the data in both tabular and graph form.

VISUALIZING TIME SERIES DATA

HydroDesktop takes a series-centric view of temporal data, meaning that it provides access to the data at the time series level. An example of a time series is all of the temperature values measured at a certain point on the Blanco River. Let's take a look at the time series that you just downloaded.

To visualize time series data in HydroDesktop:

1. Click the **Graph** tab in the ribbon to activate it.

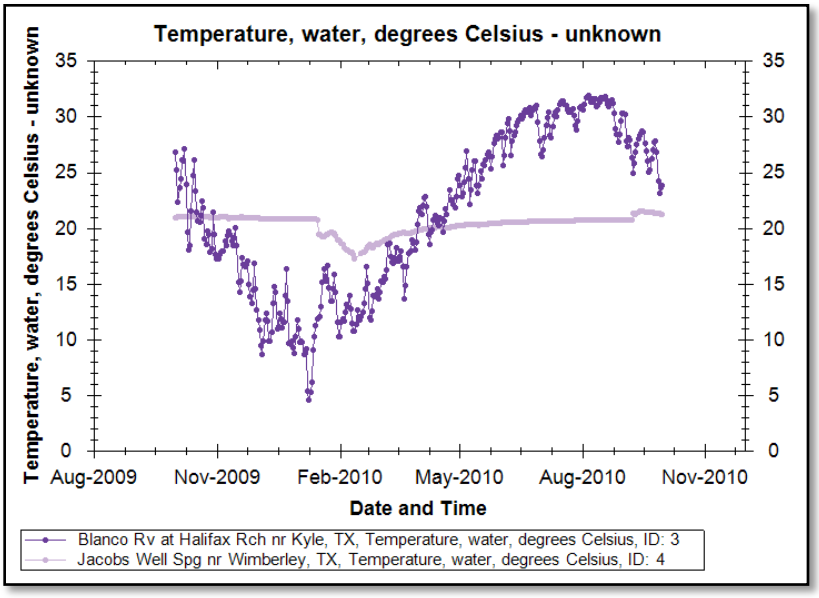
On the left you will see a list of all the time series in your database. You could use filters to restrict the time series that are shown, but you only retrieved a handful in this exercise so it's fine to leave the default view.

2. In the list of time series on the left, place a check next to temperature at the Blanco River at Halifax Ranch.

From the graph you can see how the temperature in the water changes with the seasons throughout the year. Now let's compare this time series with the one for Jacob's Well Spring.

3. Place a check next to temperature at Jacob's Well Spring.

HydroDesktop allows you to visualize multiple time series on the same graph. The plot axes automatically adjust to fit your data. In this example, there is a dramatic difference between the two temperature time series. The one for Jacob's Well Spring shows much less variation throughout the year than the one for the Blanco River at Halifax Ranch.



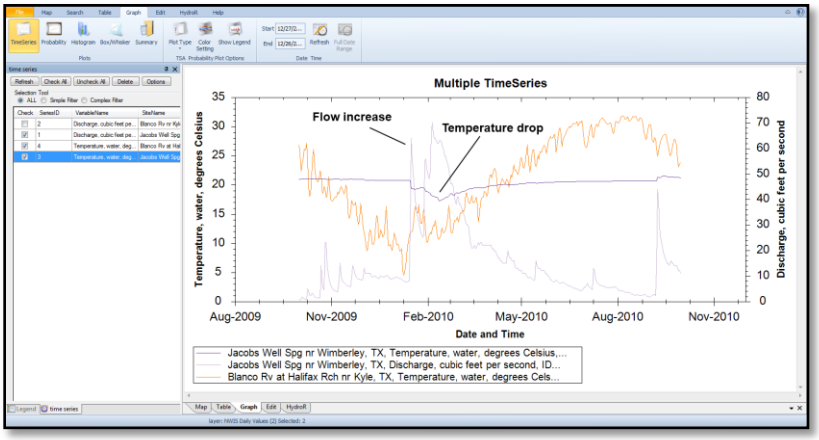
Comparing Temperature Time Series

4. In the ribbon, click **Probability** to show a probability plot of the data, further illustrating the difference between the two time series.
5. Click **TimeSeries** to restore the time series view.

The dramatic difference in the shapes of the two time series plots is caused by the source of water for these two rivers. The Blanco River at Halifax Ranch is largely a surface water system while Jacob's Well Spring is fueled by groundwater. While the groundwater system does maintain a much more steady temperature than the surface water system, notice how jumps still exist, such as the sudden decrease in temperature in mid-January, 2010. Let's plot flow on this graph to see why this might be happening.

6. Place a check next to **Discharge at Jacob's Well Spring**.

Notice the sharp increase in streamflow around the same time that the water temperature dropped. It seems like the system is experiencing a large influx of surface water, which is colder than the groundwater in the winter. Similarly, you can see an increase in streamflow in late summer, 2010, which results in an increase in water temperature.



Examining Changes in Flow and Temperature

7. Uncheck the two temperature time series, and place a check next to **Discharge at the Blanco River near Kyle**.

The flow of the Blanco River dwarfs that of Jacob's Well Spring, but you can still see increases in flow in the Blanco River at about the same time as those observed in the spring. Also notice the peak flow in September, 2010. This flow is the result of tropical storm Hermine as it swept through Texas.

DELINEATING WATERSHEDS

At this point, it might be nice to see precipitation data in this watershed for this water year. You can delineate watersheds for any river in the conterminous U.S. using a Web service provided by the EPA. All you have to do is click on the desired watershed outlet location in the map, and then HydroDesktop sends that point location to the EPA service. The service figures out which National Hydrography Dataset (NHD) reach the clicked point is closest to, and then finds all catchments that the reach drains. The catchments are merged into a single watershed and returned to HydroDesktop.

Note that the watershed returned is for the outlet of the entire reach, so if the point you clicked isn't at the reach outlet, then the resulting watershed will include some additional area downstream of your clicked point. Thus, this tool is useful for helping to identify an area of interest but should not be used to determine watershed parameters such as area. Future versions of the tool will support more precise delineation.

In this portion of the exercise you will delineate a watershed for the area draining to Jacob's Well Spring. The watershed delineation tool is part of a HydroDesktop extension called EPA Delineation.

To delineate a watershed for the area draining approximately to the Jacob's Well Spring location:

1. On the **Map** tab, in the **Zoom** panel, activate the (zoom) **In** tool. Draw a box around the site at Jacob's Well Spring to zoom in to it a bit. This helps ensure that you click exactly at the spring outlet.

2. In the **Legend**, uncheck **U.S. Counties** to hide that layer.
3. In the **EPA Tool** panel, click **Delineate** to activate the delineation tool.
4. The tool prompts you for where to save the resulting datasets. Accept the defaults by clicking **OK**.
5. Click on the site location for Jacob's Well Spring.

After a moment, the watershed is shown in the map. The NHD reaches flowing to the point that you clicked and the point itself are also shown.

Delineated Watershed

If you didn't get the correct watershed delineated then you can activate the tool and try again. It's OK to overwrite previous results.

Note
Recall that the watershed is actually delineated for the outlet of the nearest NHD reach, which happens to be very close to Jacob's Well Spring in this example. Also be aware that the surface watershed you just delineated defines some but not all of the area contributing water to the aquifer for Jacob's Well Spring. However, the area will suffice for this exercise which merely demonstrates how to delineate watersheds and use those watersheds to find data.

With the watershed delineated, now you're ready to search for data in this watershed.

FINDING DATA IN A WATERSHED

Now you'll search for daily precipitation data from the National Weather Service (NWS) in the watershed for Jacob's Well Spring.

1. In the ribbon, click the **Search** tab.
2. Choose the delineated watershed as the area of interest.
    a. Click **Select by Attribute,** which is located in the area section of the Search tab.
    b. Select **Watershed** as the active layer. The default field of Id will suffice.
    c. Select the only value present, which is probably a value of 1.
    d. Click **OK**.
3. In the **Keyword** panel, enter **Precipitation**.
4. Restrict the search to the NWS West Gulf River Forecast Center's (WGRFC) multi-sensor precipitation estimates.

a. In the **Data Sources** panel, click the currently selected data source, **NWIS Daily Values**.
b. In the Data Sources dialog, click **Select None**.
c. In the list of data sources, find and place a check next **NWS-WGRFC Daily Multi-sensor Precipitation Estimates**.
d. Click **OK** to close the Data Sources dialog.

5. In the **Search** panel, click **Run Search**.
6. Once the search has completed, close the progress dialog.

When the search finishes, you'll see some regularly-spaced dots over the watershed. These dots represent the centroids of NEXRAD HRAP cells. In other words, this Web service provides discrete point locations where you can basically sample this gridded rainfall dataset. Each of these points is like a virtual rain gauge. For this exercise, you'll just pick one near Jacob's Well Spring.

In addition to choosing time series from the Attribute Table Editor as you have already done in this exercise, you can also hover your mouse over a site and download time series from the pop-up bubble that appears.

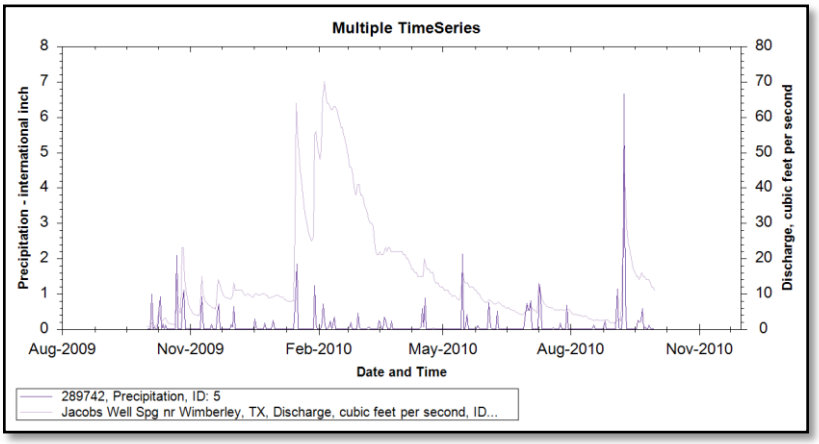
7. Hover your mouse over one of the precipitation sites.
8. In the pop-up bubble that appears, click **Download**.

Pop-up windows summarize time series available at a given location

9. Hide the Download Manager when the download is complete.

The precipitation data are added to your database. Now let's view the results.

1. Click the **Graph** tab.
2. Plot a graph with one of the **precipitation** time series you just downloaded and **Streamflow from Jacob's Well Spring**. Notice how quickly Jacob's Well Spring responds to rainfall events.



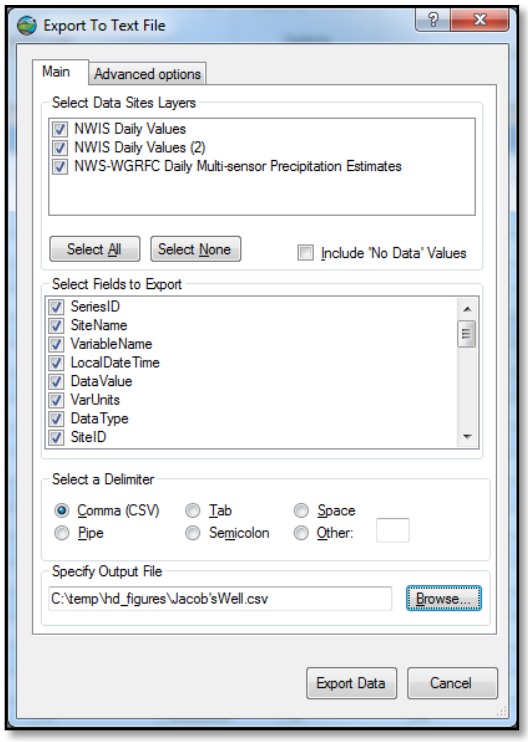
EXPORTING DATA

HydroDesktop can export data to a variety of output file types for further study and analysis. For example, you can export individual time series by right-clicking them in Table or Graph view. For this exercise, you will export all time series that you have downloaded.

To export time series data:

1. Click the **Table** tab in the ribbon to activate it.
2. In the **Data Export** group, click **Export**.

This tool exports data to a delimited text file. In the Export To Text File dialog, notice that the time series are organized into "data sites" layers. Each "data sites" layer corresponds to a given data source and search parameter. You can choose to only export data for a given data source if desired. You can also control the fields that are included in the export and choose a delimiter. For this exercise, you will accept all defaults to produce a comma delimited text file.



Export To Text File Dialog

3. In the **Export To Text File** dialog, specify the output file location and name.
4. Click **Export Data.**
5. Close the **Export To Text File** dialog when it is finished.
6. Find the file on your computer and open it to verify that the data were exported.

Congratulations! With your data in hand, you have completed the exercise and learned how to use HydroDesktop to discover and access water data. Feel free to experiment with other functionality such as creating and printing a map, and be sure to give feedback using the Help tab. This concludes the main portion of the exercise. For an example of more advanced analysis, continue with the section below to learn how to use the R statistical environment with HydroDesktop.

ADVANCED: ANALYSIS WITH R

The work above has illustrated how to download temperature, precipitation and discharge data and suggested that variations in temperature in Jacob's Well Spring may be related to the mixing of surface and subsurface water sources. In this section, you will use the HydroR plug-in in HydroDesktop to explore this phenomenon. The HydroR plug-in provides an interface between HydroDesktop and the free R statistical software environment.

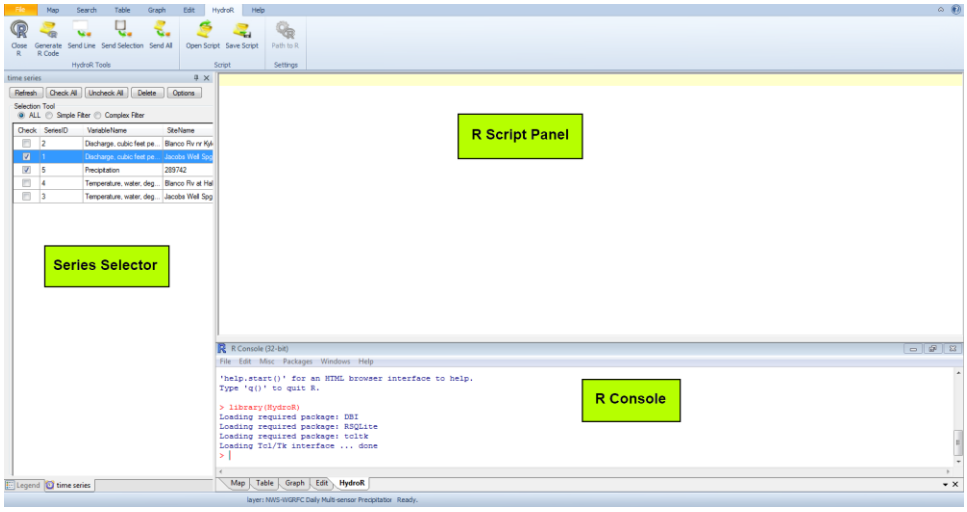
ENABLING HYDROR

Once R is installed, you will need to enable HydroR in HydroDesktop.

To enable HydroR:

1. Click the **HydroR** tab in the ribbon.
2. In the **HydroR Tools** panel, click **Start R**.
3. If prompted for the path to R.exe, enter the path where it was installed on your computer. Note that R may include more than one R.exe file. The one you typically need is in the **bin\i386** folder, as in C:\Program Files\R\R-2.13.0\bin\i386\R.exe. Click **OK** once the path is entered. HydroDesktop will remember this path the next time you use the HydroR extension.
4. HydroDesktop needs some additional R libraries. If you are using the HydroR extension for the first time, you may be prompted for a CRAN mirror to download these libraries. Select the mirror closest to your location and click **OK**. The appropriate libraries are downloaded automatically.

R should now start and give you a blank R script in the top panel and R Console in the bottom panel. Standard R commands can be entered in the R Console. HydroR makes it easy to provide R access to the data you have downloaded with HydroDesktop using the HydroR tab.



HydroR Layout

PLOTTING A GRAPH WITH R

To get familiar with how HydroR works, you'll plot a hydrograph for Jacob's Well Spring.

To plot a graph in HydroR:

1. In the **HydroR** tab, in the list of time series on the left, select a time series that you would like to import as a data frame into R. For this exercise, select **discharge at Jacob's Well Spring**. Make sure no other time series are selected.
2. In the ribbon, click **Generate R code**. The R code to get the selected data series is entered into the script.
3. Click **Send All**. This sends the script text to the console and executes it. The result is an object named **data0**, which contains a list of R data frames.
4. In the **R Console**, enter `labels(data0)` to see a list of data frames that make up data0.

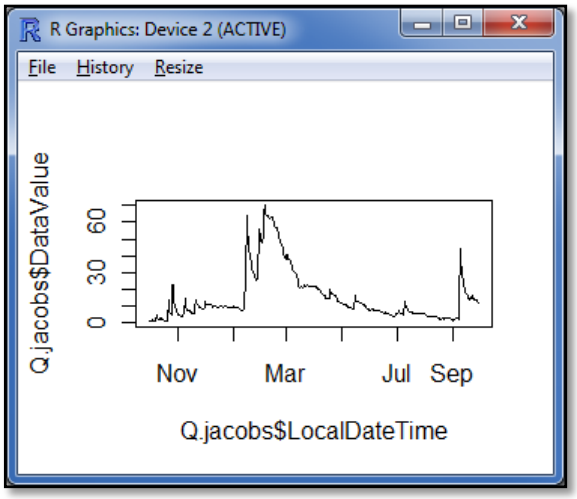
These data frames are basically tables from your HydroDesktop database. The key table we're interested in for this exercise is the DataValues table.

5. To see the first few rows of DataValues, in the **R Console**, enter `head(data0$DataValues)` (R is case sensitive, so type the command exactly as it appears in this text). You may have to scroll up in the R Console to see the full result.

You'll use the LocalDateTime and DataValue columns to provide data for the graph.

6. To make it easier to access this streamflow time series, in the **R Console**, enter `Q.jacobs=data0$DataValues`. This assigns the DataValues data frame to a variable named **Q.jacobs**.
7. In the **R Console**, enter

`plot(Q.jacobs$LocalDateTime,Q.jacobs$DataValue,type="l")` (the type is a lower case L, not a one). A time series plot of the data should appear in an R graphics window, demonstrating that the full capability of R is available to work with the data that has been imported.



Jacob's Well Spring Hydrograph Plotted Using R

Let's add a title to this graph.

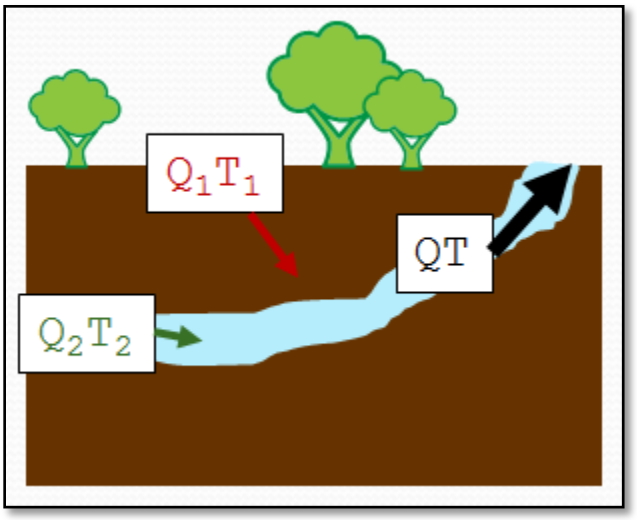
8. In the **R Console**, enter `data0$Variable` to see all attributes for the Variable table.
9. In the **R Console**, enter `title(data0$Variable$VariableName)` to add the variable name as the title for the plot.
10. After verifying that the title was added, close the R graphics window showing the graph.

Analyzing Flow in Jacob's Well Spring

Let's use mixing theory to estimate the fractions of Jacob's Well Spring flow that are from the surface and subsurface based on temperature. Assume the surface source has temperature equal to the temperature in Blanco River. Assume groundwater source is at a fixed temperature. The following equations then apply.

Energy Balance: $QT=Q_1T_1+Q_2T_2$
Mass Balance: $Q=Q_1+Q_2$

where Q is discharge in Jacob's Well Spring, T is Temperature in Jacob's Well Spring, T_1 is the temperature of the surface source (assumed equal to Blanco River temperature), and T_2 is the temperature of the subsurface source (assumed constant and taken as the average of last 60 days). Q_1 and Q_2 are the unknown discharge contributions from surface and subsurface sources respectively (Figure 22).



Surface and subsurface contributions to Jacob's Well Spring outflow and temperature

Two linear equations, two unknowns can be easily solved (see your high school algebra book). The solution is

$$Q_1/Q = (T-T_2)/(T_1-T_2)$$

The R scripts in Appendix A use data from HydroDesktop to solve this equation. You'll assign the relevant time series to simple variable names and then use the R scripts to plot a graph representing the amount of flow in Jacob's Well Spring inferred as coming from the surface.

To use the R scripts to compute fractional flow:

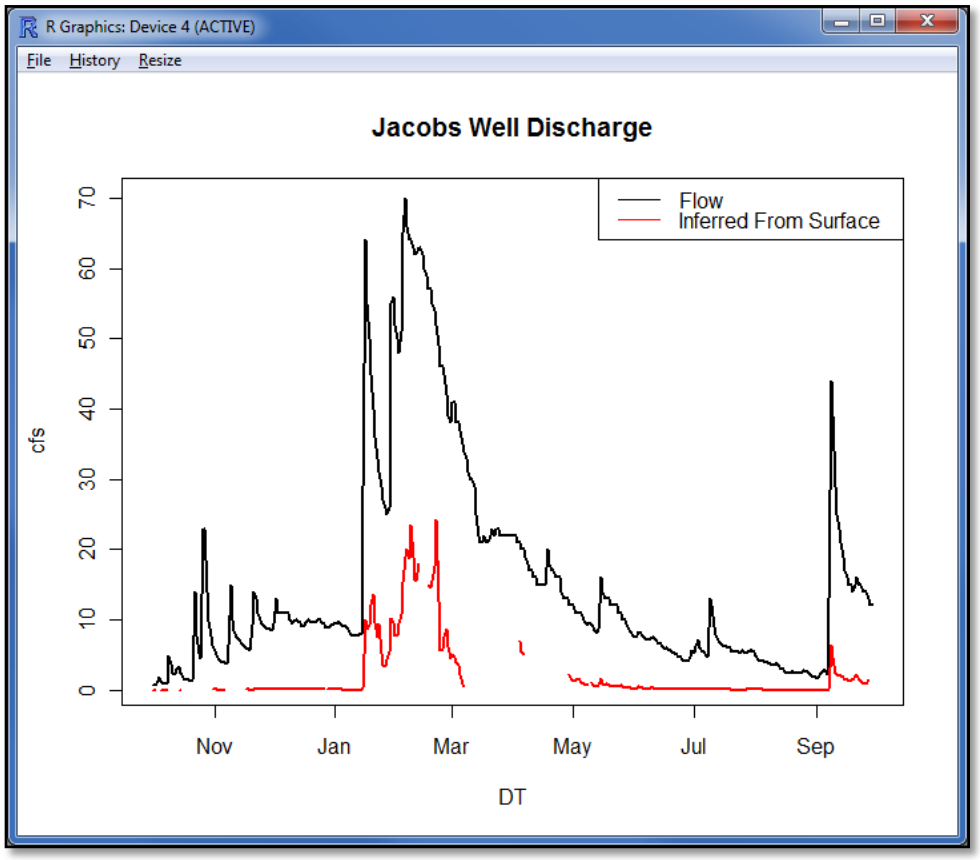
1. In the same manner that you created the Q.jacobs variable above and assigned it to be the discharge at Jacob's Well Spring, create and assign the following R variables (remember, the variable names are case sensitive). In other words, for each variable, clear the R script panel, select a series, generate the R code, send it to R, and assign the variable in the R Console.
    a. Q.blanco – Discharge at the Blanco River near Kyle
    b. t.blanco – Water temperature at the Blanco River at Halifax Ranch
    c. t.jacobs – Water temperature at Jacob's Well Spring**

****IMPORTANT**
You may encounter a bug when generating R code for water temperature at Jacob's Well Spring. In the R script panel, if the endDate is not "2010-09-30" then edit the script to use "2010-09-30" before sending the script to the R Console.

2. Enter **Script 1** found in Appendix A into the **R Console** to execute the script. This script prepares inputs for the analysis and plots graphs of the input temperature and flow.
3. Once you have reviewed the graphs of temperature and streamflow generated by Script 1, close the two R Graphics Windows containing the graphs.

4. Enter **Script 2** found in Appendix A into the **R Console** to execute the script. This script smoothes the temperature time series and then performs the analysis to determine the fraction of flow in Jacob's Well Spring from surface water.

The resulting graphs show smoothed temperature time series and the portion of flow in Jacob's Well Spring inferred to be from the surface (the red line in the graph). Note that the analysis requires differences between the assumed groundwater temperature and surface water temperature, so the graph will be missing segments when those temperatures are nearly the same.



Fractional Flow in Jacob's Well Spring

Congratulations! You have completed the exercise and seen how advanced analysis environments such as R can be integrated into HydroDesktop using the power of plug-ins. This concludes the advanced portion of the exercise.

APPENDIX A: R SCRIPTS

SCRIPT 1: PREPARING INPUTS FOR FLOW ANALYSIS

```
#  SCRIPT 1: PREPARING INPUTS FOR FLOW ANALYSIS

#  This code plots input time series of flow and temperature.
#  The code assumes the following variables have already been set to
#  the DataValues data frame for these time series:
#    Q.jacobs - Discharge at Jacob's Well Spring
#    Q.blanco - Discharge at the Blanco River near Kyle
#    t.jacobs - Water temperature at Jacob's Well Spring
#    t.blanco - Water temperature at the Blanco River at Halifax Ranch
#  The code handles intermittent missing values

#  Start one day earlier because queries seem to be based on UTC
DT = seq(from=as.Date("2009-09-30"),to=as.Date("2010-09-30"),by=1)
ind=match(as.Date(t.blanco$LocalDateTime,"%Y-%m-%d %H:%M:%S"), DT)
T1=rep(NA,length(DT)) T1[ind]= t.blanco$DataValue

ind=match(as.Date(t.jacobs$LocalDateTime,"%Y-%m-%d %H:%M:%S"), DT)
T=rep(NA,length(DT))
T[ind]=t.jacobs$DataValue
T2 = T[1]  #  The first value

ind=match(as.Date(Q.jacobs$LocalDateTime,"%Y-%m-%d %H:%M:%S"), DT)
Q=rep(NA,length(DT))
Q[ind] = Q.jacobs$DataValue
plot(DT,T1,type="l",ylab="T")
lines(DT,T,col=2)
legend("bottomright",c("T Blanco","T Jacobs"),col=c(1,2),lty=1)
windows()
plot(DT,Q,type="l")
```

SCRIPT 2: COMPUTING SURFACE WATER FLOW FRACTION

```
#  SCRIPT 2: COMPUTING SURFACE WATER FLOW FRACTION

#  This script solves the equation Q1/Q = (T-T2)/(T1-T2)
#  and plots a graph showing the portion of flow inferred
#  to be directly from surface water sources in Jacob's
#  Well Spring.
#  Before running this script, you must run SCRIPT 1:
#  PREPARING INPUTS FOR FLOW ANALYSIS

#  Smoothing Blanco River temperature data using lowess

ind=!is.na(T1)  #  array indices of unmissing values
T1l<-lowess(DT[ind],T1[ind],f=0.1)
plot(DT,T1,type="l",ylab="Degrees C")
lines(T1l,col=2)
lines(DT,T,col=3)
legend("bottomright",c("Blanco T","Smoothed Blanco T","Jacobs
T"),col=c(1:3),lty=1)
title("Temperatures")

#  Match the dates of the output for use in calculations
ind=match(T1l$x,DT)
T1s=rep(NA,length(DT))
T1s[ind]=T1l$y

#  For results to be reasonable T1 and T2 have to be different.
#  Only evaluate answers when T1 and T2 differ by at least 3 degrees
#  Also only accept positive answers

#  Calculate T2 as average over last 60 days
T2p=c(rep(T[1],59),T)
T2=rep(NA,length(DT))
for(i in 1:length(DT)) T2[i]=mean(T2p[i:(i+59)],na.rm="True")



Q1f=(T-T2)/(T1-T2)  # apply the mixing solution equation
# eliminate answers when temperature difference is less than 3
indna=abs(T1-T2)<3
Q1f[indna]=NA
indna=Q1f< -0.05    # eliminate large negative values
Q1f[indna]=NA

#  Plot the results
windows()
plot(DT,Q,type="l",ylab="cfs",lwd=2)
lines(DT,Q*Q1f,col=2,lwd=2)
legend("topright",c("Flow","Inferred From Surface"),lty=1,col=c(1,2))
title("Jacob's Well Discharge")
```

REFERENCES

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San Marcos Local News. (2009, March 10). Jacobs Well area to hold incorporation vote. Retrieved November 2, 2010, from San Marcos Local News Web site: http://www.newstreamz.com/2009/03/10/area-around-jacobs-well-to-hold-incorporation-election/.

United States Geological Survey. (2007, March 26). National Surface Water Conference and Hydroacoustics Workshop. Retrieved November 1, 2010, from United States Geological Survey Web site: http://water.usgs.gov/osw/images/2007_photos/Hydroacoustics.html.