



i-Tree

Hydro

User's Manual

v. 5.0

i-Tree is a cooperative initiative



Arbor Day Foundation™



About i-Tree

i-Tree is a state-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban and community forestry analysis and benefits assessment tools. The i-Tree tools help communities of all sizes to strengthen their urban forest management and advocacy efforts by quantifying the environmental services that trees provide and assessing the structure of the urban forest.

i-Tree has been used by communities, non-profit organizations, consultants, volunteers, and students to report on the urban forest at all scales from individual trees to parcels, neighborhoods, cities, and entire states. By understanding the local, tangible ecosystem services that trees provide, i-Tree users can link urban forest management activities with environmental quality and community livability. Whether your interest is a single tree or an entire forest, i-Tree provides baseline data that you can use to demonstrate value and set priorities for more effective decision-making.

Developed by USDA Forest Service and numerous cooperators, i-Tree is in the public domain and available by request through the i-Tree website (www.itreetools.org). The Forest Service, Davey Tree Expert Company, the Arbor Day Foundation, Society of Municipal Arborists, the International Society of Arboriculture, and Casey Trees have entered into a cooperative partnership to further develop, disseminate, and provide technical support for the suite.

i-Tree Products

The i-Tree software suite v. 5.0 includes the following urban forest analysis tools and utility programs.

i-Tree Eco provides a broad picture of the entire urban forest. It is designed to use field data from randomly located plots throughout a community along with local hourly air pollution and meteorological data to quantify urban forest structure, environmental effects, and value to communities.

i-Tree Streets focuses on the ecosystem services and structure of a municipality's street tree population. It makes use of a sample or complete inventory to quantify and put a dollar value on the trees' annual environmental and aesthetic benefits, including energy conservation, air quality improvement, carbon dioxide reduction, stormwater control, and property value increases.

i-Tree Hydro is the first vegetation-specific urban hydrology model. It is designed to model the effects of changes in urban tree cover and impervious surfaces on hourly streamflows and water quality at the watershed level.

i-Tree Vue allows you to make use of the freely available National Land Cover Database (NLCD) satellite-based imagery to assess your community's land cover, including tree canopy, and some of the ecosystem services provided by your current urban forest. The effects of planting scenarios on future benefits can also be modeled.

i-Tree Species Selector is a free-standing utility designed to help urban foresters select the most appropriate tree species based on environmental function and geographic area.

i-Tree Storm helps you to assess widespread community damage in a simple, credible, and efficient manner immediately after a severe storm. It is adaptable to various community types and sizes and provides information on the time and funds needed to mitigate storm damage.

i-Tree Design is a simple online tool that provides a platform for assessments of individual trees at the parcel level. This tool links to Google Maps and allows you to see how tree selection, tree size, and placement around your home affects energy use and other benefits. This tool is in the early stages of development; more sophisticated options will be available in future versions.

i-Tree Canopy offers a quick and easy way to produce a statistically valid estimate of land cover types (e.g., tree cover) using aerial images available in Google Maps. The data can be used by urban forest managers to estimate tree canopy cover, set canopy goals, and track success; and to estimate inputs for use in i-Tree Hydro and elsewhere where land cover data are needed.

Disclaimer

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Feedback

The i-Tree Development Team actively seeks feedback on any component of the project: the software suite itself, the manuals, or the process of development, dissemination, support, and refinement. Please send comments through any of the means listed on the i-Tree support page: www.itreetools.org/support.

Acknowledgments

i-Tree

Components of the i-Tree software suite have been developed over the last few decades by the USDA Forest Service and numerous cooperators. Support for the development and release of i-Tree v. 5.0 has come from USDA Forest Service Research, State and Private Forestry, and their cooperators through the i-Tree Cooperative Partnership of Davey Tree Expert Company, the Arbor Day Foundation, Society of Municipal Arborists, the International Society of Arboriculture, and Casey Trees.

i-Tree Hydro

The i-Tree Hydro model was originally developed by Drs. Jun Wang (SUNY-ESF), Ted Endreny (SUNY-ESF), and David J. Nowak (USDA Forest Service). The model code has been improved and integrated within i-Tree based on the work of Michael Kerr (Davey Institute), Yang Yang (SUNY-ESF), Sanyam Chaudhary (Syracuse University), Rahul Kumbhar (Syracuse University), Thomas Taggart (SUNY-ESF), and Shannon Conley (SUNY-ESF).

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Introduction

i-Tree Hydro is a simulation tool that analyzes how land cover influences the volume and quality of runoff. It can analyze historical or future hydrological events and allow the user to contrast runoff volume and quality from existing land cover (referred to as the Base Case) with runoff from the Alternative Case land cover. The i-Tree Hydro model differs from other i-Tree products in the following ways:

- The model simulation area is loaded into the program either as a Digital Elevation Model (DEM) file or as a Topographic Index (TI) file. It is not hand-delineated in the program by the user. If you are interested in a watershed, you can load either a DEM or TI file. If you are interested in a city or parcel that is not defined by a single watershed, you would load a TI file.
- The model simulation can be run in calibration mode or non-calibration mode. For calibration mode, the user loads observed streamflow data from a gaging station and the model will identify the optimal hydrological parameters to fit the observed data. Streamflow gage data can be found for thousands of watershed areas. For non-calibration runs, the user can employ previously calibrated parameters or independently set the land cover and hydrological parameter values by adjusting the default values that the model provides.

Any user with reasonable knowledge of the project area can choose the TI option and run i-Tree Hydro in non-calibration mode with suggested hydrological parameters and the weather station information included in i-Tree Hydro. However, superior estimates can be derived with a watershed DEM calibrated against a USGS stream gage run in calibration mode.

Overview

i-Tree Hydro models runoff volume and water quality using inputs of elevation, land cover, weather, and various model parameters. The user can explore how the outputs change with changes in model inputs such as tree and impervious cover.

Some additional data on inputs:

- For elevation data – to simulate a watershed, the model is best suited to free Digital Elevation Model (DEM) data from the USGS or Topographic Index (TI) data prepared by the USGS. To simulate a city, you would use the TI data.
- For land cover data – percent tree cover, shrub cover, impervious surface, and other cover types are needed. These values can be obtained from updated

National Land Cover Data (NLCD) from the USGS. You can also derive these values from i-Tree Canopy, available online at www.itreetools.org.

- For weather – the model includes weather data from 2005-2012. With some formatting, you can also load your own weather files.
- For model parameters – the model provides Suggested Default Values that should be modified to represent the specific analysis area.
- i-Tree Hydro can be run for the Base Case to assess current conditions in your project area. To contrast how land cover changes affect the runoff volume and water quality, an Alternative Case can be run. To save time, both Base Case and Alternative Case can be specified at the outset. The Alternative Case can be changed and the model re-run at any time.

You can get a preview at File > Open the Sample Project.

When you are ready, get started with File > New Project.

For more information on the methodology that underlies i-Tree Hydro, visit www.itreetools.org > Resources > Archives > i-Tree Hydro Resources.

About This Manual

This manual provides information needed to conduct an i-Tree Hydro project. After installing the software and exploring a sample project, we'll move on to three general project phases:

Phase I: Creating a New Project. In this section, we'll provide an overview of the steps necessary to create a new project, input your Base Case data, and calibrate the model.

Phase II: Entering Model Parameters. In this section, we'll explain how to adjust land cover, hydrological, and Alternative Case parameters.

Phase III: Exploring Model Outputs. In the third phase, we get to the crux of i-Tree Hydro – running the model, viewing the executive summary and other model outputs, and interpreting the results.

Additional Information. This section explains some of the more challenging steps involved with running i-Tree Hydro, such as choosing your watershed, gathering input data, and calibrating the model.

The following appendices provide further detail on running i-Tree Hydro:

Appendix 1: Creating a Watershed Digital Elevation Model. This appendix describes the necessary tools and steps involved in creating a Digital Elevation Model (DEM) for a watershed using ArcGIS.

Appendix 2: Topographic Index Data. This appendix provides an overview of the Topographic Index (TI) data that can be used in place of a DEM.

Appendix 3: Calculating Pollution Load. The methodology associated with estimating how changes in hydrology affect water pollutant levels is presented here.

Appendix 4: International Support. This appendix includes a brief overview of the raw data required to run i-Tree Hydro outside of the United States.

Installation

System Requirements

Minimum hardware:

- Pentium or compatible 1.6 GHz or faster processor
- 4 GB of available RAM
- Hard drive with at least 500 MB free space
- Monitor with resolution of at least 1024 x 768

Software:

- Windows XP service pack 2 or higher OS (including Windows 7)
- .NET 4.0 framework (included in i-Tree installation)
- Adobe Reader 9.0

Installation

To install i-Tree Hydro:

- 1 Visit www.itreetools.org to download the software or insert an i-Tree Installation CD into your CD-ROM drive.
- 2 Follow the on-screen instructions to run i-Tree setup.exe. This may take several minutes depending on which files need to be installed.
- 3 Follow the Installation Wizard instructions to complete the installation (default location recommended).

You can check for the latest updates at any time by clicking **Help > Check for Updates**.

Exploring i-Tree Hydro with the Sample Project

Now that you've installed i-Tree Hydro, you would probably like to see a little of what the software can do. To allow you to explore the program, we've included a sample project based on the Harbor Brook Creek watershed near Syracuse, NY.

- 1 You begin by opening i-Tree Hydro using your computer's **Start** menu > **(All) Programs > i-Tree > Hydro**.
- 2 You will find the project under **File > Open the Sample Project**.
 - a Under **Step 1) Project Area Information**, you can review the input data fields. Additional input parameters can also be viewed by going through **Step 2) Land Cover Parameters** or **Step 3) Hydrological Parameters**.
 - b Tree and impervious cover parameters can be adjusted to see how these changes affect the hydrology of the project area. Click **Step 4) Define Alternative Case** and make adjustments as desired. On your first foray into i-Tree Hydro, we recommend leaving these inputs as they are. You can always return and make adjustments on Steps 2-4.
 - c Click **Input > 5) Run Hydro Model** to run the sample project and calculate the outputs.
 - d Under the **Output** menu, review the graphs and tables that are available for your watershed analysis over various time periods. For example:
 - **Executive Summary** – a three-page summation of basic results.
 - **Water Volume** – estimates of the water flowing out of your project area.
 - **Pollutant Estimates** – pollutant loads in the water flow.
 - **Water Flow** – tables and graphs showing how water flow and rainfall vary over time.
 - **Water Pollution** – tables and graphs presenting the pollutant load associated with Base and Alternative Case water flow.

We will, of course, explain all of these steps and outputs in greater detail, but for now, feel free to explore and see what's available.

Phase I: Creating a New Project

To begin working with i-Tree Hydro, click your computer's **Start** menu > **(All) Programs** > **i-Tree** > **Hydro**.

NOTE: The **Additional Information** section later in the manual provides directions for choosing your watershed, gathering your data, and calibrating the Hydro model. It is meant to supplement the more general directions provided in this section and you may find it beneficial to explore that section before creating a new project.

To start a new project:

- 1 Click **File** > **New Project**. In the **Save As** window that appears, navigate to the folder that you wish to save your project in.
- 2 Give your new project a name and click **Save**.

Now that your new project has been created, it is time to enter your input data and adjust the parameters of the model. Review the **Help** text in the right-side panel of the window as you navigate through each step. It will provide more detail about each of the model inputs and parameters. The **Help** text for each variable appears when you hover over the variable.

Entering the Project Area Information

Begin developing your i-Tree Hydro project by entering the Project Area Information.

- 1 Open the **Step 1) Project Area Information** window under the **Steps** menu. (This window opens automatically when you create a new project.)
- 2 Enter the Project Location for your watershed or study area. Since watersheds are not confined to political or parcel boundaries, it is important to choose the state, county, and city in which the greatest portion of your watershed is located. If your city is not listed, choose **N/A** in the alphabetical listing.
- 3 Enter the Basic Watershed Characteristics for your watershed or study area.
 - a The Watershed Land Area can be entered in either square kilometers (km²) or square miles (mi²). To toggle between the two options, simply check or uncheck the box labeled **Metric**.
 - b Choose a Start Date/Time and End Date/Time. These will denote the first

and last recorded time step of the observed streamflow data and the weather station data used in the model run.

If you are using the 2005-2012 data included in i-Tree Hydro, the weather and stream gage data will be filtered by your chosen Start and End Date/Time. If you are loading your own data, make sure you choose appropriate Date/Times that are the same for both data sets. Projects should be limited to three years or fewer, given the intensive amount of processing.

- 4 In Steps 5 and 6 to follow, you will input your observed streamflow data and weather station data. If you would like to save the raw streamflow and weather data that you chose, check the box labeled **Save raw source stream gage and weather files before processing**. You will be prompted for file names under which to save the files.
- 5 This step relates to incorporating Observed Streamflow Data. Here you have three options:

- a If you will be using the standard i-Tree Hydro data (available for 2005-2012), click **I need to pick a USGS gage from a map** and a map of local gaging stations will appear.

To select an appropriate station, you can enter the ID number directly in the ID field or click on the station marker to select it. If you hover over each marker, the station name will appear in the window status bar. After you have selected an appropriate station, click **OK**.

In the window that appears, navigate to the folder where you saved your project, give the gage data file a name (e.g., streamgage_data.dat), and click **Save**. Processing will begin.

- b If you gathered and formatted your own data, choose **Browse for my own file**, navigate to the location where you saved the file and click **Open**.
 - c If you would like to conduct an analysis as a non-gaged stream, choose **I wish to predict streamflow for a non-gaged stream** and the model will use estimated values.
- 6 Accurate, complete, and nearby weather data are critical for the best i-Tree Hydro estimates. In order to incorporate Weather Station Data, you have two options:
 - a If you will be using the standard i-Tree Hydro data for 2005-2012, click **I need to pick a weather station from a map** and a map of local weather

stations will appear.

To select an appropriate station, you can enter the ID number directly in the ID field or click on the station marker to select it. If you hover over each marker, the station name will appear in the window status bar. After you have selected an appropriate station, click **OK**.

In the window that appears, navigate to the folder where you saved your project, give the weather and evaporation files names (e.g., weather_data.dat), and click **Save**. Processing will begin.

- b** If you gathered and properly formatted your own data, choose **Browse for my own file**, navigate to the location where you saved the file, and click **Open**.

7 In order to incorporate necessary elevation information, you have a few options:

- a** If you choose to represent a watershed model simulation area using a digital elevation model (DEM), choose **Browse for my own DEM file**, navigate to the location where you saved the file, and click **Open**.

For basic instructions on the process for creating a watershed DEM, see the *Additional Information* section and *Appendix 1*.

- b** If you choose to represent the model simulation area using a topographic index (TI), choose **Use a Topographic Index**.

In the window that appears, you can **Browse for my own Topographic Index file** if you have prepared your own TI. Navigate to the location where you saved the file and click **Open**. For detailed instructions on the process of creating a TI, see the *Additional Information* section.

Alternatively, you can choose to **Select Topographic Index data from the i-Tree Hydro database**. Select the desired TI boundary from the drop-down menus. In the window that appears, navigate to the folder where you saved your project, give the file a name (e.g., TI_data.dat), and click **Save**. Processing will begin.

Once you have finished in this window, click **OK** to close. It's a good idea to save your project at this time, so click **File > Save Project**. Be sure to save your project periodically.

NOTE: If you discover later that you made an error in any of the fields in the **Step 1) Project Area Information** window, you must start over with a new project as changes to these fields require i-Tree Hydro to reprocess the weather and stream gage data.

Phase II: Entering Model Parameters

Entering the Land Cover Parameters

To continue developing your i-Tree Hydro project, enter the Land Cover Parameters that describe your project area.

- 1 Open the **Step 2) Land Cover Parameters** window under the **Steps** menu.
- 2 Enter the Surface Cover Types for your watershed or study area. These parameter values are important as they help describe the land cover conditions of the study area.

At this point, Tree Cover will already have been defined as the value set in the **Step 1) Project Area Information** window, since it was needed for various initial processing steps, such as calculating evapotranspiration, etc.

- 3 Enter the Cover Types Beneath Tree Cover for your watershed or study area.

NOTE: In this window, you are describing the entire watershed as best you can. However, to avoid over- or underestimating, total surface cover types and total sub-types should both add up to 100%.

Again, be sure to save your current project periodically.

Entering the Hydrological Parameters

Calibrating your i-Tree Hydro project involves a multi-step process of adjusting model parameters until the modeled streamflow resembles the actual streamflow. i-Tree Hydro features an auto-calibration routine that uses the observed streamflow data from a gaging station to identify the optimal hydrological parameters to fit the observed streamflow data. The user can also manually enter hydrological parameter values by adjusting the default values that the model provides. Ideally, you will then have a few parameter sets for comparison and can select one to run the model. However, you can also choose to rely on the default values and skip the calibration step altogether. In that case, simply click OK and skip to [Entering the Alternative Case Parameters](#) below.

NOTE: Calibration cannot be performed on non-gaged watersheds as stream gage data are required. However, you can adjust soil type, depth to root zone, and soil saturation parameters if desired.

The model simulates various hydrologic processes (e.g., precipitation, interception, infiltration, evaporation, transpiration, snowmelt, flow routing, and storage) in order to simulate streamflow at the gaging station. It then checks the accuracy of the simulation by comparing estimated model flow against actual flow. Results are considered in terms of peak, base, and overall flow. Because water flow is dependent upon precipitation, weather station data must be chosen with care. Model calibration can be significantly off if the local precipitation data do not match the watershed. For example, if the precipitation data were recorded too far from the watershed or if the precipitation events are very localized, calibrations will be off as it may be raining in the watershed but not at the weather station or vice versa.

Calibration process overview

- 1 Open the **Step 3) Hydrological Parameters** window under the **Steps** menu.
- 2 Create various parameter sets for comparison by first using the auto-calibration routine and then manually adjusting your hydrological parameters. Repeated adjustments and even re-running auto-calibration on adjusted values may be required.
- 3 Compare the calibration results between these parameter sets to determine which set produces the best fit between the estimated flow and the flow observed at the gaging station.
- 4 When you have a parameter set with which you are satisfied, click **OK**. Remember that the parameter set that is displayed in the **Current parameter set** drop-down menu is the one that will be used for modeling.

Calibrating the model

As a first step, try running i-Tree Hydro's auto-calibration option:

- 1 Select the Suggested Default Values parameter set from the **Current parameter set** drop-down menu.

- 2 Click **Auto-Calibrate Parameters** at the bottom of the window.

NOTE: This process may take several minutes. Your anti-virus software may show a warning regarding the file pest.exe. Allow that file to run – it is part of i-Tree Hydro. Reminder: You cannot run auto-calibration on non-gaged watersheds.

- 3 At this point, you can choose to skip any manual calibration of the model and go straight to the [Comparing the calibration results](#) section below. That will show you how the auto-calibration results from the Suggested Default Values compare to your observed streamflow. If you are not satisfied with the fit of the model for either parameter set, you can return to the instructions below to manually adjust some parameters and check the effects on the model.

To manually calibrate the model:

- 1 Select a parameter set from the **Current parameter set** drop-down menu on which to base your adjustments. Ready these parameters by clicking **Retain and Edit as NEW parameter set** and assigning a name in the window that appears. (Auto-calibrated parameters cannot be edited without first retaining as a new parameter set.)
- 2 Manually adjust the values of this new hydrological parameter set. If you want to adjust the more advanced parameter settings, check the **Advanced Settings** box. Ultimately, you can create different parameter sets for comparison purposes; you may decide to return to an older parameter set if subsequent sets prove unacceptable. Always remember to first click the **Retain and Edit as NEW parameter set** button before making adjustments.

NOTE: Detailed knowledge of hydrology is required to properly make use of the **Advanced Settings**. The option to adjust these settings is not available if you used the auto-calibrated parameters as the Current parameter set without first retaining as a new set.

- 3 Having too many parameter sets in your i-Tree Hydro project can slow down the modeling. You can delete a parameter set by selecting it from the **Current parameter set** drop-down menu and clicking **Delete THIS parameter set**.

Comparing the calibration results

i-Tree Hydro enables you to compare the results of the different parameter sets that you created using the auto- and manual calibration options.

- 1 Click **Compare Parameter Calibration Sets**.
- 2 In the window that appears, you will see the process running. It should only take a few minutes to run. Click **OK** when the top of the window reads **Model run complete!**
- 3 In the **Parameter Calibration Results** window, the CRF1, CRF2, and CRF3 values are a measure of how well the estimated flow matches the flow observed at the gaging station. With a very good fit, these CRF values will approach 1.0. The full range for all values is anywhere from negative infinity to 1.0, so negative values are not necessarily “bad.” Typically, “good” values range from 0.3 to 0.7, but higher values are better. A value of 0.0 means the model is no better than just using the observed average value to represent the observed data. In short, the calibration process is to maximize the NSE (CRF1) value.
- 4 To move on with your i-Tree Hydro project, be sure that the desired parameter set to run the model has been selected in the **Current parameter set** drop-down menu, and click **OK** to close the **Step 3) Hydrological Parameters** window.

Be sure to save your current project periodically.

Saving hydrological parameters for other i-Tree Hydro projects

Once you have calibrated your model to your satisfaction and entered all the necessary data, you have the option of saving all parameters, including **Step 3) Hydrological Parameters** (currently visible calibration values as well as advanced settings) and **Step 2) Land Cover Parameters**. This will allow you to use those same parameters in another project.

To save parameters for future use on a new i-Tree Hydro project, click **File > Save Hydrological Parameters**.

To start a new project using the saved parameters from a previous project, click **File > Build New with Hydrological Parameters**.

Entering the Alternative Case Parameters

One of the primary uses of i-Tree Hydro is to show how changes in the amount of tree canopy cover or changes in the surface cover (transforming impervious surface into herbaceous cover, for example) would affect the hydrology of your watershed. Up to this point, you have created a new project and defined the Base Case for your analysis area by entering your input data and calibrating your model.

Although optional, the next logical step would be to define an Alternative Case. If you run the i-Tree Hydro model without defining an Alternative Case, several outputs will not be available for viewing. If you try to open these outputs, you will be prompted to follow the steps below.

To model how different management scenarios affect a watershed's hydrology:

- 1 Go to **Step 4) Define Alternative Case**.
- 2 To define the Alternative Case that you wish to model, change the surface cover types, leaf area indexes, and/or cover types beneath tree cover. Make sure that the covers total 100%. Click **OK**.

NOTE: The current version of i-Tree Hydro will allow only one Alternative Case to be saved in the project at a time. If you wish to model several different scenarios, we suggest saving each as a new project, under **File > Save Project As**, and giving each scenario a different name – for example:

- Denver_IncreaseTreeCover30Percent.iHydro
- Denver_IncreaseTreeCover40Percent.iHydro

All variables, calibration settings, and inputs are saved with the project, so it is easy to open each one after saving.

Phase III: Exploring i-Tree Hydro Outputs

i-Tree Hydro offers a variety of graphs, tables, and other model outputs that allow you to take a closer look at the hydrology and water quality modeled for your study area. Once you have run your model, you can explore these to interpret your results.

NOTE: Several outputs will not be available for viewing if you ran the Hydro model without defining an Alternative Case. If you try to open these outputs, you will be prompted to set the values in the **4) Define Alternative Case** window. Refer to the last section of Phase II: Entering Model Parameters for more information about defining an Alternative Case.

Running the i-Tree Hydro Model

In Phases I and II, you described your project area and set up your Base Case hydrologic parameters, and possibly specified an alternative case. The final step in the process is to run the i-Tree Hydro model and view the results. Any changes to the Phase II inputs require the model to be run again in order to update the outputs.

To run the i-Tree Hydro model:

- 1 Open **Step 5) Run Hydro Model**. In the window that appears, you will see the process running. It should only take a few minutes to run. Click **OK** when the top of the window reads **Model run complete!**

Executive Summary

One of the outputs provided by i-Tree Hydro is the Executive Summary. To open that document, go to **Outputs > Executive Summary**.

The Executive Summary provides a broad overview of several model parameters, including the watershed area, total rainfall, total runoff, and land cover (for both the Base Case and Alternative Case, if defined). The table on the first page provides noteworthy streamflow predictions, such as highest flow, lowest flow, and average flow for the modeled Base Case and Alternative Case.

There are also several graphs included in the Executive Summary:

- 1 **Water Volume** – compares the total volume of observed discharge of the stream gage (supplied as an input) to the total volume of predicted streamflow of the Base Case (in cubic meters).
- 2 **Predicted Runoff Volume Components** – displays the breakdown of the predicted streamflow of the Base Case according to the three types of streamflow the model predicts: pervious flow, impervious flow, and baseflow.
- 3 **Pollutants: Base Case vs. Alternative Case** – displays the pollutant load (kg/month) of ten pollutants for the modeled watershed. The different pollutant loads are the predicted outputs for both the Base Case and Alternative Case.

Each output has a toolbar at the top of the window. In the Executive Summary toolbar, you will find the following tools:

- 1 **Print** – to print the output that you are viewing. When you click this tool, the **Print** window will appear. Select your printer name from the drop-down menu and click **OK**.
- 2 **Export** – to export the output that you are viewing and save it to your computer. Next to the **Export** button, you will see a drop-down menu with several format options.

Outputs in a report form can be exported in RDP or RTF format. The RTF format is compatible with Microsoft Office Word, which provides editing options.

Graphs and Tables

i-Tree Hydro produces multiple graphs and tables to display watershed hydrology. These hydrology charts can be used to contrast and compare the total volume, total flow, and streamflow components across the modeled time period. By observing the differences between the Base Case and Alternative Case, users can explore the effect of changes in land cover parameters.

i-Tree Hydro can also help clarify the impacts of changes in surface cover and vegetation on pollutant load in streams by making use of a statistical parameter known as event mean concentration (EMC) (see Appendix 3 for more information). An EMC value represents the flow-proportional average concentration of a given pollutant during a storm event and is measured in units of mass per volume, usually milligrams per liter. EMC can be multiplied by actual flow to estimate the mass of pollutants entering a body of water, such as grams per hour. Changes in flow owing to changes in cover and tree canopy will

therefore be reflected in changes in pollutant load. Below are the results that i-Tree Hydro presents.

NOTE: EMC values can be derived from many sources, including actual measured data from your watershed. Because such actual data are hard to come by, Hydro makes use of average national values. More information about the methods used to estimate these values can be found in [Appendix 3](#).

It is important to note that these are national values and therefore do not take into account local pollutant conditions and local management actions (such as street cleaning). Therefore, it is not certain how well the national EMC values will represent local conditions.

Water volume

The following Hydro outputs can be found under **Outputs > Water Volume**:

- 1 **Total Streamflow** – compares the total volume of observed discharge of the stream gage (supplied as an input) to the total volume of predicted streamflow of the Base Case (in cubic meters).
- 2 **Base Case Predicted Streamflow Components** – displays the breakdown of the predicted streamflow of the Base Case according to the three types of streamflow the model predicts: pervious flow, impervious flow, and baseflow.
- 3 **Base Case vs. Alternative Case Total Runoff** – compares the total volume of predicted discharge of the Base Case and Alternative Case, in cubic meters.
- 4 **Base Case vs. Alternative Case Predicted Streamflow Components** – compares the breakdown of the predicted streamflow of the Base Case and Alternative Case according to the three types of streamflow the model predicts: pervious flow, impervious flow, and baseflow.

Each of the water volume outputs has a toolbar at the top of the window, in which you will find the following tools:

- 1 **View** – to change the view of your model output. Next to the **View** label, you will see a drop-down menu with options to view All, By Month, or By Week.

The View All option means that you can see the total water volume for the entire modeled time period. If you choose to view your output By Month or By Week, then the total volume will be aggregated and displayed for each month or week,

respectively, of the modeled time period.

- 2 **Export** – to export the output that you are viewing and save it to your computer. Next to the **Export** button, you will see a drop-down menu with several format options.

Outputs in a graphic form can be exported as a JPG, GIF, or PNG image. Note that the exported image will be of the current view that is displayed on your screen. Graph legends are added automatically.

The water volume outputs are also customizable. Choose the colors for each bar by clicking on the colored box next to each component and then choosing your new color in the window that appears. To turn components on and off, click the check box next to the name. It may take a minute for the chart to update.

Pollution estimates

The following Hydro outputs can be found under **Outputs > Pollution Estimates**:

- 1 **Base Case** – displays the pollutant load (kg/unit of time) of ten pollutants for the modeled watershed. The different pollutant loads are the predicted outputs for the Base Case.
- 2 **Base Case vs. Alternative Case** – displays the pollutant load (kg/unit of time) of ten pollutants for the modeled watershed. The different pollutant loads are the predicted outputs for both the Base Case and Alternative Case.

Each of the pollution estimate outputs has a toolbar at the top of the window, in which you will find the following tools:

- 1 **View** – to change the view of your model output. Next to the **View** label, you will see a drop-down menu with options to view All, By Month, or By Week.

The View All option means that you can see the total pollution load (kg) for the modeled time period. If you choose to view your output By Month or By Week, then the pollution load will be aggregated and displayed for each month or week, respectively, of the modeled time period.

- 2 **Export** – to export the output that you are viewing and save it to your computer. Next to the **Export** button, you will see a drop-down menu with several format options.

Outputs in a graphic form can be exported as a JPG, GIF, or PNG image. Note that

the exported image will be of the current view that is displayed on your screen. Legends are added automatically.

The pollution estimate outputs are also customizable. Choose the colors for each bar by clicking on the colored box next to each component and then choosing your new color in the window that appears. To turn components on and off, click the check box next to the name. It may take a minute for the chart to update.

Water flow

The following Hydro outputs can be found under **Outputs > Water Flow**:

- 1 **Base Case** – displays the rainfall (mm/h) and total flow (m^3/h) for the modeled watershed. The rainfall values are the recorded measurements that were inputs to the model via the weather station data. The total flow is the predicted streamflow of the Base Case, including its components: baseflow, pervious flow, and impervious flow.
- 2 **Alternative Case** – displays the rainfall (mm/h) and total flow (m^3/h) for the modeled watershed. The rainfall values are the recorded measurements that were inputs to the model. The total flow is the predicted streamflow of the Alternative Case, including baseflow, pervious flow, and impervious flow.
- 3 **Base Case vs. Alternative Case** – displays the rainfall (mm/h) and compares the total flow (m^3/h) of both the Base Case and Alternative Case for the modeled watershed. The rainfall values are the recorded measurements that were inputs to the model. The total flow is displayed for the predicted streamflow of both the Base Case and Alternative Case, including baseflow, pervious flow, and impervious flow.
- 4 **Alternative Case - Base Case** – displays the rainfall (mm/h) and result of the predicted Alternate Case flows (m^3/h) minus the predicted Base Case flows (m^3/h) for the modeled watershed. The rainfall values are the recorded measurements that were inputs to the model. The results of subtracting the predicted Base Case flows from the predicted Alternative Case flows are displayed to demonstrate the increase or decrease in the flows (total and component) due to changes in land cover parameters.

All of the water flow graphs show rainfall on the top of the graph, with larger rainfall events stretching towards the bottom of the graph; the rainfall rates correspond to the graph's right-hand y-axis. Streamflow curves are on the bottom of the chart and are associated with the values on the left-hand y-axis. The x-axis represents time.

Each water flow output has a toolbar at the top of the window, in which you will find the following tools:

- 1 **Show All** – to return the graph view to full extent. For example, if you were to zoom in on a specific segment of the graph, **Show All** would be used to quickly zoom back out to display the graph in its entirety.
- 2 **Zoom In/Zoom Out** – to zoom in and out on specific segments of the graph and view the output in more detail. This is particularly useful as the full extent of the graph displays the entire modeled time period, oftentimes by month. Zooming in would allow you to view the water flow at a more specific time period, such as a day or week.
- 3 **Pan** – to move from side to side along the graph when zoomed in.
- 4 **Export** – to export the output that you are viewing and save it to your computer. Next to the **Export** button, you will see a drop-down menu with several format options.

Outputs in a graphic form can be exported as a JPG, GIF, or PNG image. Note that the exported image will be of the current view that is displayed on your screen. Legends are added automatically.

The water flow outputs are also customizable. Choose the colors for each line by clicking on the colored box next to each component and then choosing your new color in the window that appears. To turn components on and off, click the check box next to the name. It may take a minute for the chart to update.

You can also view the water flow outputs in a tabular format:

- 1 Click on the **Table** tab located above the toolbar. These tables present the data numerically on an hourly basis.
- 2 There are several tools available for the tables:
 - a **Export** – to export the output that you are viewing and save it to your computer. Next to the **Export** button, you will see a drop-down menu with several format options.

Outputs in a tabular form can be exported in Excel or comma-separated values (CSV). Both of these file types are compatible with Microsoft Office Excel, which provides relatively easy editing.

- b **Total by** – to change the view of your model output. In the **Total by** drop-

down menu, you can choose to display daily totals, weekly totals, monthly totals, or a total for the entire model run period (usually, but not always, one year).

Water pollution

The following Hydro outputs can be found under **Outputs > Water Pollution**:

- 1 **Base Case** – displays the rainfall (mm/h) and pollutant load (kg/h) of ten pollutants for the modeled watershed. The different pollutant loads are the predicted outputs for the Base Case.
- 2 **Alternative Case** – displays the rainfall (mm/h) and pollutant load (kg/h) of ten pollutants for the modeled watershed. The different pollutant loads are the predicted outputs for the Alternative Case.
- 3 **Alternative Case - Base Case** – displays the rainfall (mm/h) and change in pollutant load (kg/h) between the Base Case and Alternate Case for the modeled watershed. The rainfall values are the recorded measurements that were inputs to the model. The pollutants loads are the predicted model outputs for the Base Case and Alternative Case. Displaying the pollutant loads against the rainfall allows the user to observe how the pollutant load changes during and after a precipitation event. This graph enables a user to compare the pollutant loads of the current Base Case against the pollutant loads of an Alternative Case. Such a comparison allows for observation of the effects (positive or negative) on the pollutant load present in the total flow (discharge) associated with the proposed changes to tree cover, land cover, etc.

All of the water pollution graphs show rainfall on the top of the graph, with larger rainfall events stretching towards the bottom of the graph; the rainfall rates correspond to the graph's right-hand y-axis. Pollutant load measurements are on the bottom of the chart and are associated with the values on the left-hand y-axis. The x-axis represents time.

Each water pollution output has a toolbar at the top of the window, in which you will find the following tools:

- 1 **Show All** – to return the graph view to full extent. For example, if you were to zoom in on a specific segment of the graph, Show All would be used to quickly zoom back out to display the graph in its entirety.
- 2 **Zoom In/Zoom Out** – to zoom in and out on specific segments of the graph and view the output in more detail. This is particularly useful as the full extent of the graph displays the entire modeled time period, oftentimes by month. Zooming in

would allow you to view the pollutant load at a more specific time period, such as a day or week.

- 3 **Pan** – to move from side to side along the graph when zoomed in.
- 4 **Export** – to export the output that you are viewing and save it to your computer. Next to the **Export** button, you will see a drop-down menu with several format options.

Outputs in a graphic form can be exported as a JPG, GIF, or PNG image. Note that the exported image will be of the current view that is displayed on your screen. Legends are added automatically.

The water pollution outputs are also customizable. Choose the colors for each line by clicking on the colored box next to each component and then choosing your new color in the window that appears. To turn components on and off, click the check box next to the name. It may take a minute for the chart to update.

To view the water pollution outputs in a tabular format:

- 1 Click on the **Table** tab located above the toolbar. These tables present the data numerically on an hourly basis.
- 2 There are several tools available for the tables:
 - a **Export** – to export the output that you are viewing and save it to your computer. Next to the **Export** button, you will see a drop-down menu with several format options.

Outputs in a tabular form can be exported in Excel or comma-separated values (CSV). Both of these file types are compatible with Microsoft Office Excel, which provides relatively easy editing.

- b **Total by** – to change the view of your model output. In the **Total by** drop-down menu, you can choose to display daily totals, weekly totals, monthly totals, or a total for the entire model run period (usually, but not always, one year).

DEM 2D/3D Visualization

To view two-dimensional and three-dimensional representations of your Digital Elevation Model (DEM) go to **Outputs > DEM 2D/3D Visualization**. Given the Universal Transverse

Mercator (UTM) projection of the DEM data, the watershed may appear distorted. This option is not available for projects using a Topographic Index (TI) instead of a DEM.

When viewing the 3D simulation, press and hold the cursor in the viewing window while moving the cursor to change the view of your DEM.

In the toolbar located near the top of the window:

- 1 Use the **View** drop-down menu to toggle back and forth between the 2D and 3D views.
- 2 Click **Reset Orientation** to return to the default view of the DEM.
- 3 Use the **Export** tool to export the output that you are viewing and save it to your computer. Next to the **Export** button, you will see a drop-down menu with several format options.

Outputs in a graphic form can be exported as a JPG, GIF, or PNG image. Note that the exported image will be of the current view that is displayed on your screen.

Calibration Comparison

Calibrating the model is an important step. i-Tree Hydro allows you to test different parameter sets to see which will provide the best fit for your model.

The different calibration schemes can be displayed in graph form under **Outputs > Calibration Comparison**. In the window that appears, you will see the process running. It should only take a few minutes to run. Click **OK** when the top of the window reads **Model run complete!**

A window will open that displays your calibration comparison graph. In the upper left-hand corner, check or uncheck the calibration parameter sets that you would like to compare. The resulting graph shows rainfall at the top with rainfall values along the graph's right-hand y-axis. Measured total streamflow (from the stream gage station) and predicted total streamflow according to the different parameter sets are on the bottom of the chart and are associated with the values on the left-hand y-axis. The recorded measurements are displayed along with the results of different model runs using the weather data input and the chosen or calibrated watershed and hydrological parameters. The x-axis represents time.

Similar to other i-Tree Hydro outputs, the **Calibration Comparison** has a toolbar at the top of the window, in which you will find the following tools:

- 1 **Show All** – to return the graph view to full extent. For example, if you were to zoom in on a specific segment of the graph, **Show All** would be used to quickly zoom back out to display the graph in its entirety.
- 2 **Zoom In/Zoom Out** – to zoom in and out on specific segments of the graph and view the output in more detail. This is particularly useful as the full extent of the graph displays the entire modeled time period, oftentimes by month. Zooming in would allow you to view the pollutant load at a more specific time period, such as a day or week.
- 3 **Pan** – to move from side to side along the graph when the zoomed in.
- 4 **Export** – to export the output that you are viewing and save it to your computer. Next to the **Export** button, you will see a drop-down menu with several format options.

Outputs in a graphic form can be exported as a JPG, GIF, or PNG image. Note that the exported image will be of the current view that is displayed on your screen. Legends are added automatically.

Additional Information

Choosing Your Watershed and Gaging Station

If you pursue a watershed analysis instead of the Topographic Index (TI) option, then the first, and perhaps most difficult, decision you have to make is selecting a watershed to analyze. One challenge here is that many people are more accustomed to thinking in terms of political or parcel boundaries (e.g., a city or a university campus) and considering what impacts might result from changes within those areas. Hydrological modeling often occurs at the watershed level, which is unlikely to align with political or parcel boundaries.

A second challenge relates to the availability of data. i-Tree Hydro makes use of hourly stream gage data from the U.S. Geological Survey (USGS). Although there are many stream gage stations across the country, data are not available for every stream and its associated watershed.

A third challenge relates to scale. Gages are located in streams that capture water from watersheds of vastly different scales. A stream gage in a small creek might be associated with a watershed of a few square kilometers. A stream gage at the mouth of the Mississippi River would be associated with a watershed that includes half of the United States. Because changes in tree cover and impervious surface are unlikely to have measurable effects over the scale of a very large watershed, you need to analyze a watershed that is small enough to be influenced by changes in these factors.

With these limitations in mind, your goal in this first step is to choose the best stream gage station in your area of interest and estimate the boundaries of the associated watershed. You'll use these boundaries in conjunction with obtaining your digital elevation model data.

Tools for choosing the best stream gage station and watershed

The easiest method for visualizing stream gage stations and their associated watersheds is Google Earth. Begin by downloading the two files necessary:

- 1 At the EPA's Waters website (http://water.epa.gov/scitech/datait/tools/waters/tools/waters_kmz.cfm), download the WATERS Data 1.5(Vector).kmz file (or the most current version posted).

NOTE: Links were correct at time of publication but may have changed. If necessary, please use the EPA website's search box and relevant key words ("KMZ") to search for updated links.

- 2 From www.itreetools.org > Resources > Archives under the Hydro section,

download the zip file of the stream gage stations available in Hydro: i-Tree_Hydro_Gaging Stations_2005.

- 3 Open Google Earth on your computer (version 5.0 or higher) and open the two files. Zoom in to your area of interest (see Fig. 1).

A few hints: (1) The EPA Waters file is live – that is, it updates from the internet while you are using it. Therefore it can be very slow. You'll know it is gathering data when the little colored boxes next to the field names under Places are spinning. To speed things up, uncheck every box under Surfacewater Features, except Streams, and all boxes associated with Water Program Features, and zoom in to your area. (2) The streams are only visible at very local scales. If you can't see them, continue zooming in until the scale at the bottom of the map is approximately 1 inch = 3 miles. Remember to wait for the data to load.

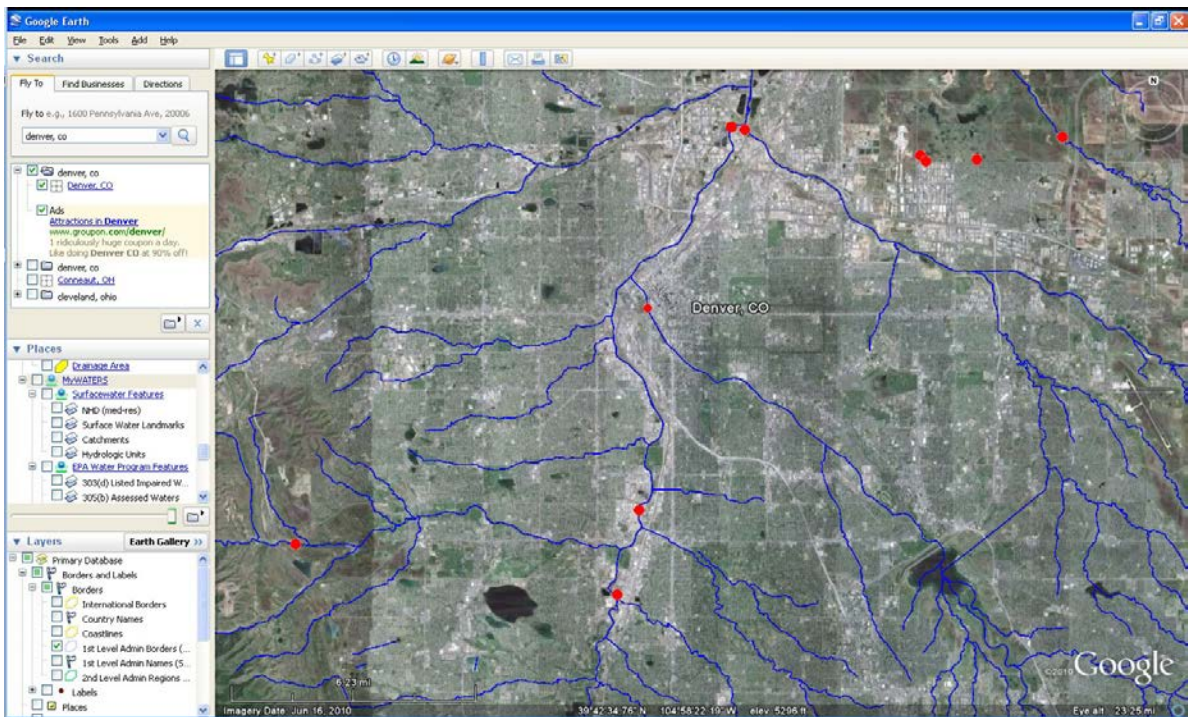


Fig. 1: Streams and stream gage stations around Denver

- 4 The next step is to explore the watersheds associated with each station to choose the best one. To do this:
 - a Click on the stream itself just downstream of the station. A window will appear describing the features of the stream. At the bottom, under **Tools**, click **Drainage Area Delineation**.
 - b In the window that appears, choose **Stop When: Maximum Distance (KM) = 30** and click **Start Search**. The watershed upstream from that point for

the first 30 km will be identified. You might have to repeat this process a few times, increasing the maximum distance to capture the entire watershed (see Fig. 2).

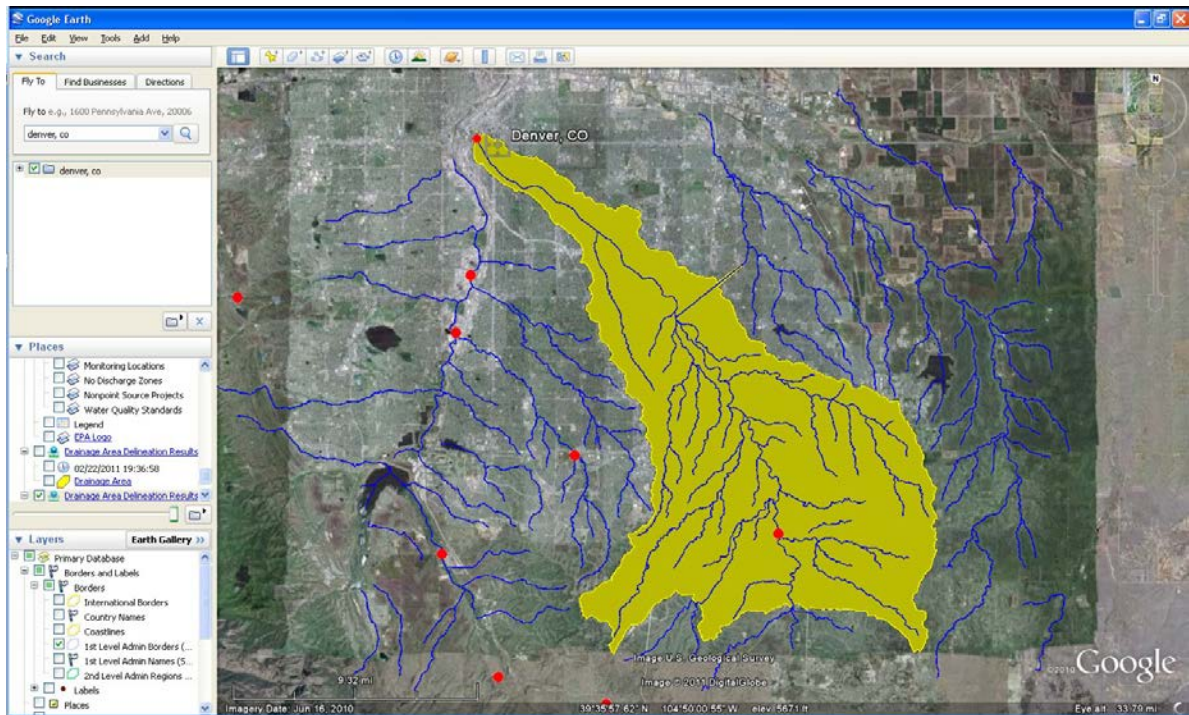


Fig. 2: A watershed near Denver

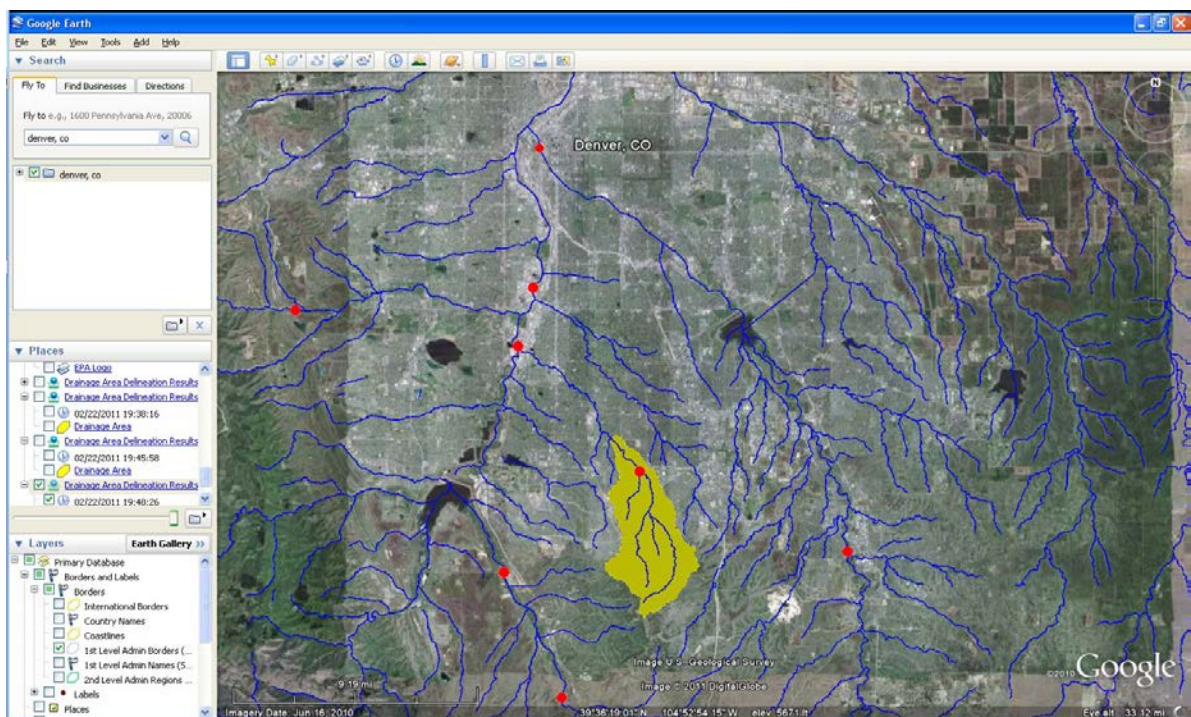


Fig. 3: A smaller watershed near Denver

- c Once you have determined the outline of the watershed, judge whether it is appropriate for your study.

Does it capture your area of interest?

Is the watershed of a scale that would be appropriate for modeling changes in canopy and impervious cover? (As explained above, if the watershed is very large, changes in cover are unlikely to have a measurable impact.)

- d Delineate the drainage areas for other stream gage stations until you have found the best one (see Fig. 3).

5 Once you have made your selection:

- a Note the name of the stream by clicking on the stream.
- b Note the ID number of the stream gage station (SITENO), by clicking on its red dot.
- c Capture an image of the stream gage station and watershed using your computer's **Print Screen** function or Google Earth's **File > Save > Save Image** function.

Gathering Data

Now that you have selected your watershed of interest and the appropriate stream gage, it is time to start gathering your input data. In *Phase I: Creating a New Project*, we described the general input data that is needed for a new project in i-Tree Hydro. The tables and directions below will assist you in collecting the data that you will need in order to run i-Tree Hydro, including some possible data sources or suggested default values.

Basic watershed characteristics

The following input data can be entered by going to **Step 1) Project Area Information**:

Table 1. Basic Watershed Characteristics

Category	Source ^a	Default value	Units
Watershed Land Area	DEM	N/A	km ² or mi ²
Percent Tree Cover	Eco , Canopy, UTC, GIS	N/A	%
Tree Leaf Area Index ^b	Eco , Canopy, UTC, GIS	5	none
Evergreen Tree Cover	Eco	10	%
Evergreen Shrub Cover	Eco	10	%
State Date/Time (Local)	N/A	N/A	mm/dd/yyyy hh:mm:ss
End Date/Time (Local)	N/A	N/A	mm/dd/yyyy hh:mm:ss

^a *DEM* = Digital Elevation Model data (see Appendix 1). *Eco* = An existing i-Tree Eco study; although it is unlikely that the Eco study area and the Hydro study area will align exactly, your Eco results might offer some insight. *Canopy* = i-Tree Canopy. Visit www.itreetools.org for more information on i-Tree Eco and i-Tree Canopy. *UTC* = An existing urban tree canopy analysis. *GIS* = Your local government or university GIS department.

^b Leaf area indexes (LAI) can be calculated from Eco results for leaf area, which are presented in units of m²/ha. Divide those results by 10,000, to get LAI.

Observed streamflow

Streamflow data are used in i-Tree Hydro to calibrate the model. Hydro tries to find the best fit between the streamflow predicted by the model and the streamflow measured at the stream gage station. However, stream gage availability varies and not every stream has a gage located on it.

Within i-Tree Hydro, hourly streamflow data are available as standardized, complete data sets. These data were obtained from the U.S. Geological Survey and pre-processed for 2005-2012. If you choose to use the available data, follow the steps provided in Phase I: Creating a New Project to choose your gage from a map. If you are interested in using data from a different year or you would like to use data for a gage that is not included in Hydro, then you have the option of using your own streamflow data.

Once you have obtained your streamflow data, it is very important that the data are properly formatted for use in i-Tree Hydro. Observed streamflow data must consist of the following fields:

Table 2. Observed Streamflow Data Fields

Field name ^a	Definition ^b	Units
site_no	site identification number	N/A
date_time	date and time of observation	YYYYMMDDhhmmss
tz_cd	time zone	N/A
dd	data descriptor	N/A
accuracy_cd	accuracy code	N/A
value	discharge	cfs
precision	digits of precision in the discharge	N/A
remark	optional remark code	N/A

^a Required fields include: date_time, tz_cd, and value. See note below.

^b For a list of accuracy codes and optional remark codes, see the example at **Resources > Archives > i-Tree Hydro (beta) Resources > i-Tree Hydro** at www.itreetools.org.

To make your data compatible with Hydro, the fields should be organized in tab-separated columns using the field names listed above and saved as an .rdb file. When streamflow data are properly formatted, you will be able to navigate to the folder in which you saved it and load it into the **1) Project Area Information** form as described in Phase I.

NOTE: Not all of the fields listed are used in i-Tree Hydro. If you cannot find certain information, the field name still needs to be included, but you can populate the column with dummy values. For example, i-Tree Hydro does not use the accuracy code, but due to formatting of the data, a placeholder value is needed to keep the application on track.

An example of correctly formatted streamflow data can be found at www.itreetools.org > Resources > Archives > i-Tree Hydro Resources.

Weather station

Weather station data are an important input because they are used to simulate the streamflow of your study area. When selecting your weather station be sure to select a station that is representative of your entire study area. Bear in mind that precipitation events may be highly localized, so there may be times when it is raining in the watershed but not at the weather station or vice versa. For that reason, it can be difficult to choose the best weather station and may mean that you have to try several different options.

Within i-Tree Hydro, hourly weather and evapotranspiration data are available as standardized, complete data sets. These data are obtained from the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC) and pre-processed for 2005-2012. If you choose to use the available data, then follow the steps provided in [Phase I: Creating a New Project](#) to choose your station from a map. If you are interested in using data from a different year or you would like to use data from a weather station that is not included in Hydro, then you have the option of using your own weather station data.

Required weather data include wind direction and speed, cloud ceiling, sky cover, temperature, dewpoint, altimeter setting, pressure, and precipitation. Once you have obtained your weather station data, it is very important that the data are properly formatted for use in i-Tree Hydro. Weather station data must consist of the following fields:

Table 3. Weather Station Data Fields

Field name ^a	Definition ^b	Units
USAF	Air Force catalog station number	N/A
WBAN	NCDC WBAN number	N/A
YR--MODAHRMN	year-month-day-hour-minute in GMT	YYYYMMDDhhmm
DIR	wind direction in compass degrees	N/A
SPD	wind speed	mph
GUS	wind gust	mph
CLG	cloud ceiling – lowest opaque layer with 5/8 or greater coverage	hundreds of ft
SKC	sky cover (clr-clear, sct-scattered [1/8 - 4/8], bkn-broken [5/8 - 7/8], ovc-overcast, obs-obscurated, pob-partial obscuration)	N/A
L	low cloud type	N/A
M	middle cloud type	N/A
H	high cloud type	N/A
VSF	visibility in statute	mi (nearest tenth)
WW WW WW ^b	present weather	N/A
W ^b	past weather indicator	N/A
TEMP	temperature	°F
DEWP	dewpoint	°F

SLP	sea level pressure	mbar (nearest tenth)
ALT	altimeter setting	in (nearest hundredth)
STP	station pressure	mbar (nearest tenth)
MAX	maximum temperature	°F
MIN	minimum temperature	°F
PCP01	1-hour liquid precipitation	in (nearest hundredth)
PCP06	6-hour liquid precipitation	in (nearest hundredth)
PCP24	24-hour liquid precipitation	in (nearest hundredth)
PCPXX	liquid precipitation for a period other than 1, 6, or 24 hours	in (nearest hundredth)
SD	snow depth	in

^a Required fields include: date_time, tz_cd, and value. See note below.

^b For weather code tables, go to **Resources > Archives > i-Tree Hydro (beta) Resources > i-Tree Hydro weather abbreviation codes** at www.itreetools.org.

To make your data compatible with Hydro, the fields should be organized in tab-separated columns using the field names listed above and saved as an .rdb file. When your weather station data are properly formatted, you will be able to navigate to the folder in which you saved it and load it into the **1) Project Area Information** form as described in Phase I.

NOTE: Not all of the fields listed are used in i-Tree Hydro. If you cannot find that information, the field name still needs to be included, but you can populate the column with dummy values. For example, i-Tree Hydro does not use the altimeter setting, but due to formatting of the data, a placeholder value is needed to keep the application on track.

An example of correctly formatted weather station data can be found at www.itreetools.org > Resources > Archives > i-Tree Hydro Resources.

Digital Elevation Model (DEM)

Once you have identified your target watershed and noted the stream name and stream gage station number, your next step is to create a Digital Elevation Model (DEM) of the watershed. The end product should be a DEM clipped to the boundaries of your watershed, projected in the proper Universal Transverse Mercator (UTM) coordinate zone in meters, and converted to ASCII computer code format.

For more specifics on this process, see Appendix 1.

Topographic Index (TI)

The Topographic Index (TI) data were derived from DEM data within various polygon boundaries. So if you opt to use a Topographic Index (TI), you can skip creating a DEM for your watershed. In addition, going the TI route will enable you to pick project areas that have boundaries other than actual watersheds, such as a city or college campus. i-Tree Hydro contains a TI histogram database based on USGS calculations, with tables for States, Counties, Places, gaged Watershed Basins, and HUC8 watersheds. In each table there is a minimum and maximum topographic index value and a count of the number of pixels in the area of interest. The B1 - B30 fields contain the proportion of the pixels in the area of interest that fall within that histogram bin.

For a brief overview on how the TIs were constructed, see [Appendix 2](#).

Land cover parameters

The following input data can be entered by going to **Step > 2) Land Cover Parameters**:

Table 4. Land Cover Parameters

Category	Source^a	Default value	Units
Surface Cover Types (should total 100%)			
Tree Cover	Eco , Canopy, UTC, GIS	N/A	%
Shrub Cover	Eco , Canopy, UTC, GIS	12.3	%
Herbaceous Cover	Eco , Canopy, UTC, GIS	N/A	%
Water Cover	Eco , Canopy, UTC, GIS	N/A	%
Impervious Cover	Eco , Canopy, UTC, GIS	N/A	%
Soil Cover	Eco , Canopy, UTC, GIS	N/A	%
Tree Leaf Area Index ^b	Eco, Literature	5.0	none
Shrub Leaf Area Index ^b	Eco, Literature	2.2	none
Herbaceous Leaf Area Index ^b	Eco, Literature	1.6	none
Directly Connected Impervious Cover ^c	GIS	40	%

Cover Types Beneath Trees (should total 100%)

Pervious Cover	Eco	N/A	%
Impervious Cover	Eco	6.1	%

^a *DEM* = Digital Elevation Model data (see Appendix 1). *Eco* = An existing i-Tree Eco study; although it is unlikely that the Eco study area and the Hydro study area will align exactly, your Eco results might offer some insight. *Canopy* = i-Tree Canopy. Visit www.itreetools.org for more information on i-Tree Eco and i-Tree Canopy. *UTC* = An existing urban tree canopy analysis. *GIS* = Your local government or university GIS department. *Literature* = Some data may be available for certain locations in the scientific literature or from the appropriate university department.

^b Leaf area indexes (LAI) can be calculated from Eco results for leaf area, which are presented in units of m²/ha. Divide those results by 10,000, to get LAI.

^c This value can be particularly difficult to find. One strategy is to adjust the value in the calibration process until the model streamflow resembles the observed streamflow; see Calibrating the Model to learn more.

Calibrating the Model Manually

Calibrating the model involves a multi-step process of adjusting model parameters until the modeled streamflow closely resembles the actual streamflow. The model simulates various hydrologic processes (e.g., precipitation, interception, infiltration, evaporation, transpiration, snowmelt, flow routing, and storage) in order to simulate streamflow at the gaging station. It then checks the accuracy of the simulation by comparing estimated model flow against actual flow. Results are considered in terms of peak, base, and overall flow.

i-Tree Hydro features an auto-calibration routine that uses the observed streamflow data from a gaging station to identify the optimal hydrological parameters to fit the observed streamflow data. If you are not satisfied with the fit of the model, you can adjust some parameters to see the effects on the model. See Table 5 below for ranges of possible values.

Ideally, you create a few parameter sets for comparison and can select one to run the model. However, having too many parameter sets saved can slow down the modeling. You can delete a parameter set by selecting it from the **Current parameter set** drop-down menu and clicking **Delete THIS parameter set**.

Table 5. Hydrological Parameters

Category	Range	Default value	Units
Annual Average Flow at Gaging Station	N/A	0.000016	cms
Soil type	N/A	N/A	N/A

Wetting Front Suction	0.03 – 0.4	0.12	m
Wetted Moisture Content	0.1 – 0.7	0.48	m
Surface Hydraulic Conductivity	0.0001 – 0.3	0.002	cm/h
Depth of Root Zone		0.5	m
Initial Soil Saturation Condition		50	%
Advanced Settings			
Leaf Transition Period (days)	N/A	28	N/A
Leaf-on Day (day of year, 1 - 365)	N/A	defaults are regionally specific	N/A
Leaf-off Day (day of year, 1 - 365)	N/A	defaults are regionally specific	N/A
Tree Bark Area Index	N/A	1.7	N/A
Shrub Bark Area Index	N/A	0.5	N/A
Leaf Storage	N/A	0.2	mm
Pervious Depression Storage	0.1 – 7.5	1.0	mm
Impervious Depression Storage	0.1 – 300	2.5	mm
Scale Parameter of Power Function	1 – 2	2	none
Scale Parameter of Soil Transmissivity	0.01 – 0.05	0.023	m
Transmissivity at Saturation	0.0005 – 100	0.13	m ² /h
Unsaturated Zone Time Delay	0.01 – 150	10	h
Time Constant for Subsurface Flow: B)	0.01 – 0.240	1.3	h
Time Constant for Surface Flow: Alpha	0.01 – 0.240	1	h
Time Constant for Surface Flow: Beta	0.01 – 0.240	2	h
Watershed area where rainfall rate can exceed infiltration rate	0 – 100	30	%

Appendix 1: Creating a Watershed Digital Elevation Model

In the *Additional Information* section, we discussed criteria for choosing a watershed and some tools for doing so. This Appendix covers the steps necessary to create a Digital Elevation Model (DEM) of that watershed using ArcGIS. These instructions assume that you are familiar with DEM data, watershed concepts, and ArcGIS tools.

The basic steps of this procedure are as follows:

- 1 Download DEM data from the USGS for an area that covers the watershed boundaries you determined in the *Additional Information* section.
- 2 Use ArcGIS to build a DEM from the downloaded data and clip it to the borders of the watershed.

Tools

ArcGIS (v. 9.3.1. was used for this guide, but other versions can be used)

ArcGIS Spatial Analyst

Results

The end product of the steps described here will be a DEM clipped to the boundaries of your watershed, projected in the proper UTM zone in meters, and converted to ASCII format.

Downloading DEM Data from USGS

With your watershed and stream gage selected using the methods described in *Phase I: Creating a New Project*, the first step in creating a DEM is to download the necessary data from the USGS. If you have your own source of DEM data, it can certainly be used, but keep in mind that DEM data should have a resolution of 10–30 m. Finer resolution data are available, but are more likely to cause complications in modeling associated with bridges and elevated roadways.

- 1 Navigate to the USGS DEM website: <http://viewer.nationalmap.gov/viewer/>.

NOTE: Links were correct at the time of publication but may have changed. If necessary, please use Google and the relevant key words to search for the correct

links.

- 2 Display the **Overlays** tab on the left-hand side of the screen to manage visible layers to help with orientation. (These choices do not affect which data are downloaded.) The following are recommended:
 - a Under the Base Data Layers, turn on Hydrography.
 - b Under the Base Data Layers, expand Governmental Unit Boundaries. Expand Features. Uncheck all of the boxes except County or Equivalent and State or Territory.
- 3 Use the tools to zoom in or out and pan to your region.
- 4 Click on **Download Data** to choose the data that you want to download.
- 5 In the **Download options** window, choose **Click here** to define the area that you want to download or choose a reference area from the pull-down menu. Now, comparing the image you saved from Google Earth of the streams in your region and your watershed of choice (Fig. 4), select an area of coverage that extends comfortably beyond the boundaries of your watershed (Fig. 5).
- 6 In the **USGS Available Data for download** window, check the box for Elevation then select **Next**.
- 7 Choose the National Elevation Dataset (1/3 arc second) in ArcGrid format then select **Next**.

NOTE: It is much better to overestimate the size of your watershed when downloading the DEM data than to underestimate because if you miss even a small corner of the watershed you will have to begin again. On the other hand, the larger your download size, the longer it will take and the more likely it is to “time out,” forcing you to begin again, so don’t go overboard.

- 8 When you are satisfied with the dataset(s) that you have selected, click the **Checkout** button in the panel on the left. Enter your email address as directed and **Place Order**.
- 9 When you receive your order email, select the download link. Depending on the size of your download, this request may take some time or require you to download your order in several parts.

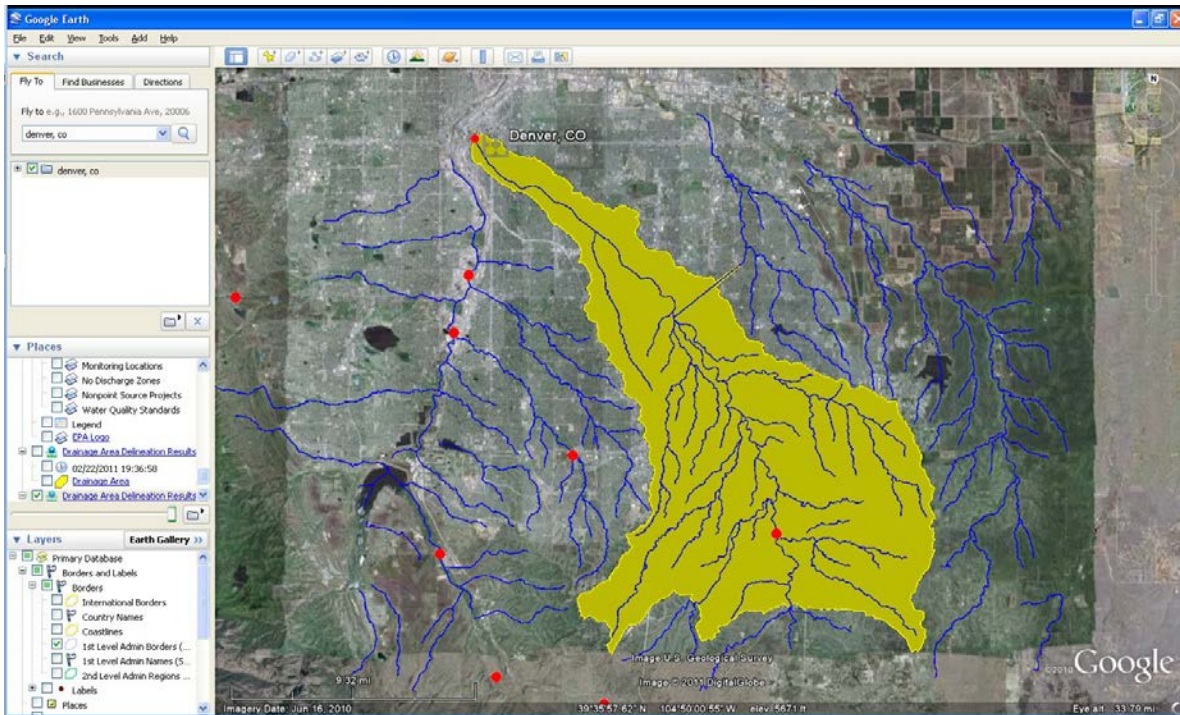


Fig. 4: Watershed boundaries determined using Google Earth, EPA stream file, and Hydro stream gage file.

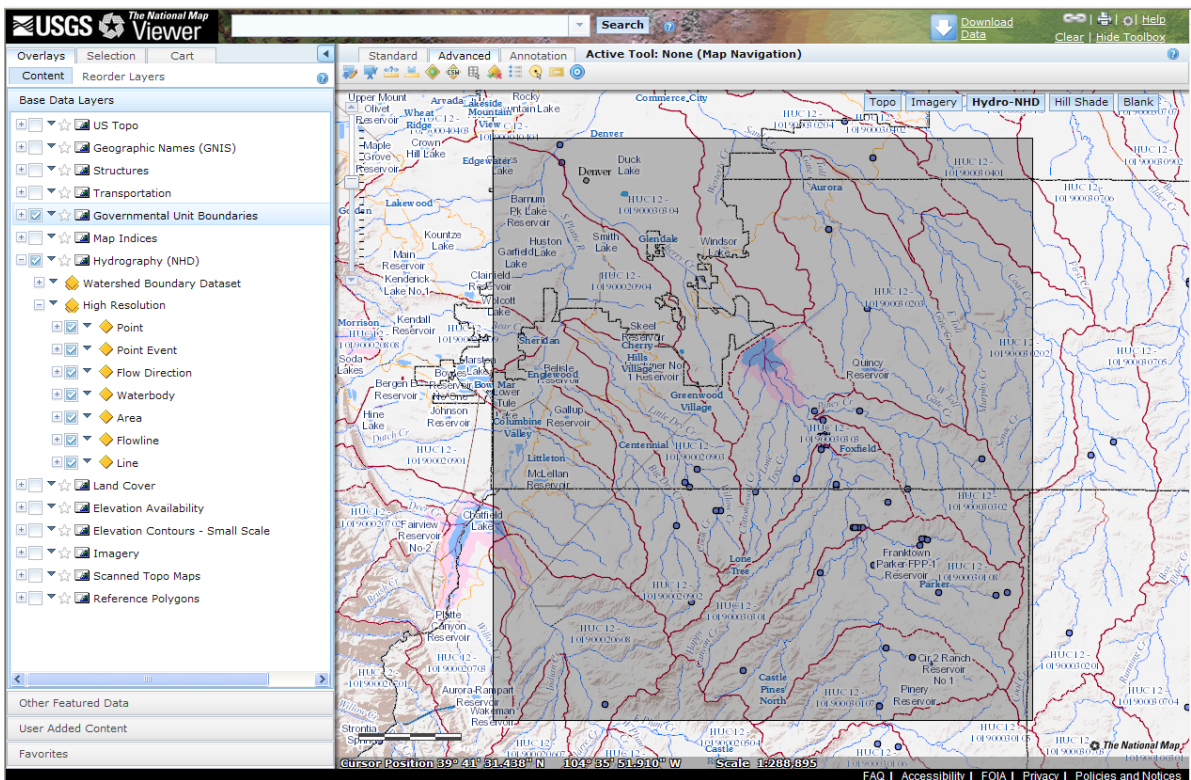
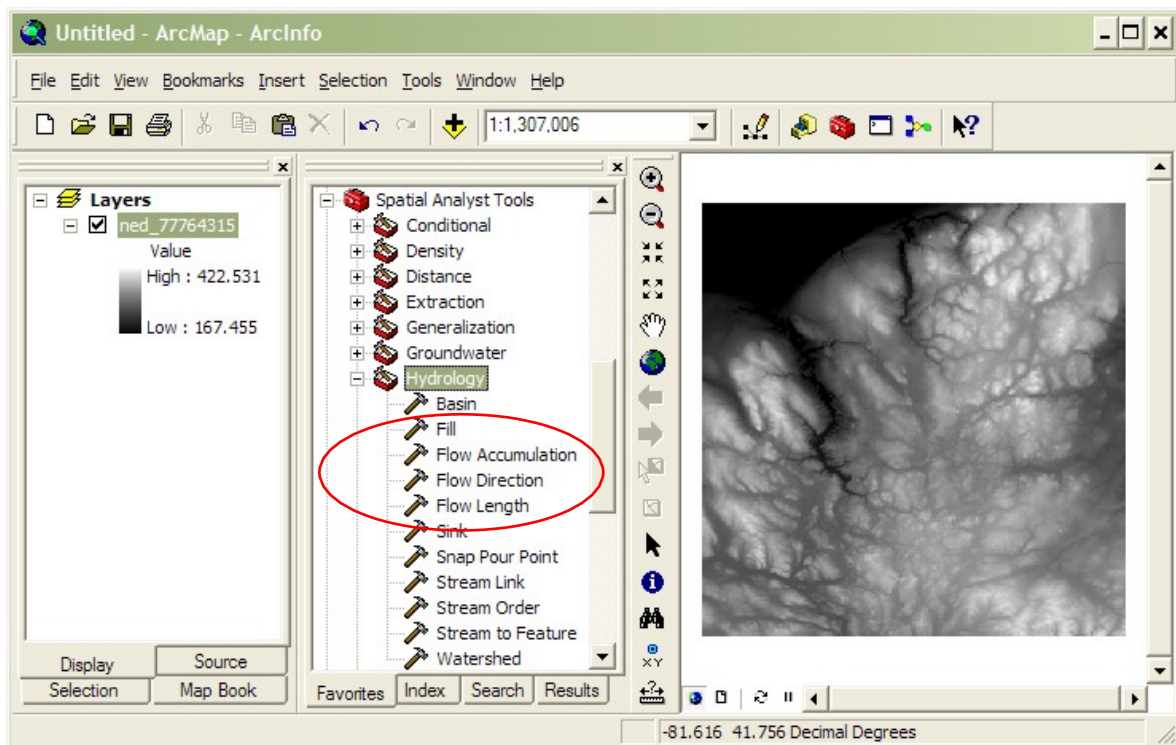


Fig. 5: The same stream system. The outlined area includes all of the yellow area in the figure above.

Working with ArcGIS

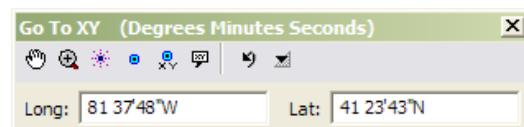
Once you have your data downloaded and unzipped, you can begin the process of transforming it into a hydrological model and clipping it in ArcGIS. You'll need to load and enable the ArcGIS Spatial Analyst Hydrology Tools.

- 1 Open the DEM data in ArcMap. Important: Do not set any projection information at this time.
- 2 Open ArcToolBox and navigate to **Spatial Analyst Tools > Hydrology**.

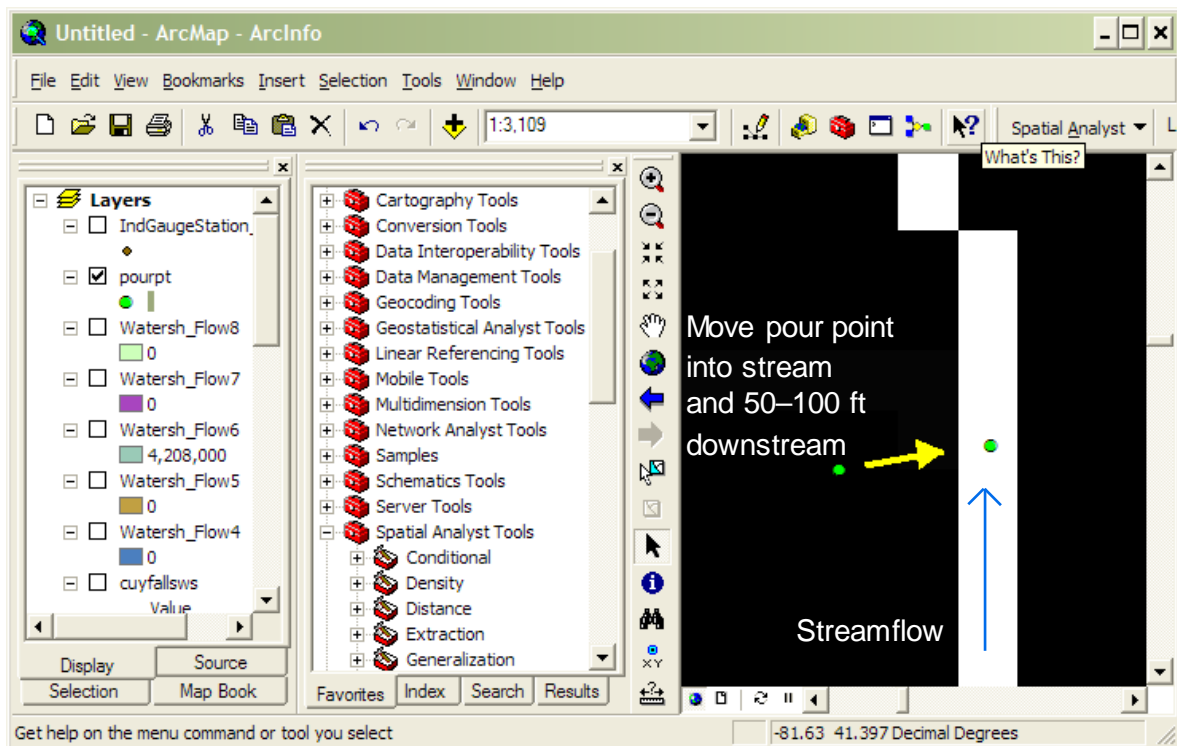


- 3 First choose the option to fill the DEM model, using the **Fill** tool.
- 4 Next, compute flow direction on the filled DEM layer (from Step 3) using the **Flow Direction** tool.
- 5 Next, compute flow accumulation on the flow direction layer (from Step 4) using the **Flow Accumulation** tool.
- 6 Create a "pour point" for the watershed based on the location of your stream gage station.

- a On the ArcGIS **Tools** toolbar, select the **Go To XY** tool.



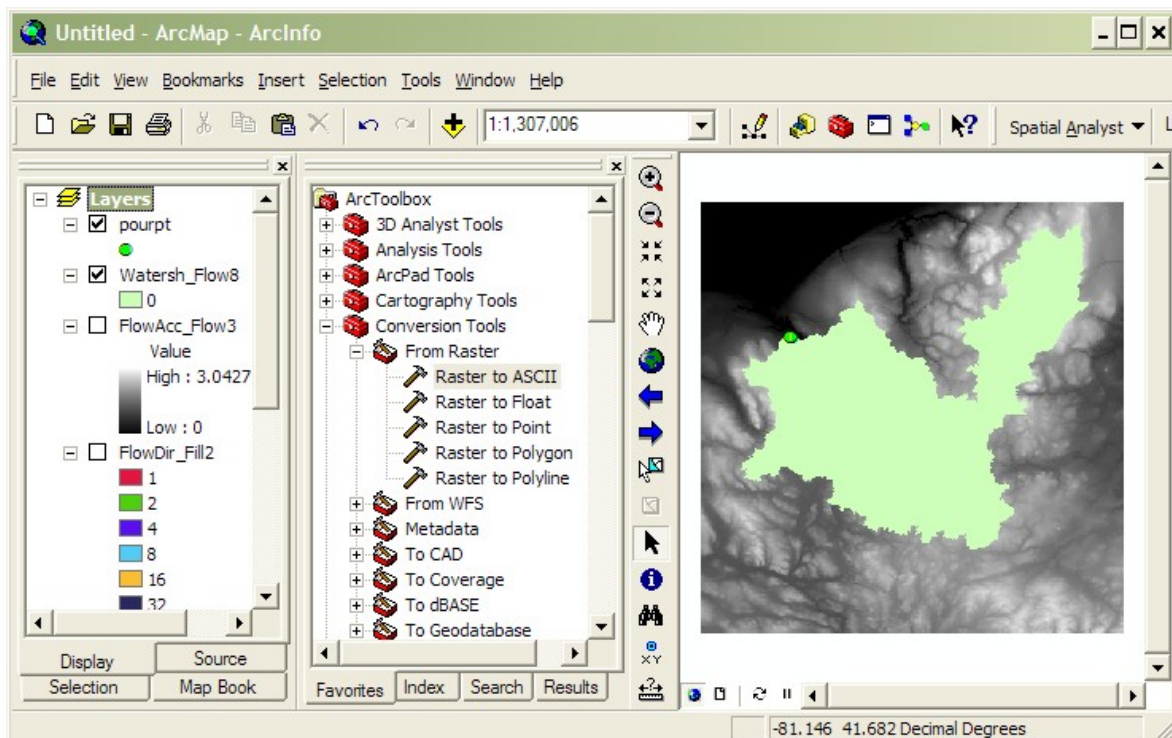
- b Enter the degrees, minutes, and seconds of your stream gage station in the following format: Long: 81 37'48"W Lat: 41 23'43"N. (Use a space in place of the degree symbol, use single quotes for minutes, double quotes for seconds, and direction letters rather than negative signs.)
- c Select the **Add Point** button to place a marker on the stream gage location/ watershed pour point.
- d Because of the mechanics of creating a DEM, it is unlikely that your stream gage marker will line up exactly with the stream created by the DEM. Drag the point so that it sits within the primary outlet stream of your watershed. The distance should be fairly small and the move obvious. If not, verify that you have entered the coordinates correctly. Now, drag the pour point slightly downstream ~50–100 feet to simplify later steps.



7 Capture this pour point within a shapefile.

- a In ArcCatalog create a new POINT shapefile.
- b Set the projection system to that of the original DEM data projection system via the **Create New Shapefile > Spatial Reference > Edit > Import > Browse** to DEM data option.

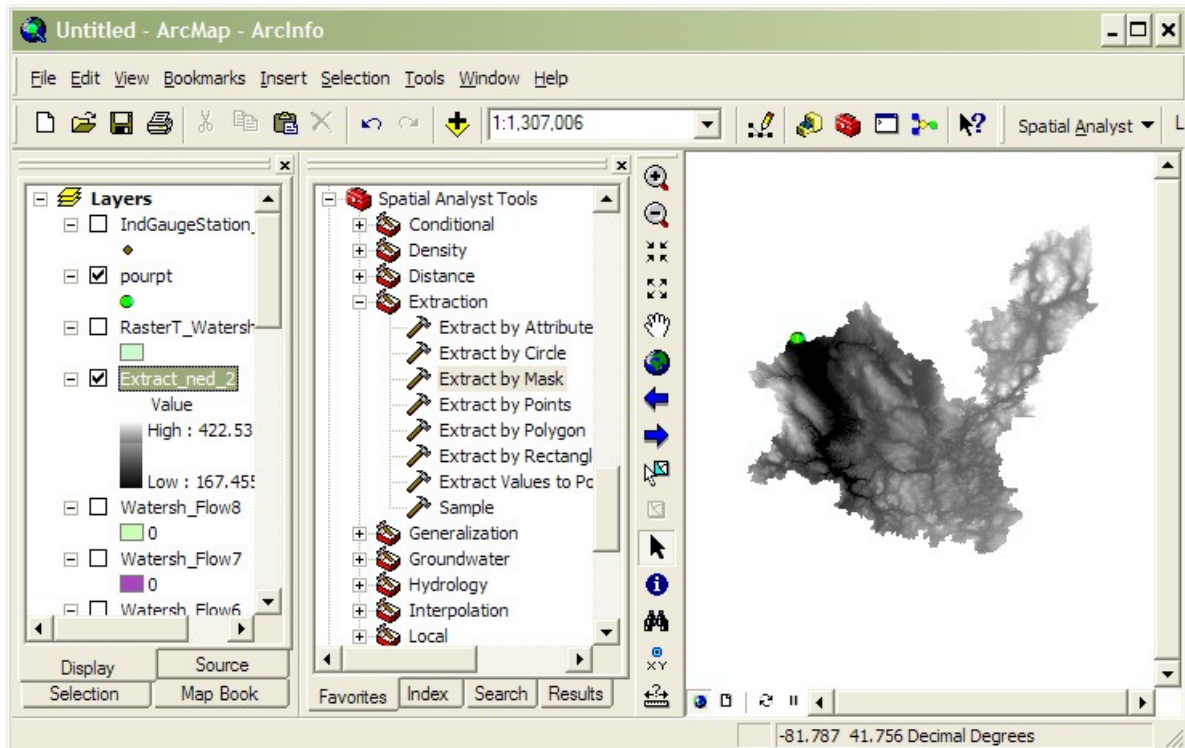
- c Open the pour point shapefile in the current ArcMap session.
 - d Edit the pour point shapefile and create a new point feature right on top of the Pour Point marker. Stop editing and save edits.
- 8 Compute the watershed using the flow direction layer (created in Step 4) and the pour point layer (created in Step 7), using the **Watershed** tool (not the Basins tool).
- a For the pour point field, choose any of the numeric fields. (While the on-screen instructions indicate that this is optional, it is not.)
- 9 Compare the resulting image of the computed watershed with the image of your watershed that you found in the Additional Information section. If they are not similar:
- a Try moving the pour point another 50–100 ft downstream and repeat Step 8.
 - b Verify that the spatial extent of the original downloaded DEM data covers the entire watershed. If it does not, you'll need to do another download and perform these steps again.



- 10 Convert the derived watershed raster layer (from Step 8) into a polygon using **ArcToolbox > Conversion Tools > From Raster > Raster to Polygon**.

- 11 Clip the *original DEM* (Step 1) with the converted watershed polygon (from Step 10) using **ArcToolbox > Spatial Analyst Tools > Extraction > Extract by Mask**.

NOTE: This is not the same process as ArcToolbox > Analysis Tools > Extract > Clip.



- 12 Re-project the clipped DEM (from Step 11) to UTM meters using **ArcToolbox > Data Management Tools > Projections and Transformations > Raster > Project Raster**.

- a The UTM zone is dependent on the project area. For UTM zones guidance: <http://egsc.usgs.gov/isb/pubs/factsheets/fs07701.html>
- b Output coordinate system should be: WGS_1984 datum
- c Geographic transformation should be: NAD_1983_TO_WGS_1984_1
- d Leave other values as defaults.

- 13 To calculate the area of the watershed, re-project the converted watershed layer (from step 10) following the directions from step 12. Select **Open Attribute Table**. Use the table tools to add a new field for area, then right-click on the added field and select **Calculate Geometry**. Select Area and square kilometers.

- 14 Export the clipped, re-projected DEM (from step 13) to ASCII format using **ArcToolBox > Conversion Tools > From Raster > Raster to ASCII**.
- 15 In Windows Explorer, change the file type extension of the ASCII file (from Step 14) from .TXT to .DAT for use within i-Tree Hydro.

Appendix 2: Topographic Index Data

A Topographic Index (TI) is constructed using a 30-meter DEM as follows:

- 1 TI approximates spatial distribution of the depth to water table. It is calculated using the following formula:

$$TI = \ln(a/\tan B)$$

where:

a= specific catchment area defined = (# of upslope cells + 1) * grid cell length

$\tan B$ = slope gradient defined as the rise over run along the steepest path from the cell center to its neighbor

- 2 This dataset was generated using a 30-meter resampled DEM. Output dataset was 100-meter resolution.

TI Histograms were generated in ESRI's ArcGIS with the following input datasets: Topographic Index Raster, Zone Boundary Files (State, County, Place, gaged and HUC8 watersheds), and NHD high-res water bodies.

- 1 The High Resolution National Hydrography Dataset water bodies dataset was used to erase all portions of the zone boundary within a water body that crosses the outline of the zone boundary. This was only done for States, Counties and Places.
- 2 ArcGIS SpatialAnalyst Tools >Zonal>Tabulate Area was run to compute the cross-tabulated area between the Topographic Index dataset and the zones in the area of interest boundary file (State, County, Place, gaged, and HUC8). This process outputs a table containing a record for each location with fields containing the total area of each pixel value.
- 3 ArcGIS SpatialAnalyst Tools >Zonal>Zonal Statistics As Table was run to summarize the values (max, min, sum) of the TI raster within the zones of the boundary file (State, County, Place, gaged, and HUC8).
- 4 The range of TI values in each zone was split into 30 bins (or histogram classes) and the number of pixels in each bin is calculated.

Appendix 3: Calculating Pollution Load

The term “event mean concentration” (EMC) is a statistical parameter used to represent the flow-proportional average concentration of a given parameter during a storm event. It is defined as the total constituent mass divided by the total runoff volume, although EMC estimates are usually obtained from a flow-weighted composite of concentration samples taken during a storm. Mathematically (Sansalone and Buchberger, 1997; Charbeneau and Barretti, 1998):

$$EMC = \bar{C} = \frac{M}{V} = \frac{\int C(t)Q(t)dt}{\int Q(t)dt} \approx \frac{\sum C(t)Q(t)\Delta t}{\sum Q(t)\Delta t}$$

where $C(t)$ and $Q(t)$ are the time-variable concentration and flow measured during the runoff event, and M and V are pollutant mass and runoff volume as defined in Equation 1. It is clear that the EMC results from a flow-weighted average, not simply a time average of the concentration. EMC data is used for estimating pollutant loading into watersheds. EMCs are reported as a mass of pollutant per unit volume of water (usually mg/l).

The pollution load (L) calculation from the EMC method is

$$L = EMC * Q = EMC * d_v * A$$

where EMC is event mean concentration (mg/l, mg/m³, ...), Q is runoff of a time period associated with EMC (l/h, m³/day...), d_v is runoff depth of unit area (mm/h, m/h, m/day...), and A is the land area (m², ...), which is catchment area in i-Tree Hydro.

Thus, when the EMC is multiplied by the runoff volume, an estimate of the loading to the receiving water is provided. As is evident from Fig. 6, the instantaneous concentration during a storm can be higher or lower than the EMC, but the use of the EMC as an event characterization replaces the actual time variation of C versus t in a storm with a pulse of constant concentration having equal mass and duration as the actual event. This process ensures that mass loadings from storms will be correctly represented. EMCs represent the concentration of a specific pollutant contained in stormwater runoff coming from a particular land use type or from the whole watershed. Under most circumstances, the EMC provides the most useful means for quantifying the level of pollution resulting from a runoff event (USEPA, 2002).

Since collecting the data necessary for calculating site-specific EMCs can be cost-prohibitive, researchers or regulators will often use values that are already available in the literature. If site-specific numbers are not available, regional or national averages can be

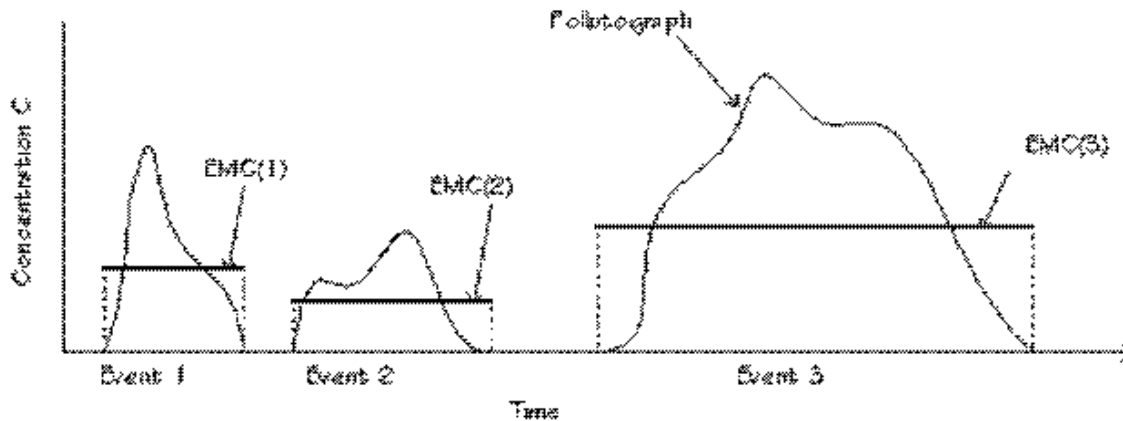


Fig. 6. Interstorm variation in pollutographs and EMCs.

used, although the accuracy of using these numbers is questionable. Due to the specific climatological and physiographic characteristics of individual watersheds, agricultural and urban land uses can exhibit a wide range of variability in nutrient export (Beaulac and Reckhow 1982).

To understand and control urban runoff pollution, the U.S. Congress included the establishment of the Nationwide Urban Runoff Program (NURP) in the 1977 Amendments of the Clean Water Act (PL 95-217). The U.S. Environmental Protection Agency developed the NURP to expand the state knowledge of urban runoff pollution by applying research projects and instituting data collection in selected urban areas throughout the country.

In 1983, the U.S. Environmental Protection Agency published the results of the NURP, which nationally characterizes urban runoff for 10 standard water quality pollutants, based on data from 2,300 station-storms at 81 urban sites in 28 metropolitan areas.

Two important conclusions from NURP investigations:

- The variance of the EMCs when data from sites are grouped by land use type or geographic region is so great that difference in measures of central tendency among groups statistically are not significant;
- Statistically, the entire sample of EMCs, and the medians of all EMCs among sites, are lognormally distributed.

Thus the numbers in Table 6 do not distinguish between different urban land use types. Subsequently, the USGS created another urban stormwater runoff base (Driver et al. 1985), based on data measured through mid-1980s for over 1,100 stations at 97 urban sites located in 21 metropolitan areas. Additionally, many major cities in the United States

collected urban runoff quality data as part of the application requirements for stormwater discharge permits under the National Pollutant Discharge Elimination System (NPDES). The NPDES data are from over 30 cities and more than 800 station-storms for over 150 parameters (Smullen et al, 1999).

The data from the three sources (NURP, USGS, and NPDES) were used to compute new estimates of EMC population means and medians for the 10 pollutants with many more degrees of freedom than were available to the NURP investigators (Smullen et al, 1999). A “pooled” mean was calculated representing the mean of the total population of sample data. The NURP and pooled mean EMCs for the 10 constituents are listed in Table 6 (Smullen et al, 1999). NURP or pooled mean EMCs were selected because they are based on field data collected from thousands of storm events. These estimates are based on nationwide data, however, so they do not account for regional variation in soil types, climate, and other factors.

Table 6. National Pooled EMCs and NURP EMCs

Constituent	Data source ^a	EMCs		No. of events
		Mean	Median	
Total suspended solids: TSS	Pooled	78.4	54.5	3047
	NURP	17.4	113	2000
Biochemical oxygen demand: BOD ₅	Pooled ^b	14.1	11.5	1035
	NURP	10.4	8.39	474
Chemical oxygen demand: COD	Pooled	52.8	44.7	2639
	NURP	66.1	55	1538
Total phosphorus: TP	Pooled	0.315	0.259	3094
	NURP	0.337	0.266	1902
Soluble phosphorus: soluble P	Pooled ^c	0.129	0.103	1091
	NURP	0.1	0.078	767
Total Kjeldhal nitrogen: TKN	Pooled	1.73	1.47	2693
	NURP	1.67	1.41	1601
Nitrite and nitrate: NO ₂ and NO ₃	Pooled	0.658	0.533	2016
	NURP	0.837	0.666	1234
Copper: Cu	Pooled	13.5	11.1	1657
	NURP	66.6	54.8	849

Lead: Pb	Pooled	67.5	50.7	2713
	NURP	175	131	1579
Zinc: Zn	Pooled	162	129	2234
	NURP	176	140	1281

^a Pooled data sources include: NURP, USGS, NPDES

^b No BOD₅ data available in the USGS dataset; pooled includes NURP+NPDES

^c No TS data available in NPDES dataset; pooled includes NURP+USGS

For i-Tree Hydro, the pooled median and mean EMC value for each pollutant (Table 6) were applied to the runoff regenerated from pervious and impervious surface flow, not the baseflow values, to estimate effects on pollutant load across the entire modeling time frame.

All rain events are treated equally using the EMC value, which means some events may be overestimated and others underestimated. In addition, local management actions (e.g., street sweeping) can affect these values. However, across the entire season, if the EMC value is representative of the watershed, the estimate of cumulative effects on water quality should be relatively accurate. Accuracy of pollution estimates will be increased by using locally derived coefficients. It is not known how well the national EMC values represent local conditions.

Appendix 4: International Support

We recognize that users outside of the United States may wish to experiment with i-Tree Hydro. It should be noted that the application and model have been built with specific U.S. data in mind. Users in other countries will need to find and format appropriate data to meet the requirements of i-Tree Hydro. This can be a difficult process; please review the following suggestions for guidance. Please also periodically visit the online forums at forums.itreetools.org to see if other users have posted additional information. Additional support for users outside the U.S. may be added in future versions of i-Tree Hydro.

- 1 A DEM file should be created for the project watershed with GIS software. See Appendix 1 for more information.
- 2 The user should select a U.S. location similar to the project location based on latitude and elevation.
- 3 Weather data is required with the following fields:
 - DIR (wind direction)
 - SPD (wind speed in mph)
 - CLG (cloud ceiling – lowest opaque layer with 5/8 or greater coverage, in hundreds of feet)
 - SKC (sky cover)
 - TEMP (temperature in Fahrenheit)
 - DEWP (dew point in Fahrenheit)
 - STP (station pressure in millibars; can be converted from ALT) or
 - ALT (altimeter setting in inches; can be converted to STP)
 - PCP01 (hourly precipitation in inches and hundredths)

The weather file must be a fixed-width text file. The model will interpolate gaps in the data, though they should be kept under 72 hours. This data should be in GMT.

Example:

```
USAF WBAN YR--MODAHRMN DIR SPD GUS CLG SKC L M H VSB WW WW WW W TEMP DEWP SLP ALT STP MAX MIN PCP01 PCP06
PCP24 PCPXX SD
724666 99999 200701010053 150 5 *** 722 SCT * ** 10.0 ** ** ** 18 5 1029.3 30.18 ***** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** **
724666 99999 200701010153 170 7 *** 722 SCT * ** 10.0 ** ** ** 18 3 1029.4 30.18 ***** ** ** **^**^**^**^**^**^**^**^**^**
```

- 4 Stream gage data* is required if the user wants to calibrate the model. The file must be tab-delimited and contain headers similar to the U.S. data.

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