VOLUME 4.

hydrobid

STEP BY STEP GUIDE

HydroBID Series: Technical Information

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The present volume is part of the "HydroBID: Technical Information" series from the Inter-American Development Bank. HydroBID is a simulation tool created by the Inter-American Development Bank (IDB) to support Latin America and the Caribbean regions in the planning and management of water resources. The publications in this series are intended to present the technical characteristics of the model, including the calculation modules of the tool, the analytical hydrographic database for Latin America and the Caribbean (LAC AHD) as well as the manuals and reference guides for its implementation. Volume 4 presents the step by step manual of HydroBID with the idea of facilitating the learning process in the use of the model and the Analytical Hydrographic Database for Latin America and the Caribbean (LAC-AHD). The instructions found in this manual are supported by the material distributed in the installation package of HydroBID and are based on the simplified case study of the Una River basin in the state of Pernambuco, Brazil. This material can be downloaded from the Code for Development page of the Inter-American Development Bank (code.iadb.org).

Table of Contents

Introduction

The following manual has been prepared in order to facilitate the learning process in the use of the HydroBID model and the Analytical Hydrographic Database for Latin America and the Caribbean (*LAC-AHD*). The instructions below are supported by the material distributed in HydroBID's installation package which is based on the simplified case study of Una River basin in the state of Pernambuco, Brazil.

By following the instructions you should be able to understand how to set up a simulation in HydroBID, how to proceed for the interpolation of climate data, how to calibrate the model and how to visualize the results obtained.

The technical information relating to the model and the LAC-AHD database can be obtained by downloading the technical notes from our website.

The necessary support material for the development of the processes described in this guide are available through the following link: https://code.iadb.org/es/repositorio/12/hydro-bid

Links to Technical Notes:

- Hydro-BID: An Integrated System for Modeling impacts of Climate Change on Water Resources
- Analytical Hydrology Dataset for LAC
- Hydro-BID: New Functionalities (Reservoir, Sediment and Groundwater Simulation Modules

I. Installation

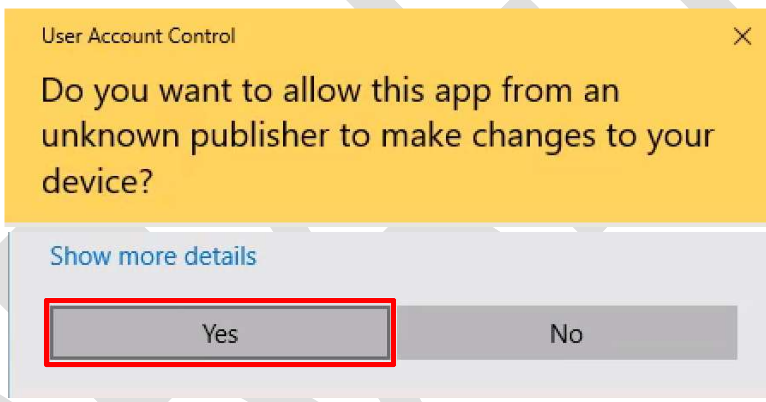
A. How to Install HydroBID Supporting Software?

In this chapter you will find a tutorial of how to install and verify the installation of the HydroBID 3.0 Setup executable, which will automatically install QGIS, SQLite and Java software, necessary components of the model, as well as the HydroBID 3.0 resource folder.

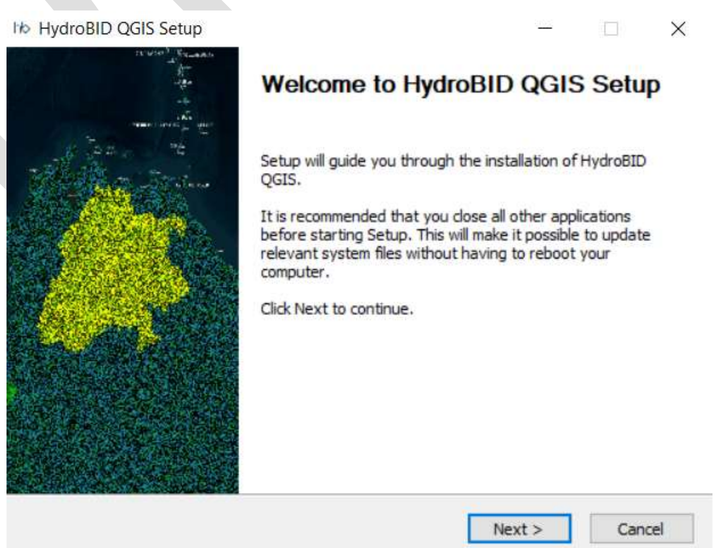
Note: this Installer only works for Windows computers. If you would like to install on a Mac computer, please contact HydroBID Support to learn how to use the AHD tool.

1. Click on the HydroBID 3.0 Setup executable
   HydroBID3.0_Setup.exe

2. Press "**Run**" on executable. Note: some computer security systems will not recognize the installer; however, the installer is safe. If the prompt appears "Do you want to allow this app from an unknown publisher to make changes to your device?", click "**Yes**"



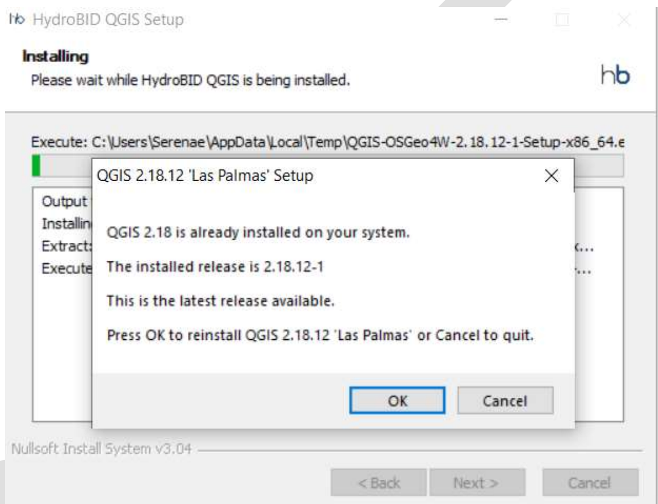
3. The HydroBID Setup Window will now appear. Click '**Next**'



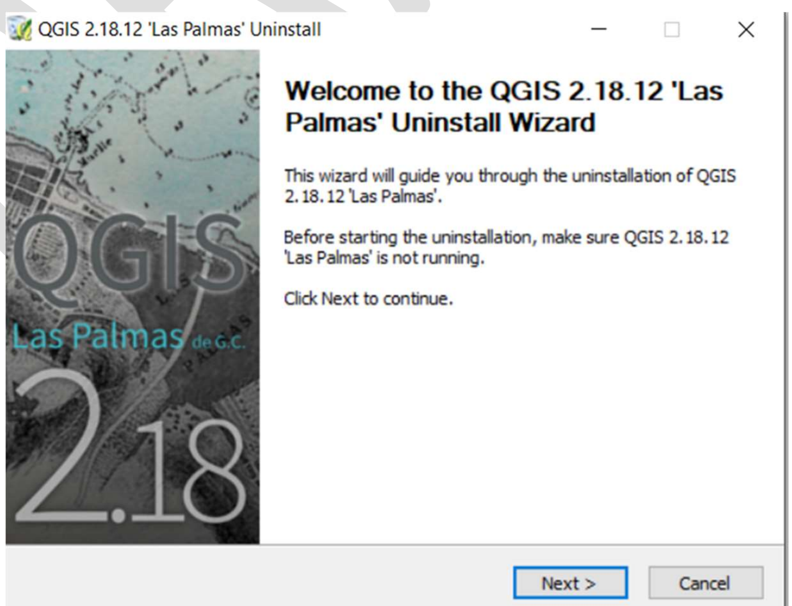
4. Click “I Agree” in response to the license agreement.

5. The installation process will now begin. Throughout the installation process the screen might ask permission to install or re-install the versions of QGIS and SQLIte necessary to run the model, click **‘OK’** when prompted. Note: if you have another version of QGIS already installed on your computer, you will be able to keep both versions.

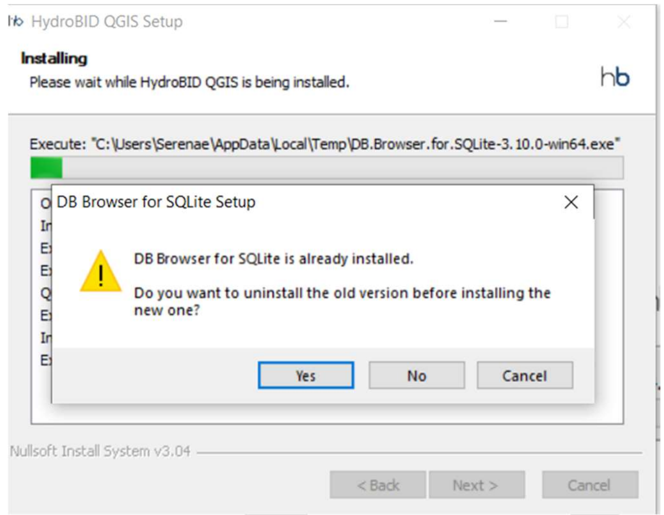
6. If prompted, click **‘OK’** to begin the reinstallation process of QGIS 2.18 and proceed through the Uninstall Wizard.



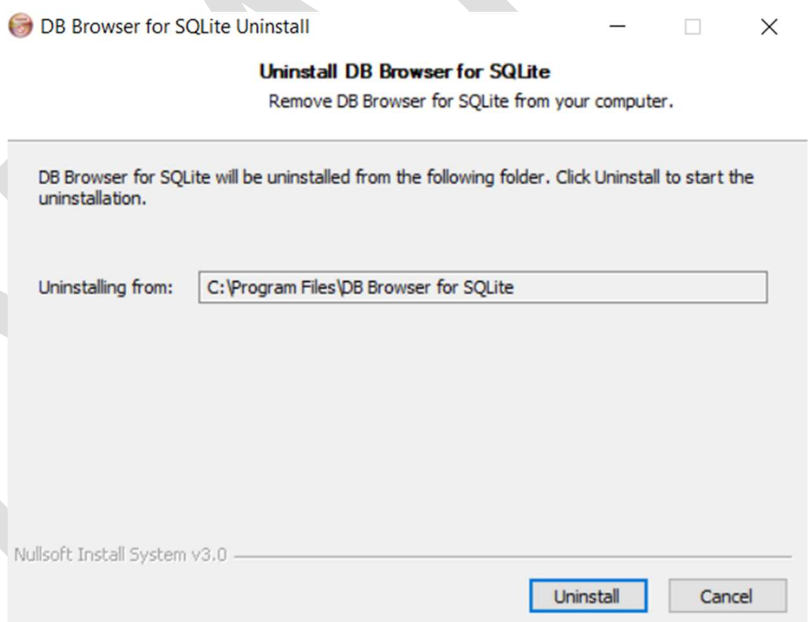
7. Proceed through the uninstallation wizard, click ‘**Uninstall**’ when prompted and **‘Finish’** to close the wizard and proceed with the installation process.



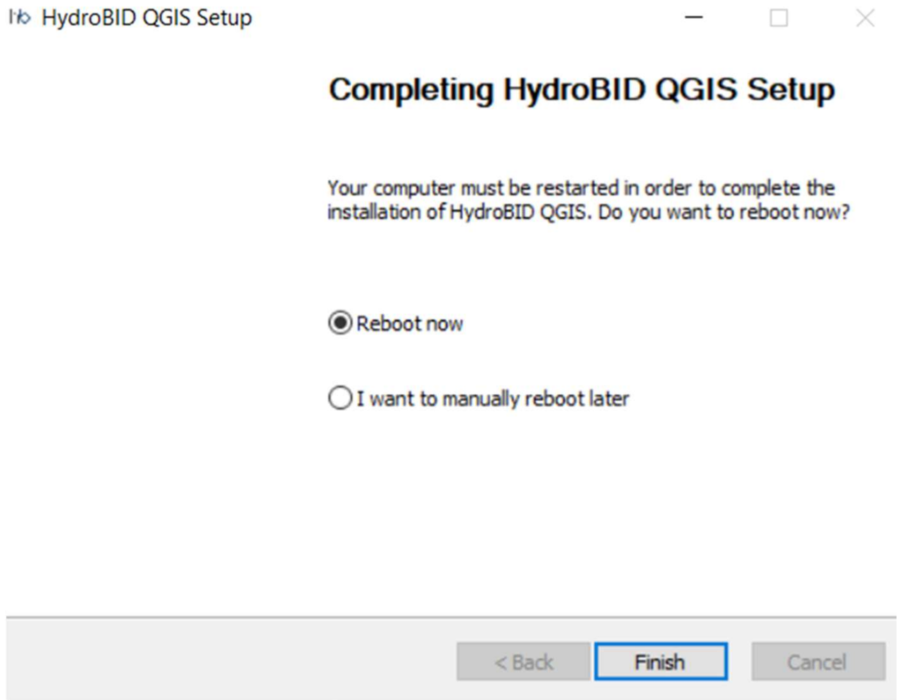
8. If the prompt appears to uninstall the previous DB Browser for SQLite, click **'Yes'**



9. Click **'un-install'** and then **'close'** when the process is complete. Then, wait for the installation process to complete.



10. Then, a screen will appear indicating the installation has finished and the computer needs to reboot. If you are ready to reboot now, choose the Reboot Now option and click **'Finish'**. Please restart our computer before verifying the installation was successful.



11. After restarting your computer, verify that the following programs have been installed:
    a. QGIS 2.18 "Las Palmas" (search for the program in the **Search** bar of your computer toolbar)
        i. Note: The AHD Tools should also be installed during the installation process. The successful installation of this tool will be verified during the subsequent step, Step 2. How to install the navigation AHD-Tool plug-in
    b. SQLIte browser (search for SQLite Browser using the '**Search**' Bar on your computer toolbar)
    c. **HydroBID 3.0** Resource Folder in **'Documents'**

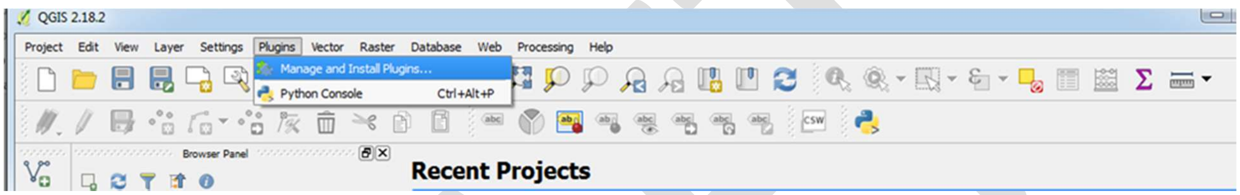
12. If upon verifying the installed programs and documents, there is an element missing, try re-installing. Note: as there are prompts throughout the installation process, the computer should remain on (be sure the computer doesn't enter "sleep" mode and the user should not leave during installation.

B. How to install the navigation AHD-Tool plug-in

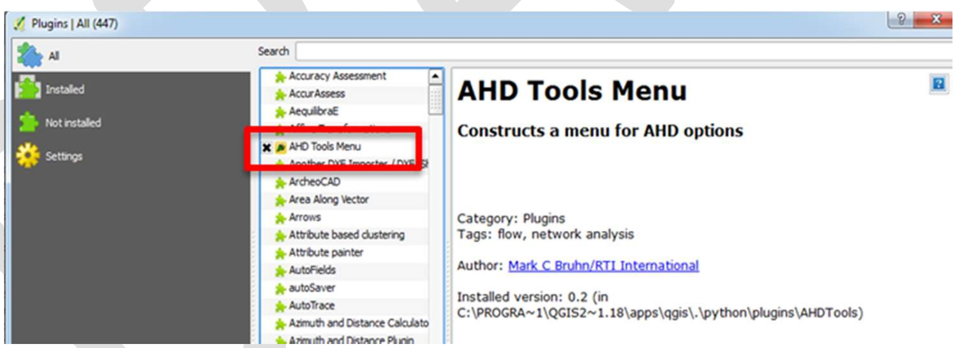
1. After the installation process is finished please verify that the AHD Tool is installer and active on your QGIS 2.18. Note: this must be done in QGIS 2.18; this will not work on any other version of QGIS installed on your computer.

2. To install the AHD Tool plug-in in QGIS 2.18, first open QGIS 2.18 and follow the subsequent steps.

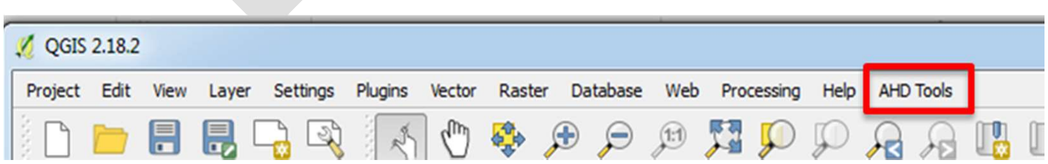
3. In QGIS select **'Plugins'** and then **'Manage and Install Plugins'**



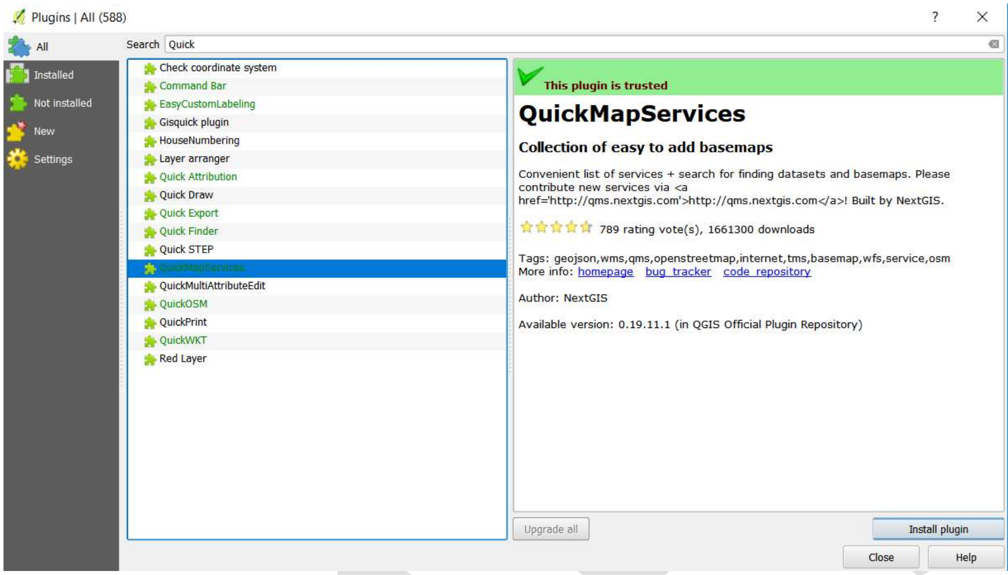
4. Browse and click on **'AHD Tools Menu'** to install the AHD Tool. Note: if this plug-in does not appear, there was a problem with the installation. Try restarting your computer or re-installing the software.



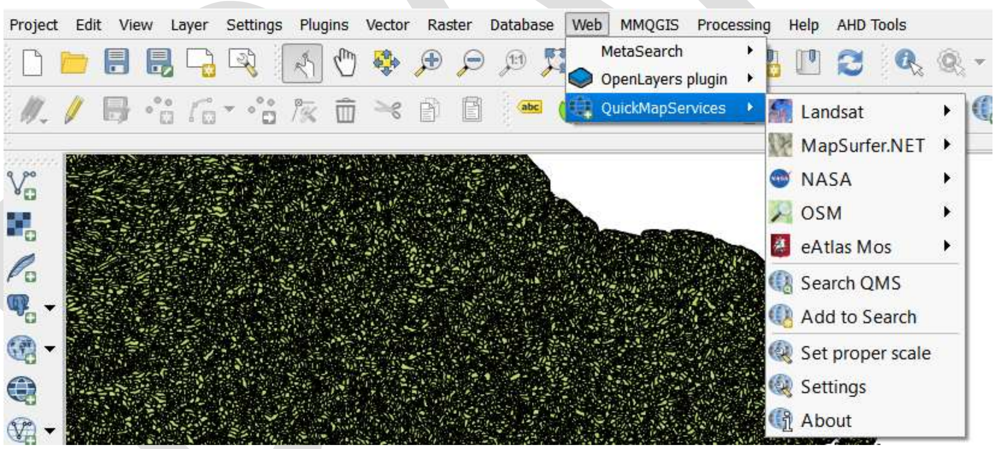
5. Now, the AHD tool will be visible on the toolbar.



6. Now, we will install Quick Maps using a similar process. Follow the instructions from Step 2 to search for **’QuickMapServices‘** within **’All‘** Plug-Ins. Click on the plug-in to access a wide variety of basemaps. Once the plug-in is highlighted, click **‘Install’**.

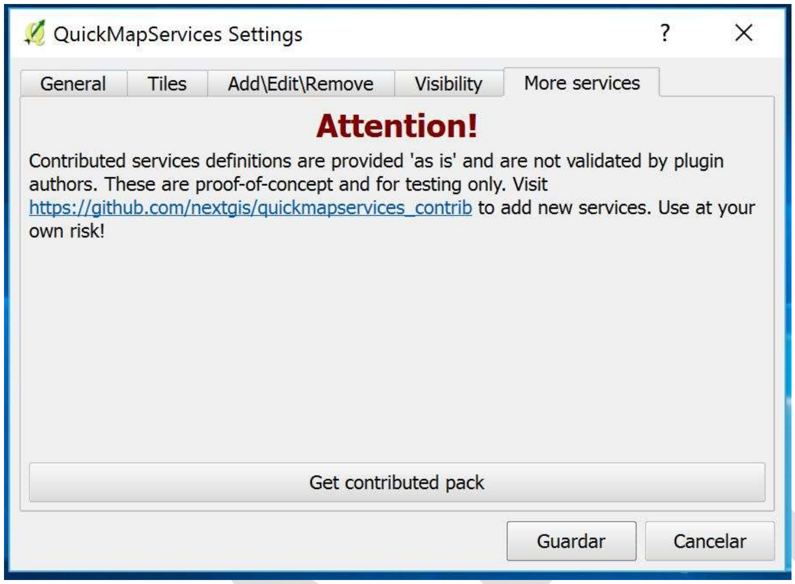


7. QuickMapServices Plugin will appear on the **’Web‘** tab of the toolbar and all the support imaging options will appear on the displayable menu



8. Once you select the map type by clicking on it, the map will be automatically loaded into the project

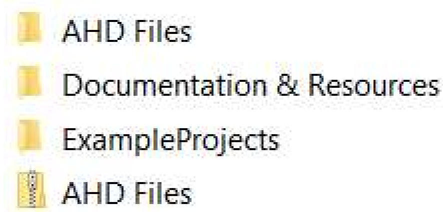
9. Once installed, navigate to the plug-in's menu options, select **'Settings'**, go to the **'More Services'** tab and click on **'Get contributed pack'** to access the Google mapping tools.



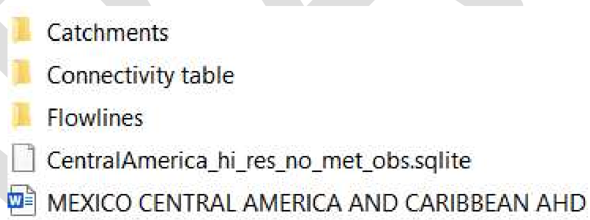
C. Organization of the HydroBID 3.0 Resource Folder

In addition to the installation of QGIS and AHD Tools detailed in Chapters A and B, a Resource folder containing supporting materials is automatically installed in the "Documents" folder on your PC, named "**HydroBID 3.0".**

The **HydroBID 3.0** folder contains 3 sub-folders: **AHD Files, Documentation & Resources, and Example Projects**



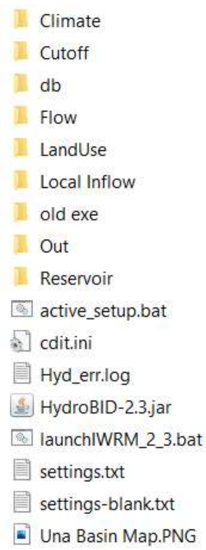
You will notice that the AHD Files folder is zipped. First, right click on the zipped folder, and click 'Extract all', being sure to extract to the HydroBID 3.0 folder. Once unzipped, in the **AHD Files** sub-folder you will find the hydrology dataset for Latin America and the Caribbean (AHD-LAC) divided into two sub-regions: Central America and the Caribbean, and South America. Within each of these sub-regions, you will find the following:



- **Catchments** (shp file comprising all of the sub-region's subwatersheds)
- **Connectivity table** (table with the connectivities between catchments and streams)
- **Flowlines** (shp file with the delineation of streamlines)
- **CentralAmerica…..sqlite** (sqlite database for Central America)
- **MEXICO…word** (word file describing AHD properties)

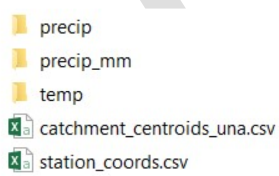
The South America AHD folder contains similar files organized in an identical format which are specific to the sub-region.

In the sub-folder, Example Projects, you will find the example **HydroBID Una** for the Una River Basin (or Río Una) in the State of Pernambuco, Brazil, which contains sub-folders with shapefiles, data files and the executable file[1].



The structure of the internal sub-folders is as follows:

1. **"Climate" folder**: This folder contains the climate data and location of weather stations and catchment centroids, and presents the following structure



- **precip** is the folder that contains precipitation historical data
- **temp** is the folder containing temperature historical data
- **catchment_centroids_una.csv** is the file with the coordinates of the catchment centroids
- **stations_coords.csv** is the file with the coordinates of the weather stations

Note: files in **precip** and **temp** folders should correspond to the same stations and must match in name.

The files are comma separated values "csv” with the following structure:

precip

[1] Folder and data file names can be changed by the user without affecting the simulations

Header	**Date**	**Precip_cm** or **Precip_mm**
Format/units	DD/MM/YYYY	cm or mm

Note: the column headers for precipitation must be exact (either Precip_cm or Precip_mm).

temp		
Header	**Date**	**Temp**
Format/units	DD/MM/YYYY	Celsius

Catchment_centroids_una.csv			
Header	**Centroid_x**	**Centroid_y**	**COMID**
Format/units	degrees	degrees	Catchment Identifier

COMID: is the identifier number unique to each catchment in the AHD-LAC.

Stations_coords.csv			
Header	Name	Lat_deg	Long_deg
Format/units	Station name	rad	rad

2. **"db" folder**: This folder contains the database with the parameters of the catchments.

   You will find the database with the Una catchment parameters in SQLITE format.

   una.sqlite

   -

3. **"Flow" folder:** This folder contains the flow data required for the calibration of the model.

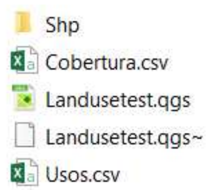
The files are comma separated values "csv" with the following structure:

FlowStation.csv		
Header	Date_format	Flow
Format/units	DD/MM/YYYY	m^3/s

4. **GIS Folder**: The folder contains the following files relating to the AHD for the case study Río Una for use in GIS:
   - **Rio Una Example.qgs** (project with the catchments in QGIS)
   - **Rio Una_Catchments** (shp file with the delineation of catchments)

- **Rio Una_Streamline** (shp file with the delineation of streamlines)
- **AHDFlow.dbf** (table with the connectivities between catchments and streams)
- **Climate stations** (vector shp file with the locations of weather stations)
- **Flow stations** (vector shp file with the locations of the hydrometric stations)
- **Reservoirs** (vector shp file with the location of the reservoirs)

5. **Land Use** Folder : this folder contains land use cover and soil type files data to be used during the CPT tutorial in Chapter L. The folder presents the following structure



- **Shp** this folder must contain the new shape files for land use, land cover and the catchments where the CN and AWC variables are going to be modified.
- **LU_look-up_table.csv** table with the modified Land Use conditions
- **Soil_look-up_table.csv** table with the modified land cover conditions

The files are comma separated values "csv" with the following structure:

LU_look-up_table.csv	
Header	nlcd_id
USE	No unit

Soil_look-up_table.csv				
Header	hydgrp	AWC	kfact	Is_factor
TEXTURE	No unit	No unit	No unit	No unit

6. **"Out" Folder**: this folder is initially empty and it stores the output files after running the model.
   - **Monthlysummary.csv** (monthly time series of precipitation, temperature, simulated and observed flows)
   - **Outlet.csv** (Simulated time series of output variables by catchment)
   - **summary.csv** (total number of catchments, drainage area, computational time, and COMID of the outlet catchment)
   - **spatial_file.csv** (catchment averages of temperature, precipitation, runoff, and sediment load)
   - **Annual_file.csv (**annual time series of precipitation, temperature, runoff, and sediment load)

- **Settings.txt** (all input parameters and model configuration that correspond to the last simulation performed)
- **flowDurationObs** (observed data for the duration curve)
- **flowDurationSim** (simulated data for the duration curve)

7. **"Cdit.ini":** file of the AHD tool

8. **"Hyd_err.log"**: file of the log of simulation errors

9. **Executable file "HydroBID-3.0.jar"**: HydroBID executable (double-click to launch the HydroBID interface)

10. **"launchIWRM.bat"**: batch file pre-loaded with the files of the case study.

11. **"Settings.txt":** file with the input and model set-up parameters

12. **"Una Basin Map.PNG"**: image of pre-visualization of the catchment (added for reference only)

II. QGIS and the AHD Tool

D. Visualization of the AHD-LAC in QGIS

The AHD-LAC contains the delineation of sub-basins for the entire region, divided into two sub-regions, Central America and the Caribbean and South America.

To be able to access the hydrographic databases of the AHD-LAC you must load files in QGIS that characterize the delineation of catchments, flows and additionally, you will need to upload the file that contains the connectivity between catchments and flowlines (**AHDFlow.dbf**).

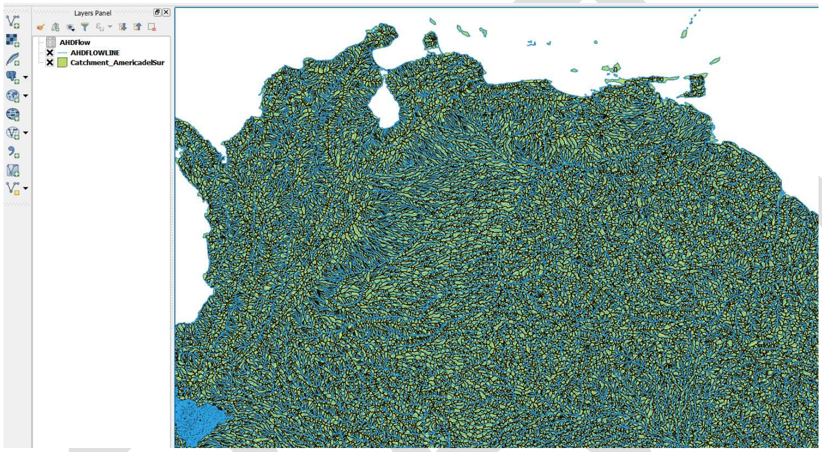
First, we will load the South America AHD to understand the AHD on a larger scale. Then, we will demonstrate using the AHD and AHD Tools Menu with our example, the Una River. *Note:* If you wish to skip this step, the delineation is already done for you, and can be found in the GIS folder within the HydroBID Una Example Folder.

1. Firstly, open QGIS and start a new project. Be sure to save your project in your HydroBID 3.0 Folder and save frequently throughout this process.

2. Before beginning, be sure the QGIS Browser Panel and Layers Panel are visible on your screen as they will be referenced throughout this section. If these Panels do not appear, click on the '**View'** window, and then click the '**Panels**' menu option. Select any Panels that are helpful for you, including the '**Browser Panel**' and the '**Layers Panel**'.

3. In order to load the necessary files you can simply locate the AHD Files Folder within the QGIS browser panel (**Documents→HydroBID 3.0→AHD Files→ South America AHD**) and double click on each one, or drag the files from their location within HydroBID 3.0 Folder from File Explorer into the Layers Panel.

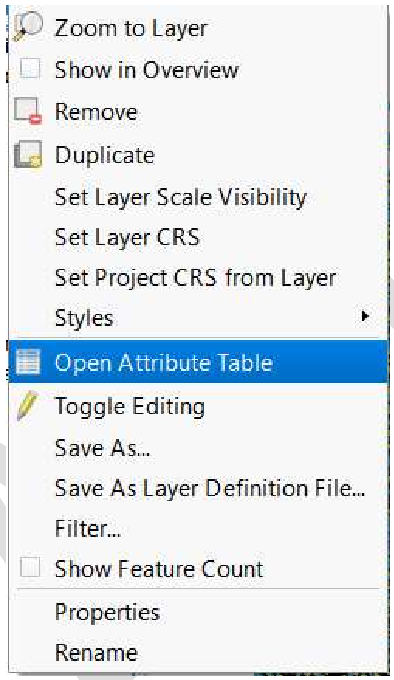
4. Using either method describe above, drag/import the following files from the **AHD Files→ South America AHD** Folder:
    a. **Catchment.shp**, found in 'Catchments' Folder
    b. '**AHDFlow.dbf**', found in 'Connectivity Table' folder
    c. '**AHDFLOWLINE.shp'**, found in 'Flowlines' Folder
    d. Your screen should now resemble the following:



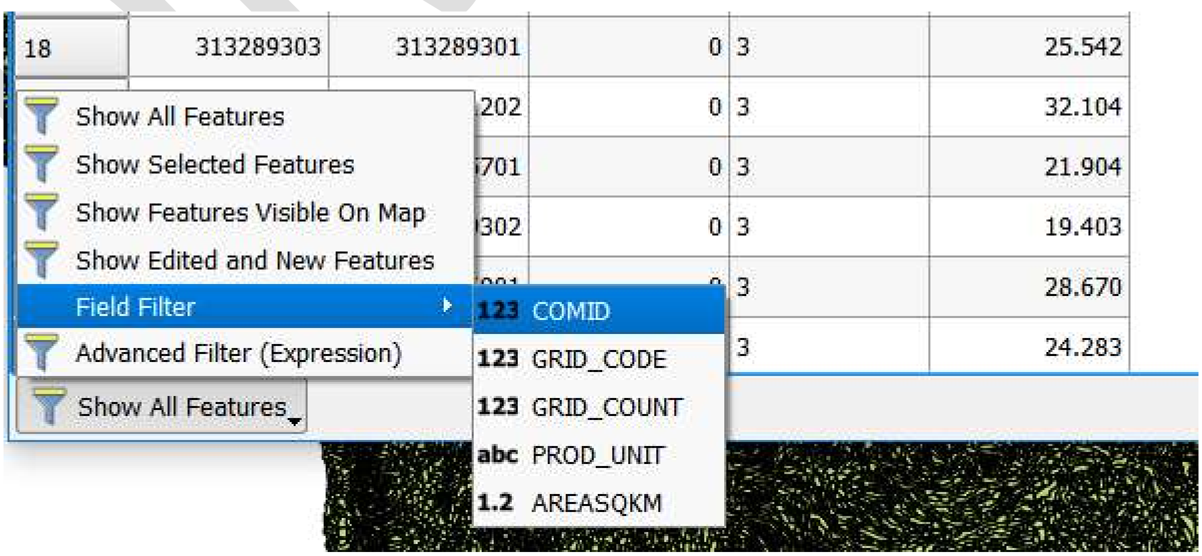
5. Now, we will narrow in on the region of interest. Throughout this guide we will reference the Una River Watershed located in the State of Pernambuco, Brazil, as an example. Therefore, we will search for this watershed using QGIS functions.

6. This can be done by navigating visually, or using the basemaps from 'QuickMapServices' for reference. However, if the specific sub-basin identification number, or COMID, is known, it is possible to search by COMID. In order to search for the Una Basin by COMID, following these steps :
    a. Highlight the '**Catchment_AmericadelSur.shp'** in the Layers Panel:

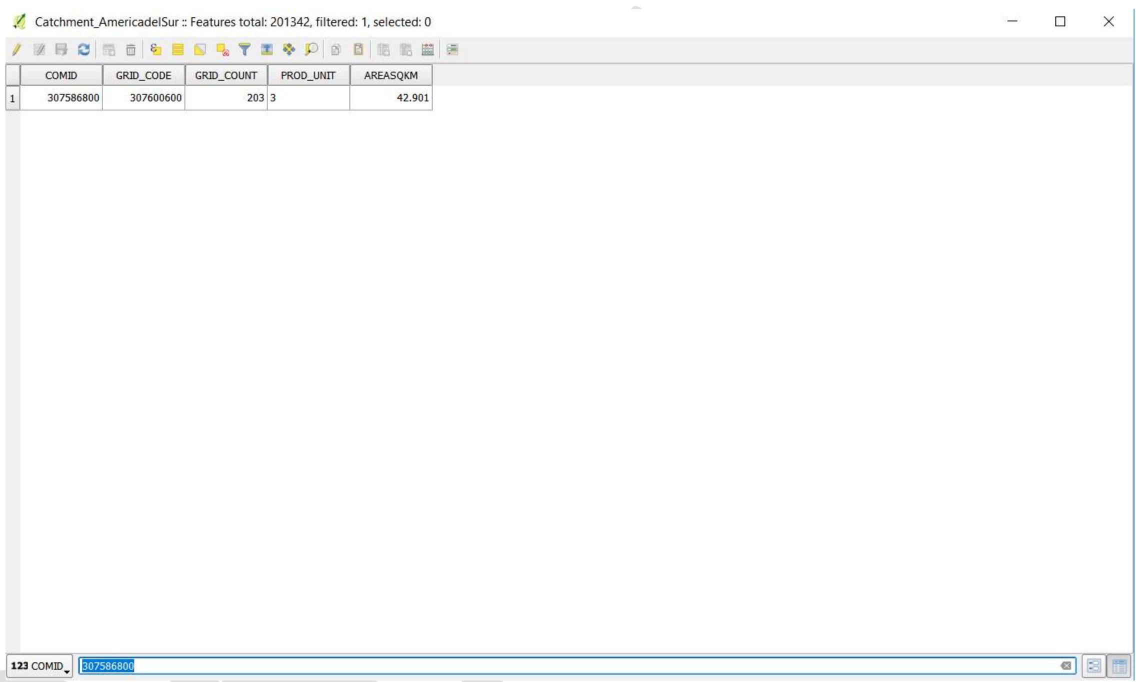
b. Right click on the layer. Select '**Open Attribute Table'**



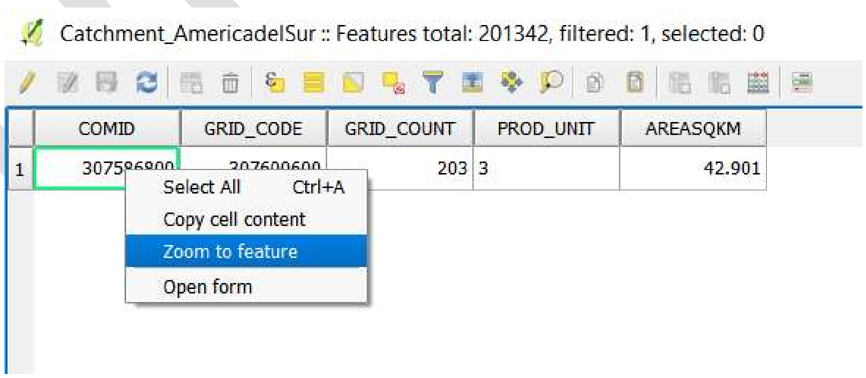
c. Navigate to the bottom of the window and click "**Show All Features**" and then "**Field Filter**" and "**COMID**"



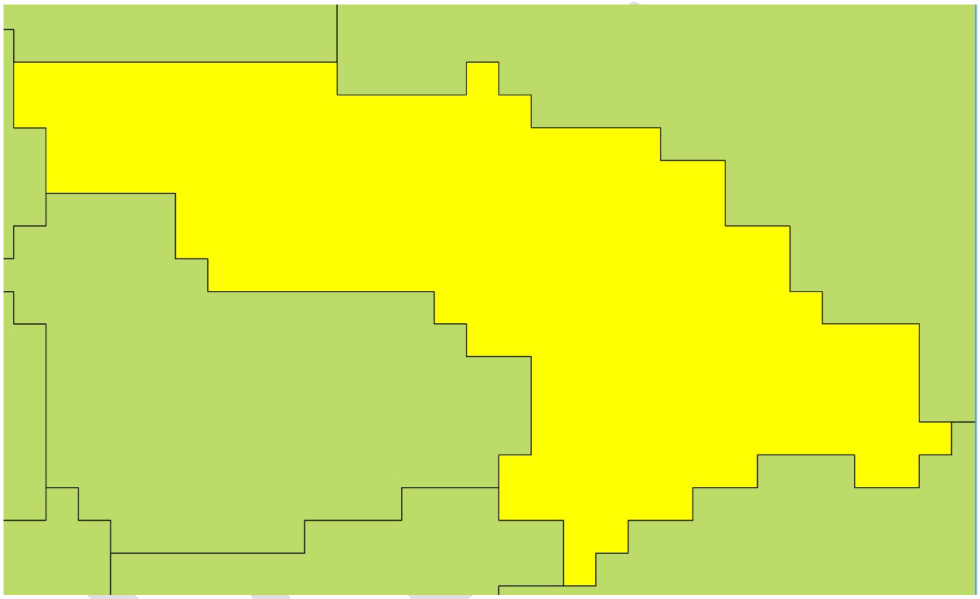
d. Enter the starting COMID of the catchment; in this case, the COMID for the Una River Watershed, beginning at the Segunda hydrometric station is **307586800**



e. Right click on the COMID value, and click '**Zoom to Feature**'



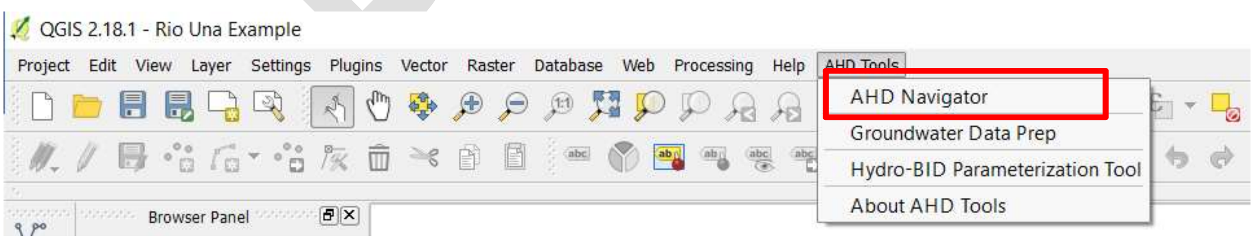
f. This will be the starting catchment we will use in the AHD navigator described in Chapter E. How to use the AHD-TOOL Navigator



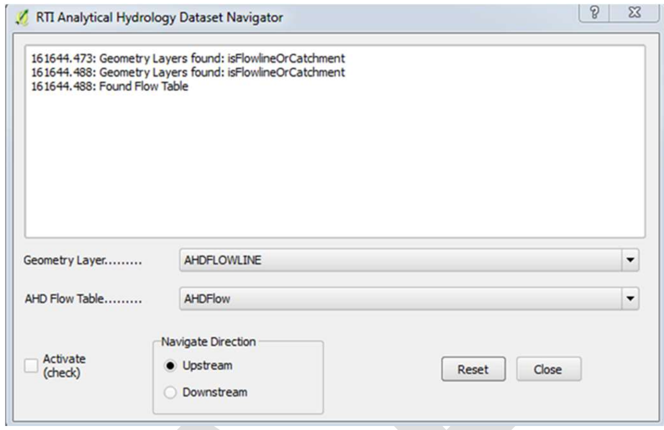
E. How to use the AHD-TOOLS Navigator

The AHD-Tool navigation allows you to identify the drainage patterns both upstream or downstream from any of the catchments or streamlines defined in the AHD-LAC.

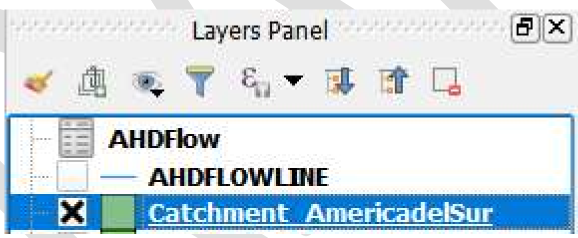
1. On the options within QGIS, open the tool by clicking on **AHD Tools → AHD Navigator**



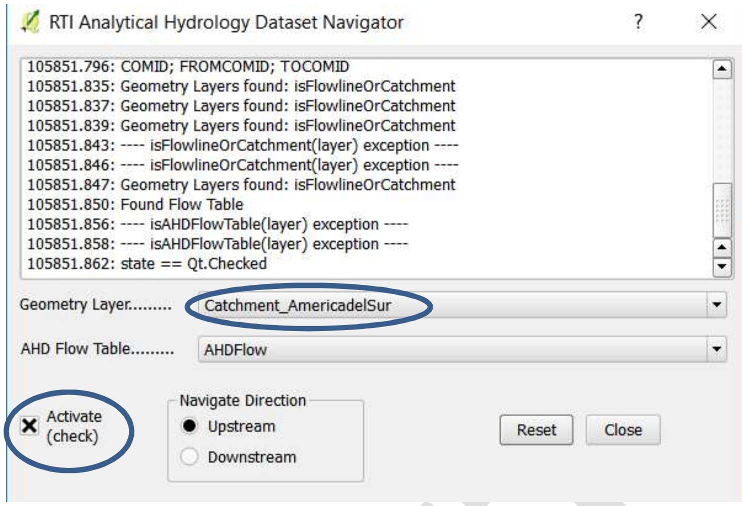
2. The AHD Navigator, after following the connectivities that are stored in the **AHDFlow.dbf** file, will select the catchment or rivers according to the direction of the flow and will provide important statistics



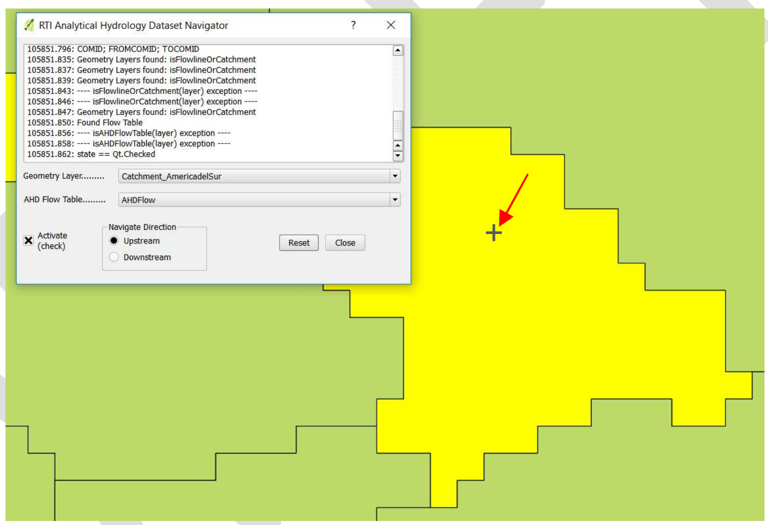
3. Selection of upstream catchments
   a- Be sure the "**Catchment**" layer is active by clicking on it



   b- After opening the AHD Navigator and highlighting the desired Geometry Layer, select the "**Catchment_AmericadelSur**" layer from the Geometry Layer menu, make sure that the direction of navigation is set to "**Upstream**" and the "**Activate**" box is enabled

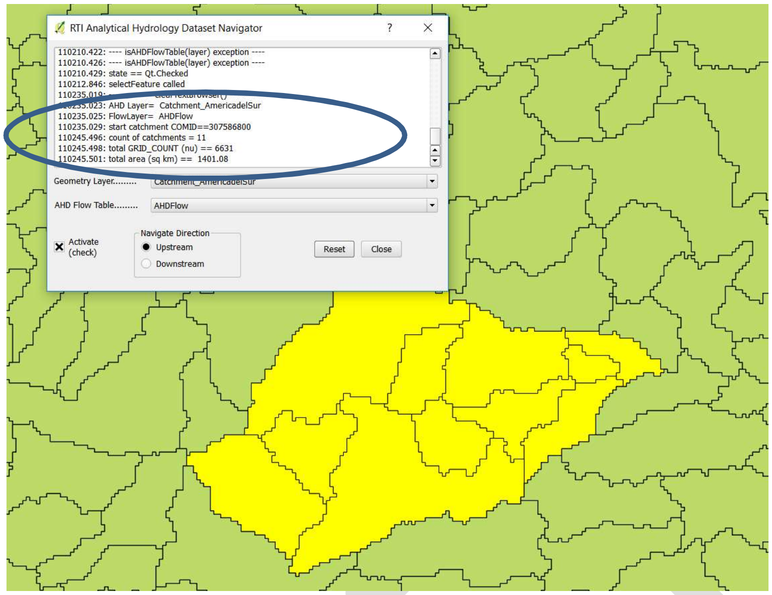


c- Move the cursor over the map, and you should notice the cursor is now a plus sign

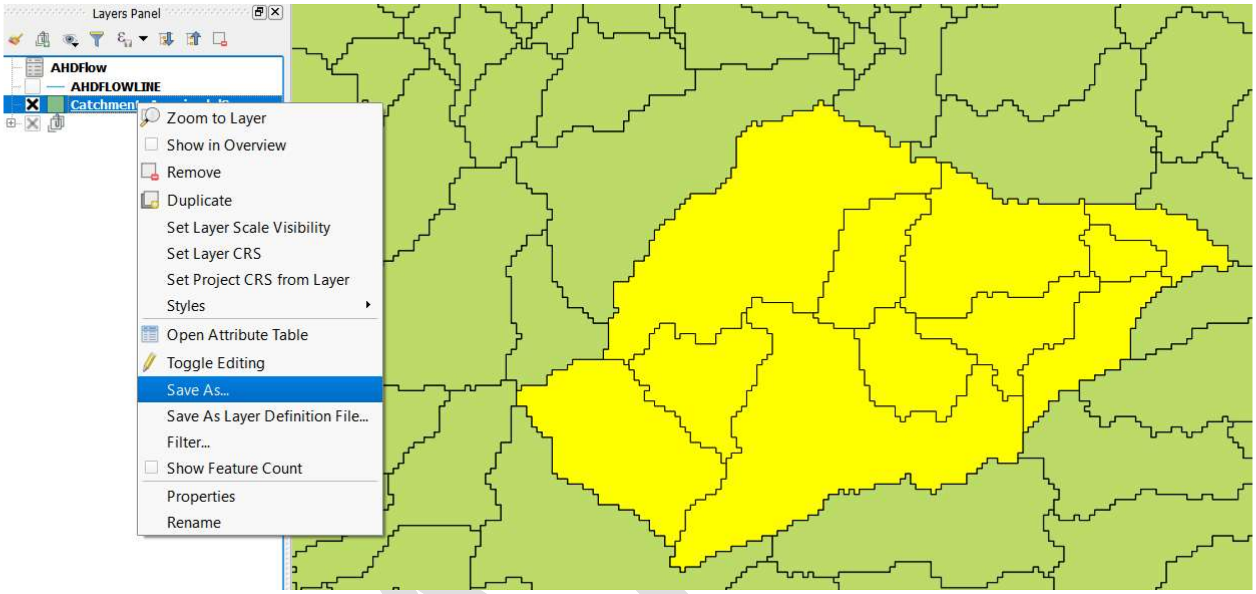


d- Click on the catchment highlighted in the previous step, COMID 307586800, that is the most downstream catchment of the Una River Basin, and the AHD Navigator will select all the sub-basins that drain to the COMID

e- The AHD Navigator window will show the COMID of the sub-basin that is the most downstream (the start catchment COMID), the number of sub-basins selected and the total area of the catchment.

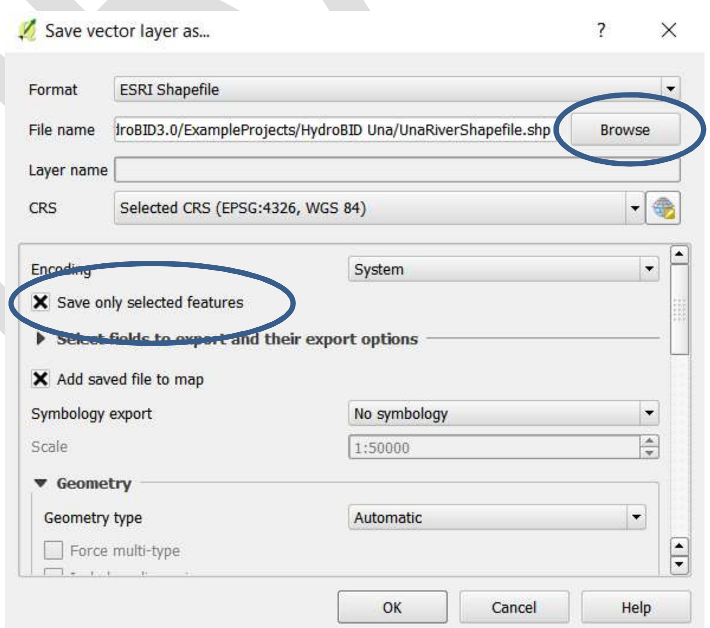

RTI Analytical Hydrology Dataset Navigator
110210.422: ---- isAHDFlowTable(layer) exception ----
110210.426: ---- isAHDFlowTable(layer) exception ----
110210.429: state == Qt.Checked
110212.846: selectFeature called
110235.019:
AHD Layer= Catchment_AmericadelSur
110235.025: FlowLayer= AHDFlow
110235.029: start catchment COMID==307586800
110245.496: count of catchments = 11
110245.498: total GRID_COUNT (nu) == 6631
110245.501: total area (sq km) == 1401.08
Geometry Layer.........
AHD Flow Table.........
AHDFlow
Activate (check)
Navigate Direction
Upstream
Downstream
Reset
Close

4. How to save selected features (watersheds) as shapefiles
   1. Now, in order to save this catchment, right click on the Geometry Layer used, in this case “**Catchment_AmericadelSur**” and select “**Save As..”**

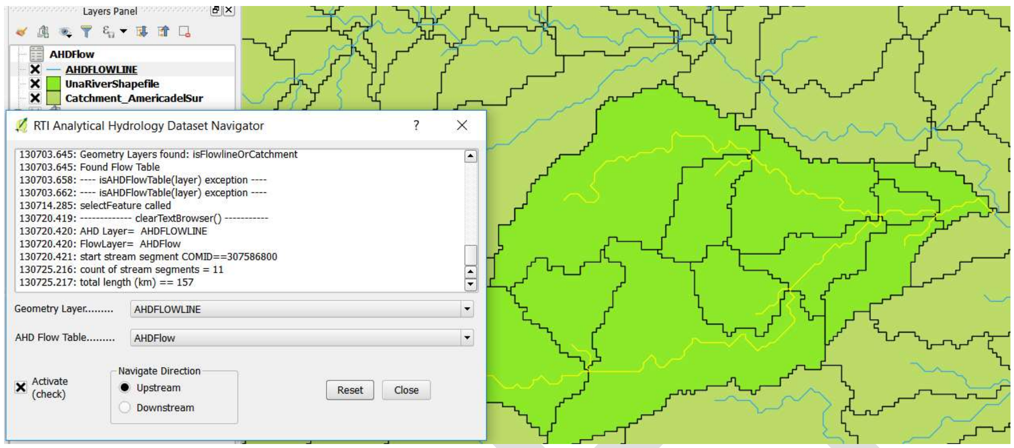


   2. A new window will appear: ‘**Save Vector Layer as…**’. Click “**Browse**” and save the shapefile in the same folder as your QGIS project.

   3. Next, check ‘**Save only selected features’**. This is a very important step; otherwise the entire catchment will be saved.



5. The procedure is the same to delineate downstream drainage and for the streamlines (flowlines) Geometry Layer. However, this time, highlight the AHD Flowlines layer in the '**Layers Panel**' and select '**AHD Flowlines**' as the '**Geometry Layer**' in the AHD Navigator tool. The process to save the 'cropped' flowlines is also identical to the process for catchments.



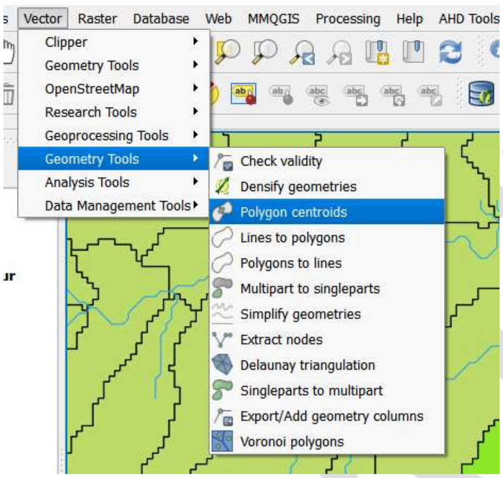
6. This process can be repeated for any other watershed. In the case of the Una River, the COMID 307621000 can be used to delineate and save a sub-watershed of the Una River, the Catende River basin, which will be used throughout this tutorial. Repeat steps a) through i) to obtain these shapefiles. *T* Note: a QGIS project with a set of complete, relevant shapefiles for both the Catende sub-basin and the Río Una watershed (Segunda Watershed) are also available in the Example Projects Folder for reference.

7. *Note:* the 'Start catchment COMID' of your region of interest should be saved for future use within the HydroBID Model Interface. One recommendation is to save each sub-basin shapefile with the 'Start catchment COMID' in the name.

F. How to find centroids of each sub-basin

1. After selecting the watershed of study within QGIS, in this case the Una River, it is important to calculate the centroids of each sub-basin to be modeled. This information will be required upon running the Climate Interpolation Tool in the HydroBID interface.

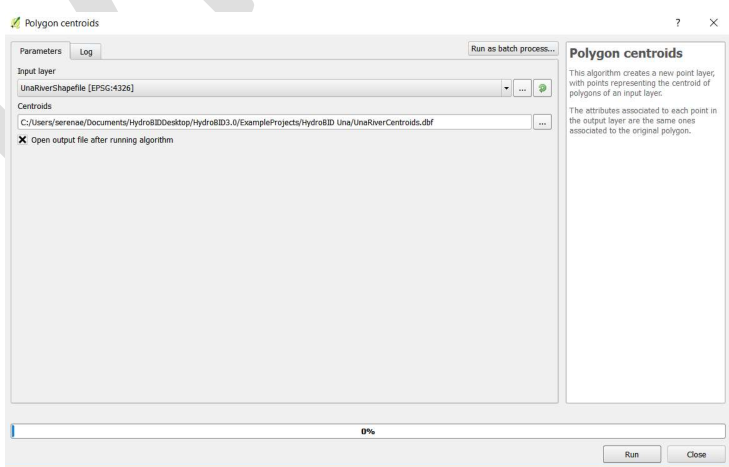
2. In order to calculate the centroids of each sub-basin, select the '**Vector**' window→**'Geometry Tools'** options and then '**Polygon Centroids'**.



3. A new window will appear: '**Polygon Centroids'**. Within the Input Layer, select your newly saved watershed shapefile (in this case, '**Rio Una Shapefile'**).

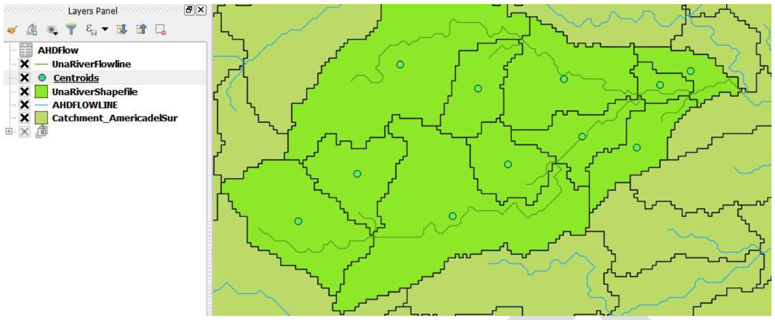
4. Upon clicking the icon with three dots for the '**Centroids**' option, select '**Save to file**' to save the centroids within your QGIS project folder or simply leave the '**Create Temporary Layer** option (note: the temporary layer will need to be saved separately before closing the project if you would like to view it upon reopening the project).

5. Click 'Run

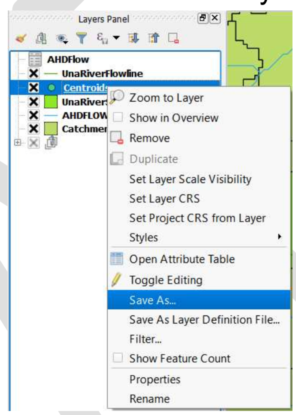


.

6. Now, a centroids layer should appear within the Layers Panel and in your map view. If you do not see the centroids layer in the map view, try moving the layer above the other Layers in the Layer Panel.



7. In order to export this Centroids Layer as a CSV with GPS coordinates, which is required for the HydroBID Interface, right click on the Centroids layer, and click “Save as…”

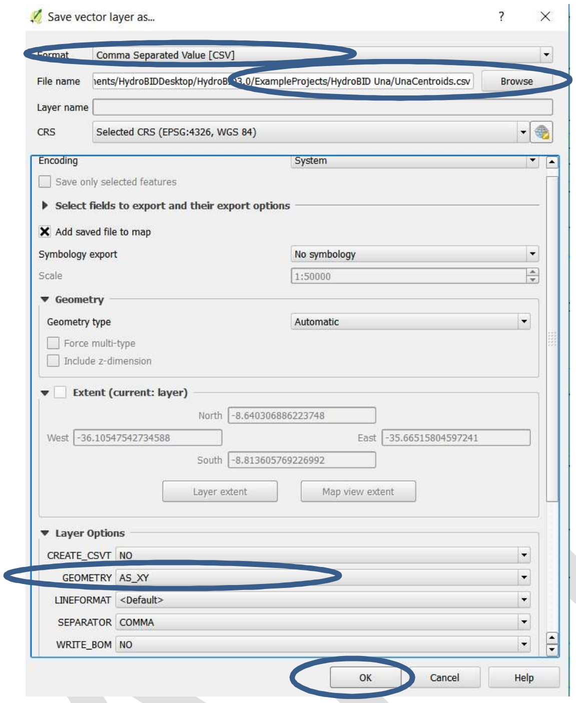


8. In the window that appears,’Save Vector Layer as…’, change the option for ‘Format’ to ‘Comma Separated Value [CSV]’

9. Next, click ‘Browse’ to save the CSV in the appropriate location within your project folder.

10. Lastly, under ‘Layer Options’ change the Geometry from ‘Default’ to ‘AS_XY’. This will add X & Y (Longitude and Latitude) GPS coordinates to the CSV along with the COMID and other attributes.

13. Click 'OK' and check your project folder to verify the file was saved correctly and with the information needed.

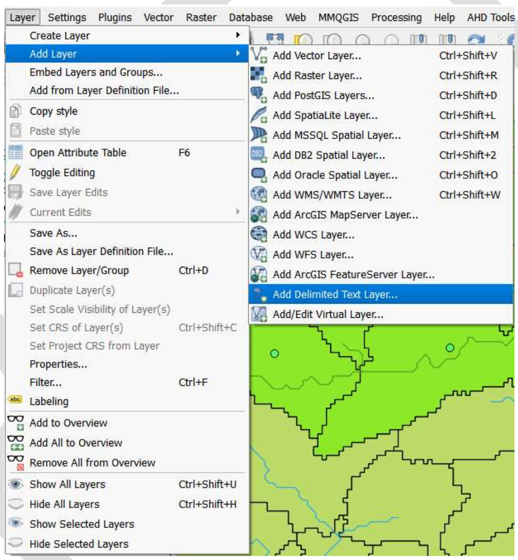


14. Note: This file will need to be reformatted with the appropriate headers and column order detailed below and in Chapter C (Part 1. Climate Data) before importing to the HydroBID model. The COMID Centroids for the Una Watershed with the correct formatting and numbers are available within your Example Projects Folder for reference.

Header	Centroid_x	Centroid_y	COMID
Format/units	degrees	degrees	Catchment Identifier

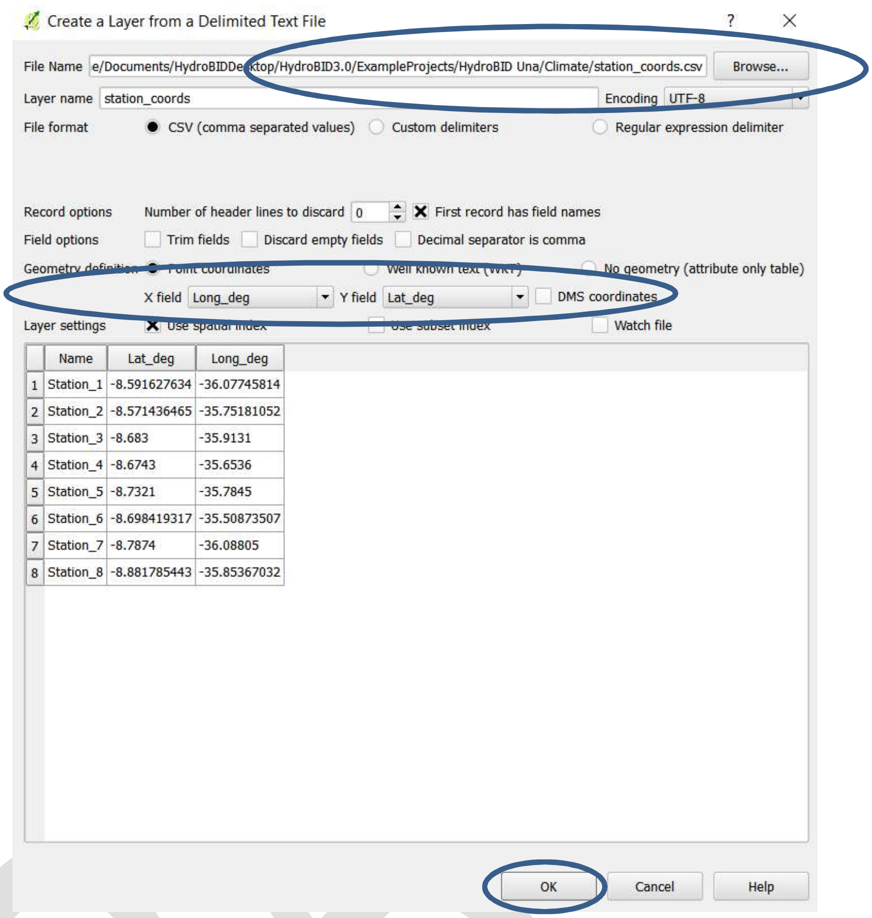
G. How to import a CSV with station coordinates into the QGIS environment

1. Note: this step is not required but can be helpful in order to visualize the model as well as for map creation. This method can be used to import climate station coordinates, flow station coordinates, reservoir coordinates, or any other CSV with geometry information.
2. In order to import a CSV with climate station coordinates, the CSV should contain separate columns for the X and Y coordinates and an additional column for the station name. In this case, we will use the CSV for the Una River Climate Stations found within the HydroBID 3.0 Folder → Example Projects → HydroBID Una → Climate → **station_coords.csv**
3. Within QGIS, navigate to the ‘Layer’ window and select ‘**Add Layer**’ and then ‘**Add Delimited Text Layer…**’ menu option with a comma icon. You will notice this icon is also available on the lefthand menu to add this and other layers to your project.



4. Next, click ‘**Browse**’ and navigate to the Station Coordinates file.

5. Be sure ‘**Point coordinates’** is selected for Geometry definition and select the appropriate column from the CSV that correlates with the X field (Longitude coordinates) and the Y Field (Latitude coordinates). Review the preview to be sure the headers and columns are formatted correctly, and then click ‘OK’



6. Now, the station locations should appear within the Layers Panel and QGIS map view. If you do not see the centroids layer in the map view, try moving the layer above the other Layers in the Layer Panel.

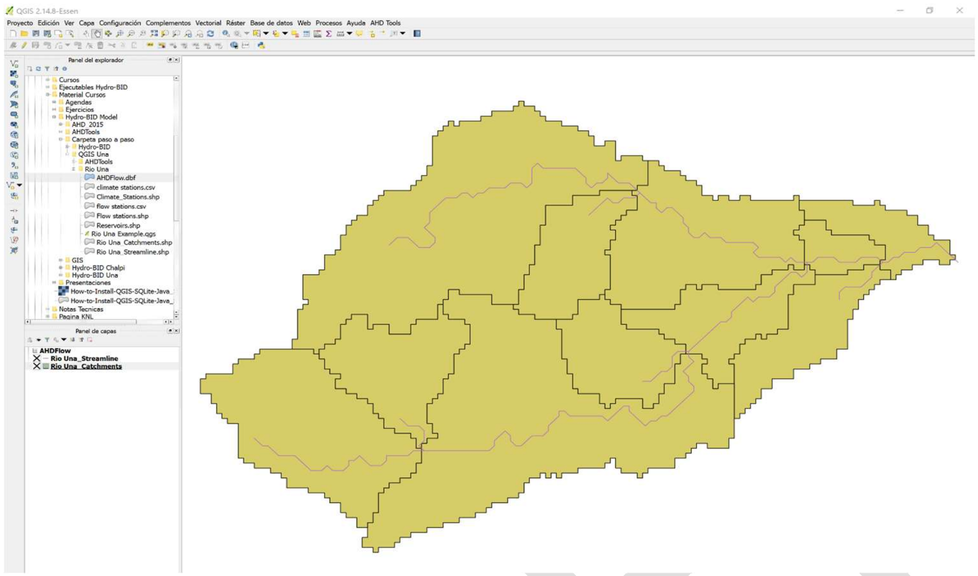
7. To save this imported CSV as a shapefile for view upon subsequent openings of the project, right click on the layer and save as an 'ESRI Shapefile' in your project folder.

8. For reference, a shapefile with the Station Coordinates is already available in the HydroBID Una Example Projects folder.

This completes the steps within the QGIS Environment to visualize and prepare for running the model within the QGIS interface. As noted, the files explained in the previous steps are already created and available for use within the **HydroBID Una → QGIS** Folder. The following files can be loaded into QGIS using the Browser Panel or by dragging the files from File Explorer into the Layers Panel:

- **Rio Una_Catchments.shp**
- **Rio Una_Streamline.shp**
- **AHDFlow.dbf**

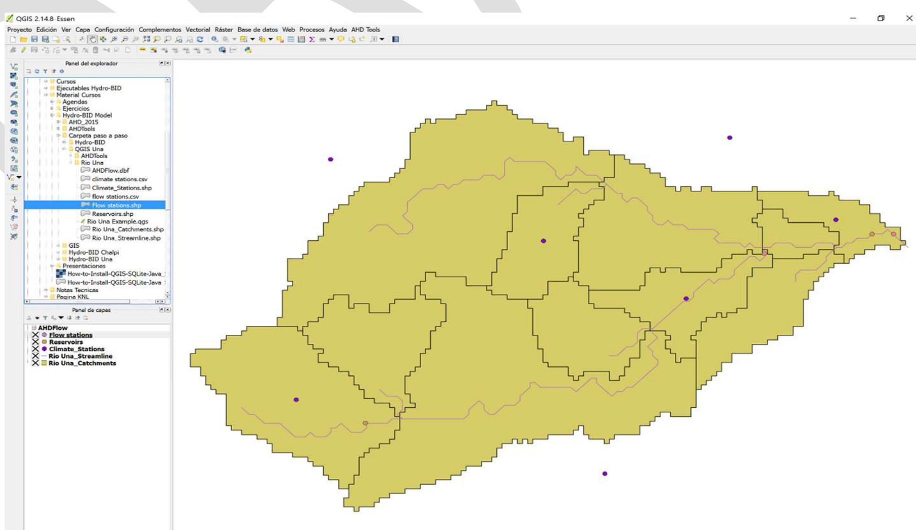
Upon dragging these files into the QGIS environment, the following image will appear in the QGIS work pane.



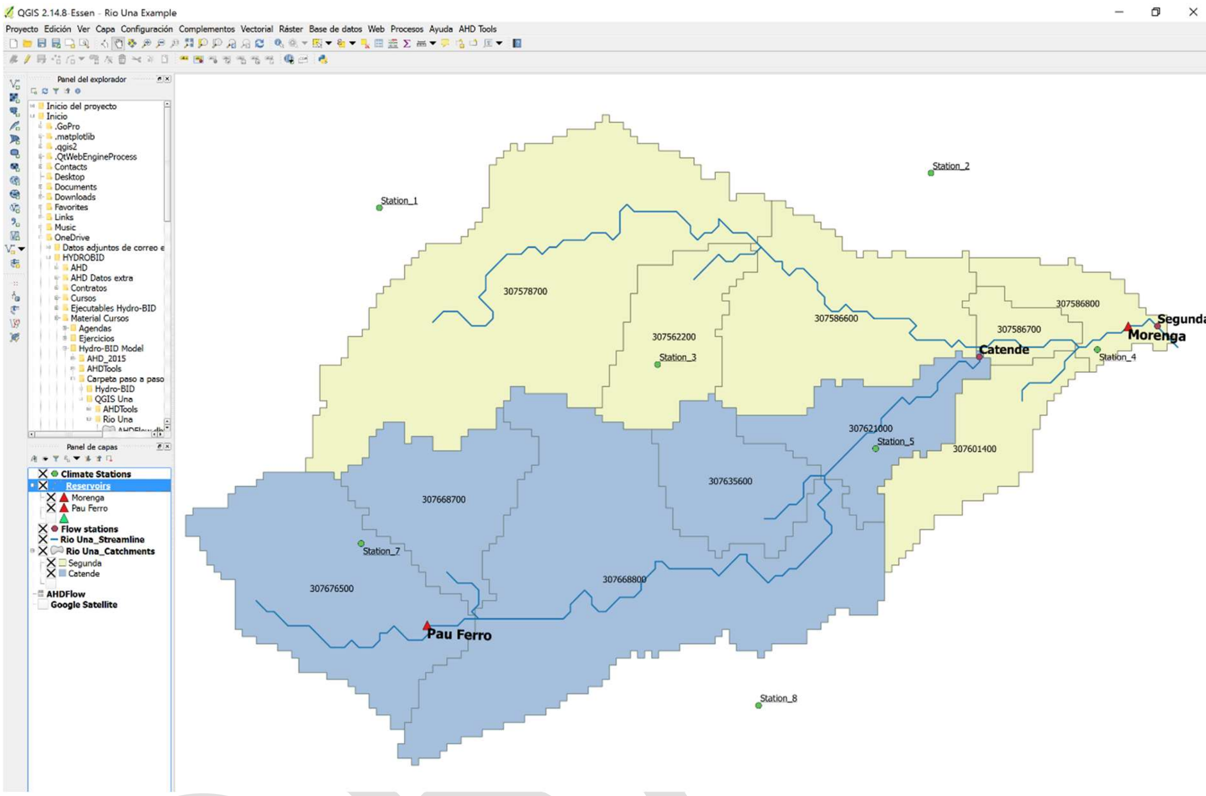
These files are also available for reference (which you learned how to import in Chapter G).

- **Climate_Stations.shp**
- **Flow stations.shp**
- **Reservoirs.shp**

Upon dragging these files into the QGIS environment this mapview should appear.



You can eventually use the Properties window that appears when you right-click on each of the shapefiles (shp) in order to graphically customize each layer. If you want, this final set-up is already pre-developed in the **Rio Una Example.qgs** project file, defining both the Catende sub-basin, which will be used for the majority of this tutorial, and the Una Watershed as a whole, which is defined by the Segunda hydrometric station located at its most downstream point.



III. SQLite Database

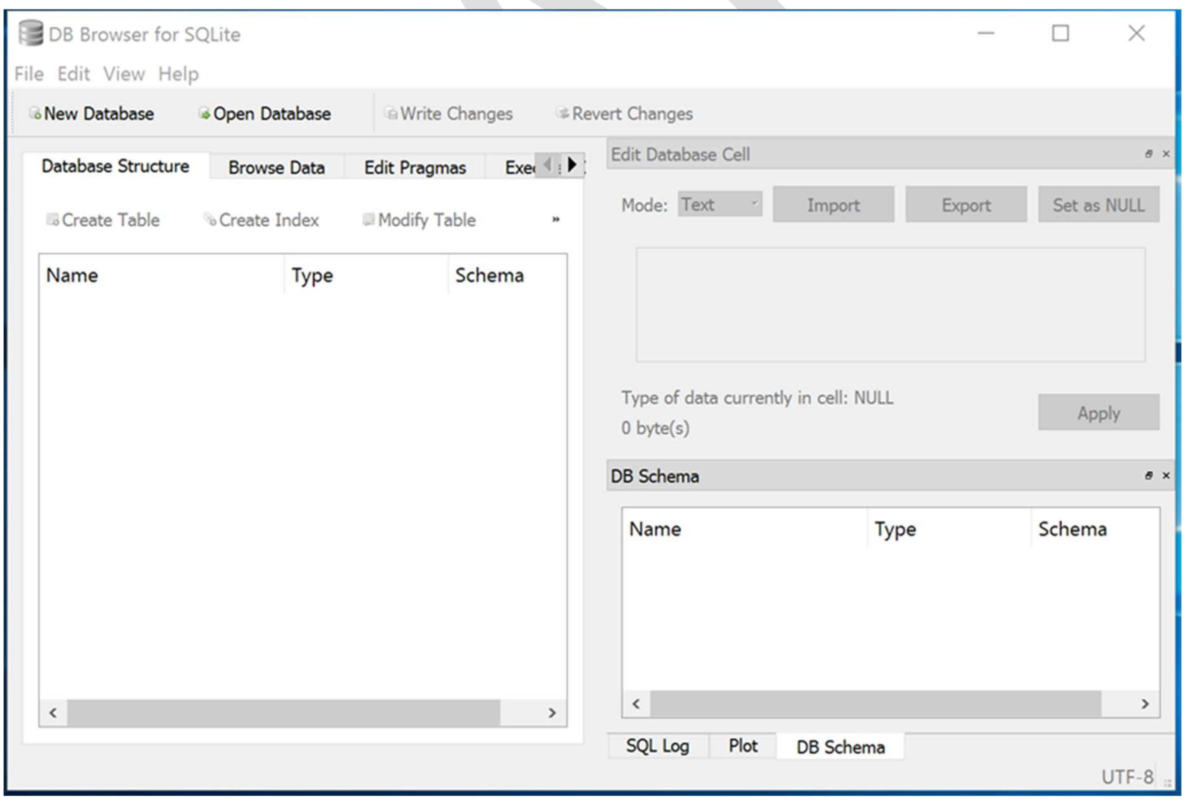
H. Visualization of the SQLite database

The database with pre-loaded and pre-validated variables is stored in SQLITE format; to view its structure and the values of the variables you can use the **DB Browser for SQLite**. The file for this case study is located inside the **db** folder.

To display the database of the Una river basin you must follow these steps:

1. Open the browser and go to the Start menu and type "**DB Browser for SQLite**" in the search bar. Click on the icon:

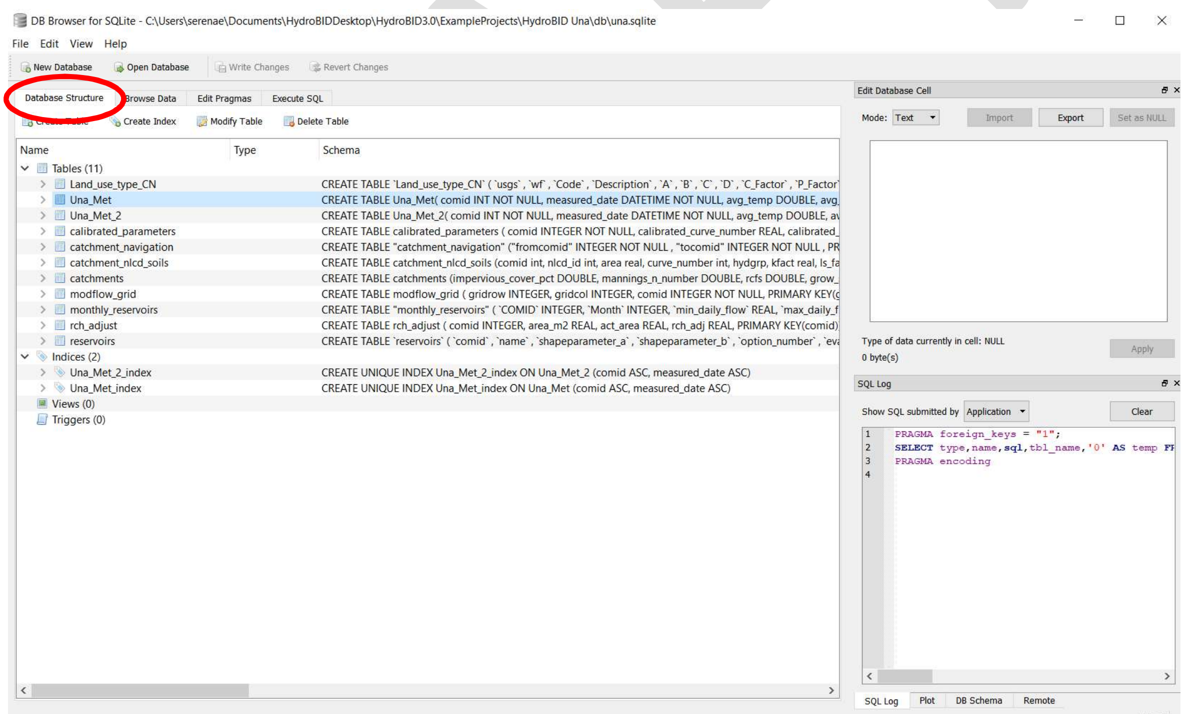
2. The DB Browser will open in its initial window



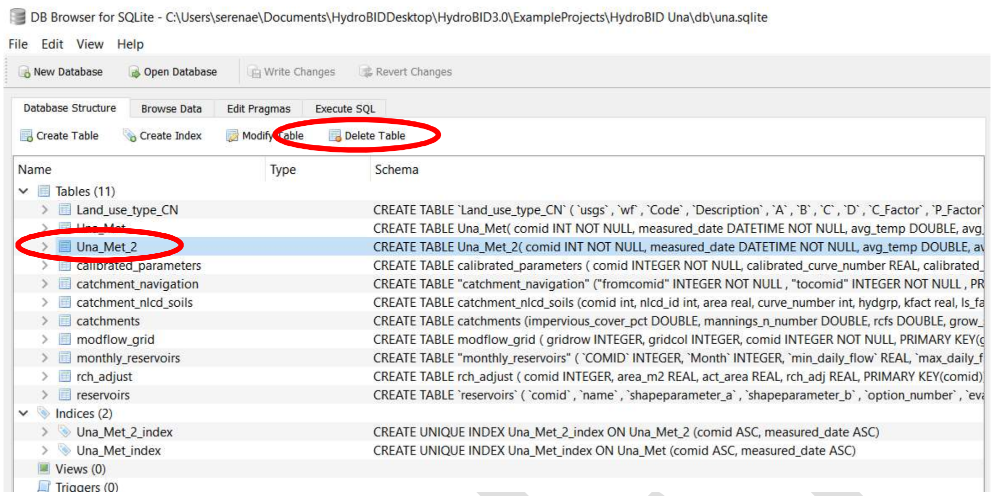
3. To open the database, click on "**File**" and "**Open Database**"

4. Browse to the SQLite file you want to open, in this case select "**una.sqlite**". All of the input data for this Catchment is stored in this database

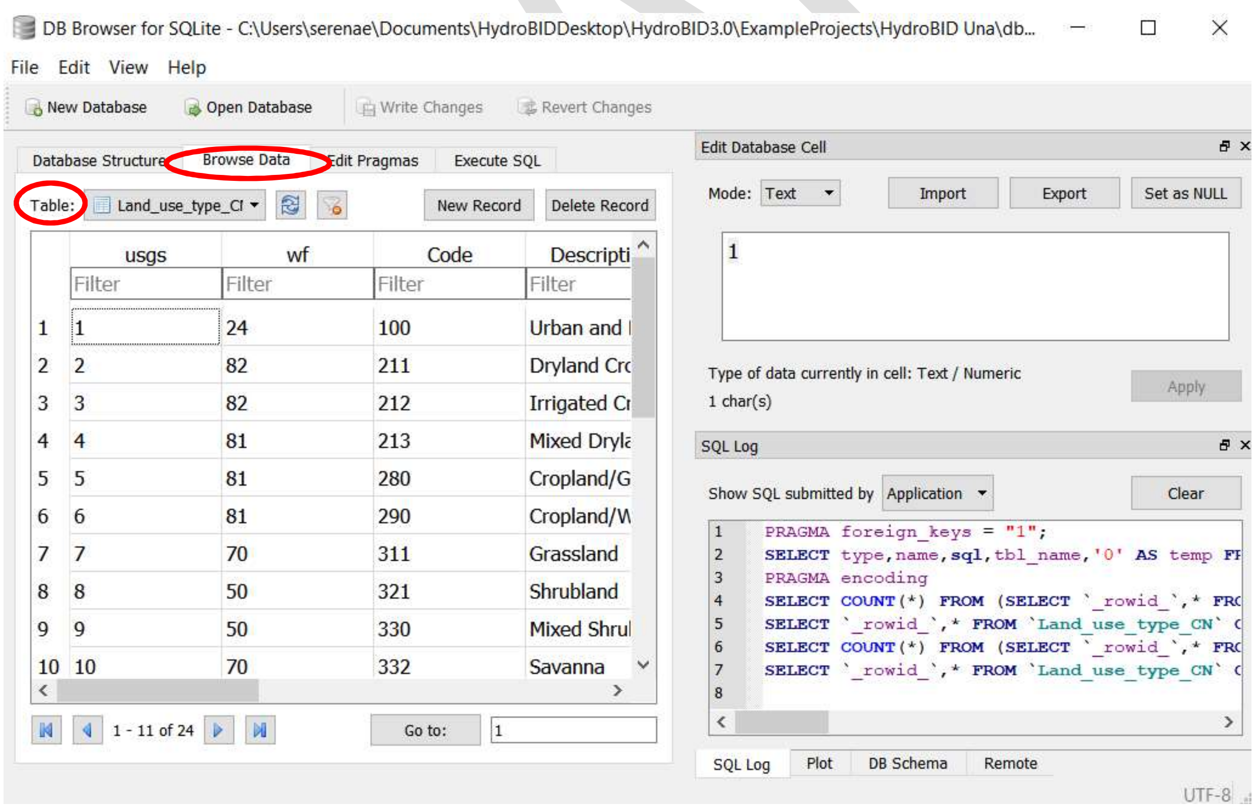
5. To visualize the structure of the data, in the "**Database Structure**" tab, expand the tables by clicking on the arrows next to the name



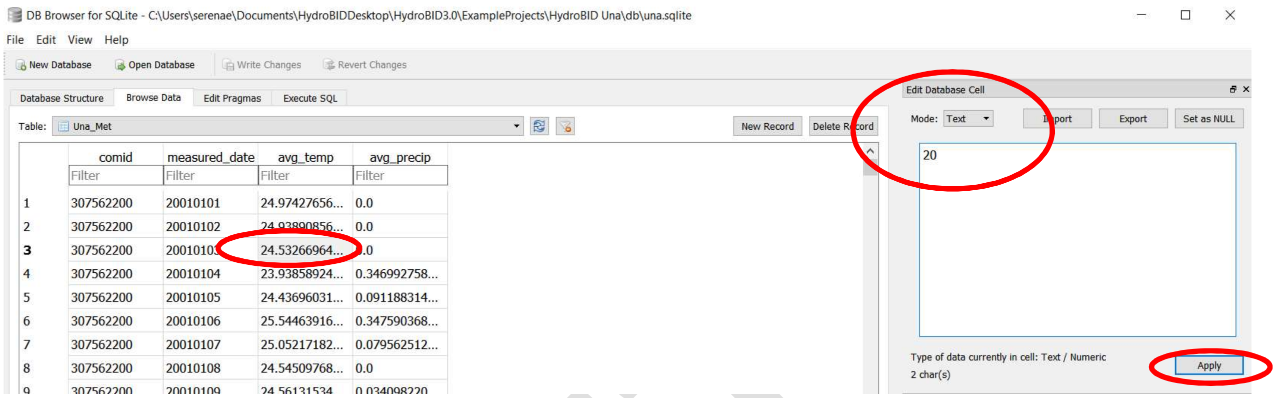
6. To delete a table, in the Database Structure window, click on the Table you would like to delete, and then click 'Delete Table'



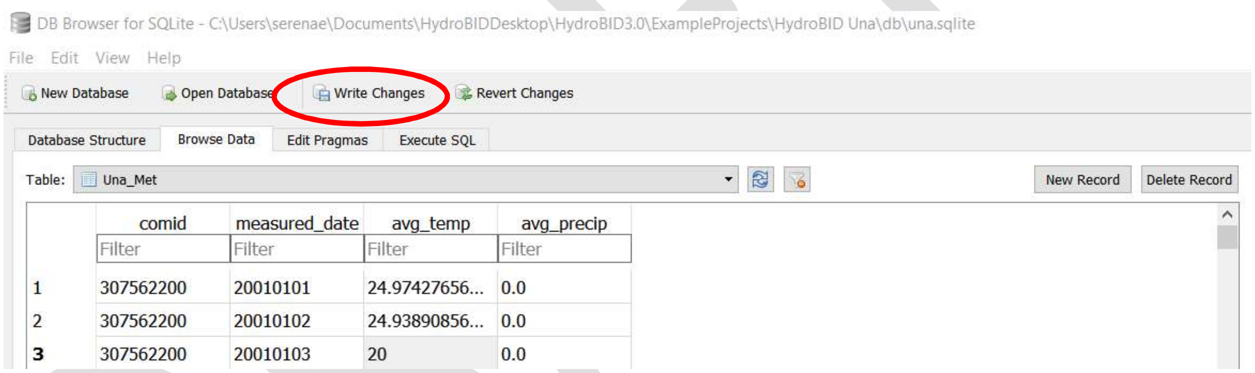
7. To view and search the tables, click on the "**Browse Data**" tab and select the table from the "**Table**" menu



8. To edit the tables, click on value you would like to edit, change the value in the 'Edit Database Cell' window on the upper righthand side of the interface, and click 'Apply'



To save these changes, click 'Write Changes' on the interface menu. You may also undo the changes made by clicking 'Revert Changes'.



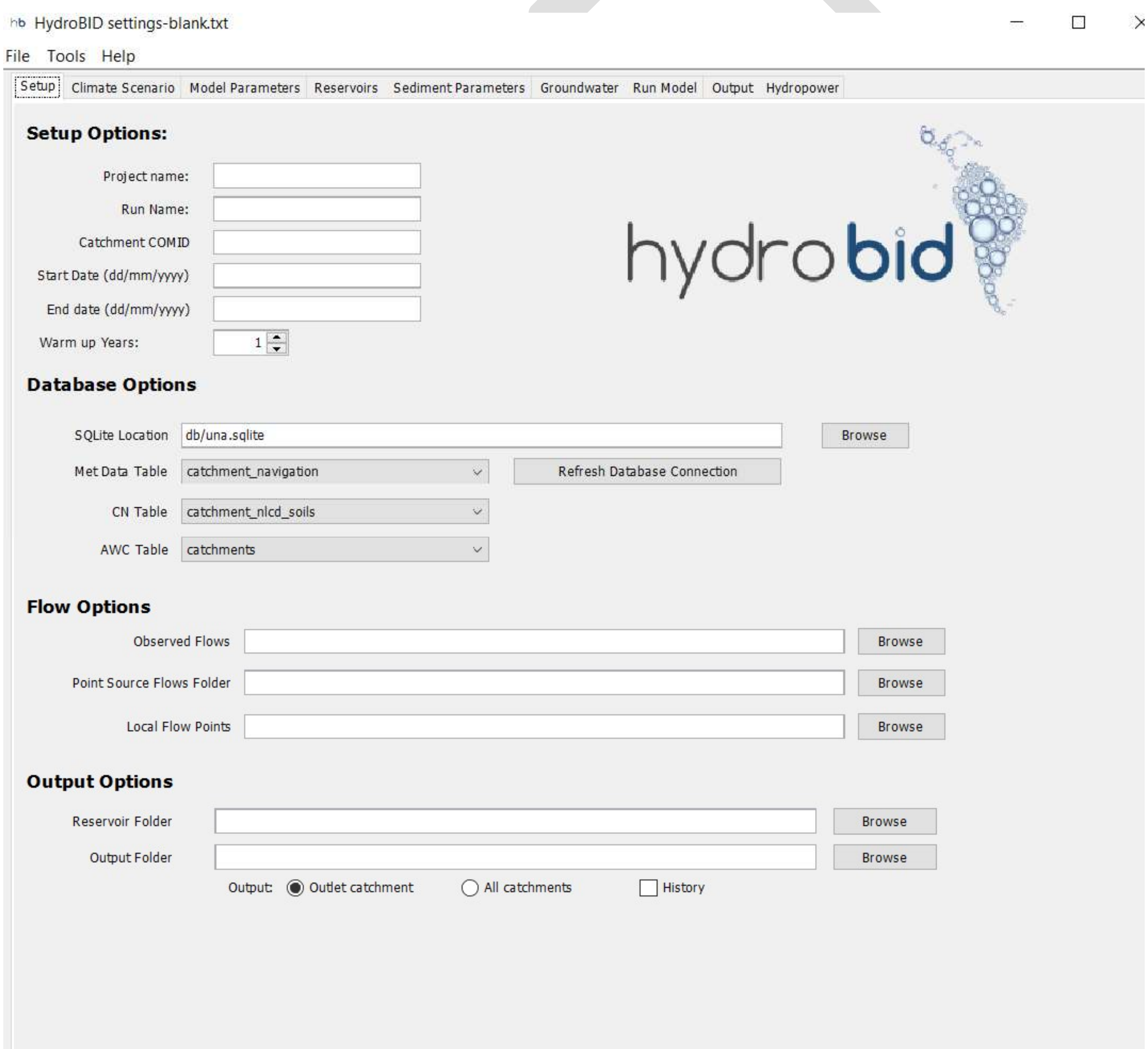
IV. the HydroBID Model Interface

I. Running a simulation with HydroBID

The AHD-Tool is used not only to display the catchments, view the location of stations and reservoirs and consequently confine the area of study, but it is also important to locate the COMID (unique catchment identifier) of the catchment more downstream of the system subject of analysis. In the HydroBID interface, it is vital to identify the COMID of the initial catchment of the study and which will be used to obtain the total water balance.

In this chapter we will be using the files and sub-folders that we find in the **"HydroBID 3.0" resource** folder.

1. To open the HydroBID interface of the case study, double-click on the executable "**HydroBID 2.3.jar"** to start an analysis from scratch.

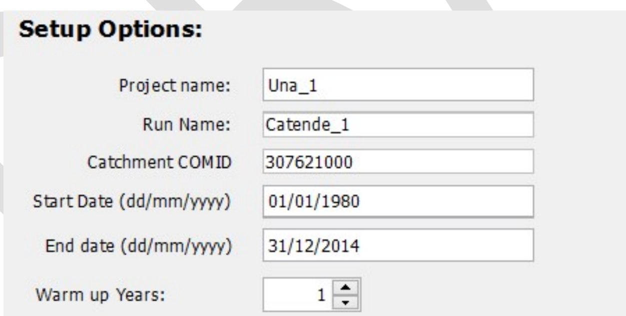


Note: The settings.txt file does not use a pattern for saving relative to the folders, therefore you must verify that the pre-loaded directories correspond to the location of these files on your computer; if they do not correspond then click "**Browse**" to locate the correct directory.

In the interface's main window you will find the following variables. Follow the instructions below to begin filling out the information required to run the model:

a) Fill out the **Setup Options:**

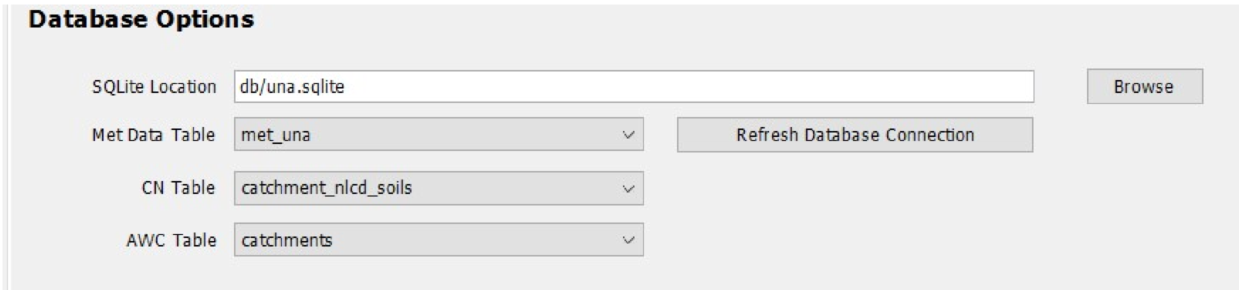
- **Project Name:** This allows you to name the series of simulations you are running. For example, if you are running multiple simulations using different climate scenarios for the Model Una, the Project might be called Una_1 and each run would be called Una_ClimateScenario1. All simulations with the same Project Name will be saved in the same folder.
- **Run Name**: The name of the simulation run
- **Catchment**: The COMID of the catchment more downstream of the system subject of study. In this case, it corresponds to the sub-basin of the **Catende** hydrometric station identified with the **COMID "307621000"**
- **Start date**: start date of the simulation (dd/mm/yyyy). In this case, use 01/01/1980.
- **End date**: date of completion of the simulation (dd/mm/yyyy). In this case, use 31/12/2014.
- **Warm Up Period**: the number of years of data the simulation will use to 'warm-up'; One year is the default warm-up period. For this case use 1.
- **Note:** The simulation period must be within the availability of climate data.
- **Note:** The simulation period must be within the availability of climate data. The first year is considered as a warm-up period.



b) Select Database (DB) File Options:

- **SQLite Location**: Name of the database for the project. Click the "Browse" button to navigate to the folder where you saved the DB. In this case the name is **Una.sqlite**
- **Met Data Table**: Select the table with the meteorological data to be used. Note: a subsequent chapter will cover the creation of this DB. Once you create the table, you will find it in this list as 'met_una', or whatever name you choose.
- **CN Table:** Select the table with CN parametrization: *"catchment_nlcd_soils". A following chapter will cover the creation of new CN parametrization table.*

- **AWC Table:** Select the table with the AWC parametrization: *“catchments”. A following chapter will cover the creation of new AWC parametrization table.*



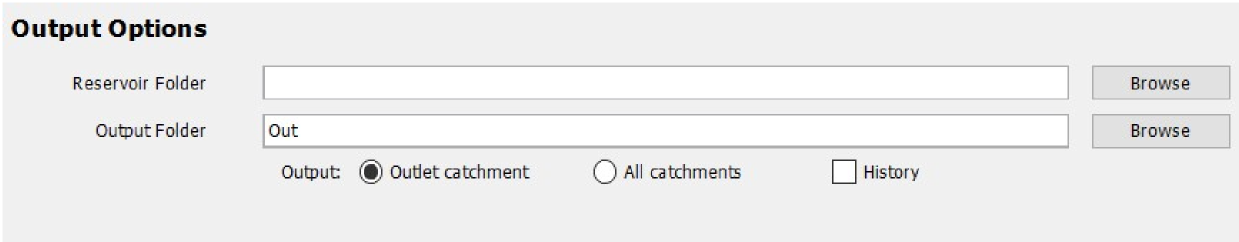
NOTE: Once the path to access the DB is provided, click on “**Refresh Database Connection**" for updating the options of “**DB Met Data Table**"

c) Flow Options:

- **Flows to Compare**: input file with the time series of observed flow rates. This file is used to compare the simulated flows. Time series can be daily or monthly in cubic meters per second. In this case use the catende-flow.csv file.
- **Point Source Flows Folder (Cutoff)**: Contains a list of files with time series of upstream catchment flows (this file is optional). Leave this space empty for now.
  <u>This option allows you to add contributions of water to the catchment and/or subtract losses.</u>
- **Local Flow Points**: input file with COMIDS where discharge time series is needed as output. Leave this space empty for now.

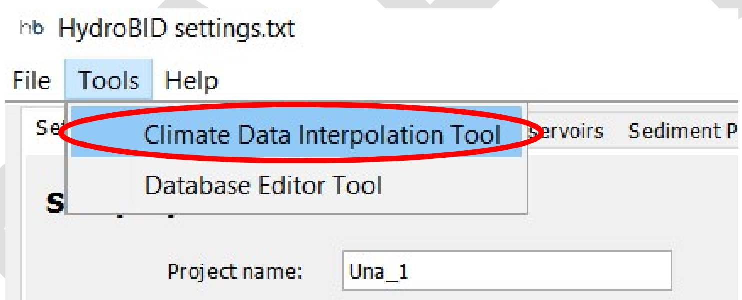
d) Output File Options:

- **Reservoir Folder**: If the reservoirs are included in the model, this directory will include the data of demand, in and out flows of the reservoir. Leave this space empty for now.
- **Output Folder**: Directory where the results of the model are saved
- **Outlet Catchment**: Select this option to save the output files only for the catchment furthest downstream. Use this option for the calibration process.
- **All Catchment**: Select this option to save the output files of all catchments included in the simulation.
- **History**: option to retrieve statistics from the calibration process

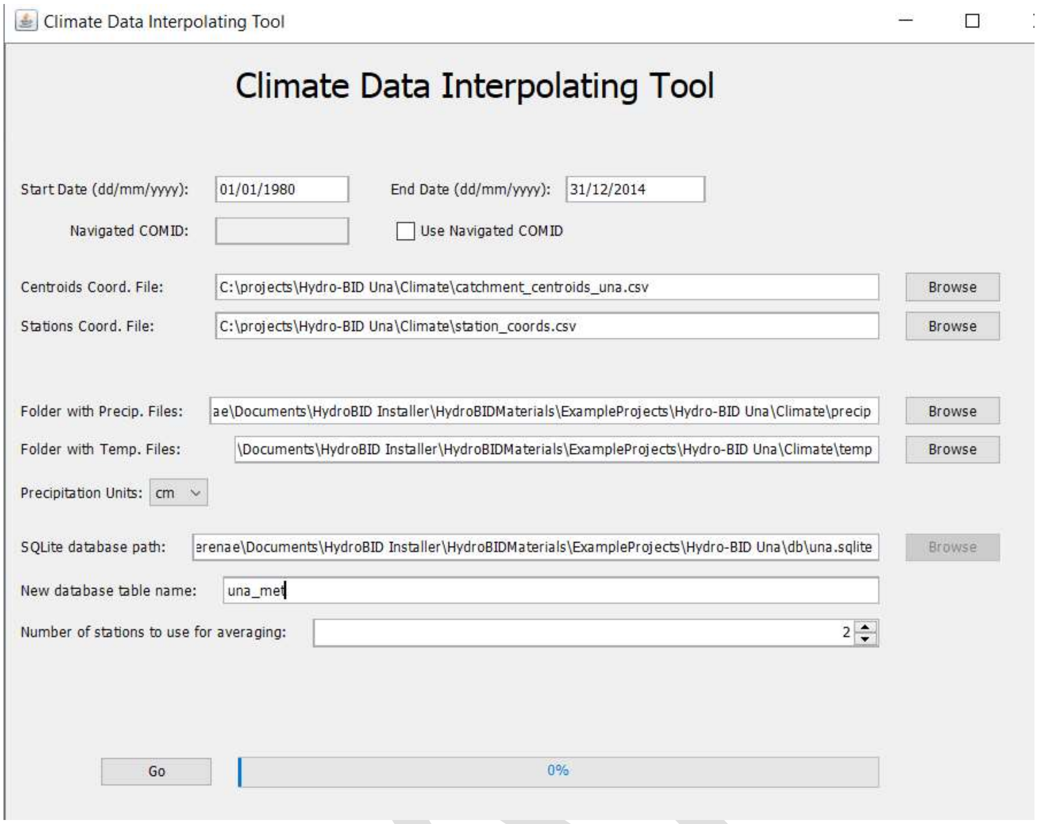


2. Hydro-BID's **"Climate Data Interpolation Tool"** is necessary in order to create a DB Met Table, as specified in part 1b above. The tool obtains climate data in the centroid of each one of the catchments; and is a preprocessor that interpolates the daily time series of temperature and rainfall of the weather stations in each catchment using the weighted average distance method of interpolation.

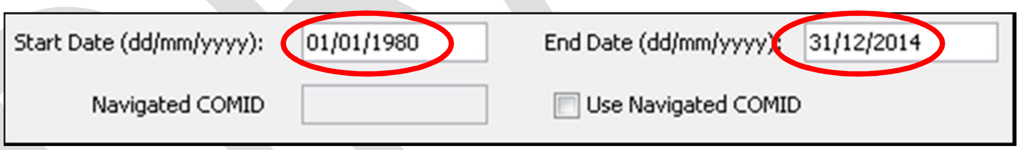
3. In order to run the tool, click on "**Tools**", select "**Climate Data Interpolation Tool**" in the upper left corner of HydroBID



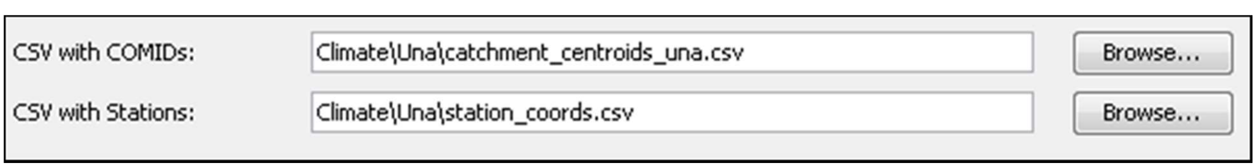
4. The the pop-up window of the interpolator will appear.



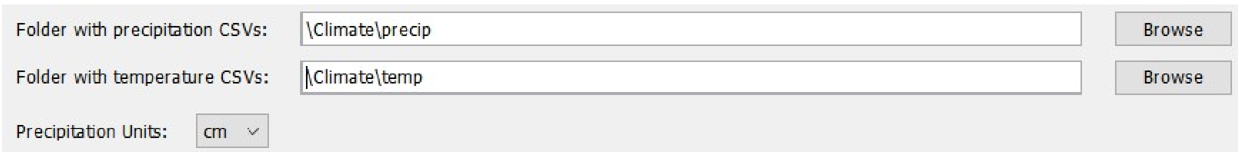
5. Verify that both the Start date and the End date correspond to the period used to perform the simulation (in this case, with the pre-assigned period that you can see in HydroBID's main screen). This period can be longer than the simulation time but never shorter.



6. In the option "**CSV with COMIDS**" upload the file "**catchment_centroids.csv**" with the COMIDs of the catchments and their latitude and longitude coordinates that are located in the folder "**climate**". Repeat the same operation in the option "**CSV with Stations**, uploading the file **"station_coord.csv"** with the weather stations and their latitude and longitude coordinates.

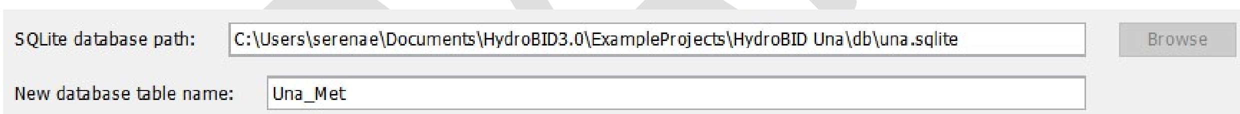


7. In the options "**Folder with precipitation CSVs**" and "**Folder with temperature CSVs**" upload the folders that contain daily data of each station in .csv format (subfolders **Precip** and **Temp** in the folder **climate**). Then, choose the precipitation units used, either centimeters (cm) or millimeters (mm). *Note:* the units must be accordingly specified in the column header of each station as Precip_cm or Precip_mm.



8. The option "**SQLite database path"** contains the path for the database that will be used to run the tool. Here, is the place to save the table with the interpolated climate data. The location of the database should match automatically with the one imposed in HydroBID's initial screen. However, it is recommended to verify that it is correct, otherwise, to search for the SQLite database, you must find the correct "**.sqlite**" address in the main folder of the exercise.

   In the option of "**New database table name**", you should write the name of the table that will contain the interpolated climate data. When you run HydroBID from the main window, this table is then selected in **Met Data Table"** for use of the interpolated values. For this exercise we will use the name "**Una_Met**".



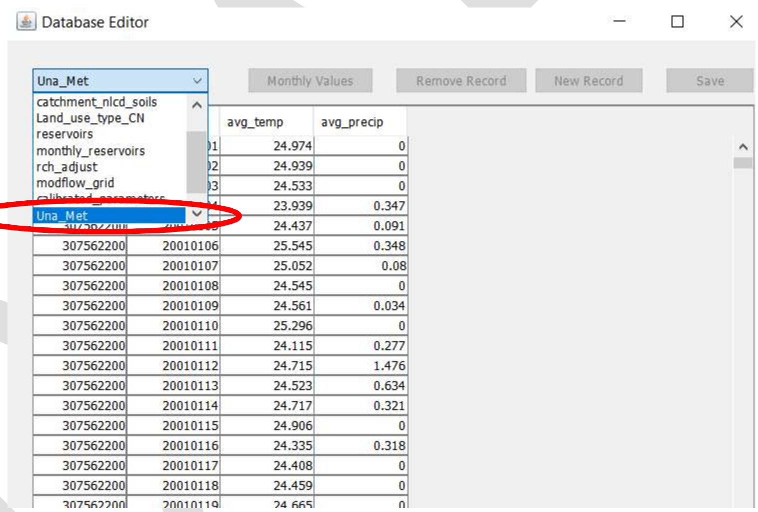
9. In the window "**Number of stations to use for averaging**" you indicate the number of nearby stations used to calculate the interpolated climate variable. The higher the number it will result in greater accuracy but will make the model run longer. It is recommended that you use a number between 2 and 4 stations.

10. Now click "**Go**" to run the CDIT tool. Once HydroBID ends running successfully, the progress bar turns blue and the message "**Done!**" appears. You may close the window to return to the main HydroBID interface after this message appears.

Note: To understand more about the capabilities and limitations of HydroBID's climate interpolator we invite you to read the Technical Note: **Hydro-BID: An Integrated System for Modeling Impacts of Climate Change on Water Resources**, which you can download at this link.

11. If you want to view the interpolated time series for each sub-basin you must click on "**Tools**" at the top left corner and select "**Database Editor Tool**".[2]

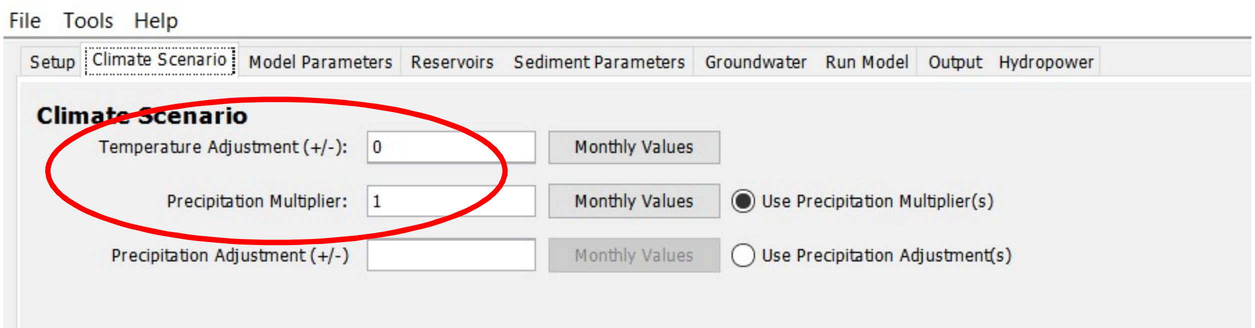
12. Once the pop-up window appears, from the list of tables, select the table you just created. In this case it is "**Una_Met"** or that the name you assigned to the table in step 8 of this chapter.



13. Now, close the window to return to the main HydroBID interface. There are only a few more pieces of required information before you can make your first simulation with HydroBID.
14. Click on on the **Climate Scenario** Window on the interface menu. This is where various Climate Scenarios can be run using Climate Change Data. Further information on this functionality will be detailed in a later chapter, but for now default parameters need to be entered. In this first run, indicate there will be no temperature adjustment by inputting a '**0**' and there will be no precipitation adjustment by inputting the precipitation multiplier as

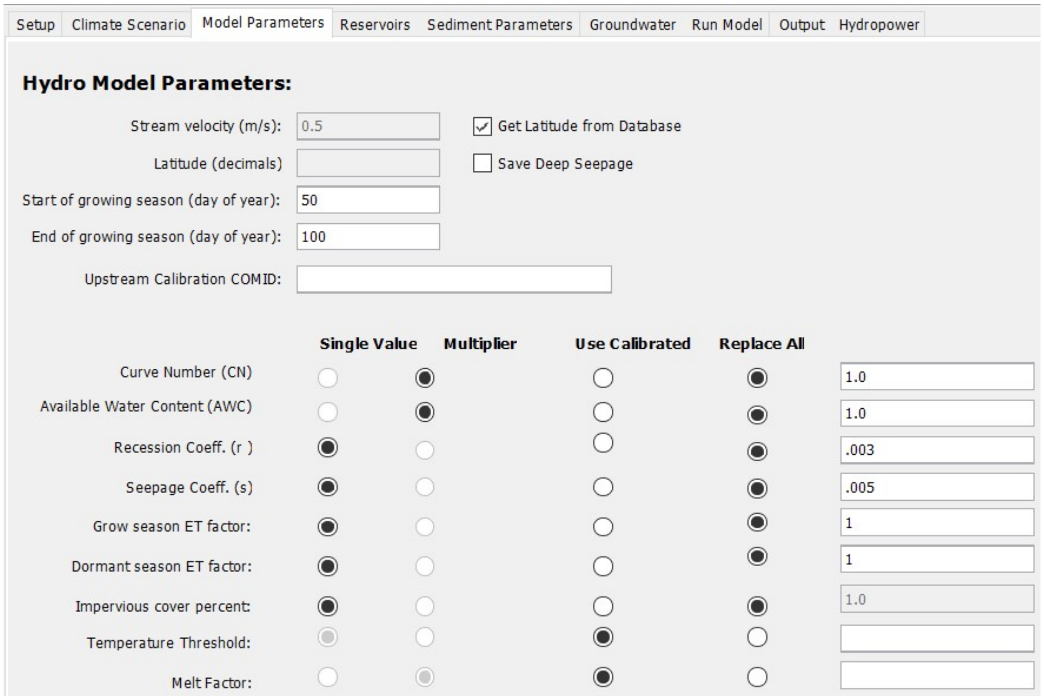
[2] **Note:** you may need to restart HydroBID to upload the new table.

‘**1**’,(in other words, the temperature data will be adjusted by 0 degrees Celsius and the precipitation data will be multiplied by 1).



15. Lastly, click on the **Model Parameters** Window from the interface menu. This is where calibration will be done, which is explained in a further chapter.
    1. For this first run, check ‘Get Latitude from Database’, HydroBID will automatically obtain Latitude data from the sqlite.
    2. input ‘50’ and ‘100’ as start and end of growing season, respectively, and leave the Upstream Calibration COMID empty. These values will depend on the start and end of growing seasons of each case study.
    3. Then, enter the default parameters, indicated below. The calibration chapter will explain all these variables with detail.
        a. CN is included in the sqlite database so the initial value will be always 1.
        b. AWC is included in the sqlite database so the initial value will be always 1. The calibration chapter will show how to modify this parameter.
        c. An initial value for r is required, the initial value must be in a range between 0,001 - 0.75 (day-1). In this case use 0.003
        d. An initial value for S is required, the initial value must be in a range between 0,005 - 0.1 (day-1). In this case use 0.005
        e. If no variation on ET factor for growing season is needed, then use 1. Otherwise the the initial value must be in a range between 0.5 - 1.5
        f. If no variation on ET factor for dormant season is needed, then use 1. Otherwise the the initial value must be in a range between 0.5 - 1.5

    4. These parameters will be modified for the specific case later on during the model calibration stage. Please Note that Impervious cover percent is a blocked option and that **Temperature Threshold** and **Melt Factor** do not need to have a value in this stage; they may use the calibrated value.



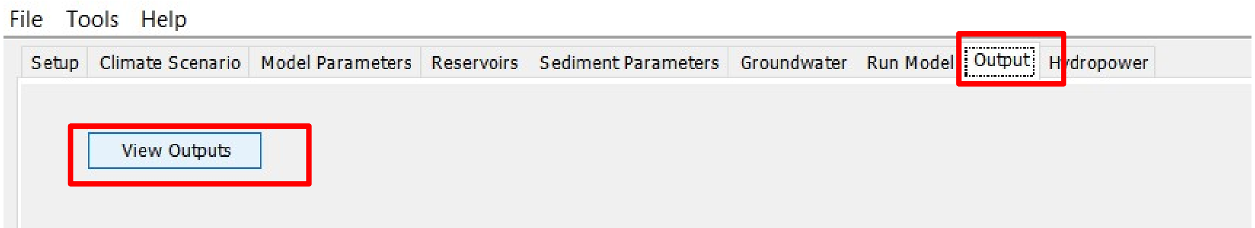
16. The remaining Windows, such as Reservoirs, Sediment Parameters, Groundwater, and Hydropower are optional and do not need to be filled out at this time. See subsequent chapters for further explanation on these modules.

17. Once you are ready to make the first simulation, select the module "**Run Model**" in HydroBID's main screen and click on "**GO**". Automatically, the model will start running.

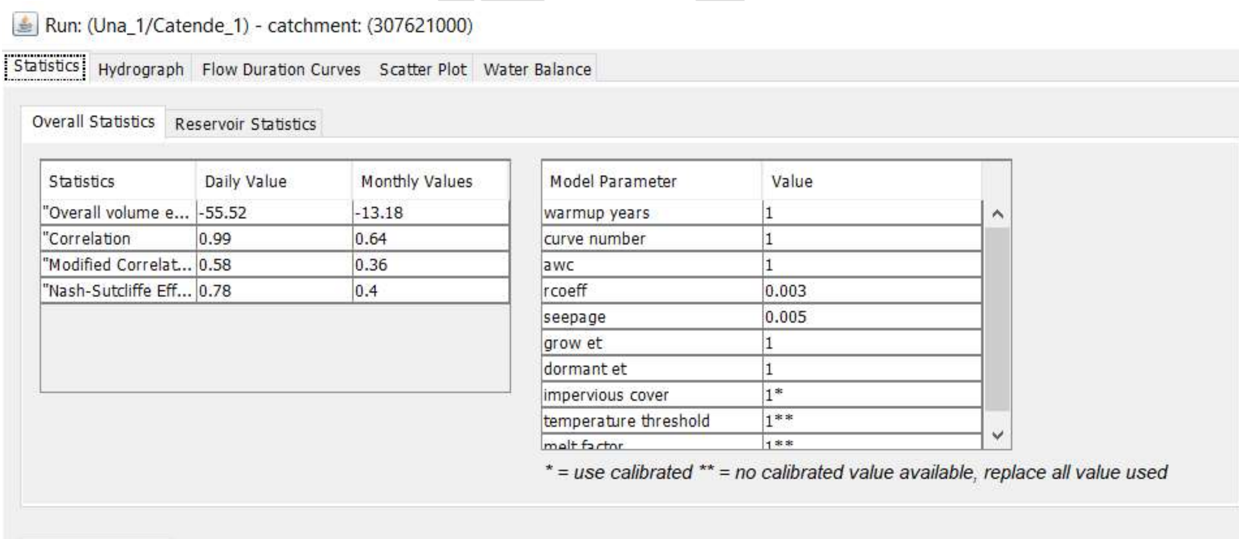
18. For reference, after the first run, the file "**launchIWRM.bat**" will open the HydroBID model with the corresponding data and settings of the last automatically created "Settings.txt".

J. Understanding HydroBID Results

19. To view the results you must click on the "**Output"** tab in HydroBID's main screen. Then click on "**View Outputs**"



20. In the pop-up window, you will see all the options for visualization of the results. In addition, HydroBID provides daily and monthly statistics to evaluate the model's performance, such as: **Overall volume error**, **Ove (%), correlation, r (-)**, **modified Correlation**, **Rmod** and **Nash-Sutcliffe Efficiency, R^2** and also includes the model parameter values used in the simulation



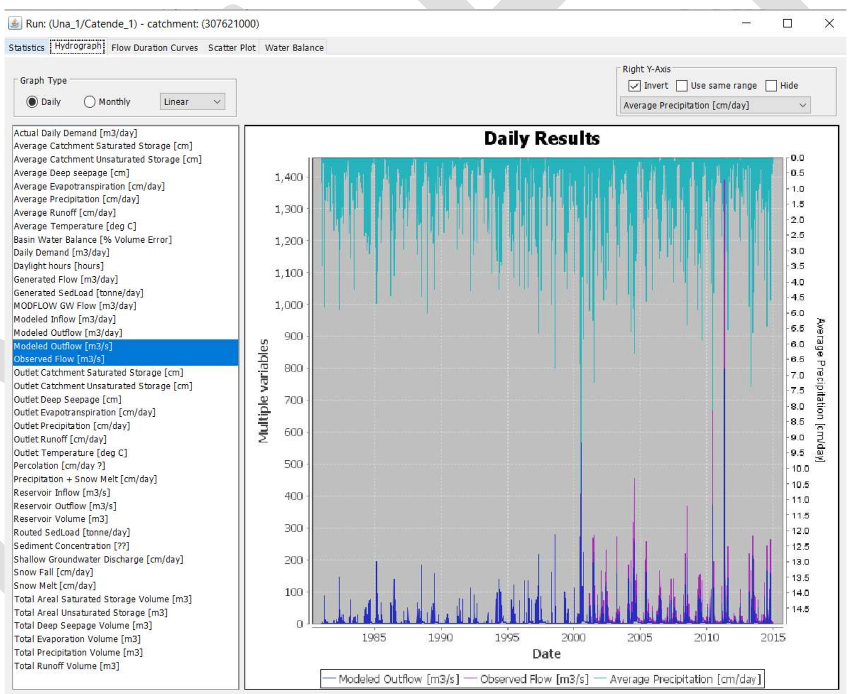
21. In addition, errors of monthly and annual volume are provided, as well as the number of days that are missing data.

Monthly Statistics | Annual Statistics

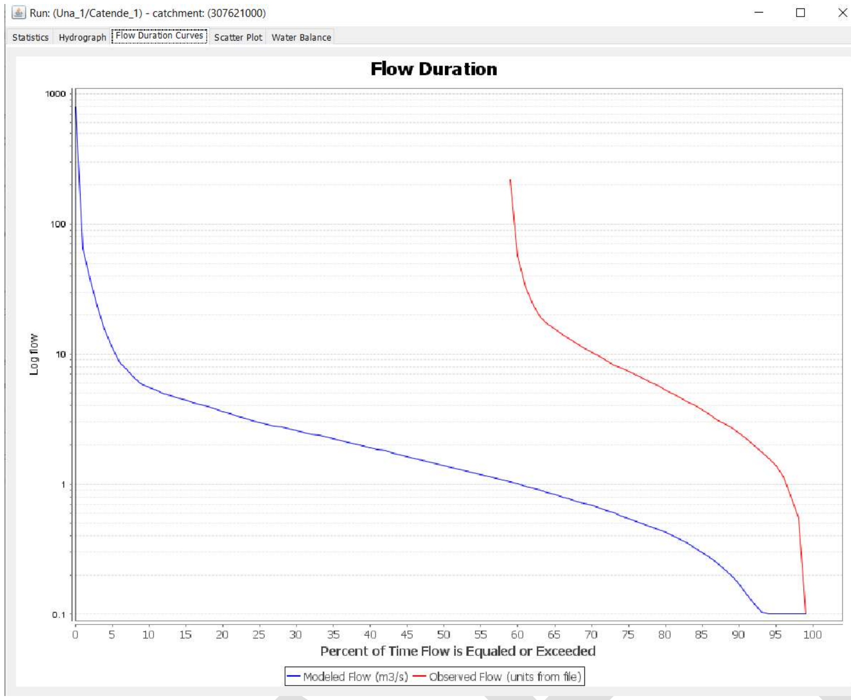
Mean Monthly Flows

Month	Observed Mean (m^3/s)	Simulated Mean (m^3/s)	Ove(%)	Days missing data
January	NaN	2.18	NaN	620
February	NaN	2.46	NaN	565
March	NaN	2.88	NaN	620
April	NaN	3.6	NaN	600
May	NaN	6.24	NaN	620
June	NaN	9.26	NaN	600
July	NaN	8.42	NaN	620
August	NaN	5.78	NaN	620
September	NaN	3.99	NaN	600
October	NaN	2.83	NaN	620
November	NaN	2.19	NaN	600
December	NaN	1.66	NaN	620

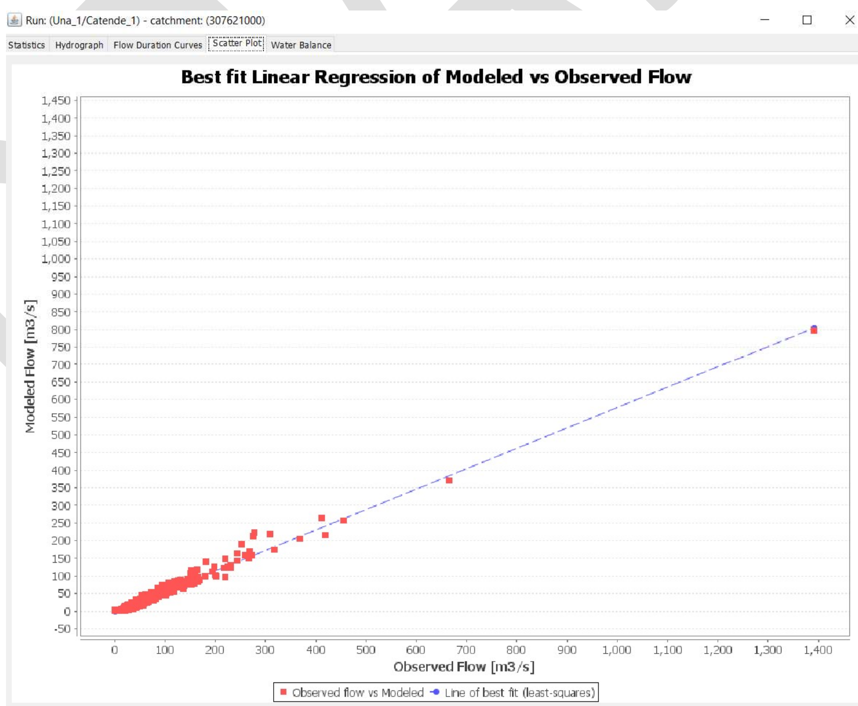
22. The "**Graph"** tab shows a hydrograph and allows other time-series to be displayed in a daily or monthly time scale and with a logarithmic or normal scale.



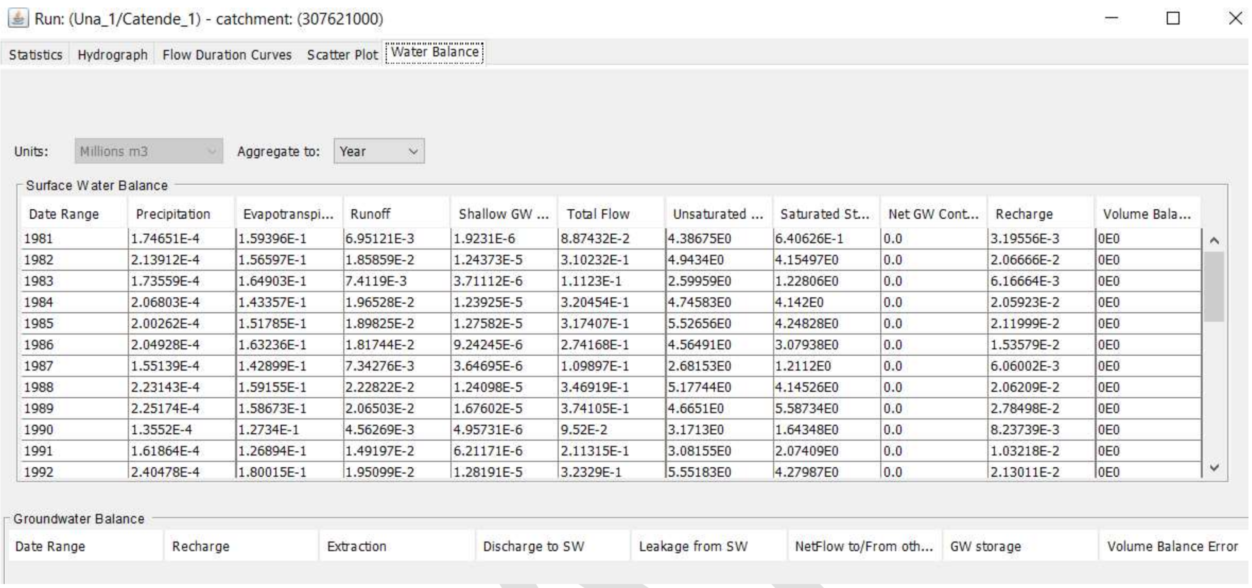
23. **Flow Duration Curve:** A graph to show the percentage of time that a given flow is being matched or exceeded. It is useful to evaluate the model's performance during the calibration. Note: the parameters used in this run are before calibration.



24. **Scatter Plot:** The pattern of points reveals any correlation between the observed flows and the simulated flows.

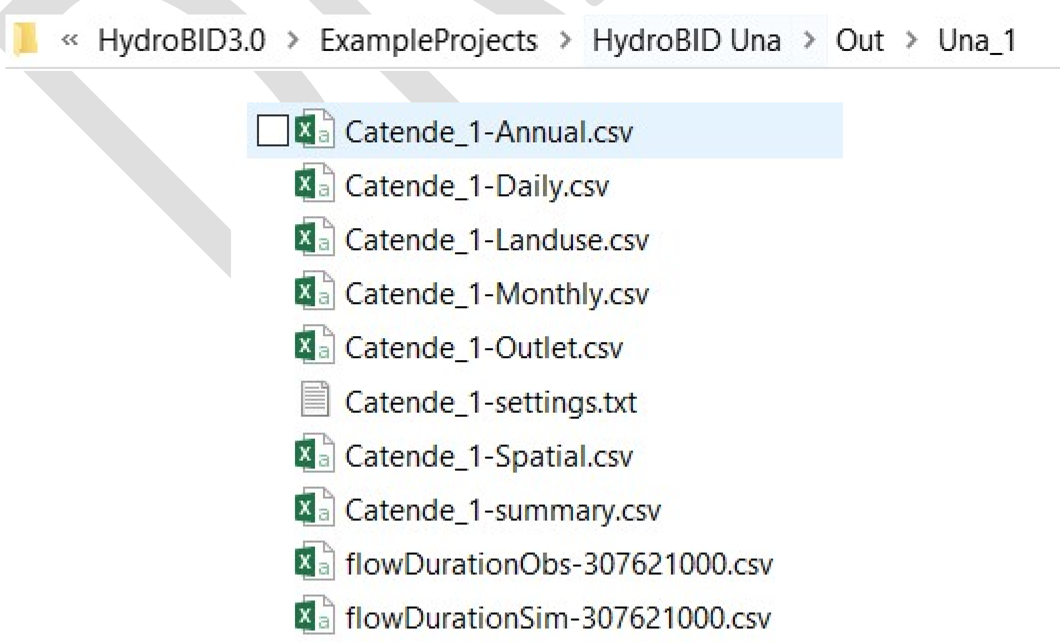


25. **Water Balance :** This output provides an annual summary of all of the parameters included in the water balance, including a groundwater balance, if the module is included in the simulation.



Date Range	Precipitation	Evapotranspi...	Runoff	Shallow GW ...	Total Flow	Unsaturated ...	Saturated St...	Net GW Cont...	Recharge	Volume Bala...
1981	1.74651E-4	1.59396E-1	6.95121E-3	1.9231E-6	8.87432E-2	4.38675E0	6.40626E-1	0.0	3.19556E-3	0E0
1982	2.13912E-4	1.56597E-1	1.85859E-2	1.24373E-5	3.10232E-1	4.9434E0	4.15497E0	0.0	2.06666E-2	0E0
1983	1.73559E-4	1.64903E-1	7.4119E-3	3.71112E-6	1.1123E-1	2.59959E0	1.22806E0	0.0	6.16664E-3	0E0
1984	2.06803E-4	1.43357E-1	1.96528E-2	1.23925E-5	3.20454E-1	4.74583E0	4.142E0	0.0	2.05923E-2	0E0
1985	2.00262E-4	1.51785E-1	1.89825E-2	1.27582E-5	3.17407E-1	5.52656E0	4.24828E0	0.0	2.11999E-2	0E0
1986	2.04928E-4	1.63236E-1	1.81744E-2	9.24245E-6	2.74168E-1	4.56491E0	3.07938E0	0.0	1.53579E-2	0E0
1987	1.55139E-4	1.42899E-1	7.34276E-3	3.64695E-6	1.09897E-1	2.68153E0	1.2112E0	0.0	6.06002E-3	0E0
1988	2.23143E-4	1.59155E-1	2.22822E-2	1.24098E-5	3.46919E-1	5.17744E0	4.14526E0	0.0	2.06209E-2	0E0
1989	2.25174E-4	1.58673E-1	2.06503E-2	1.67602E-5	3.74105E-1	4.6651E0	5.58734E0	0.0	2.78498E-2	0E0
1990	1.3552E-4	1.2734E-1	4.56269E-3	4.95731E-6	9.52E-2	3.1713E0	1.64348E0	0.0	8.23739E-3	0E0
1991	1.61864E-4	1.26894E-1	1.49197E-2	6.21171E-6	2.11315E-1	3.08155E0	2.07409E0	0.0	1.03218E-2	0E0
1992	2.40478E-4	1.80015E-1	1.95099E-2	1.28191E-5	3.2329E-1	5.55183E0	4.27987E0	0.0	2.13011E-2	0E0

26. Each "**run**" or execution of the model is saved in the Project folder and produces ten files with the name of the run (**Run Name**) provided by the user in the set-up window (**Set up**). The files are saved in the "**Out**" folder. Additionally, two files relating to the duration curves for observed and simulated flows are produced.



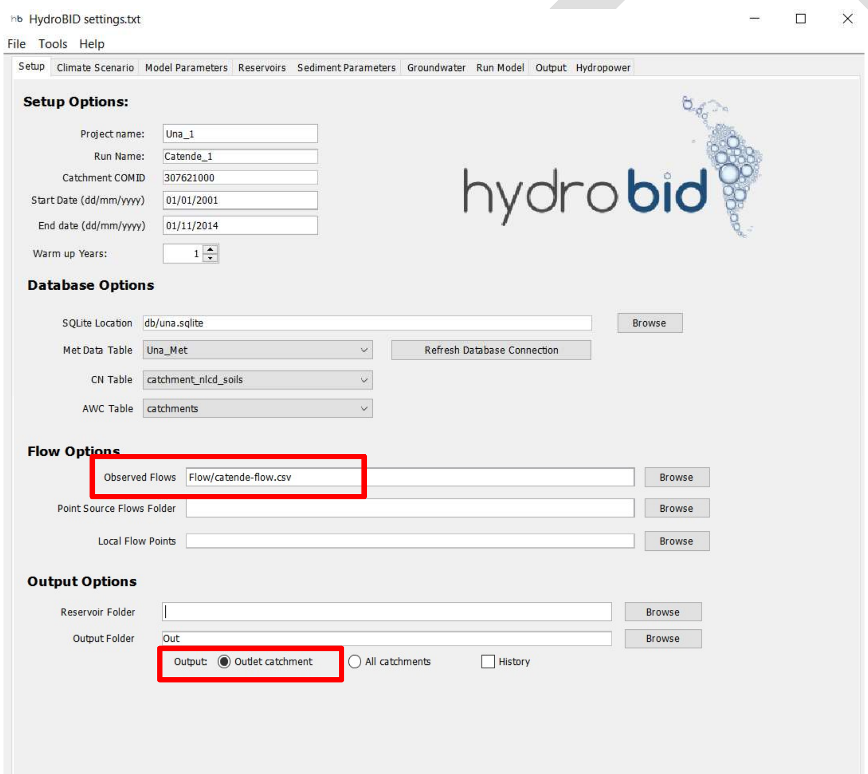
- **RunName-Monthly**: monthly time series of precipitation, temperature, simulated flow and observed flow.
- **RunName-Summary**: The total number of catchments, drainage area, computational time, and the COMID of the outlet catchment.
- **RunName-Annual:** Results, including water availability, by year.
- **RunName-Landuse:** The distribution of land uses within the study.
- **RunName-Outlet:** simulated time series of output variables by catchment.
- **RunName-Spatial:** Results by each subwatershed, or COMID
- **RunName-Daily:** The results by day for each subwatershed (COMID)
- **RunName-Settings**: All the input parameters and model set-up.
- **flowDurationObs-COMID:** observed flow statistical data for the given start COMID
- **flowDurationSim-COMID:** simulated flow statistical data for the given start COMID

J. Model Calibration

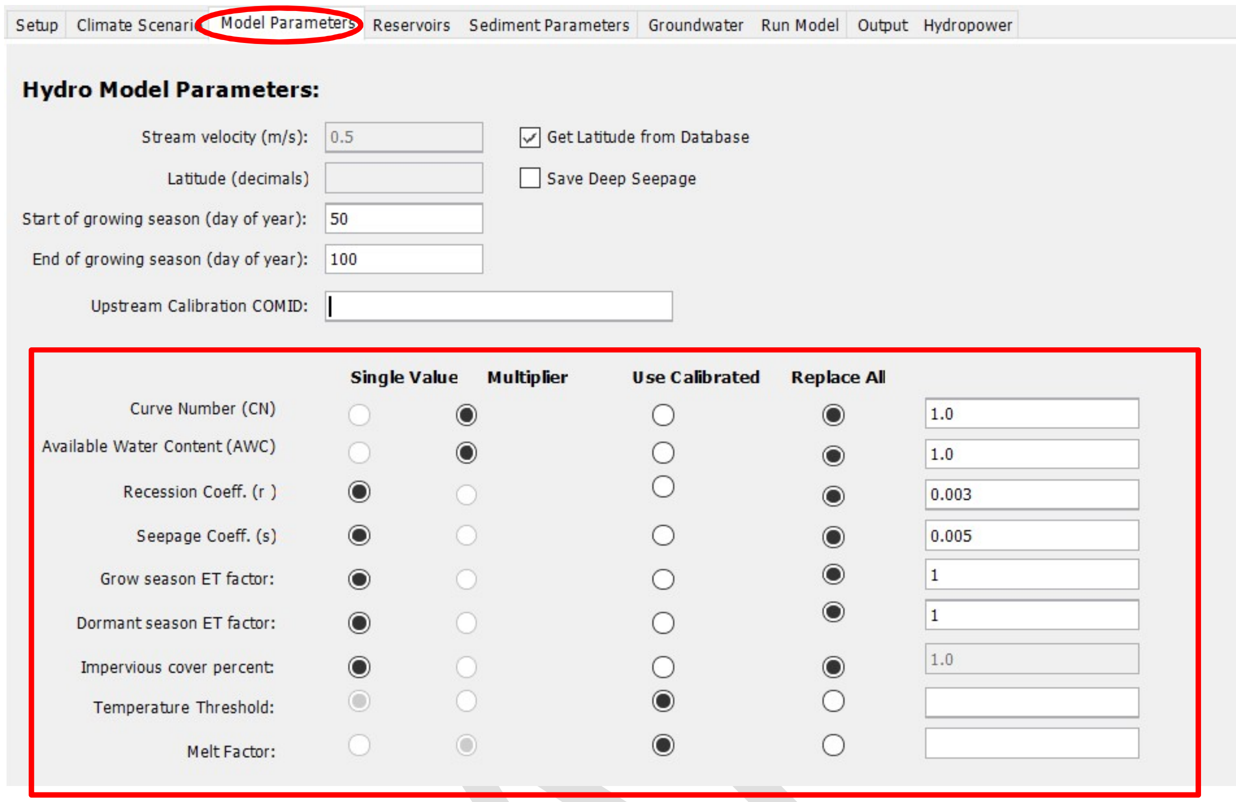
1. The HydroBID database is parameterized and pre-calibrated using values from regional databases, for this reason the process of calibration and validation is necessary to ensure that the model represents the reality as correctly as possible.

2. During the calibration, the values of the measured flows that are located in the flow files in the folder **"Flow"** are used to compare with the flows simulated by HydroBID.

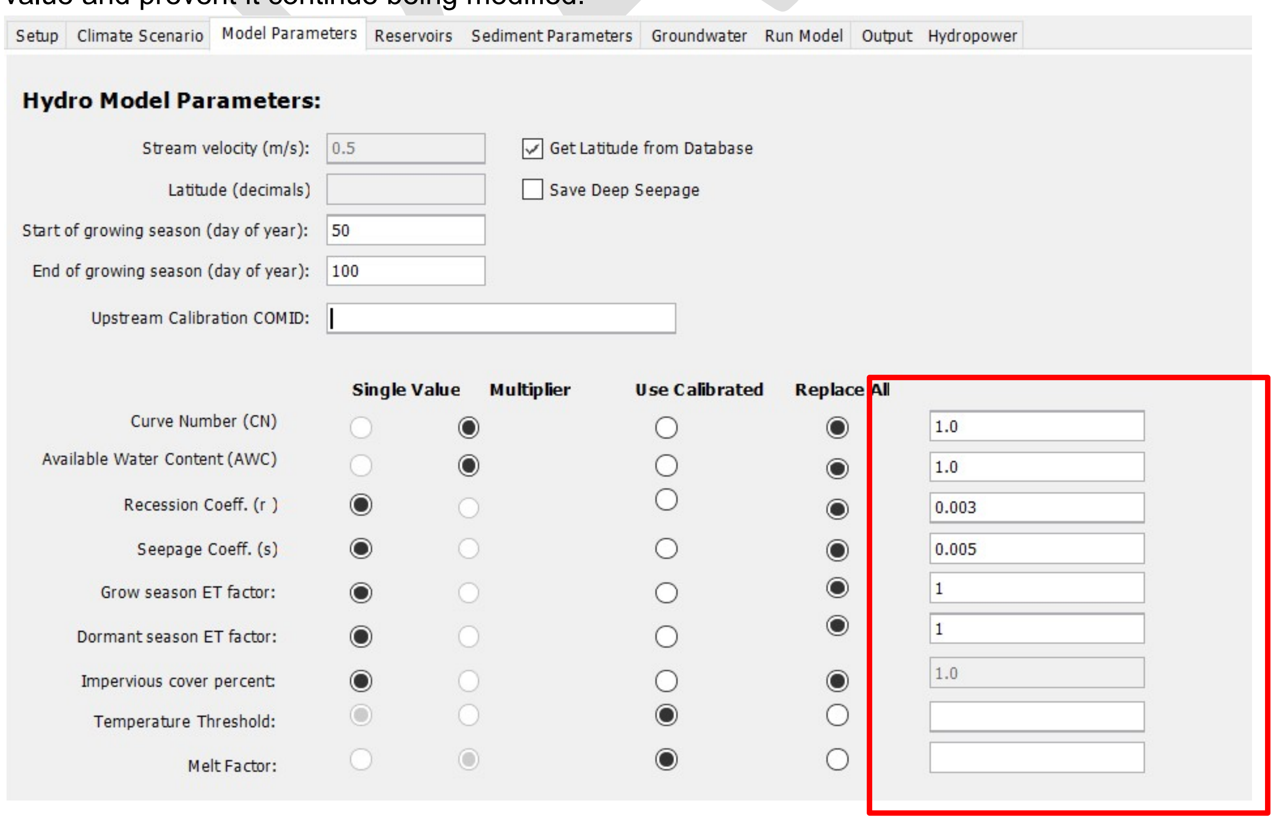
3. First , ensure that the "**Outlet Catchment**" option is enabled in the main screen. Once the process is complete the option "**All Catchment**" option can be activated if you want detailed information in each sub-basin of the system under study. Additionally, verify that the file corresponding to the flow measurement station that you want to calibrate is loaded in the "**Flows to Compare**" option.



4. For the calibration you must click on the "**Model Parameters"** tab in HydroBID's main screen (the **"Setup"** tab and at the bottom you will find all the calibration parameters.



5. To calibrate a particular parameter you need to activate the "**Replace All**" option; once the parameter has been calibrated you must activate the "**Use Calibrated**" option to fix the value and prevent it continue being modified.



6. The parameters to calibrate are the following:

   - **Curve Number**: parameter used to characterize the type of land use and represent the land's hydrology. A curve number is assigned to each sub-basin in the database.
   - **Available Water Content (AWC)**: AWC estimates the amount of water that can be stored in the soil to be used by plants, affecting the infiltration into the groundwater. A value is assigned to each sub-basin in the database.
   - **Coefficient of recession (R)**: The coefficient R characterizes how ground water near the surface contributes to the flow in the rivers after an event of great flows.
   - **Losses (seepage)**: is the exchange between groundwater close to the surface and the deepest groundwater.
   - **Grow season ET factor:** used to simulate the effect of the variation on the ET due plant/crops growth in certain periods of the year
   - **Dormant season ET factor:** used to simulate the effect of the variation on the ET in the periods of the year when the plant/crops growth stops mostly due to environmental conditions.
   - **Temperature Threshold:** minimum temperature needed for snow precipitation and accumulation
   - **Melt Factor:** used to relate the mean daily temperature to the snow melting process

The following table presents ranges of values "recommended" for each of the variables used in the calibration process:

Stream Velocity	Estimated average velocity of the river segments.	0.5 m/s
Curve Number (CN)	Curve number. Controls the initial amount of abstraction used to calculate runoff. The default values are available in the database.	0.8 - 1.2 (multiplier)
Available Water Content (AWC)	Available capacity of water in the soil. It activates the beginning of percolation. The default values are available in the database.	0.2 - 1.2 (multiplier)
Recession Coefficient (r)	Recession Coefficient. Controls the rate of groundwater flow from the saturated storage.	0,001 - 0.75 (day-1)
Seepage Coefficient (S)	Coefficient of percolation. Coefficient that controls the rate of filtration in the underground aquifer	0,005 - 0.1 (day-1)
Grow season ET factor	Evapotranspiration factor during the growing season	0.5 - 1.5
Dormant season ET factor	Factor of evapotranspiration during the dormant season.	0.5 - 1.5
Impervious cover percent	The estimated percent of the impervious portion of the catchment.	1%
Temperature Threshold	minimum temperature needed for snow precipitation and accumulation	
Melt Factor	used to relate the mean daily temperature to the snow melting process	

7. To verify the simulations of calibrations, you can use the variables of error, the time series graph and the flow duration curve as described in the 'Output' chapter of this guide and elaborated upon in the Una Example below.

8. The variables used in the statistical determination of the errors in HydroBID's simulations are the following:

   - **Overall Volume Error**: it indicates the average percent of error between the simulated values and the observed values. Optimum value close to the % of maximum permissible error.

- **Correlation (r)**: it analyzes the standard deviations of the time series of observed and simulated flows. Optimal value close to 1.
- **Modified Correlation Coefficient (r_{mod}):** it analyzes the standard deviations of the time series of observed and simulated flows, by applying a factor that relates the maximum and minimum values. Optimal value close to 1.
- **Nash-Sutcliffe Efficiency Index (R^2):** it analyzes the magnitude of the relation between the variances of the simulated flows and the variances of the observed flows. Optimal value is close to 1.

Note: to understand more about the calibration parameters and the statistics presented for HydroBID's simulations, we invite you to read the Technical Note: " **Hydro-BID: An Integrated System for Modeling Impacts of Climate Change on Water Resources**, which you can download at this link.

9. The following steps will guide you how to perform a calibration in HydroBID. After that, if you want to continue to practice the calibration process you must follow these steps:

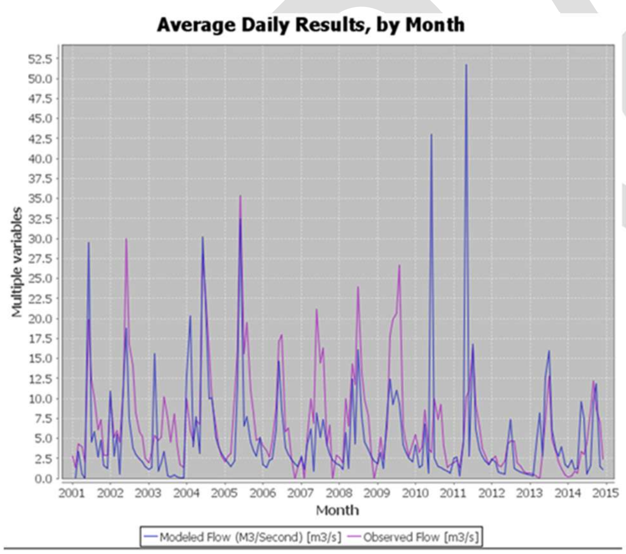
    a. The initial run corresponds to the sub-basin identified by the "**CATENDE"** hydrometric identified by the **COMID "307621000"** and is used below to illustrate the influence of each parameter in the calibration process.

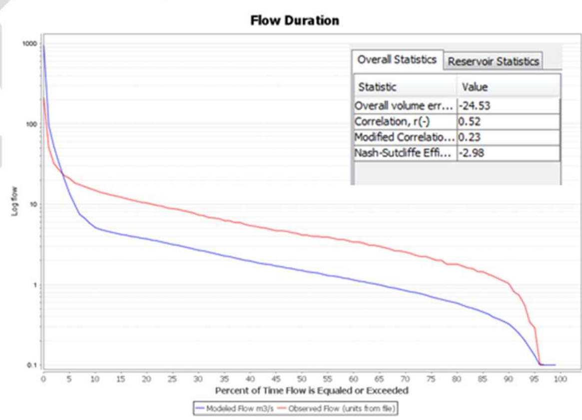
    b. To practice the calibration process, you must use the catchment identified with the hydrometric "**SEGUNDA"**; it is characterized by the **COMID "307586800"**. This is the catchment most downstream of the Una River and it is the one that, once calibrated, allows obtaining the water balances for the entire catchment.

10. The following points illustrate the relevance of each of the parameters used in the calibration process of the catchment identified by Catende Catchment with the **COMID "307621000"** which is the sub-basin we have been using throughout this tutorial.

Note: There is no specific order to calibrate each parameter, this will depend on each simulation to be calibrated depending on the first comparison between observed and simulated values.

a. The following figure shows the initial parameterization of the simulation with their respective graphs and final errors of simulation. Note: not all parameters will be calibrated during this tutorial, rather only the four parameters shown below will be altered:

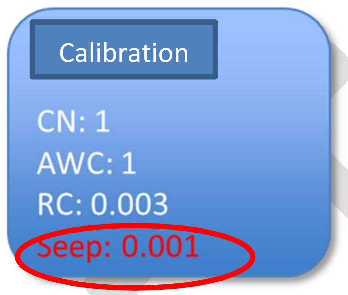


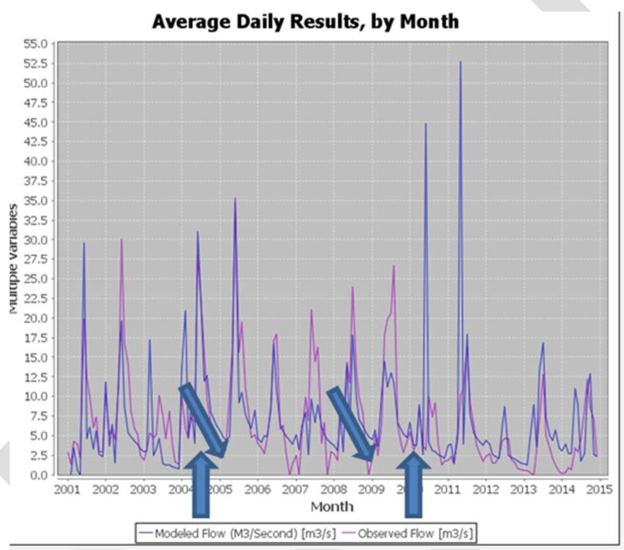


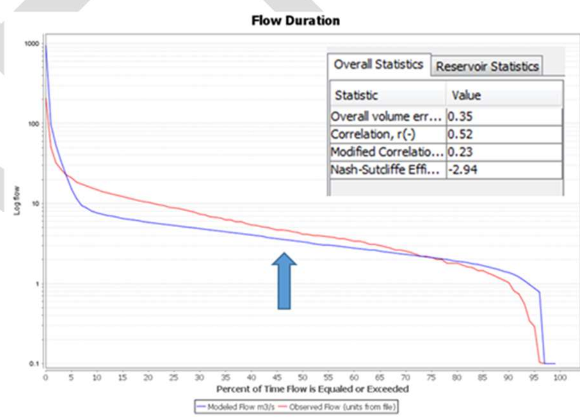
b. The graph of flow duration of this initial simulation shows how the simulated volume is less than the observed volume; in addition, you can see the mismatch of the flow peaks in the average monthly hydrograph.

c. In this particular case, the first problem to be solved was the total volume. Hence, as a first step the parameter “**SEEPAGE (SEEP)**" was reduced in order to consequently reduce the infiltration and increase the runoff.

d. The new value of "**SEEPAGE**" was reduced from 0.005 to **0.001**.

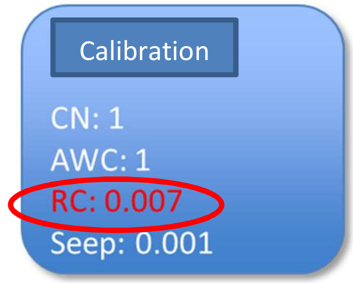


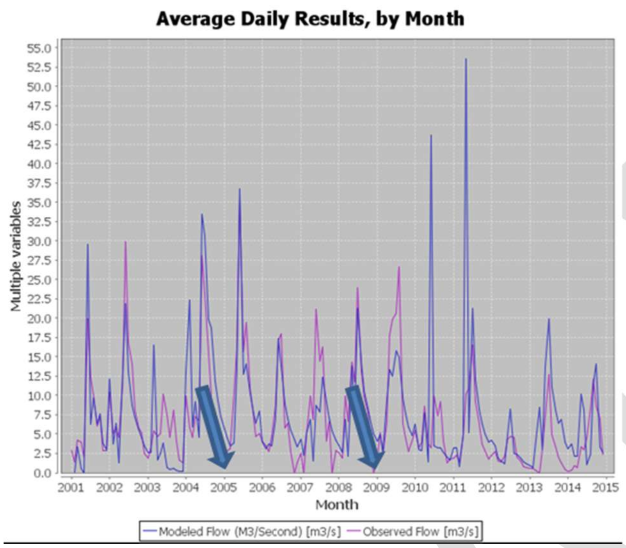


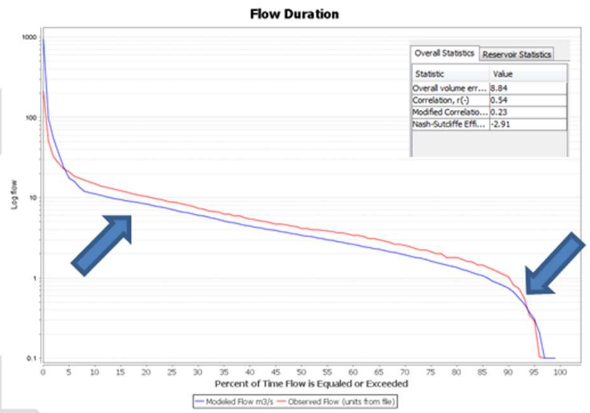


e. Although this variation improved significantly the difference in volume, it is noted that the simulation overestimated the values of lower flows and underestimated the values in a higher range.

f. For this reason, the second step was to increase the "**Coefficient of recession (RC)**" parameter from 0.003 to **0.007**, in order to force the higher flows to have a greater repeatability and similarly to reduce the lower flows. The effect can also be seen in the length of the spikes in the monthly hydrographs.

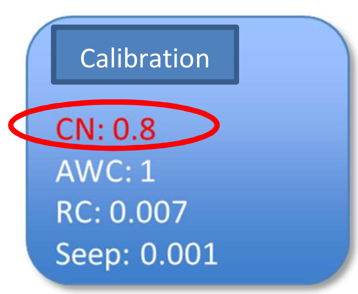


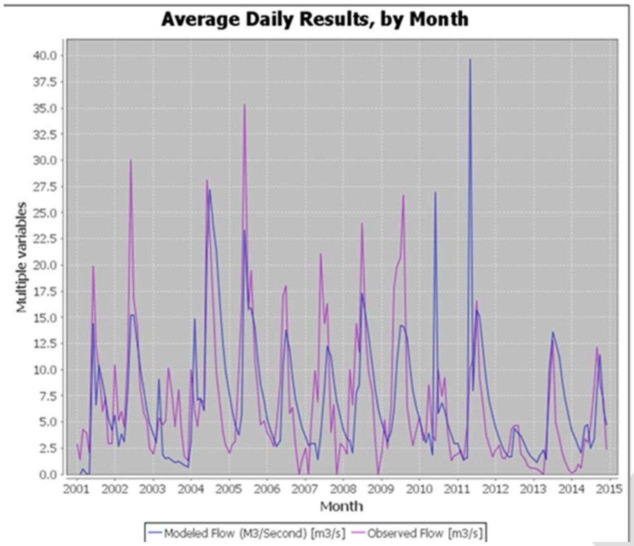


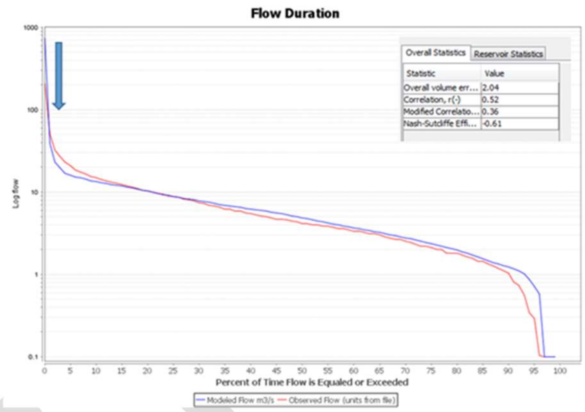


g. Once the slope of the flow duration curve was adjusted, first, it became necessary to finish adjusting the overestimated peaks that could be seen both in the curve of the monthly hydrographs as well as in the flow duration curve.

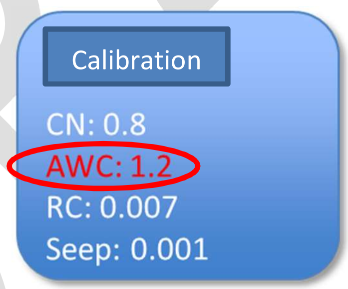
h. This is accomplished by reducing the "**Curve Numbers (CN")**, as it reduces the runoff and the sensitivity to precipitation events; in this case it was reduced by 20%, which represents a value of **0.8** once it is included in the interface.

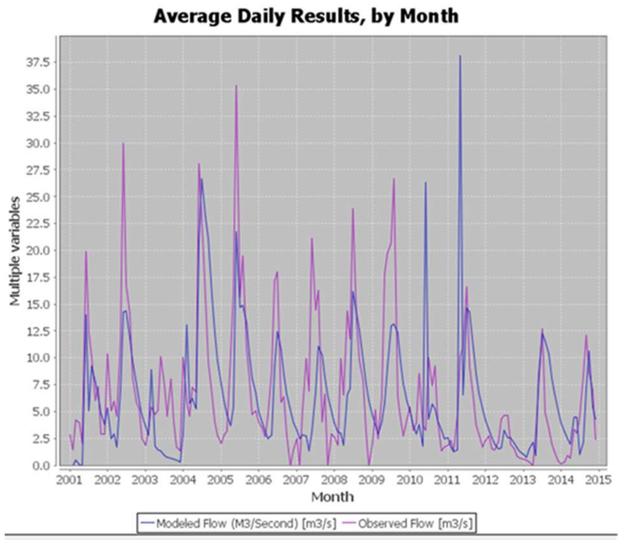


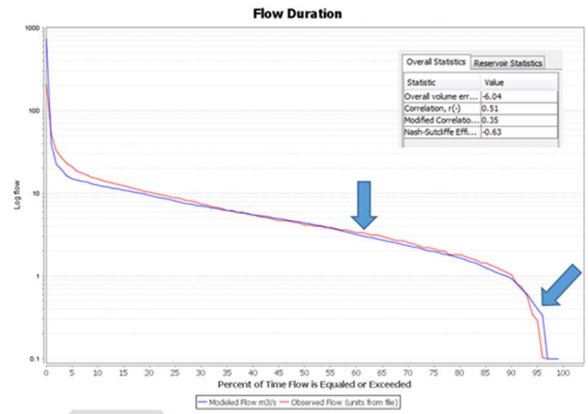




i. Finally the **"Available Water Content (AWC)"** was used to adjust the small differences in the ends. In this case, the parameter AWC was increased by 20%, which would mean a value of **1.2** to somewhat reduce the higher flows.

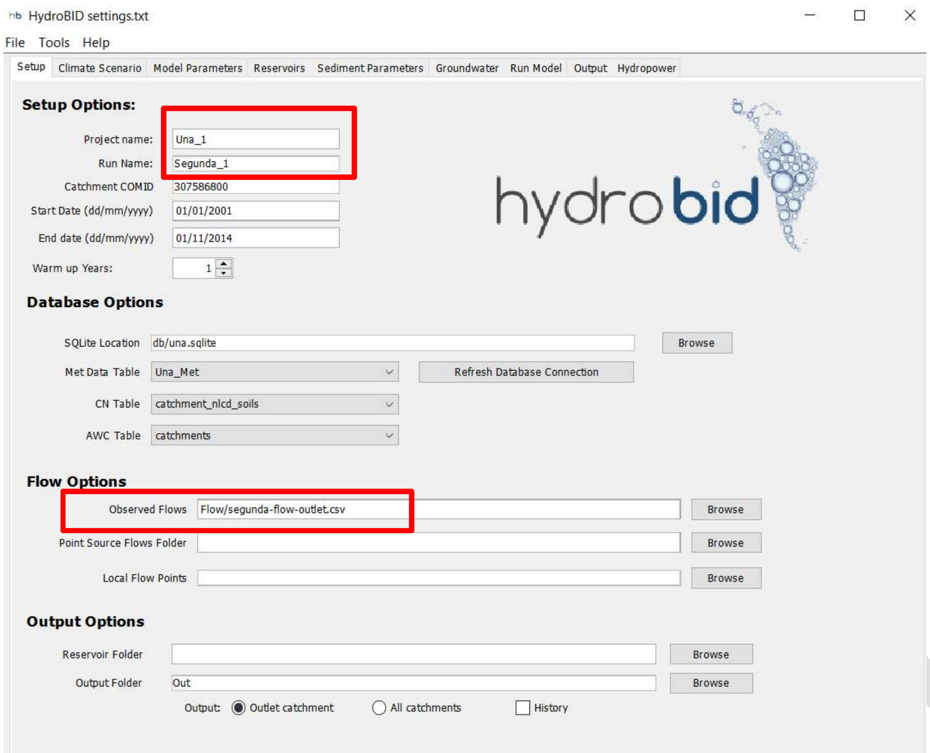






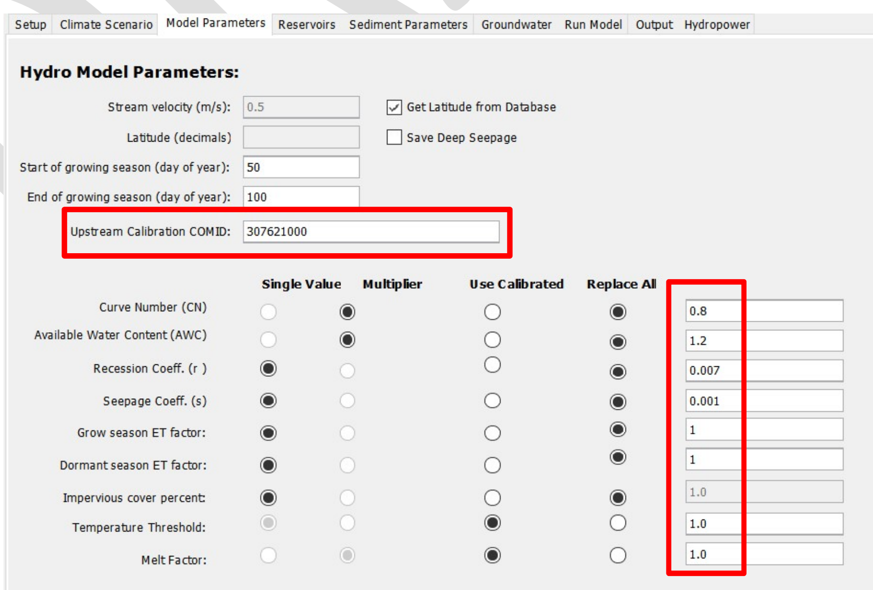
Note: As of this moment, by modifying **AWC** and **Rc** the desired accuracy calibration can be obtained. This will depend on each specialist, the quality of the existing data and the sensitivity pre-established for the study (maximum percent of error allowed).

11. if you want to continue to practice the calibration process you must follow these steps:
    - The procedure that follows will guide you on the calibration exercise of the 'Segunda' catchment identified by the **COMID "307586800"** which will allow for the modelling and calibration of the entire Una River basin:
    - In "**Run Name**" change the name to **Segunda_1** or a name of your choosing, and in "**COMID**" place the identifier of the SEGUNDA catchment "**307586800**".
    - In "**Flows to Compare**" use "**Browse**" to load the file that corresponds to this station, which you can find in the "**FLOW**" folder.
    - The dates **"Start Date"** and **"End Date"** should remain the same because the simulation belongs to the same simulation period.



- In the "**Model Parameters**" window, add the **COMID of the CATENDE catchment, "307621000"**, on the "**Upstream Calibration COMID**" label ; this will prevent the model from modifying the parameters that have been already calibrated for this sub-basin.

- Select the option "**Replace All**" in the parameters you want to calibrate.



- Now you can run HydroBID and begin to calibrate the complete model of the Una river basin.

- Once the process is complete, it is not necessary to repeat the calibration unless in the catchments of the study a noticeable alteration in land use occurs, or that the construction of a significant work of infrastructure is planned (reservoir, artificial canal, diversion, etc.).

- You must repeat this process for every flow station available and always calibrate from upstream to downstream.

- It there are 2 stations on watersheds that flows into the same watershed the you must repeat the calibration process on both stations and then include and separate each Upstream Calibration COMID using ‘,’.

K. Climate Change Scenarios Simulation

HydroBID includes a tool to run simulations for the analysis of climate change scenarios; this tool allows for variations of precipitation and temperature on an annual or monthly basis.

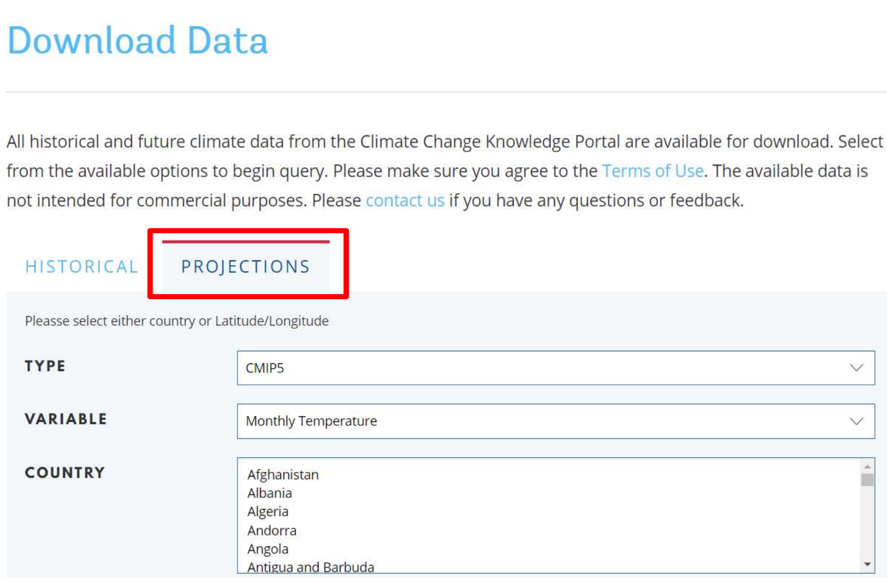
Below you will find how to simulate a climate change scenario for the Una River basin.

1. To obtain the climate change scenario we will use the information from The World Bank Climate Change Knowledge Portal (https://climateknowledgeportal.worldbank.org/), a platform designed for use by 'development practitioners and policy makers'. Note: Downscaled Climate Change Data for the region of study may also be used (and will provide more region-specific results) if available.

2. HydroBID requires Climate Change information in terms of the increase of temperature (Celsius) and the change in precipitation (%).

   Note: If you want to use the **"Precipitation"** option, be sure the results in Climate Change Knowledge Portal are converted to **cm or mm before calculating the percentage or numerical difference**.

3. To obtain the values from the Climate Change Knowledge Portal for the case of Catende, follow the following steps
   a. On the main screen of the Knowledge Portal, you may choose to search for Climate Change information by Country, Region, or Watershed. In this case, we will use the 'Download Data' feature, the most direct manner of downloading precipitation and temperature data. Click 'Download Data on the options.
   b. Next, you will be directed to a data download form. 'Historical' data is currently highlighted. Instead, click on the 'Projections' tab.



c. Proceed to fill out relevant information related to the study.

d. For the ‘**Type**’, leave the ‘CMIP5’ climate change models collection option, which represents the collection of 35 models with daily data across the RCPs.

e. For **Variable**, start with ‘Monthly Temperature’

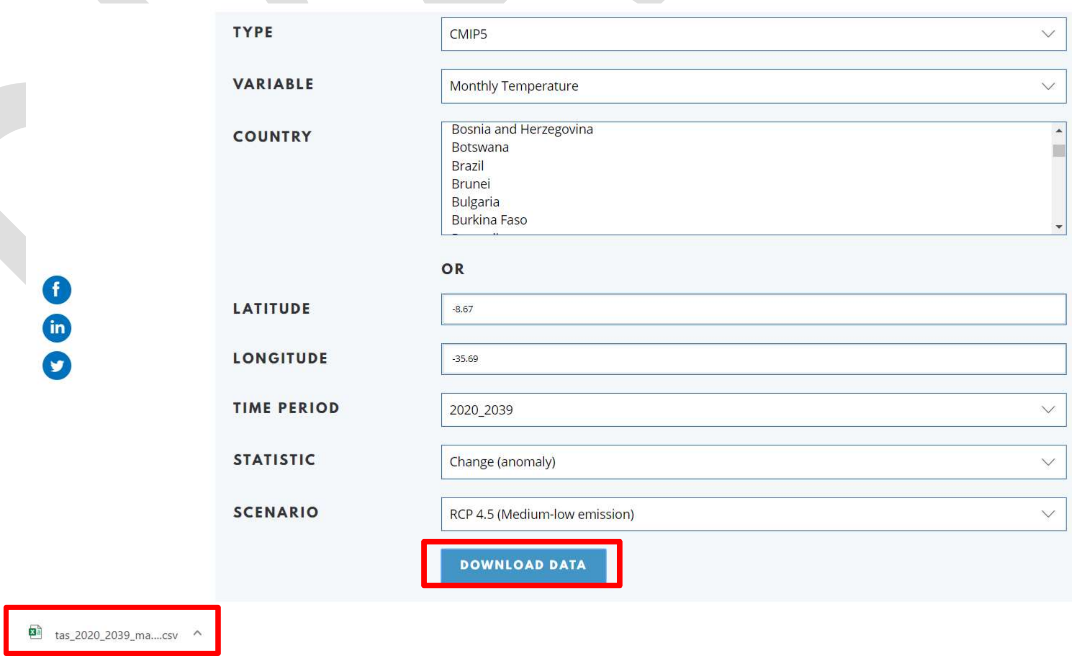
f. You may then choose to search for data using the ‘**Country**’ Option as ‘Brazil’ or the **Latitude and Longitude** Option. In the case of Catende, the latitude and longitude is Lat: -8.67°, Lon: -35.69. Note: Data is presented at a 1°x1° global grid spacing produced through bi-linear interpolation, so using the Latitude and Longitude Option will usually produce more accurate results.

g. Next, choose the **time period** for your climate change simulation. In this case, the time period of 2020 to 2039 will be selected, ‘2020_2039’.

h. In the **Statistic** option, select **‘Change (anomaly)’**. This will output the change in temperature (in degrees Celsius) from the current baseline period of 1986-2005, which is the information necessary in the HydroBID Climate Scenario Module.

i. Lastly, choose the **Climate Scenario** you wish to use out of the four Representative Concentration Pathways (RCP)s adopted and used for climate modelling by the International Panel on Climate Change (IPCC). As described within each option, the RCP scenarios range from a more optimistic view, with low emissions to high emissions, a more pessimistic scenario. In this case, we will select RCP 4.5 (Medium-low emission). However, it is recommended that when displaying climate change results, all scenarios are displayed in the same graph to represent a greater range of possible climatic outcomes.

j. Once the desired options are selected, click ‘Download Data’ and a .csv file be begin downloading.



k. Upon opening the CSV, you will notice a series of monthly temperature change (anomaly) data for various model types. To learn more about this model collection, read the MetaData Report here: https://climateknowledgeportal.worldbank.org/themes/custom/wb_cckp/resources/data/CCKP_Metadata_Description_2018.pdf

l. Choose the climate change parameters you would like to use in your simulation. You may choose one of the models' monthly averages or, using the Filter Option from the 'Data' tab in Excel, average all models together to arrive at overall monthly averages for all models. In other words, filter the ''Statistics' column for 'Jan Anomaly', find the average, and repeat for the remainder of the months.

m. Note: any formatting or additional tabs added to this file will not be saved, unless the .csv file is saved as an Excel file.

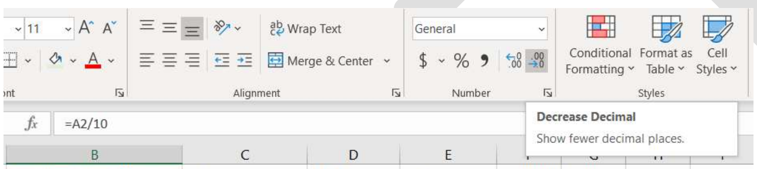
n. In this case, the first Climate Change model 'bcc_csm1_1' parameters will be used, as highlighted in green below:

Monthly Tempe	Year	Model	Statistics	Longitude	Latitude
0.711355209	2020-2039	bcc_csm1_1	Jan Anomaly	-35.69	-8.67
0.678171158	2020-2039	bcc_csm1_1	Feb Anomaly	-35.69	-8.67
0.567121506	2020-2039	bcc_csm1_1	Mar Anomaly	-35.69	-8.67
0.710641861	2020-2039	bcc_csm1_1	Apr Anomaly	-35.69	-8.67
0.715913773	2020-2039	bcc_csm1_1	May Anomaly	-35.69	-8.67
0.586948395	2020-2039	bcc_csm1_1	Jun Anomaly	-35.69	-8.67
0.594640732	2020-2039	bcc_csm1_1	Jul Anomaly	-35.69	-8.67
0.598777771	2020-2039	bcc_csm1_1	Aug Anomaly	-35.69	-8.67
0.705591202	2020-2039	bcc_csm1_1	Sep Anomaly	-35.69	-8.67
0.759613037	2020-2039	bcc_csm1_1	Oct Anomaly	-35.69	-8.67
0.648670197	2020-2039	bcc_csm1_1	Nov Anomaly	-35.69	-8.67
0.51049614	2020-2039	bcc_csm1_1	Dec Anomaly	-35.69	-8.67

o. Once arriving at the monthly temperature parameters, you wish to use for the simulation, repeat steps b through m to download projected Precipitation changes. In step e), Select 'Monthly Precipitation' as the variable of choice. Proceed to download and select climate change parameters in the same manner as the Temperature parameters. Note: the precipitation change (anomaly) in the Climate Change Knowledge Portal is shown in millimeters (mm), not centimeters(cm). If you the climate data you have imported is in cm, be sure to convert units. The 'bcc_csm1_1' model Precipitation adjustment parameters, with converted units to cm, for the Segunda location are shown below. Note the negative values indicate a projected decrease in precipitation from the baseline period of 1986-2005:

Monthly Precipitation - (MM)	Monthly Precipitation -(cm)	Year	Model	Statistics	Longitude	Latitude
0.283218384	0.028321838	2020-2039	bcc_csm1_1	Jan Anomaly	-35.69	-8.67
32.87884521	3.287884521	2020-2039	bcc_csm1_1	Feb Anomaly	-35.69	-8.67
9.995788574	0.999578857	2020-2039	bcc_csm1_1	Mar Anomaly	-35.69	-8.67
-56.8263855	-5.68263855	2020-2039	bcc_csm1_1	Apr Anomaly	-35.69	-8.67
-56.51365662	-5.651365662	2020-2039	bcc_csm1_1	May Anomaly	-35.69	-8.67
32.23117828	3.223117828	2020-2039	bcc_csm1_1	Jun Anomaly	-35.69	-8.67
2.151771545	0.215177155	2020-2039	bcc_csm1_1	Jul Anomaly	-35.69	-8.67
0.810909271	0.081090927	2020-2039	bcc_csm1_1	Aug Anomaly	-35.69	-8.67
-1.129886627	-0.112988663	2020-2039	bcc_csm1_1	Sep Anomaly	-35.69	-8.67
-0.664648056	-0.066464806	2020-2039	bcc_csm1_1	Oct Anomaly	-35.69	-8.67
-0.334238052	-0.033423805	2020-2039	bcc_csm1_1	Nov Anomaly	-35.69	-8.67
9.324138641	0.932413864	2020-2039	bcc_csm1_1	Dec Anomaly	-35.69	-8.67

p. To decrease the amount of decimal places for each of your values, click the 'Decrease Decimal Places' button within the 'Numbers' menu under the 'Home' Tab of Excel.



Monthly Precipitation -(cm)	Year	Model	Statistics	Longitude	Latitude
0.028321838	2020-2039	bcc_csm1_1	Jan Anomaly	-35.69	-8.67
3.287884521	2020-2039	bcc_csm1_1	Feb Anomaly	-35.69	-8.67
0.999578857	2020-2039	bcc_csm1_1	Mar Anomaly	-35.69	-8.67
-5.68263855	2020-2039	bcc_csm1_1	Apr Anomaly	-35.69	-8.67
-5.651365662	2020-2039	bcc_csm1_1	May Anomaly	-35.69	-8.67
3.223117828	2020-2039	bcc_csm1_1	Jun Anomaly	-35.69	-8.67
0.215177155	2020-2039	bcc_csm1_1	Jul Anomaly	-35.69	-8.67
0.081090927	2020-2039	bcc_csm1_1	Aug Anomaly	-35.69	-8.67
-0.112988663	2020-2039	bcc_csm1_1	Sep Anomaly	-35.69	-8.67
-0.066464806	2020-2039	bcc_csm1_1	Oct Anomaly	-35.69	-8.67
-0.033423805	2020-2039	bcc_csm1_1	Nov Anomaly	-35.69	-8.67
0.932413864	2020-2039	bcc_csm1_1	Dec Anomaly	-35.69	-8.67

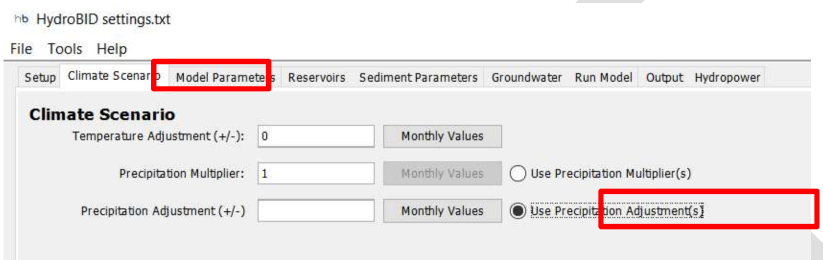
q. It is recommended to combine the precipitation values and temperature values into the same document and then save as an Excel for future reference. Future climate change scenario parameters can also be saved in this master document.

Monthly Precipitation -(cm)	Monthly Temperature - (Celsius)	Year	Model	Statistics
0.03	0.71	2020-2039	bcc_csm1_1	Jan Anom
3.29	0.68	2020-2039	bcc_csm1_1	Feb Anom
1.00	0.57	2020-2039	bcc_csm1_1	Mar Anon
-5.68	0.71	2020-2039	bcc_csm1_1	Apr Anom
-5.65	0.72	2020-2039	bcc_csm1_1	May Anon
3.22	0.59	2020-2039	bcc_csm1_1	Jun Anom
0.22	0.59	2020-2039	bcc_csm1_1	Jul Anoma
0.08	0.60	2020-2039	bcc_csm1_1	Aug Anom
-0.11	0.71	2020-2039	bcc_csm1_1	Sep Anom
-0.07	0.76	2020-2039	bcc_csm1_1	Oct Anom
-0.03	0.65	2020-2039	bcc_csm1_1	Nov Anon
0.93	0.51	2020-2039	bcc_csm1_1	Dec Anor

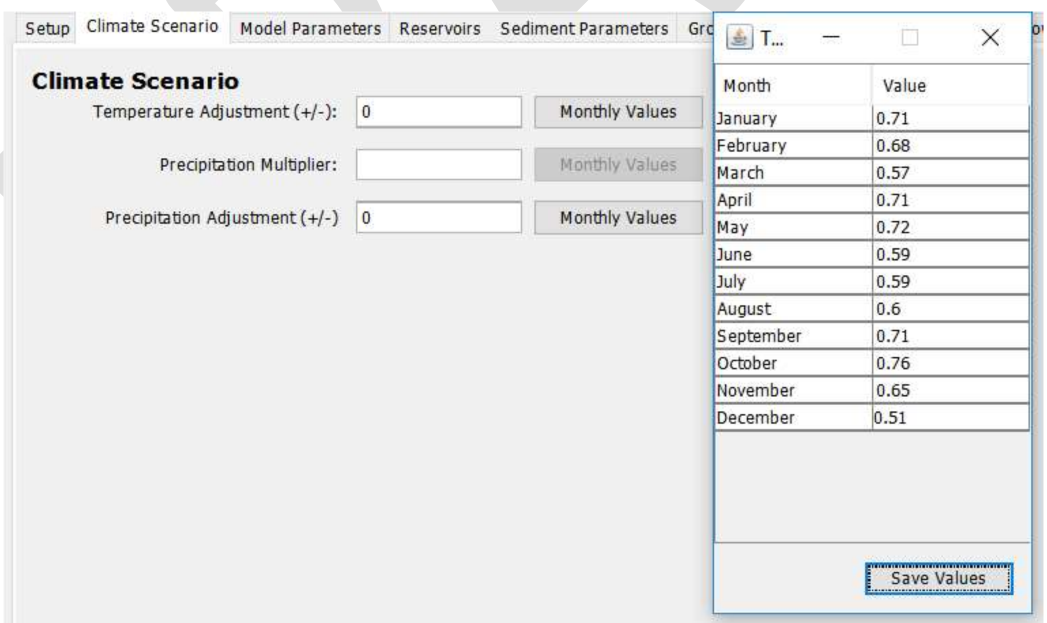
4. Now, return to the HydroBID interface with the simulation information you wish to run, and select **"Climate Scenario"**; in this case we will only make a simulation with temperature

and precipitation adjustment. Check that the option **"Use Precipitation Adjustment"** is active.

> ***Note:*** Precipitation Multiplier also be used, but requires the download of baseline data in order to calculate the factor by which the current Precipitation information needs to be multiplied. For example, if we enter a value of 1, it means that there will be no variation in precipitation. If, on the other hand, we know that the precipitation will increase by 20%, we would enter a value of 1.2. As the Climate Change Knowledge Portal provides adjustment information, we will use this option.



5. Now, we will include the monthly averages of the temperature anomalies by clicking on the '**Monthly Values'** box and entering the value for each month. Then, enter the **Precipitation Adjustment** (or Precipitation Multiplier if that method is selected) values in the same way.

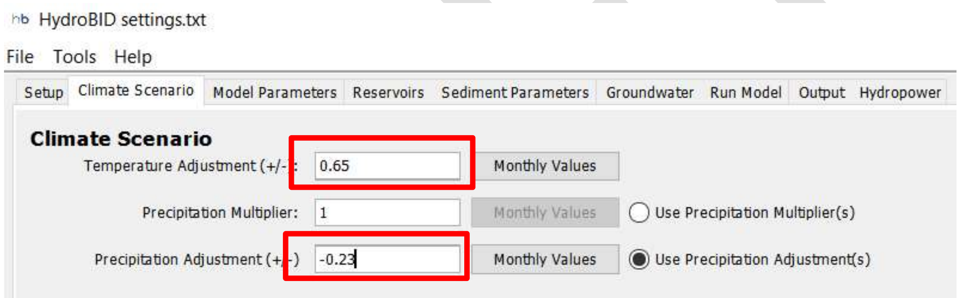


6. To simplify the process, these monthly values could be averaged, and a singular averaged value (in this case, 0.65) could be entered into the **Temperature Adjustment**

box. Then, enter the **Precipitation Adjustment** values in the same way, entering the averaged value of -0.23.

fx =AVERAGE(C2:C13)

B	C	D
Statistics	Monthly Precipitation -(cm)	Monthly Temperature - (Celsius)
Jan Anomaly	0.03	0.71
Feb Anomaly	3.29	0.68
Mar Anomaly	1.00	0.57
Apr Anomaly	-5.68	0.71
May Anomaly	-5.65	0.72
Jun Anomaly	3.22	0.59
Jul Anomaly	0.22	0.59
Aug Anomaly	0.08	0.60
Sep Anomaly	-0.11	0.71
Oct Anomaly	-0.07	0.76
Nov Anomaly	-0.03	0.65
Dec Anomaly	0.93	0.51
Average	-0.23	0.65



7. Now, you can proceed to the **"Run Model"** window to run the new simulation and verify changes in the volume available within the climate change scenario that was selected. Repeat this process for all Climate Scenarios (for both different RCP scenarios and different time period projections) you wish to model. Be sure to take advantage of Project name and run name conventions to organize and retrieve the various simulations.

8. It is important to understand that HydroBID will simulate the same time series that is found in the original simulation but, in this case, the results will represent the same time series but beginning on the year 2050 as the first year and modified with the applied changes. In this case the values of observed flow which are used to build the flow duration curve will

help you obtain a good image of the possible change of behavior of the catchment due to the effects of climate change.

DRAFT

V. Advanced HydroBID Modules

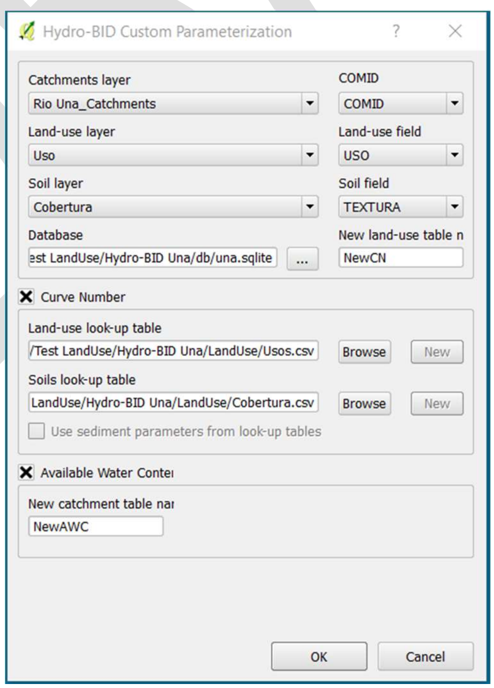
L. Using the Custom Parametrization Tool (CPT).

Changes in soil use may have a positive or negative impact on the runoff. Hydro-BID has been using predefined Land Use and Soil data taken from global satellite images from USGS and FAO that in some areas is too coarse. The CPT allows to use customized land use and soil data to parameterize key hydrologic parameters used in HydroBID to calculate daily runoff, such as the CN and the AWC.

The CPT creates a new table to the database, identical to the original “catchment_nlcd_soils” table except that the CN values for each COMID are assigned to those land-uses by user defined shapefiles. CPT also creates a table identical to the original “catchments table”, except that the AWC values for each COMID are assigned by soil type provided in user defined shapefiles

The CPT is included in the V3 version of the AHDTool, the tool opens by clicking on AHD Tools > Hydro-BID Parametrization Tool

The CPT will open as follows



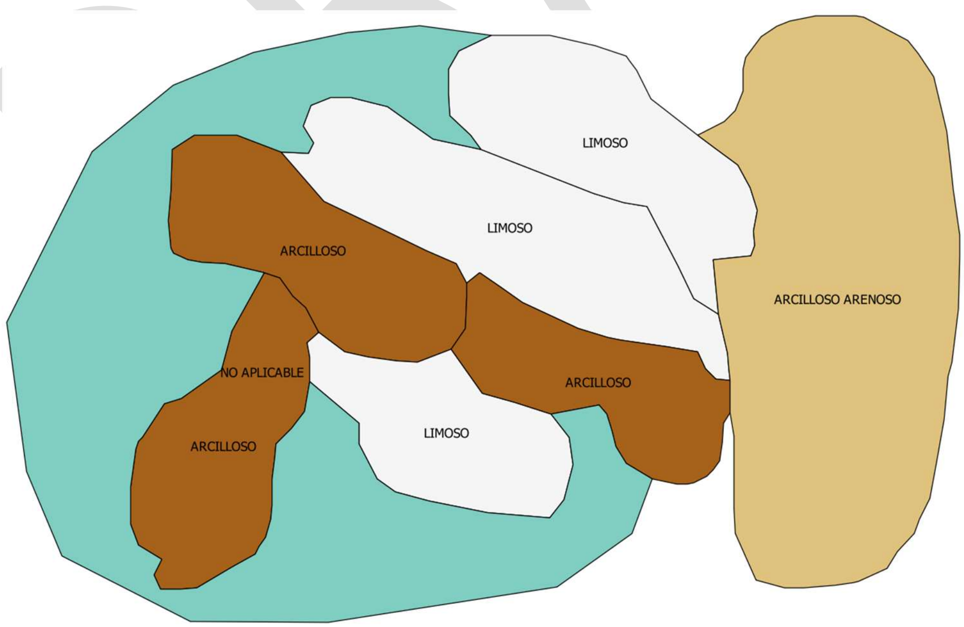
The CPT use the following variables:

- **Catchment Layers:** the original AHD catchment shapefile (Una catchment)
- **COMID:** variable to read the catchment COMIDS
- **Land-use Layer:** the new land-use classification shapefile
- **Land-use field:** variable that contains the new land-use classification
- **Soil layer:** the new soil classification shapefile
- **Soil field:** the new soil classification variable
- **Database:** the project sqlite where the new tables will be created
- **New land-use table name:** name of the new land-use table
- **Curve Number:** this option needs to be activated if a new CN table is needed
- **Land-use look-up table:** table with the new land-use classification
- **Soils look-up table:** table with the new soil type classification
- **Available Water Content:** this option needs to be activated is a new AWC table is needed
- **New catchment table name:** name of the AWC table

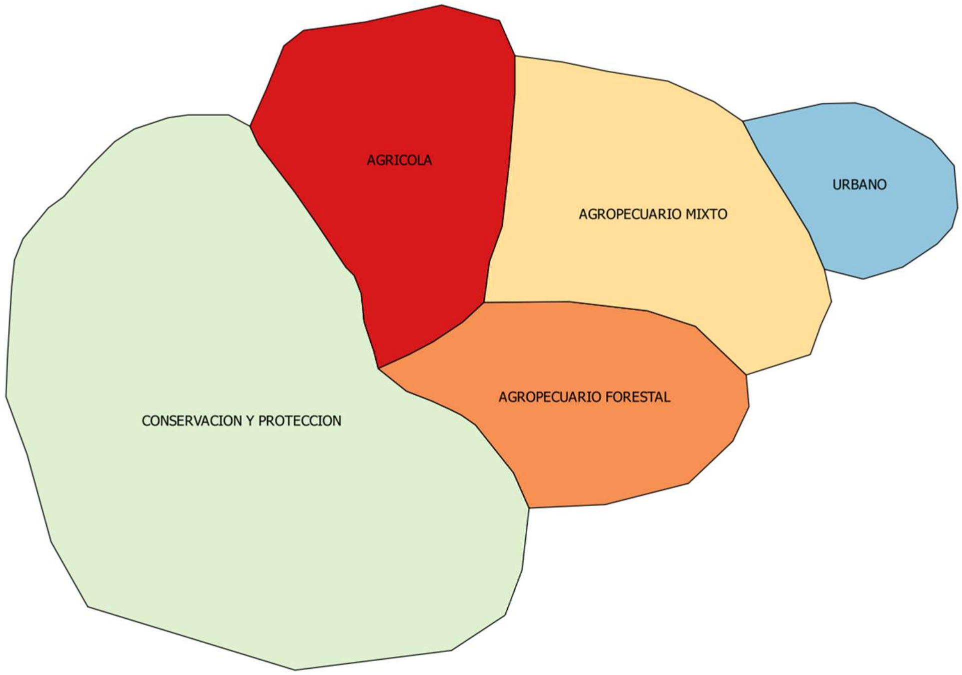
The following are the steps to customize Soil and Land Use in Hydro-BID

1. Be sure that the HydroBID model is closed before using the CPT

2. We need to prepare 2 shapefiles one with the new land-use and other with the soil type, these 2 files need to be included in the active QGIS project. For this exercise 2 shapefiles where prepared "Uso.shp" for land-use



3. and “Cobertura.shp” for soil type.



4. The following tables need to be created for the table of content of the land-use layer
   - USE: a list of the unique descriptors for an attribute in the land-use layer (USO for the example)
   - DESCRIPTION: a description of the soil type (Uso_Desc for the example)

	id	USO	Uso_Desc
1	1	CONSERVACION Y PROTECCION	Areas de protección ecológica
2	2	AGRICOLA	Caña de azucar
3	4	AGROPECUARIO FORESTAL	50% cultivo 50% ganadería
4	5	AGROPECUARIO MIXTO	60% Ovino 40% Bovino
5	3	URBANO	Población Rural

5. A look-up .csv table need to be created matching the name of the variable in the attribute table and with the respective Curve Number attached in a second column (Cobertura.csv for this example).
   - Land-use table need to match the name and descriptor name must match the attribute table exactly (spelling, capitalization, spaces, etc.)
   - Look-up table header for Curve Number column must be “nlcd_id”
   - The land-use attribute descriptors must be unique but an NLCD ID do not need to be

USO	nlcd_id
CONSERVACION Y PROTECCION	15
AGRICOLA	5
AGROPECUARIO FORESTAL	6
AGROPECUARIO MIXTO	4
URBANO	1

6. The following table need to be created for the table of content of the soil type layer
   - TEXTURE: a list of the unique descriptors for an attribute in the land-use layer (TEXTURA for the example)

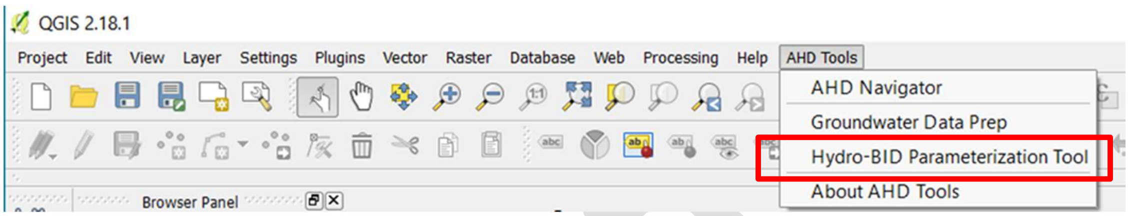
id	TEXTURA
1	NO APLICABLE
2	ARCILLOSO
3	LIMOSO
4	LIMOSO
5	ARCILLOSO
6	LIMOSO
7	ARCILLOSO ARENOSO
8	ARCILLOSO

7. look-up .csv table need to be created matching the name of the variable in the attribute table and with the respective Curve Number attached in a second column (Cobertura.csv for this example).
   - Land-use table need to match the name and descriptor name must match the attribute table exactly (spelling, capitalization, spaces, etc.)
   - Look-up table header for the hydrologic soil group column must be "hydgrp"
   - Look-up table header for the AWC column must be "AWC"
   - The soils attribute descriptors must be unique, but the hydrologic soil group do not need to be
   - All unique soil attribute descriptors in the catchments of interest must be included
   - Only hydrologic soil group classifications A, B, C, or D may be used
   - Single area-weighted AWC value assigned to each COMID
   - AWC is only needed if that option is activated

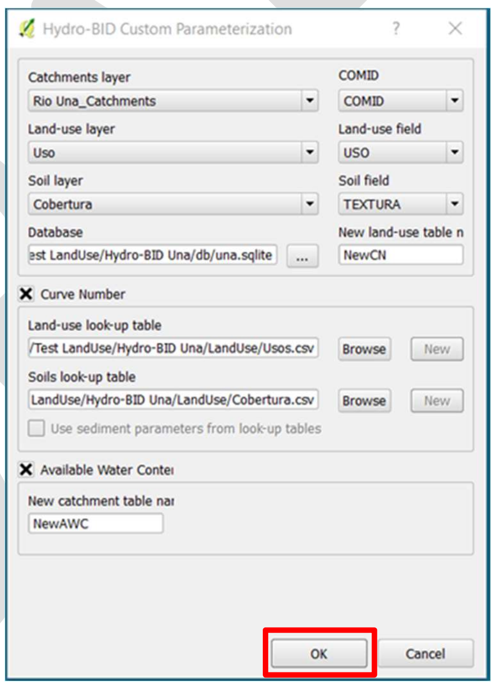
TEXTURA	hydgrp	AWC
NO APLICABLE	D	5
ARCILLOSO	A	5
LIMOSO	B	30
LIMOSO	B	30
ARCILLOSO	A	5
LIMOSO	B	30
ARCILLOSO ARENOSO	C	5
ARCILLOSO	A	5

8. To use the CPT, both layers, Uso.shp and Cobertura.shp needs to be added to the Una River project in QGIS.

9. Open the CPT by clicking on AHD Tools > Hydro-BID Parametrization Tool:

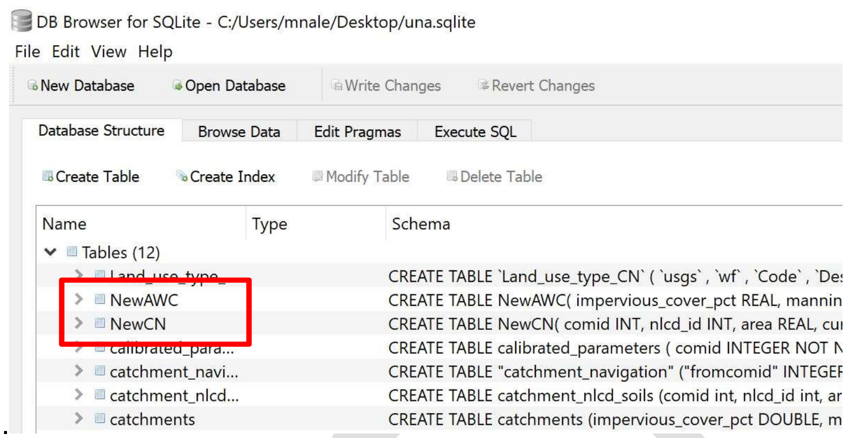


10. Set the variables as showed in the following image, activate “Curve Number” and “Available Water Content” and click **“OK”**

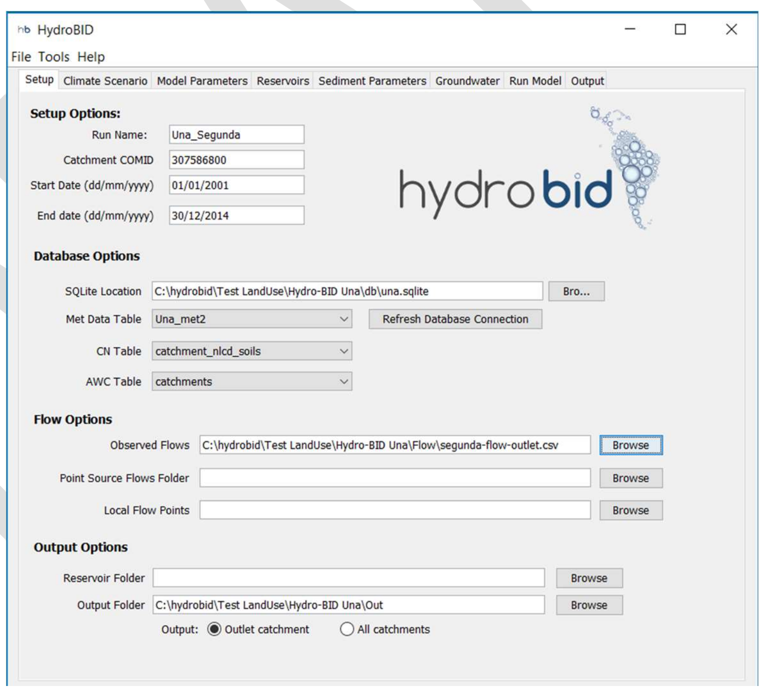


11. Once the process is finished your tables will be incorporated into the sqlite (no message will appear on the QGIS screen).

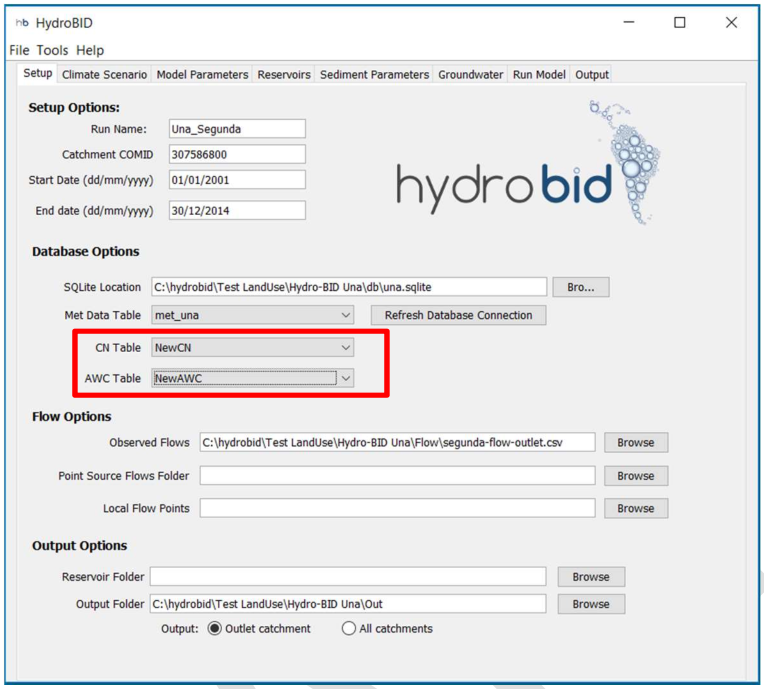
12. To check if the tables where created correctly you can use the DB Browser for SQLite. Simply open the sqlite, go to Browse Data and look for the new tables NewCN and NewAWC



13. In order to perform a simulation with the new parametrization first launch the Una Basin Model.



14. Now set the CN table variable to the created table “NewCN” and the AWC Table to the created table “NewAWC”



15. Now you can go to Run Model and start your new simulation.

M. Using the Reservoir Module.

Additional Advanced Module Guides Coming Soon

N. Sediment Module

Additional Advanced Module Guides Coming Soon

O. Groundwater Module

Additional Advanced Module Guides Coming Soon

P. Water Quality Module

Additional Advanced Module Guides Coming Soon

Q. Hydropower Module

Additional Advanced Module Guides Coming Soon

VI. Additional Resources

R. SWAT Weather Data and Macro Processor

This HydroBID DataInput Macro can be found in the '***Documentation Folder'*** and currently works for SWAT Climate data from January 1, 1979 to July 31, 2014. The only input for the code is the raw data files downloaded from the website: https://globalweather.tamu.edu/

The code should do the following:

- Interpolate missing data files in SWAT Climate database: 5/30/1986 and 12/24/1986-12/31/1986
- Find the average of the min and max temperature
- Convert precipitation into centimeters and add appropriate header
- Save station coordinate file with station name from weather data file and corresponding Latitude and Longitude coordinates
- Prepare precipitation and temperature data files, each saved as their station name in their appropriately named folder, with modified precipitation/temperature data as indicated above, and dates in the format HydroBID can process: d/m/yyyy

To access the code for the Macro (and change any of the specifications above) you can:

- Enable developer tab by clicking "Options"→ "Customize ribbon" → Check "developer tab option"
- Once developer tab is enabled, click on "Developer"→ "Visual Basic"

Volume 4

STEP BY STEP GUIDE

HydroBID Series: Technical Information