Read Me

To semi-automate the results extraction of five evaluation parameters (depth, duration, percent time inundated, stream power, and velocity) in 2D HEC-RAS (2D Hydrologic Engineering Center's River Analysis System), the River Scenario Evaluation Tool (RiverSET) was developed in Python. RiverSET runs multiple modeling scenarios (i.e., specific combinations of terrain modifications and culvert/bridge modifications) consecutively and calculates the results at the five evaluation parameters at user defined regions of interest (ROIs). To calculate the scenario results consecutively, multiple input files are imported into Python (See Worley et al. 2021; Figure S1). These files are described below, and sample file templates are provided in the GitHub Repository.

<u>*HEC-RAS Files*</u>

In order to run the modeling scenarios consecutively, the Python wrapper, RiverSET reads in the HEC-RAS project file (.prj file), the geometry files (.g# and .g#.hdf files), and the results file (.p#.hdf) for each run. The number symbol, #, represent different scenario files created in HEC-RAS (.g# for different geometry files, and .p# for different results runs).

<u>*Model Project File*</u>

The HEC-RAS project file (Figure 1A) is read into RiverSET and runs using the HEC-RAS controller (Dysarz, 2018). The desired storm must be loaded into HEC-RAS and saved as the current file (Figure 1B) to be run from Python.

<u>*Geometry Files*</u>

Geometry files must be created for each scenario the user wishes to run in HEC-RAS. The Geometry files contain the terrain alterations and structures (e.g., culverts and bridges) necessary for each HEC-RAS simulation. Once these different scenarios are created in HEC-RAS, there is an associated geometry file and geometry Hierarchical Data Format (HDF) file that HEC-RAS creates (each given a different geometry file number). The geometry file can be opened as a text file and a free HDF view program (The HDF Group, 2006) can be downloaded to view the HDF file. The geometry text file includes the culvert and bridge information while the geometry HDF file includes the terrain information. A Geometry Template text file is created for each model run and the correct options (e.g., structures such as culverts or bridges) and terrain information is included (the template number must match the number currently saved in HEC-RAS, Figure 1D, see *Options Text File and Scenario Text File* Sections).

<u>*Results Files*</u>

The results file (Figure 1C) that is currently saved in the HEC-RAS model is read into RiverSET. The values needed to calculate the five evaluation parameters (See Worley et al. 2021; Figure 3) – depth, duration, percent time inundated, stream power, and velocity are extracted from the file at the user defined locations (see *Location Results Text File* Section).

<u>*User Created Files*</u>

In order to run each scenario consecutively and extract the results, three user defined text files (Options, Scenarios, and Location Results text files) must be created. These files are created once and can then be run for as many storms as desired. See the GitHub site for example file formats.

Options Text File

The Options text file includes the terrain options and the structures options. These different options are numbered from one to the total number of options. The terrain options must include the geometry number for the associated terrain and the structures options can be copy and pasted from the original geometry text file. The options template should include anything that will change between the scenarios. If a culvert or bridge is constant, then it can stay in the Geometry Template text file that will be read into 2D HEC-RAS for each scenario.

Scenarios Text File

A Scenario's text file is created that includes the numbers of each of the options that should be included in that run. Each scenario should have an associated terrain and the structures to be included for that run. The associated number in the Scenarios text file is used to pull the terrain and structure information from the Options text file to create the geometry files that will be read into HEC-RAS for that run.

Location Results Text File

Every scenario that is listed in the Scenario text file is run consecutively in 2D HEC-RAS and the five evaluation parameter values are calculated. To estimate values from 2D HEC-RAS at a particular location we calculated these values on a cell basis in RiverSET. In order to export these values, "Cells" "Faces", and "Face Points" text files are created by the user and are imported into Python. The cell numbers are the locations where the user would like the results calculated. The face and face point numbers should be the values that surround the cell (See Worley et al. 2021; Figure 3). These values are extracted by hand once by the user in HEC-RAS and then used for every scenario. The specific cell, face, and face point numbers are used to reference necessary calculation values that are stored on a cell, face, or face point level in the results HDF file.

RiverSET

The 2D HEC-RAS files and the user created files are read into Python and RiverSET uses the HEC-RAS controller to run the model (Dysarz, 2018). Using the scenarios text file, the correct options are placed on the Geometry Template text file for each model run (Figure 1D). The geometry HDF file being read into RiverSET is also saved as this template number, so the desired terrain is read into HEC-RAS. After each model run the geometry HDF is saved back to its original number in order to be used in future scenarios. To calculate the results, RiverSET reads in the results HDF file after each model run. The code extracts the appropriate user-defined cell, face, or face point values from the results HDF file and calculates the results for each location. RiverSET saves the results for each scenario at every location in a csv file, and results can be visualized in a heat map and 3D plot.

RiverSET Software Requirements

The RiverSET tool was coded in Python (version 3.7), using the imported packages: numpy, pandas, os, matplotlib, win32com.client, and h5py.

Note (See Worley et al. 2021; Figure S2):

Future communication with HEC-RAS developers at ACOE may suggest refinement of RiverSET to improve parameter calculations as it is not obvious from the HEC-RAS manual how the face velocities reported by HEC-RAS are calculated. However, through trial and error we believe that HEC-RAS calculates face velocity as follows. We believe that the V_{X1} and V_{Y1} values recorded in the HDF file are the components of the total velocity vectors (V_1) parallel to the axes of the map grid coordinate system. HEC-RAS then calculates the vector rejection (V_R) of V relative to the face (V_R is the component of V that is normal to the face) for each face point. We believe that the velocity of a particular face (VF) is calculated as a combination of the magnitudes of the V_R vectors (V_{R1} and V_{R2}) at the two cell points that define a particular cell face, but we were unable to determine the exact method of combination. We tried calculating the average of V_{R1} and V_{R2}. This magnitude is very similar to but is consistently less than the face velocity reported by HEC-RAS. This could be due to an adjustment to preserve mass balance based on the topology underlying the cell and the velocities of the other cell faces. In addition, we are uncertain how the cell face points and faces are calculated with the interpolation of values from adjacent cells.

Figures

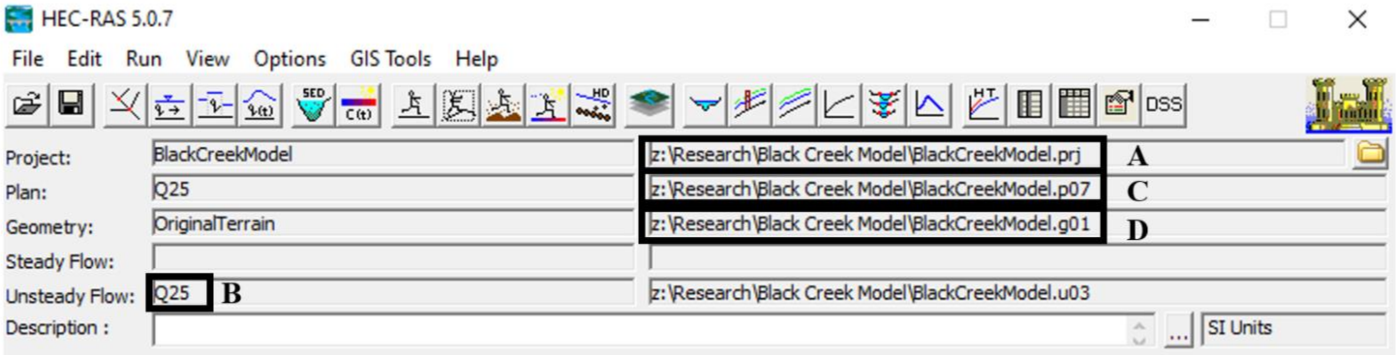

Figure 1. 2D HEC-RAS main window. A) Project name file. B) Storm to be run by RiverSET. C) Results file. D) Geometry file (this numbered file will be the template that is saved for each scenario model run).

References

Dysarz, T. (2018). Application of Python Scripting Techniques for Control and Automation of HEC-RAS Simulations. *Water*, *10*. https://doi.org/10.3390/w10101382

The HDF Group (2006). The HDF5 Library & File Format. Retrieved from: https://www.hdfgroup.org/solutions/hdf5/

Worley, L.C., Underwood, K.L., Vartanian, N.L.V., Dewoolkar, M.M., Matt, J.E., Rizzo, D.M. (2021). "Semi-Automated Hydraulic Model Wrapper to Support Stakeholder Evaluation: A Floodplain Reconnection Study using HEC-RAS" *River Research and Applications Journal* (Submitted for review August 2021).