SWMM5+ Installation Guide

1 Quick Start Guide

Preface The SWMM5+ computational engine is an alternative to the traditional EPA SWMM hydraulic routing module. At the present time, the SWMM5+ computational engine **cannot** be accessed from the EPA SWMM5 GUI, and must be called explicitly through command line arguments. This Quick Start Guide is intended to provide users a step-by-step instruction for *installing, running, and viewing the output of* the SWMM5+ software. Further details on the SWMM5+ code are provided in the main Beta Release Documentation.

System Requirements: This installation guide supports **Windows 10** (via Docker) and Ubuntu **Linux** 16+. Other up to date Linux distributions will likely work, but have not been tested. Currently, **MacOS** users can run SWMM5+ via Docker in serial (one processor) mode only.

Windows 10/MacOS users begin in §1.1.

Linux users begin in §1.2.

1.1 Windows 10/MacOS - Using Docker

1.1.1 Installing the SWMM5+ Docker container

Install the Docker Desktop application from `https://www.docker.com/get-started`

Note: If you need admin privileges to install the Docker Desktop application, you will likely need to run the following commands also as an administrator.

After installation of the Docker Desktop application, open a command terminal in a directory of your choosing and execute

```
$ docker pull cimmresearch/swmm5plus-docker
```

This command pulls a Docker image from the CIMM Research DockerHub repository. The Docker image contains the dependencies required to build and run the SWMM5+ executable.

Note: This takes some time (approx. 30 minutes) and requires about 30GB of disk space.

The Docker image itself is immutable, and cannot save any output files once the image is closed. For output files and edits to be recoverable between Docker image launches, we need to attach a "volume" folder from Docker to a local directory.

```
$ docker volume create SWMM5plus
$ docker run --mount source=SWMM5plus,destination=/SWMM_5_Plus
    cimmresearch/swmm5plus-docker
```

Note: Beware the return line for copy-pasting the above commands. The argument `cimmresearch/swmm5plus-docker` is separated from the rest of the command by a simple space.

At this point any changes made within the `cimmresearch/swmm5plus-docker` container will be saved and persisted in the SWMM5plus mounted volume. To test this, we can run a quick test within the Docker Desktop app. The test will be to create a textfile, and verify that the file is recoverable once the container is restarted.

Open the Docker Desktop app, there should be an entry in the Containers/Apps window with a funny two part name, autogenerated by Docker, with a "cimmresearch" tag.

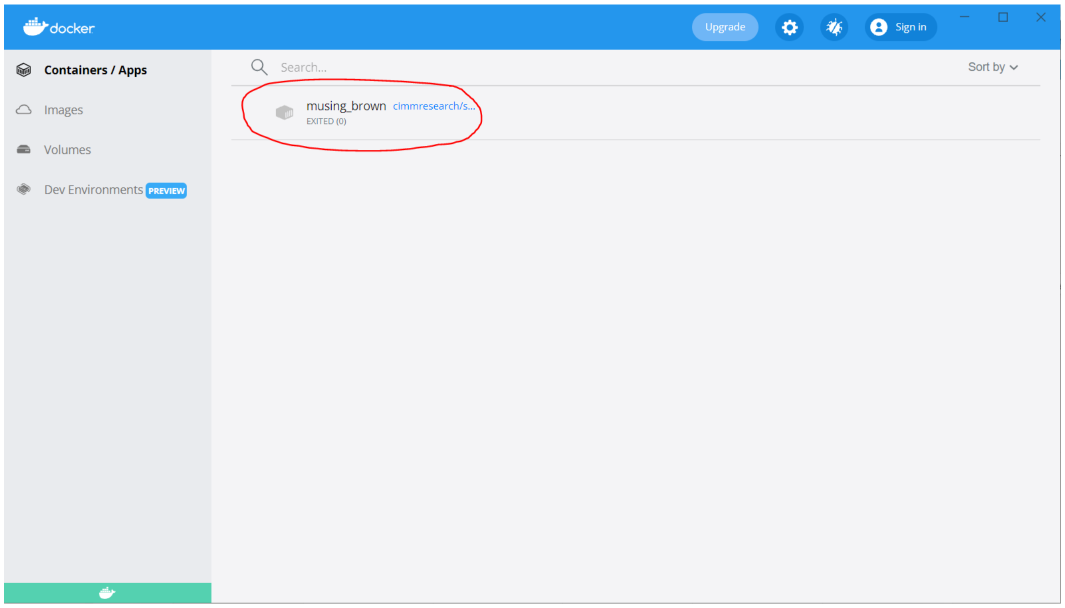


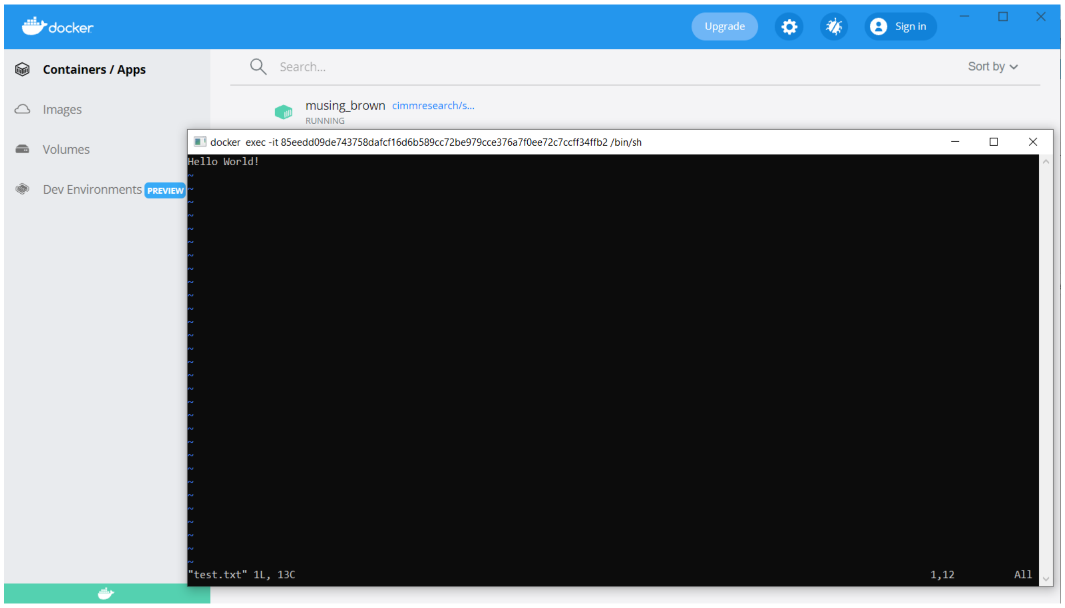
Figure 1: Docker Desktop GUI

Hold the cursor over the container, and click "Start" to activate the container. Then click the "CLI" button to launch a Docker terminal.

Note: This new terminal is running in the Docker container's Linux image, so Linux command syntax should be used.

Create a new file called "test.txt", write some text, then save and close the file.

```
$ vim test.txt
```



```
docker  exec -it 85eedd09de743758dafcf16d6b589cc72be979cce376a7f0ee72c7ccff34ffb2 /bin/sh
Hello World!
~
"test.txt" 1L, 13C                                                    1,12          All
```

Figure 2: Text file to test that the volume was mounted to the container correctly.

Use the command

```
$ exit
```

to close the container terminal, and click the "STOP" button to close the container itself. Then restart the container, and use the

```
$ ls
```

command to verify that the test.txt file is still there. If the test.txt file is not accessible, it means that the volume was not mounted correctly.

Note: This test can also be run in a Windows terminal. The container can be launched using the command

```
$ docker run -it -v [LOCAL_SWMM_FULLPATH]:/SWMM_5_Plus
    cimmresearch/swmm5plus-docker
```

where the [LOCAL_SWMM_FULLPATH] is the path to the directory where the SWMM5plus Volume is mounted. Unless you've navigated away from the working directory, this full path ought to be everything to the left of the commandline marker, ">".

1.1.2 Creating the SWMM5+ executable in Docker

Now that you have a Docker container with all necessary dependencies and a Volume mounted to store files, the next step is pulling the SWMM5+ code from the CIMM public github repository. From an active container (either in the Docker application GUI or in a Windows terminal), enter the command

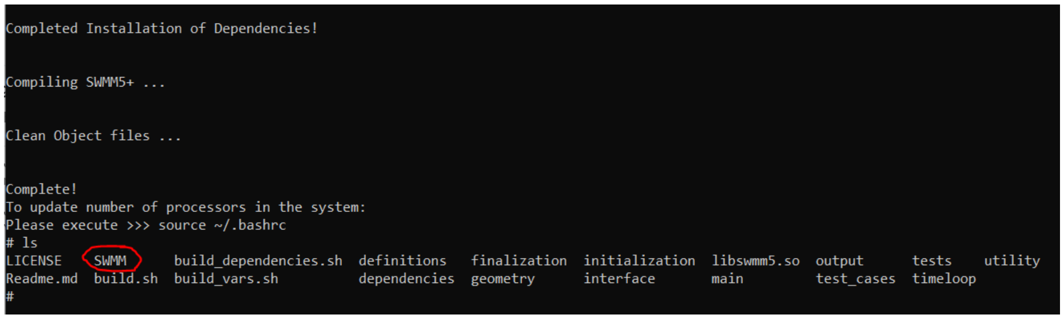
```
$ git clone https://github.com/CIMM-ORG/SWMM5plus.git
```

Navigate into the "SWMM5plus" directory, and build the SWMM5+ executable using

```
$ ./build.sh
```

Note: For more details pertaining to building the executable with optional flags, please see §3.2 of the main Beta Release Documentation.

Another $ ls command will reveal whether the executable (simply called "SWMM") has been created successfully.



```
Completed Installation of Dependencies!


Compiling SWMM5+ ...


Clean Object files ...


Complete!
To update number of processors in the system:
Please execute >>> source ~/.bashrc
# ls
LICENSE    SWMM      build_dependencies.sh  definitions   finalization  initialization  libswmm5.so  output      tests     utility
Readme.md  build.sh  build_vars.sh          dependencies  geometry      interface       main         test_cases  timeloop
#
```

Figure 3: Image of successfully compiled SWMM5+ executable. For more details about other files/folders in the SWMM5plus working directory, please see the main Beta Release Documentation.

1.2 Linux

Linux users have options for installing and running SWMM5+. The Docker Desktop app and workflow can be hosted on a Linux OS; the only difference would be selecting the appropriate Linux distribution from `https://www.docker.com/get-started`.

Alternatively, Linux users can install the requisite dependencies on their local OS to manage and run SWMM5+ without the "hassle" of dealing with containerization.

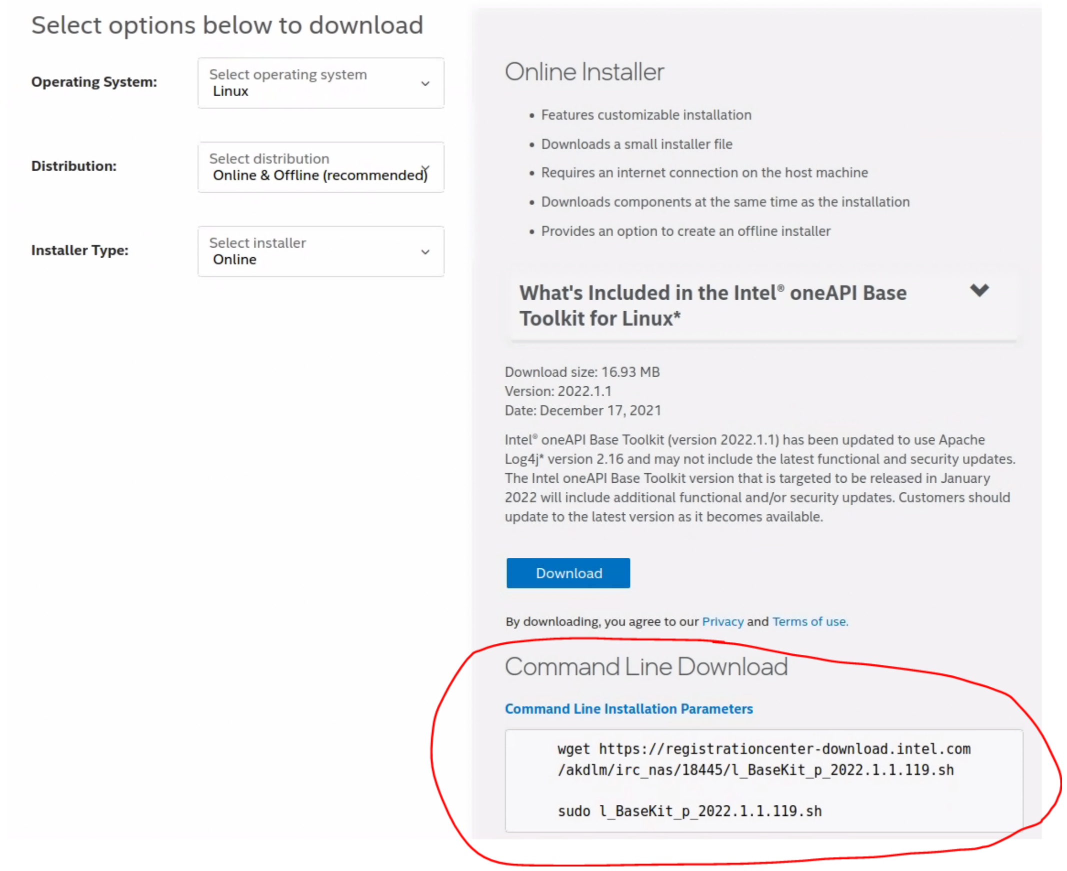
1.2.1 Installing Dependencies

The value of using the CIMM Docker container is that it comes preloaded with the dependencies needed to run SWMM5+. However, it is relatively straightforward to install these yourself on your native Linux OS.

Create a folder named "oneapi_install" where the dependencies will be installed and kept. Open a terminal in this new folder.

Open a web browser to `https://www.intel.com/content/www/us/en/developer/tools/oneapi/base-toolkit-download.html` and download the Intel oneAPI Base Toolkit for Linux. Select the Online & Offline distribution, and Online installer type.

The easier method (i.e. without requiring creating an Intel account) for downloading this toolkit is to use the Command Line Download instructions on the right side of the webpage.



Select options below to download

Operating System: Select operating system — Linux

Distribution: Select distribution — Online & Offline (recommended)

Installer Type: Select installer — Online

Online Installer

- Features customizable installation
- Downloads a small installer file
- Requires an internet connection on the host machine
- Downloads components at the same time as the installation
- Provides an option to create an offline installer

What's Included in the Intel® oneAPI Base Toolkit for Linux*

Download size: 16.93 MB
Version: 2022.1.1
Date: December 17, 2021

Intel® oneAPI Base Toolkit (version 2022.1.1) has been updated to use Apache Log4j* version 2.16 and may not include the latest functional and security updates. The Intel oneAPI Base Toolkit version that is targeted to be released in January 2022 will include additional functional and/or security updates. Customers should update to the latest version as it becomes available.

By downloading, you agree to our Privacy and Terms of use.

Command Line Download

Command Line Installation Parameters

```
wget https://registrationcenter-download.intel.com
/akdlm/irc_nas/18445/l_BaseKit_p_2022.1.1.119.sh

sudo l_BaseKit_p_2022.1.1.119.sh
```

Figure 4: Copy and paste the commands from this section to download the Intel oneAPI Base Toolkit. **Note: this requires nearly 30GB of disk space.**

Note: For me, the second command did not work, but the same effect could be achieved with

```
        $ sudo sh ./l_Basekit_p_2022.1.1.119.sh
```

Follow the installation wizard, ignore warnings about GUI packages or IDE's not being installed. This will take several minutes.

The next package required is the Intel oneAPI HPC Toolkit, which can be downloaded from `https://www.intel.com/content/www/us/en/developer/tools/oneapi/hpc-toolkit-download.html`. Install the HPC Toolkit using the same parameters as the Base Toolkit.

Once both Intel oneAPI Toolkits have been installed, we need to update the system variables using the command

```
    $ source [PATH_to_oneAPI]/setvars.sh
```

Where the [PATH_to_oneAPI] is the location where the oneAPI Toolkits were installed. If you used the autoinstallation wizard, it should tell you the installation location at the bottom left of the wizard. If the installation wizard has already closed, you can retrieve the path by repeating the command

```
    $ sudo sh ./l_Basekit_p_2022.1.1.119.sh
```

which will direct you to your installed Intel oneAPI packages.

To check that the installation of the Intel oneAPI Toolkits and the resetting of the system variables was completed correctly, execute the command

```
    $ ifort -v
```

The return should be ifort version 2021.5 or higher. If the command return says ifort version 18.0.2 (or something similar) that means there was an issue with the dependency installation that needs to be rectified before moving on.

1.2.2 Creating the SWMM5+ executable in Linux

Open a command terminal in the working directory where you want to manage the SWMM5+ code. Then pull the code from the CIMM public github repository.

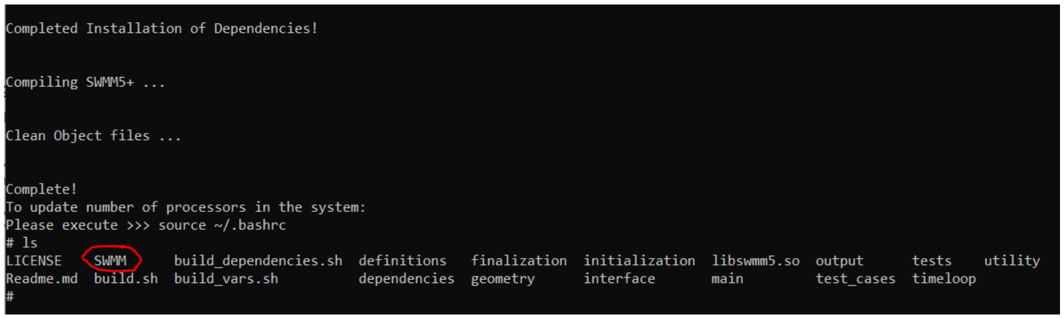
```
    git clone https://github.com/CIMM-ORG/SWMM5plus.git
```

Navigate into the "SWMM5plus" directory, and build the SWMM5+ executable using

```
    $ ./build.sh
```

Note: For more details pertaining to building the executable with optional flags, please see §3.2 of the main Beta Release Documentation.

An $ ls command will reveal whether the executable (simply called "SWMM") has been created successfully.



```
Completed Installation of Dependencies!


Compiling SWMM5+ ...


Clean Object files ...


Complete!
To update number of processors in the system:
Please execute >>> source ~/.bashrc
# ls
LICENSE    SWMM      build_dependencies.sh  definitions   finalization  initialization  libswmm5.so  output      tests     utility
Readme.md  build.sh  build_vars.sh          dependencies  geometry      interface       main         test_cases  timeloop
#
```

Figure 5: Image of successfully compiled SWMM5+ executable. For more details about other files/folders in the SWMM5plus working directory, please see the main Beta Release Documentation.

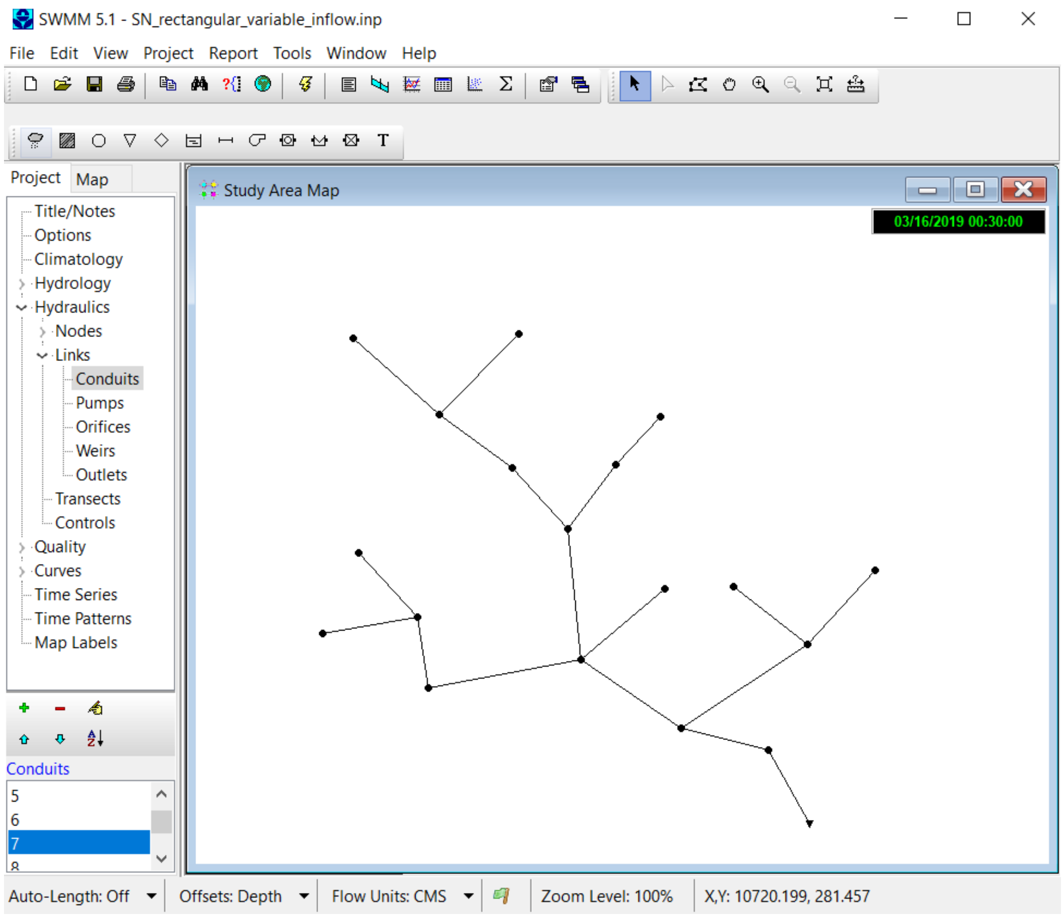
1.3 Running SWMM5+ and Viewing Output

The SWMM5+ code uses a standard EPA SWMM5 .inp input file to initialize the simulation. Once installed and compiled (the tricky part), running the SWMM5+ code is as simple as calling the executable, and pointing it to the SWMM5.inp file you want to simulate. For Windows and Linux users, running the SWMM5+ code on pre-loaded test cases requires just one command in terminal.

The following workflow illustrates an example of running the SWMM5+ code on a small network test case and viewing the simulation output.

1.3.1 Small Network Test Case

The test case in this example is a simple hydraulic network built using the EPA SWMM5 GUI. Each node receives inflow from a timeseries meant to simulate the runoff from an attached subcatchment.



Auto-Length: Off | Offsets: Depth | Flow Units: CMS | Zoom Level: 100% | X,Y: 10720.199, 281.457

Figure 6: Example SWMM5 network. All links are $1000m$ with an initial inflow of $1m^3/s$. All nodes receive the same timeseries inflow and have an initial depth of $0.5m$.

1.3.2 Run SWMM5+

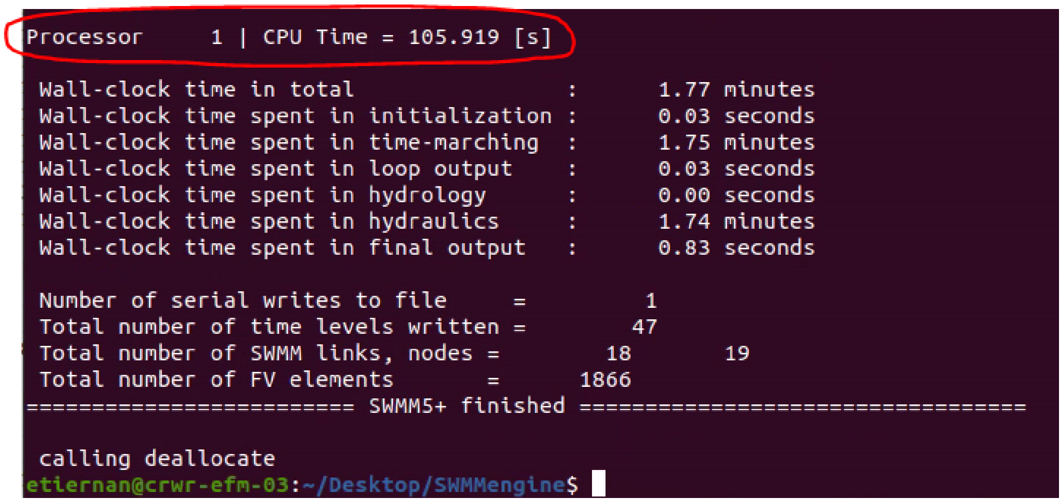
Running this example network using SWMM5+ can be accomplished by opening a terminal in the working directory (i.e. where the SWMM5+ executable was built), and entering the command

```
./SWMM ./test_cases/P_Small_Network/SN_rectangular_variable_inflow.inp
```

Note: This command is sufficient to simulate the above test case with default SWMM5+ settings. To run a SWMM5+ simulation with custom settings, please see §4 and §5 of the main Beta Release Documentation.

This command will launch the SWMM5+ simulation program, with a series of terminal print statements dictating the status of the simulation. For more details on what these print statements mean, please reference the main Beta Release Documentation.

Important information pertaining to the simulation time and network details are printed out at the end of the simulation. For this example, the simulation time took roughly 100 seconds.



```
Processor     1 | CPU Time = 105.919 [s]

 Wall-clock time in total                 :      1.77 minutes
 Wall-clock time spent in initialization :      0.03 seconds
 Wall-clock time spent in time-marching  :      1.75 minutes
 Wall-clock time spent in loop output    :      0.03 seconds
 Wall-clock time spent in hydrology      :      0.00 seconds
 Wall-clock time spent in hydraulics     :      1.74 minutes
 Wall-clock time spent in final output   :      0.83 seconds

 Number of serial writes to file     =         1
 Total number of time levels written =        47
 Total number of SWMM links, nodes =        18       19
 Total number of FV elements       =      1866
========================= SWMM5+ finished ==================================

 calling deallocate
etiernan@crwr-efm-03:~/Desktop/SWMMengine$
```

Figure 7: End of simulation summary print statements for the example network.

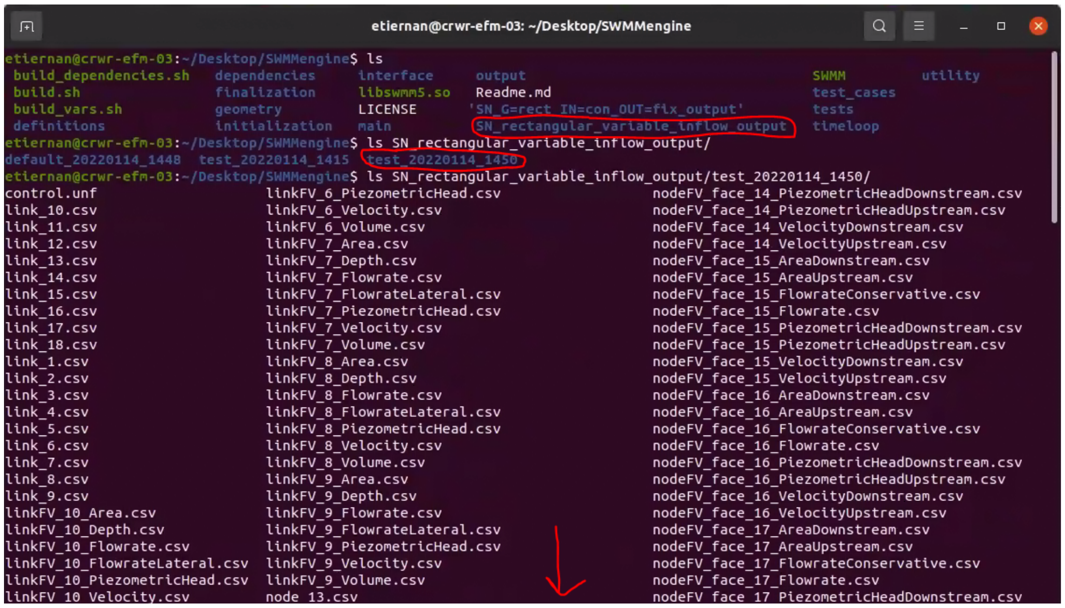
Note: The simulation for a small network (or a large network in serial) using SWMM5+ may take considerably longer than simulating the same network in EPA SWMM5. The reason for this can be seen by the difference in the number of SWMM links/nodes vs the number of FV elements in Fig. 8. Speed-up of the SWMM5+ engine (compared with EPA SWMM5) is expected only once the system is large enough for approx. 1,000 elements per processor spread across four+ processors.

1.3.3 View Output

The output from a SWMM5+ simulation currently consists of a set of .csv files. The SWMM network links and nodes each have time-stamped data on system states such as Depth, Flowrate, Volume, etc. These data were ascertained by averaging the values from each finite volume element into which the original network links and nodes were decomposed. More detailed data from each individual finite volume element and face is included in their own .csv file.

Note: The full consolidation of the simulation data into the format of an EPA SWMM5 .out output file is currently under development.

The described suite of .csv simulation output files can be found in a dedicated output folder within the working directory.

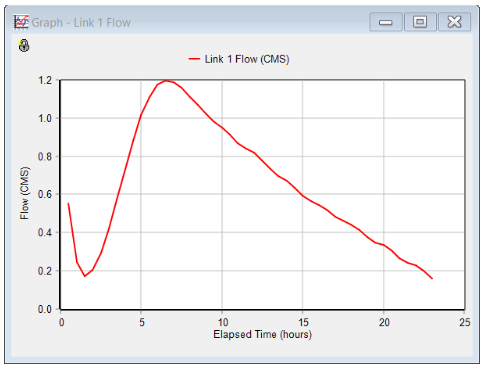


```
etiernan@crwr-efm-03:~/Desktop/SWMMengine$ ls
 build_dependencies.sh  dependencies    interface     output                                        SWMM         utility
 build.sh               finalization    libswmm5.so   Readme.md                                     test_cases
 build_vars.sh          geometry        LICENSE      'SN_G=rect_IN=con_OUT=fix_output'              tests
 definitions            initialization  main          SN_rectangular_variable_inflow_output         timeloop
etiernan@crwr-efm-03:~/Desktop/SWMMengine$ ls SN_rectangular_variable_inflow_output/
default_20220114_1448  test_20220114_1415  test_20220114_1450
etiernan@crwr-efm-03:~/Desktop/SWMMengine$ ls SN_rectangular_variable_inflow_output/test_20220114_1450/
control.unf                    linkFV_6_PiezometricHead.csv           nodeFV_face_14_PiezometricHeadDownstream.csv
link_10.csv                    linkFV_6_Velocity.csv                  nodeFV_face_14_PiezometricHeadUpstream.csv
link_11.csv                    linkFV_6_Volume.csv                    nodeFV_face_14_VelocityDownstream.csv
link_12.csv                    linkFV_7_Area.csv                      nodeFV_face_14_VelocityUpstream.csv
link_13.csv                    linkFV_7_Depth.csv                     nodeFV_face_15_AreaDownstream.csv
link_14.csv                    linkFV_7_Flowrate.csv                  nodeFV_face_15_AreaUpstream.csv
link_15.csv                    linkFV_7_FlowrateLateral.csv           nodeFV_face_15_FlowrateConservative.csv
link_16.csv                    linkFV_7_PiezometricHead.csv           nodeFV_face_15_Flowrate.csv
link_17.csv                    linkFV_7_Velocity.csv                  nodeFV_face_15_PiezometricHeadDownstream.csv
link_18.csv                    linkFV_7_Volume.csv                    nodeFV_face_15_PiezometricHeadUpstream.csv
link_1.csv                     linkFV_8_Area.csv                      nodeFV_face_15_VelocityDownstream.csv
link_2.csv                     linkFV_8_Depth.csv                     nodeFV_face_15_VelocityUpstream.csv
link_3.csv                     linkFV_8_Flowrate.csv                  nodeFV_face_16_AreaDownstream.csv
link_4.csv                     linkFV_8_FlowrateLateral.csv           nodeFV_face_16_AreaUpstream.csv
link_5.csv                     linkFV_8_PiezometricHead.csv           nodeFV_face_16_FlowrateConservative.csv
link_6.csv                     linkFV_8_Velocity.csv                  nodeFV_face_16_Flowrate.csv
link_7.csv                     linkFV_8_Volume.csv                    nodeFV_face_16_PiezometricHeadDownstream.csv
link_8.csv                     linkFV_9_Area.csv                      nodeFV_face_16_PiezometricHeadUpstream.csv
link_9.csv                     linkFV_9_Depth.csv                     nodeFV_face_16_VelocityDownstream.csv
linkFV_10_Area.csv             linkFV_9_Flowrate.csv                  nodeFV_face_16_VelocityUpstream.csv
linkFV_10_Depth.csv            linkFV_9_FlowrateLateral.csv           nodeFV_face_17_AreaDownstream.csv
linkFV_10_Flowrate.csv         linkFV_9_PiezometricHead.csv           nodeFV_face_17_AreaUpstream.csv
linkFV_10_FlowrateLateral.csv  linkFV_9_Velocity.csv                  nodeFV_face_17_FlowrateConservative.csv
linkFV_10_PiezometricHead.csv  linkFV_9_Volume.csv                    nodeFV_face_17_Flowrate.csv
linkFV_10_Velocity.csv         node_13.csv                            nodeFV_face_17_PiezometricHeadDownstream.csv
```

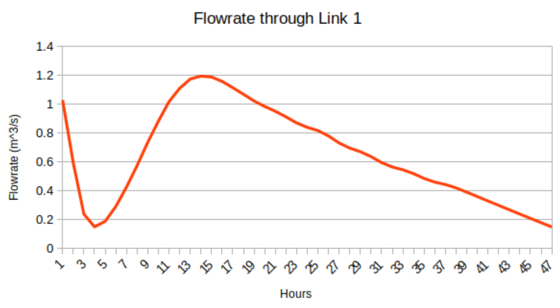
Figure 8: An output folder echoing the name of the input file is created in the working directory. Within that folder, time-stamped subfolders are dedicated to unique runs of the same input file. The arrow at the bottom of the image indicates that there are many more .csv output files than can be shown for this particular simulation.

These csv files can be exported from their Windows 10 Volume, or Linux directory, into whatever post-processing environment you chose. Post-processing tools to automatically validate SWMM5+ simulation results against EPA SWMM5 simulation results are currently being developed.

We can quickly check that the SWMM5+ simulation of our simple network ran through and produced reasonable results. Figure 9 shows a comparison of the flowrate through an arbitrary link simulated by the EPA SWMM GUI to the SWMM5+ hydraulic engine.



(a) Flowrate for Link 1 from EPA SWMM5 GUI.



(b) Flowrate for Link 1 from SWMM5+ simulation output csv.

Figure 9: Comparison of the flowrate through Link 1 of the simple network simulated by the EPA SWMM5 GUI and the SWMM5+ hydraulic engine.

The EPA SWMM GUI plot was generated using the Report -> Graph -> Time Series plotting tool, while the SWMM5+ plot was generated by opening the Link_1.csv in the Linux LibreOffice Calc program. The agreement between EPA SWMM5 and SWMM5+ is good for small systems, but can diverge for larger systems due to differences in the computational routing approach.

1.4 Additional Resources

Questions or problems pertaining to the installation of SWMM5+ on Windows or Linux computers can be directed towards PhD students/SWMM5+ developers, Edward Tiernan and Gerardo Riaño-Briceño.

Edward Tiernan: etiernan@utexas.edu
Gerardo Riaño-Briceño: griano@utexas.edu