Lower Rio Grande Valley - Development Council Flood Infrastructure Fund (TWDB Commitment No. G1001288)

Tier 3 Urban Model Determination

Project Deliverable ID: 1.4.2.3.1

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July 5, 2022

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Date: 7/5/2022

2 Introduction

The quantity and quality of urban storm water flows continue to be a matter of concern in light of continued urbanization. The EPA's Storm Water Management Model (SWMM) is a modeling framework to simulate storm water flows and is applied to evaluate performance of flood control and drainage systems. This Tier 3 Urban Model Determination (Deliverable 1.4.2.3.1) describes SWMM framework and its user interface that facilitates application of SWMM to local stormwater conveyance systems distributed throughout the Lower Rio Grande Valley (LRGV) region. SWMM will be provided as a modeling tool through RGVFlood.com user interface (Project Deliverable 1.2.1.4.3.1.1) and can augment data provided by Tier II HEC-RAS modeling regimes. Similar to Tier 1 and Tier 2 modeling effort, SWMM model datasets will be accessible through RGVFlood.com for use by storm water managers and stakeholders to address their respective data needs with respect to making informed decisions. Development of effective and meaningful database structures for SWMM applications requires prior definition of model data requirements, formats, and file structures. This document describes SWMM software information, components, applications, input data, and SWMM data files.

3 What is EPA SWMM Software?

EPA SWMM is an open source and user-friendly rainfall-runoff simulation model. The model uses various simulation options such as a single event or long term/continuous simulation of runoff quantity and quality from primarily urban areas.

3.1 How the software works?

SWMM is designed as a Windows based desktop software (Figure 1) and is free for use worldwide (i.e. Mexico and Canada have applied this software in their needs). The software is FEMA approved for National Flood Insurance Program Studies.

3.2 Physical Components

- **Subcatchment** is an area of land containing a mix of pervious and impervious surfaces whose runoff drains to a common outlet point, which could be either a node of the drainage network or another subcatchment.

- **Conduits** are pipes or channels that convey water from one junction (node) to another in a drainage system. There are various standardized cross-sectional geometries for conduits. Conduits can function as a culvert

- A **junction** is a component of the drainage system that acts as a node where links (conduits) join together. They may represent the confluence of natural surface channels, manholes in sewer systems, or pipe connection fittings.

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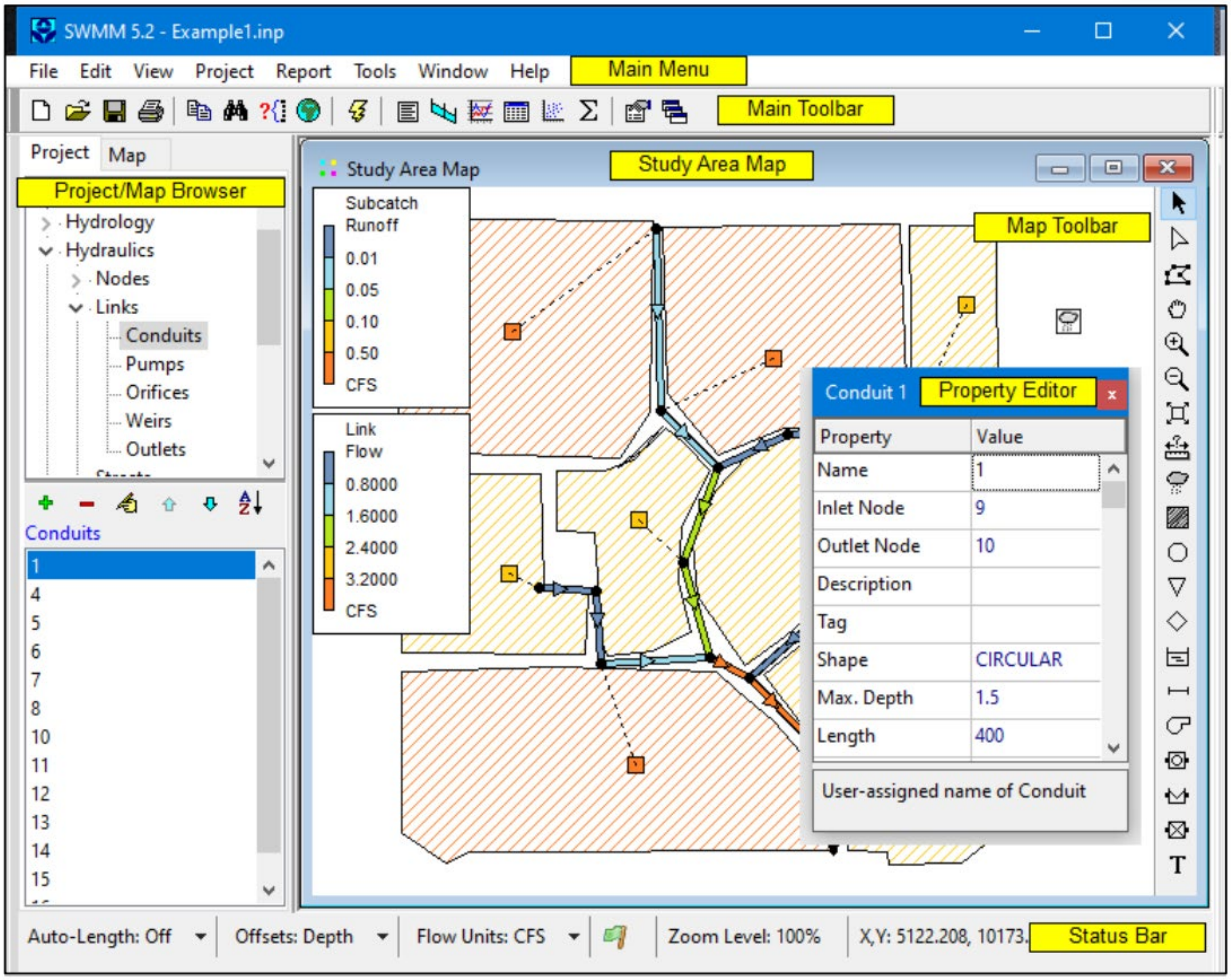


- **Figure 1: SWMM Model shows the graphical GUI showing example storm water network.**

4 SWMM Applications

SWMM interface focuses on design of drainage system components for various hydraulic and environmental applications. Typical applications encompass:

- **Flood Control**: design and sizing of drainage system components for flood control
- **Hydraulic systems**: sizing of detention facilities and their appurtenances for flood control and water quality protection
- **Stormwater Sewer Overflows**: flood plain mapping of natural channel systems, designing control strategies for minimizing joint stormwater sewer overflows
- **Sanitary Sewer**: evaluating the impact of rainfall-dependent infiltration and inflow on sanitary sewer overflows
- **Water Quality:** generating non-point source pollutant loadings for waste load allocation studies
- **Best Management Practices**: evaluating the effectiveness of BMPs for reducing wet weather pollutant loadings.

5 SWMM Model Methods

Basic model operations are described in 6 steps.

1. Specify a default set of options and object properties to use (see Section 5.4 of the manual).
    a. **ID Labels**:
        i. Prefixes for each component such as: rain gages, subcatchments, junctions, outfalls, and conduits (Figure 2).
    b. **Object Properties** include Subcatchments and nodes/links with editing parameters values.
        i. **Subcatchments:** Area, width, slope percent, impervious percent, N-impervious, N-pervious, Dstore-impervious, Dstore-pervious, Zero-impervious percent, infiltration model, Method, Suction Head, Conductivity, Initial Deficit.
        ii. **Nodes/Links:** Node invert, Node max. depth, Node Ponded Area, Conduit Length, Conduit Geometry, Barrels, Shape, Max depth, Conduit Roughness, Flow Units, Link Offset, Routing Model.

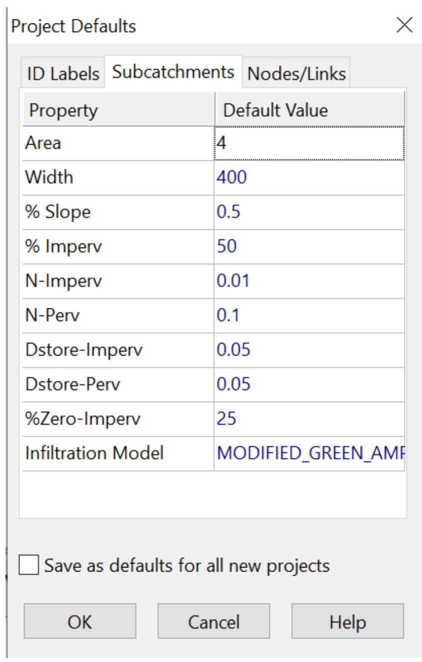


Figure 2: Default settings for subcatchments and nodes/link

2. Draw a network representing physical components of the study area. For larger areas, components can be imported from CAD and GIS to represent features needed. SWMM has special formats to import these files (see Section 6.2 of the manual).
    a. **Physical components** include: Subcatchments, Junctions, Outfalls, and Conduits. Rainfall Gage (Figure 3).

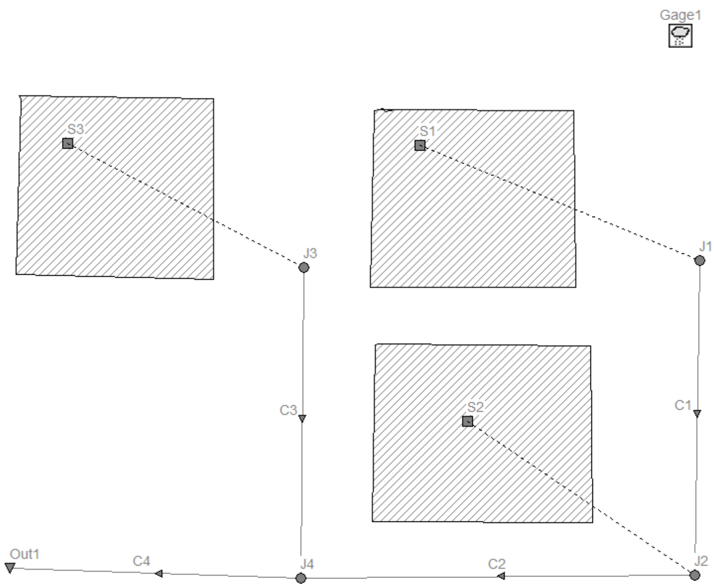
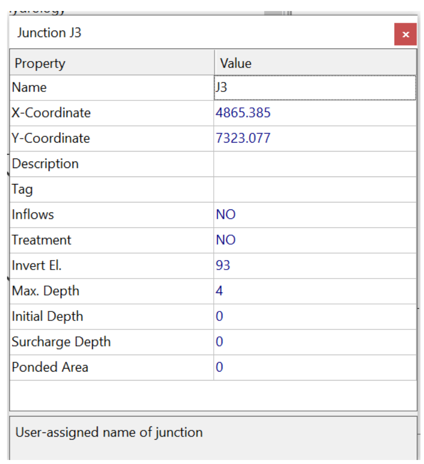


Figure 3: Physical Components for the SWMM

3. <u>Edit the properties</u> of objects that make up the system. See Section 6.4 of the manual (EPA, 2022). In this step, elevations are set for each component modeled.
    a. Invert elevations of the junctions are input are assigned in the "Junction Editor" (Figure 4).
    b. Rainfall Gage time series data are specified in the "Time Series Editor" (Figure 5)


Junction J3

Property	Value
Name	J3
X-Coordinate	4865.385
Y-Coordinate	7323.077
Description	
Tag	
Inflows	NO
Treatment	NO
Invert El.	93
Max. Depth	4
Initial Depth	0
Surcharge Depth	0
Ponded Area	0

User-assigned name of junction

Figure 4: Junction Properties to add Invert Elevations

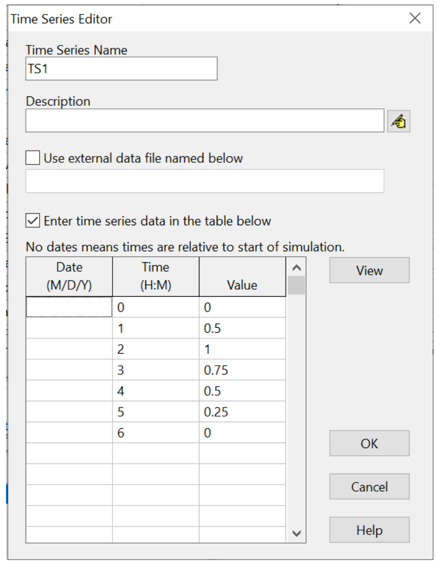


Figure 5: Time Series Editor

4. Select analysis options. See Section 8.1 of the manual (EPA, 2022).
   a. Simulation Options window is used to set general information of the simulation run such as: Type of process selected, dates, time steps, and dynamic wave (Figure 6).
   b. General Tab includes the selection of process models, routing models, infiltration models, routing options.

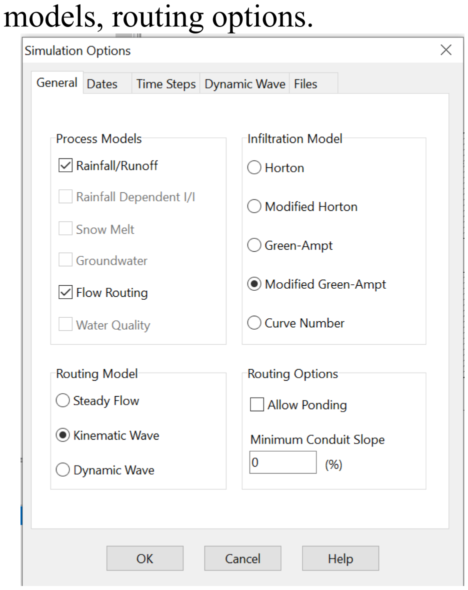


Figure 6: Simulation/Analysis Setting

5. Run a simulation. See Section 8.4 of the manual (EPA, 2022).

6. View simulation results. See Chapter 9 of the manual (EPA, 2022).
   a. Summary Report: contains tables listing results for each subcatchment, node and link in the drainage network (Figure 7).
   b. Status Report: contains useful information about the quality of a simulation run, including a mass balance on rainfall, infiltration, evaporation, runoff, and inflow/outflow for the conveyance system (Figure 8)
   c. Simulation Results
      i. Map Results (Figure 9) for each component.
      ii. Graph Results Time Series Plot (Figure 10)
         1. Comparison between Links (conduits)
         2. Comparison between Subcatchments
      iii. Water Elevation Profile for junction (Figure 11)

Topic: Subcatchment Runoff Click a column header to sort the column.

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Imperv Runoff in	Perv Runoff in	Total Runoff in	Total Runoff 10^6 gal	Peak Runoff CFS	Runoff Coeff
S1	3.00	0.00	0.00	1.50	1.48	0.00	1.48	0.16	2.03	0.495
S2	3.00	0.00	0.00	1.50	1.48	0.00	1.48	0.16	2.03	0.495
S3	3.00	0.00	0.00	2.25	0.74	0.00	0.74	0.08	1.02	0.248

Topic: Node Flooding Click a column header to sort the column.

Node	Hours Flooded	Maximum Rate CFS	Day of Maximum Flooding	Hour of Maximum Flooding	Total Flood Volume 10^6 gal	Maximum Ponded Volume 1000 ft^3
J2	1.03	0.78	0	03:01	0.018	0.000

Topic: Link Flow Click a column header to sort the column.

Link	Type	Maximum |Flow| CFS	Day of Maximum Flow	Hour of Maximum Flow	Maximum |Velocity| ft/sec	Max / Full Flow	Max / Full Depth
C1	CONDUIT	2.03	0	03:01	6.64	0.36	0.41
C2	CONDUIT	3.51	0	03:09	4.89	1.07	1.00
C3	CONDUIT	1.02	0	03:01	5.15	0.20	0.30
C4	CONDUIT	4.46	0	02:12	6.24	0.38	0.42

Figure 7: Summary Results for Subcatchment, Nodes, and Links

```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.2 (Build 5.2.0)
------------------------------------------------------------


****************
Analysis Options
****************
Flow Units ............... CFS
Process Models:
  Rainfall/Runoff ........ YES
  RDII ................... NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Infiltration Method ...... MODIFIED_GREEN_AMPT
Flow Routing Method ...... KINWAVE
Starting Date ............ 06/22/2022 00:00:00
Ending Date .............. 06/22/2022 12:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:15:00
Wet Time Step ............ 00:05:00
Dry Time Step ............ 01:00:00
Routing Time Step ........ 60.00 sec

**************************        Volume         Depth
Runoff Quantity Continuity     acre-feet        inches
**************************     ---------       -------
Total Precipitation ......         3.000         3.000
Evaporation Loss .........         0.000         0.000
Infiltration Loss ........         1.749         1.749
Surface Runoff ...........         1.237         1.237
Final Storage ............         0.016         0.016
Continuity Error (%) .....        -0.052


**************************        Volume        Volume
Flow Routing Continuity        acre-feet      10^6 gal
**************************     ---------     ---------
Dry Weather Inflow .......         0.000         0.000
Wet Weather Inflow .......         1.237         0.403
Groundwater Inflow .......         0.000         0.000
RDII Inflow ..............         0.000         0.000
External Inflow ..........         0.000         0.000
External Outflow .........         1.182         0.385
Flooding Loss ............         0.055         0.018
Evaporation Loss .........         0.000         0.000
Exfiltration Loss ........         0.000         0.000
Initial Stored Volume ....         0.000         0.000
Final Stored Volume ......         0.000         0.000
Continuity Error (%) .....        -0.050


********************************
Highest Flow Instability Indexes
********************************
Link C4 (1)
```

Figure 8: Status Report for the simulation run

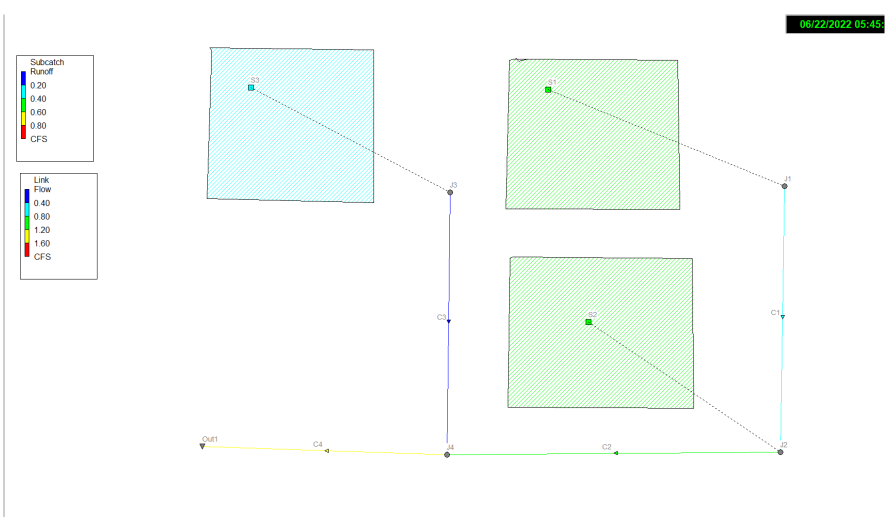


Figure 9: Map Results

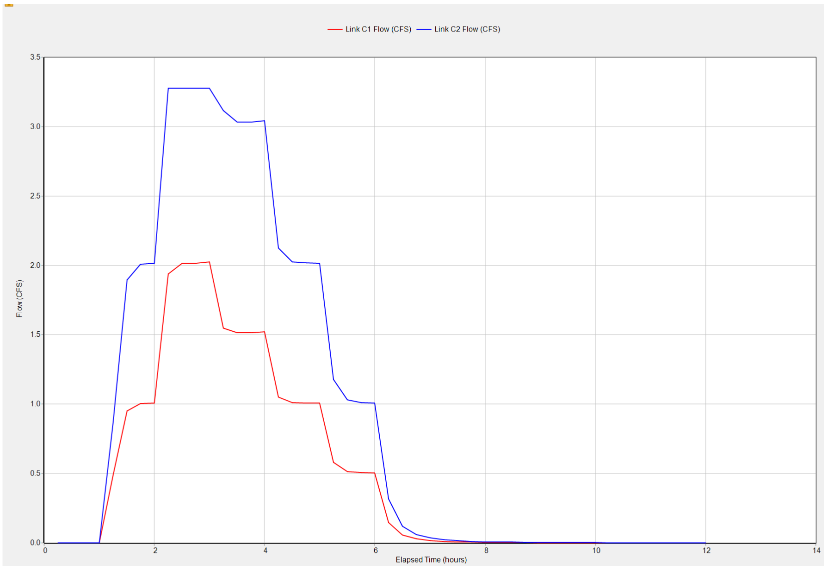


Figure 10: Flow rate results comparison between Conduit 1 and Conduit 2

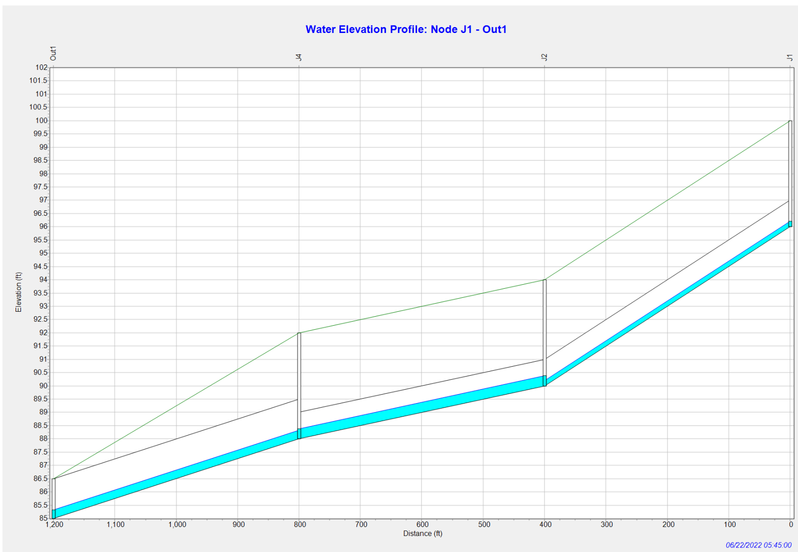


Figure 11: Water Elevation Profile

6 Input Data

Map data are only used as a visualization aid for SWMM's graphical user interface (GUI) and they play no role in any of the runoff or routing computations. Map data are not needed for running the command line version of SWMM. Physical components can be imported from various data sources such as: CAD and GISfiles with SWMM compatible data formats. SWMM input data are summarized in Table 1.

Table 1: SWMM Input data for components

Component	Input Data/Definition	SWMM Label	Source of Data
Rainfall Gage	Gage Station Intensity		Local Gage Stations NOAA (NOAA, n.d.)
Subcatchment	Area of subcatchment (ac)	Area	Can be obtained from Subwatershed GIS Layer
	Width of the overland flow path (ft)	Width	Can be obtained from Subwatershed GIS Layer
	Percent of impervious area	% Imperv	Land Cover Data ((USGS)., 2016) Use Subwatersheds Curve Number Value
	Average Surface Slope	% Slope	Can be obtained from Subwatershed GIS Layer
	Manning Roughness Coefficient for impervious and pervious	N-Imperv N-Perv	Tables from adequate sources (Chow, 1959)
	Depth of depression storage on impervious and pervious area (in)	Dstore-Imperv Dstore- Perv	
	Percent of impervious area with no depression storage (%)	% Zero-Imperv	
Junction/Node	Invert Elevation	Invert El.	Local Stormwater Manhole
	Maximum water depth (i.e., distance from invert to ground surface or 0 to use distance from invert to top of highest connecting link)	Max. Depth	
Conduit/Link	Shape	Shape	Stormwater Pipe Shape
	Maximum Depth of cross section	Max.Depth	Diameter of the pipe
	Roughness	Roughness	
	Length	Length	Length of the pipe

7 SWMM Data Files

EPA SWMM generates four (8) distinct files including: **project file**, **report file**, **output file**, **rainfall file, climate file, calibration data files, time series files, and interface files**. The **project file** contains information of the study area along with the options to analyze it, and has an extension named INP. The INP File is a plain ASCII coded file of model structure such as physical components, rainfall data, type of analyses, and other sections (Figure 12 and 13). Only the project file is needed to run a SWMM model where the other files are optional.

```
#>  [1] "aquifers"      "backdrop"     "buildup"      "conduits"
#>  [5] "controls"      "coordinates"  "coverages"    "curves"
#>  [9] "dividers"      "dwf"          "evaporation"  "events"
#> [13] "files"         "groundwater"  "hydrographs"  "iiflows"
#> [17] "infiltration"  "inflows"      "junctions"    "labels"
#> [21] "landuses"      "lid_controls" "lid_usage"    "loadings"
#> [25] "losses"        "map"          "options"      "orifices"
#> [29] "outfalls"      "outlets"      "patterns"     "pollutants"
#> [33] "polygons"      "profiles"     "pumps"        "raingages"
#> [37] "report"        "snowpacks"    "storage"      "subareas"
#> [41] "subcatchments" "symbols"      "tags"         "temperature"
#> [45] "timeseries"    "title"        "treatment"    "vertices"
#> [49] "washoff"       "weirs"        "xsections"
```

Figure 12: SWMM Input Sections of the Project File (Examples)

```
[TITLE]
Example SWMM Project

[OPTIONS]
FLOW_UNITS          CFS
INFILTRATION        GREEN_AMPT
FLOW_ROUTING        KINWAVE
START_DATE          8/6/2002
START_TIME          10:00
END_TIME            18:00
WET_STEP            00:15:00
DRY_STEP            01:00:00
ROUTING_STEP        00:05:00

[RAINGAGES]
;;Name      Format      Interval  SCF  DataSource  SourceName
;;===========================================================
GAGE1       INTENSITY   0:15      1.0  TIMESERIES  SERIES1

[EVAPORATION]
CONSTANT   0.02

[SUBCATCHMENTS]
;;Name   Raingage Outlet  Area    %Imperv   Width  Slope
;;====================================================
AREA1    GAGE1    NODE1   2       80.0      800.0  1.0
AREA2    GAGE1    NODE2   2       75.0      50.0   1.0

[INFILTRATION]
;;Subcatch    Suction    Conduct    InitDef
;;======================================
AREA1         4.0        1.0        0.34
AREA2         4.0        1.0        0.34

[JUNCTIONS]
;;Name     Elev
;;============
NODE1      10.0
NODE2      10.0
NODE3      5.0
NODE4      5.0
NODE6      1.0
NODE7      2.0
```

Figure 13: Project File

The **report file** is a plain text file of the results generated from the simulation run. This file has an extension of RPT that is able to recognize up 34 hydraulic and water quality sections (Figure 14). This refers that SWMM can run a model and report the results of these sections.

```
#>  [1] "Element Count"                      "Pollutant Summary"
#>  [3] "Landuse Summary"                    "Raingage Summary"
#>  [5] "Subcatchment Summary"               "Node Summary"
#>  [7] "Link Summary"                       "Cross Section Summary"
#>  [9] "Analysis Options"                   "Runoff Quantity Continuity"
#> [11] "Runoff Quality Continuity"          "Groundwater Continuity"
#> [13] "Flow Routing Continuity"            "Quality Routing Continuity"
#> [15] "Highest Continuity Errors"          "Time-Step Critical Elements"
#> [17] "Highest Flow Instability Indexes"   "Routing Time Step Summary"
#> [19] "Subcatchment Runoff Summary"        "LID Performance Summary"
#> [21] "Subcatchment Washoff Summary"       "Node Depth Summary"
#> [23] "Node Inflow Summary"                "Node Flooding Summary"
#> [25] "Outfall Loading Summary"            "Link Flow Summary"
#> [27] "Conduit Surcharge Summary"          "Link Pollutant Load Summary"
#> [29] "Pumping Summary"                    "Groundwater Summary"
#> [31] "LID Control Summary"                "Node Surcharge Summary"
#> [33] "Storage Volume Summary"             "Flow Classification Summary"
```

Figure 14: Report File Section (Examples)

The **output file** is a document showing the numerical results from a successful SWMM simulation run. The extension is an OUT File based on optional binary document. Once the project file simulation is executed the report and output files are automatically generated with the same name as the project file.

SWMM takes rain data and stores it as **Rain File** from a specific location (i.e., Rain Gage Station). SWMM interface recognizes rainfall data from distinct file formats including:

- National Oceanic and Atmospheric Administration (NOAA);
- National Centers for Environmental Information (NCEI) Space-delimited text format file;
    - Hourly precipitation from NCEI as DS-3240 format
    - Fifteen-minute precipitation by NCEI as DS-3260 format;
- Canadian Stations (Environment Canada),
    - Hourly as HLY03 and HLY21 formats,
    - Fifteen-minute rainfall at Canadian stations as FIF21 Format; and
- User prepared formats showing Station ID, year, month, hour, minute, and non-zero precipitation all separated by a space. See Manual Chapter 11 for more information (EPA, 2022).

Climate files contain daily air temperature, evaporation and wind speed data. SWMM uses several data format such as:

- GHCN-D files from NOAA's National Climatic Center (NCDC), Older NCDC files (DS-3200 or DS-3210);
- Canadian climate files; and
- User prepared climate file showing Station ID, year, month, day, maximum temperature, minimum temperature, evaporation rate, and wind speed.

Calibration files contain variables that can assist comparisons of simulated values in Time Series Plot. Example calibration files include: Subcatchment runoff; subcatchment groundwater flow; subcatchment groundwater elevation; subcatchment snow pack depth; subcatchment pollutant wash off; node depth; node lateral inflow; node flooding, node water quality; link flow, link velocity; and link depth.

Interface files, include input and result files from previous SWMM simulations, can be used to accelerate the new simulation processes of running the of new simulations. Interface file types include rainfall, runoff, hot start file, rainfall-dependent infiltration, and inflow (RDII) interface file, and routing interface files. See appendix Chapter 11 for more information (EPA, 2022).

8 Discussion and Conclusion

The information in this report summarizes basic requirements for setting up an urban SWMM model. Compared to Tier II (i.e. HEC-RAS) modeling approaches that model surface water flows, SWMM urban models enable modeling of both surface and underground drainage systems that characterize urbanized areas. SWMM considers data inputs that characterize urban drainage networks including, but not limited to, pipe diameters, man-hole elevations, and conduit invert elevations. SWMM model results depicting water elevations and flow-rates in urban drainage networks fill an important data gap, between Tier 1-Hydrologic and Tier 2-Hydraulic modeling applications. SWMM Tier III models will be generated for twenty-two (22) urban drainage networks in the LRGV project area. Tier III data files will be managed and made accessible to end-users through the RGVFlood.com interface. It is expected that Tier III simulations will involve the use of virtual computing hardware.

9 References

USGS., U. S. (2016). *National Land Cover Database*. Retrieved from Texas Natural Resources Information System (TNRIS): https://tnris.org/

Chow, V. (1959). Open Channel Hydraulics. *McGraw-Hill*.

EPA. (2022). *Storm Water Management Model User's Mannual Version 5.2.* Center for Environmental Solutions and Emergency Response. Retrieved from https://www.epa.gov/water-research/storm-water-management-model-swmm

NOAA. (n.d.). *NOAA ATLAS 14 POINT PRECIPITATION FREQUENCY ESTIMATES: TX*. Retrieved from NOAA's National Weather Service: https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=tx

10 Appendix

Appendix: Manning's n values for Channels (Chow, 1959).

Type of Channel and Description	Minimum	Normal	Maximum
Natural streams - minor streams (top width at floodstage < 100 ft)			
1. Main Channels			
a. clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. same as above, but more stones and weeds	0.030	0.035	0.040
c. clean, winding, some pools and shoals	0.033	0.040	0.045
d. same as above, but some weeds and stones	0.035	0.045	0.050
e. same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. same as "d" with more stones	0.045	0.050	0.060
g. sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
2. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
a. bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
b. bottom: cobbles with large boulders	0.040	0.050	0.070
3. Floodplains			
a. Pasture, no brush			
1.short grass	0.025	0.030	0.035
2. high grass	0.030	0.035	0.050
b. Cultivated areas			
1. no crop	0.020	0.030	0.040
2. mature row crops	0.025	0.035	0.045
3. mature field crops	0.030	0.040	0.050
c. Brush			
1. scattered brush, heavy weeds	0.035	0.050	0.070
2. light brush and trees, in winter	0.035	0.050	0.060
3. light brush and trees, in summer	0.040	0.060	0.080
4. medium to dense brush, in winter	0.045	0.070	0.110
5. medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. dense willows, summer, straight	0.110	0.150	0.200
2. cleared land with tree stumps, no sprouts	0.030	0.040	0.050

3. same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. same as 4. with flood stage reaching branches	0.100	0.120	0.160
4. Excavated or Dredged Channels			
a. Earth, straight, and uniform			
1. clean, recently completed	0.016	0.018	0.020
2. clean, after weathering	0.018	0.022	0.025
3. gravel, uniform section, clean	0.022	0.025	0.030
4. with short grass, few weeds	0.022	0.027	0.033
b. Earth winding and sluggish			
1. no vegetation	0.023	0.025	0.030
2. grass, some weeds	0.025	0.030	0.033
3. dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. earth bottom and rubble sides	0.028	0.030	0.035
5. stony bottom and weedy banks	0.025	0.035	0.040
6. cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-excavated or dredged			
1. no vegetation	0.025	0.028	0.033
2. light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. smooth and uniform	0.025	0.035	0.040
2. jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. dense weeds, high as flow depth	0.050	0.080	0.120
2. clean bottom, brush on sides	0.040	0.050	0.080
3. same as above, highest stage of flow	0.045	0.070	0.110
4. dense brush, high stage	0.080	0.100	0.140
5. Lined or Constructed Channels			
a. Cement			
1. neat surface	0.010	0.011	0.013
2. mortar	0.011	0.013	0.015
b. Wood			
1. planed, untreated	0.010	0.012	0.014
2. planed, creosoted	0.011	0.012	0.015
3. unplaned	0.011	0.013	0.015
4. plank with battens	0.012	0.015	0.018

5. lined with roofing paper	0.010	0.014	0.017
c. Concrete			
1. trowel finish	0.011	0.013	0.015
2. float finish	0.013	0.015	0.016
3. finished, with gravel on bottom	0.015	0.017	0.020
4. unfinished	0.014	0.017	0.020
5. gunite, good section	0.016	0.019	0.023
6. gunite, wavy section	0.018	0.022	0.025
7. on good excavated rock	0.017	0.020	
8. on irregular excavated rock	0.022	0.027	
d. Concrete bottom float finish with sides of:			
1. dressed stone in mortar	0.015	0.017	0.020
2. random stone in mortar	0.017	0.020	0.024
3. cement rubble masonry, plastered	0.016	0.020	0.024
4. cement rubble masonry	0.020	0.025	0.030
5. dry rubble or riprap	0.020	0.030	0.035
e. Gravel bottom with sides of:			
1. formed concrete	0.017	0.020	0.025
2. random stone mortar	0.020	0.023	0.026
3. dry rubble or riprap	0.023	0.033	0.036
f. Brick			
1. glazed	0.011	0.013	0.015
2. in cement mortar	0.012	0.015	0.018
g. Masonry			
1. cemented rubble	0.017	0.025	0.030
2. dry rubble	0.023	0.032	0.035
h. Dressed ashlar/stone paving	0.013	0.015	0.017
i. Asphalt			
1. smooth	0.013	0.013	
2. rough	0.016	0.016	
j. Vegetal lining	0.030		0.500