SWMM PROJECT 1 REPORT

ENGG*6610 Urban Stormwater Management

Submitted to

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Storm Water Management Model (SWMM): Project 1

Introduction to SWMM

The EPA Storm Water Management Model is an Urban Storm Water management tool. SWMM is a rainfall-runoff Simulation Model for water quality and quantity for a single storm event or continuous simulation(Rossman, 2015). EPA's Stormwater Management Model (SWMM) is used throughout the world for planning, analysis, and design related to stormwater runoff, combined and sanitary sewers, and other drainage systems.
SWMM was first developed in 1971 and since then it has been under continuous upgrading. It has been widely used throughout the world for various purposes e.g. planning, analysis, designs for runoff, sewers and other drainage systems in urban areas(Rossman, 2015).

Introduction to the Sewer System:

This project includes the combined sewer system of the town collects the wastewater and storm runoff from a city and transports it to a waster water treatment plant (WWTP), where it discharges to a river. The whole network has an area of 505 ha. And has a 25% impervious area. 12,376 inhabitants live in this area. The sewer system consists of 340 pipes, the shape of the pipes is circular or egg-shape. Node 414 constitutes the main outfall of the system. Node 1 is an emergency outlet.

Objectives of the Project:

The main objective of the project is to analyze the hydrological behavior of the sewer system. SWMM(Stormwater management tool) is used to analyze problems in the sewer system and to evaluate possible solutions.
(a).The objective of this project is to perform hydrological analysis of the sewer system of a town, based on simulations of a design Storm. Which also includes flooding problems and looking for solutions.

(b)But before the hydraulic analysis there should not be any errors in the calculations:
1. control of the input data
2. control of the mass balances (the error should be less than 5%)
3. control of the orders of magnitude of the flow volume (check roughly if the rainfall volume corresponds to the expected volume and if the runoff coefficient corresponds to what you expect)
4. control of the numerical stability (check for oscillations)
5. Report on these issues.

(c). Analysis of the behavior of the system for 3 design conditions (T=2 years) and for extreme conditions (T=5 or 10 years). Report on the parts of the system that are surcharged, on the flooding volumes and on other phenomena that you observe. Analyze possible causes.

Simulation 1: Running a model for 2 years of the return period

Design Storm: Design storm is designed from observed data, design storm for any sewer system should have minimal risk. Risk is mainly linked to flooding in this sewer system. A composite design storm with a duration of 1 hour will be constructed by using the IDF relation of the town. IDF curve used for this design storm is prepared by using data from 1898-1999.

$$i = e^{a(t)} (1+b(t) \ln T)$$

with

$$a(t) = m - \frac{m\,x}{(m-x)\,t^{-mk} + x}$$

$$b(t) = c + d \ln t$$

Where t is the rainfall duration, T is return period and i is the intensity. The parameters have the following values: m=7.166; x=0.5511, K=0.05938, c=0.6577 and d=-0.04913

- Design Storm: In the first simulation design storm is designed for 2 years of return period and the duration is 1 hour. Details the following:
  - Return period = 2 years
  - Duration = 1 hour
  - Timesteps= 10 min

- To provide a source of rainfall data to the project, rain Gage properties has been provided as follows;
  - Rain format-Volume
  - Rain interval – 10 min.
  - Data source- time-series
  - Series Name – Dstorm-T2

Time Series: In the first simulation of the sewer system of area 505 ha., a design storm of 1-hour duration and 2 years of return period is used. A time-series named Dstorm-T2 prepared for hourly rainfall intensities for design Storm. Following table 1.1 gives information about the hourly intensities of the design storm:

Table.1.1 Time series data

Time	Value
00:00	0.45
00:10	1.35
00:20	2.61
00:30	8.08
00:40	2.61
00:50	1.35
00:60	0.45

Time Patterns: This is a combined sewer system design so both dry weather flow(DWF) and wet weather flow have been provided in the simulation of the design storm.

Time patterns give periodic fashion to external Dry weather flow (DWF). DWF can be given in four patterns Monthly, Daily, Hourly and Weekend, for this sewer system hourly dry weather flow is used.

Table. 1.2 Dry Weather Flow (hourly)

Multipliers			
12 AM	0.73	12 PM	1.25
1 AM	0.68	1 PM	1.24
2 AM`	0.69	2 PM	1.19
3 AM	0.69	3 PM	1.14
4 AM	0.77	4 PM	1.04
5 AM	0.71	5 PM	1.05
6 AM	0.89	6 PM	1.07
7 AM	1.16	7 PM	1.1
8 AM	1.27	8 PM	0.97
9 AM	1.22	9 PM	0.95
10 AM	1.27	10 PM	0.87
11 AM	1.29	11 PM	0.78

Table. 1.3 Wet Weather Flow (hourly)

Multipliers			
12 AM	1.17	12 PM	0.93
1 AM	0.72	1 PM	0.84
2 AM`	0.52	2 PM	0.90
3 AM	0.31	3 PM	0.93
4 AM	0.36	4 PM	0.90
5 AM	0.45	5 PM	1.01
6 AM	0.79	6 PM	1.04
7 AM	1.74	7 PM	1.09
8 AM	1.88	8 PM	1.10
9 AM	1.36	9 PM	1.18
10 AM	1.13	10 PM	1.20
11 AM	1.05	11 PM	1.20

(a)Simulation Options: SWMM uses different types of equations for different processes by applying principles of conservation of mass, energy, and momentum where required. For this sewer design storm, by considering objectives of the project surface runoff and flow routing processes are modeled by curve number infiltration model.

Curve number Method: Curve number method is used in this design storm to simulate runoff. The NRCS Curve number approach assumes the infiltration capacity of soil from the tabulated curve number. Curve number and time are 2 input parameters for this method.

Flow Routing: For a gradually varied and unsteady flow, flow routing in a conduit link is controlled by the conservation of mass and momentum equations. SWMM gives the choice to the user to choose the level of sophistication to solve these problems(Rossman, 2015).

1. Steady Flow Routing
2. Kinematic Wave Routing
3. Dynamic Wave Routing

Dynamic Wave Routing Model: For this sewer system Dynamic Wave Routing model is used as it provides most theoretically accurate results. These equations have continuity and momentum equations for conduits and continuity equation at nodes(Rossman, 2015). It is the method of choice for systems subjected to significant backwater effects due to downstream flow restrictions and with flow regulation via weirs and orifices. This generality comes at a price of having to use much smaller time steps, on the order of a thirty seconds or less (SWMM can automatically reduce the user-defined maximum time step as needed to maintain numerical stability).

Ponding is allowed for this design storm write something about it page number 78

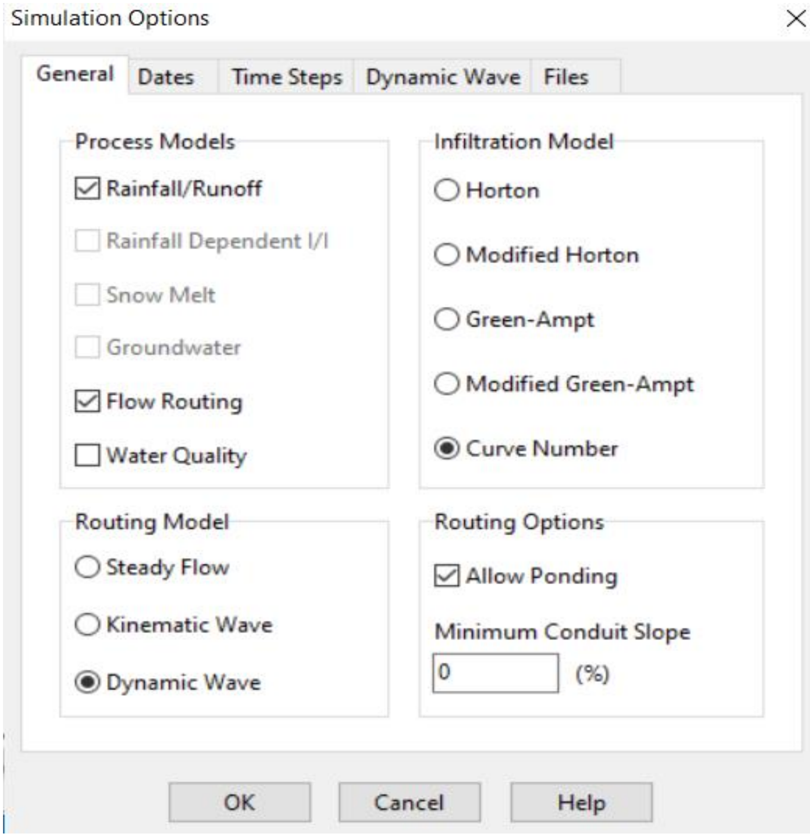


Figure 1.1 Simulation options used for 1st simulation

(b) Simulation options for the date.

As it is mentioned above that design storm is decided to design for 1 hour. 1 day of the simulation period is selected for this sewer design storm. Default values have been set for sweeping operations begins (January 1) and end as(December 31). Full details for these options is given in figure.2.

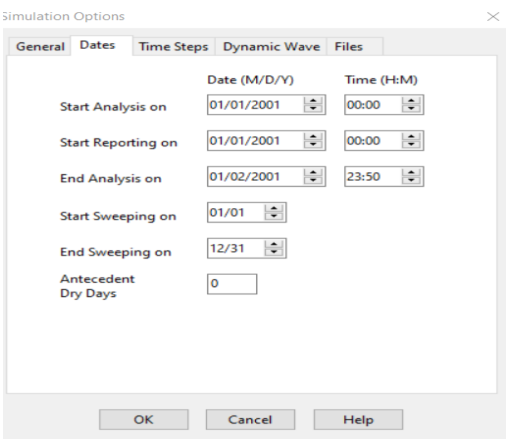


Figure.2. Simulation date options

(c)Simulation options for Time Steps:

It is already mentioned at the top that 10 min. of time steps will be used to make this design storm.

- The reporting time step is selected as 10 min.
- Runoff step: Dry weather as 1 hour
- Runoff step: Wet weather as 10 min.
- Routing Time Step: Dynamic Wave routing requires very smaller routing time steps so in the first simulation 60seconds for routing step is used (Figure.3).

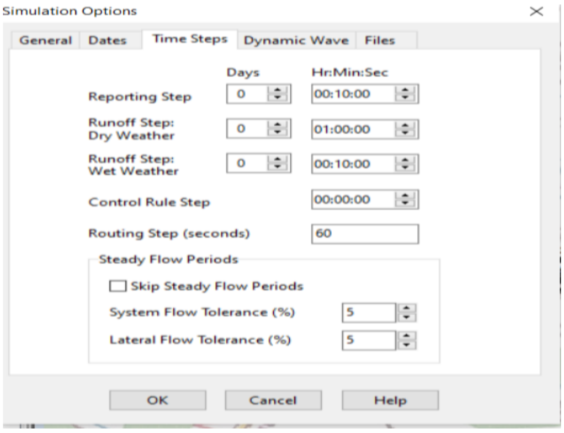


Figure.3. Simulation time step options.

(d) Simulation options for Dynamic Wave Routing.

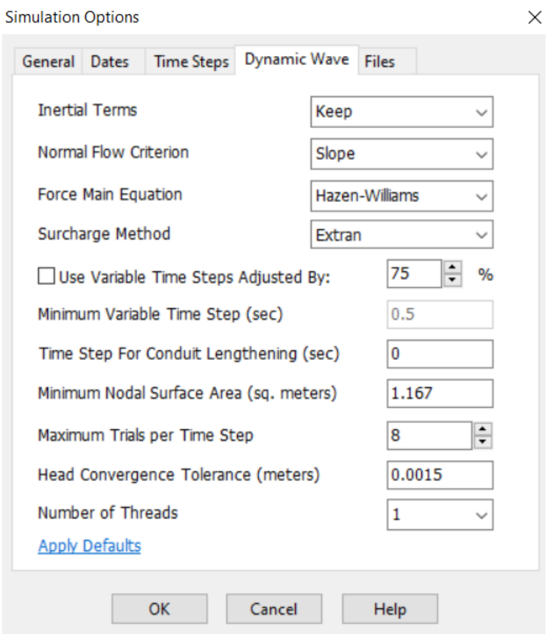


Figure .4 Simulation options for dynamic wave

Results: Simulation 1

1.Continuity Error

Continuity error for the full sewer design is resulted in (fig.1.1). As per the requirements of this project continuity error, more than 5% is considered as not reliable as continuity error represents the percent difference between initial storage+ total inflow and final storage+ total outflow for the entire drainage system. If continuity error exceeds 5%(selected for this project), the simulation results are not accurate.

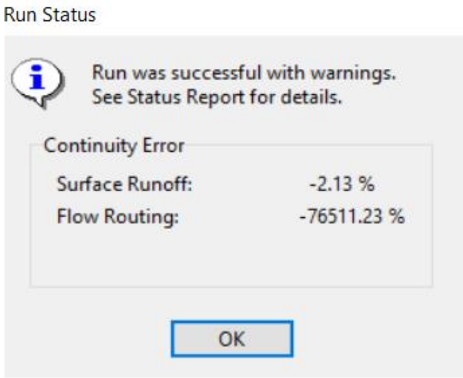
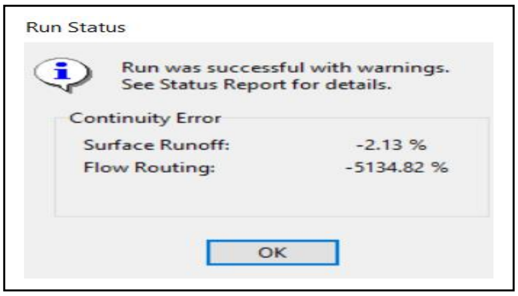


Figure. 1.1 Continuity error

Solution: These errors need to be solved, one option to solve these errors is using the short time steps for routing. As it could be the case for example conduits are too short but computational time steps are too long.

Simulation 1.2

Considerations: Everything else is kept the same just the routing time step has changed from 60 s to 15s.



Results: Continuity error for Flow Routing has decreased to(5134.82) but it is still very high. In order to fix this problem in the next simulation “variable time steps” and time step for conduit lengthening will be used.

Simulation:1.3

Considerations: 1.Using variable time steps satisfy the Courant condition within each conduit

The level of margin is considered as 75% and the computed variable time steps should not be less than 0.5 seconds as it leads to time-consuming simulations and does not have any better impact on results.

2. The time step for conduit lengthening is also used this time as 0.5 seconds. This time step artificially lengthens conduits so that they meet the Courant stability criterion under full-flow conditions.

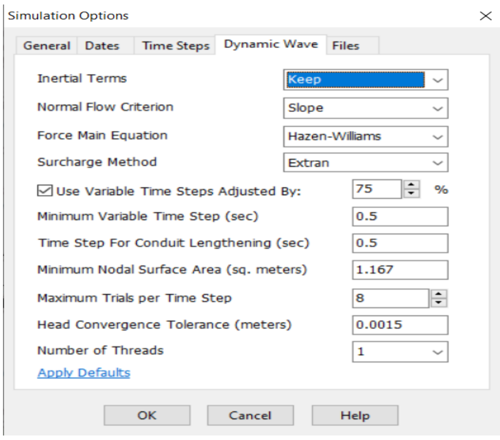


Figure .1.3.1 Simulation Options

Results: After applying the variable time step and time step for conduit length results got better as a continuity error for the whole system is less than 5%(fig.).

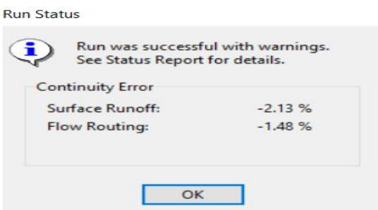
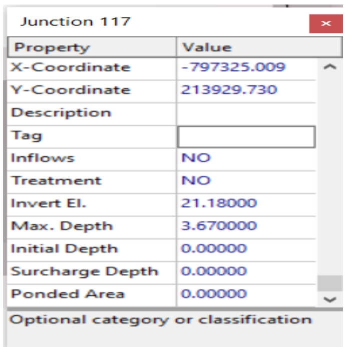


Figure .1.3.2 Continuity error

<u>Solution:</u> Flow continuity error is also associated with nodes of the drainage network, in this drainage network following continuity errors associated with junction nodes. First Node 117 is checked and it is observed that it has the highest continuity error associated with it (fig.1.3.4) To solve this problem in the first step node 117 is loaded to check it's properties(fig.1.3.3). Ponding area is 0 which means there is no flooding problem associated with node 117 and thus continuity error is due to the outflow. There is one pump(117.1) linked with node 117 at the outflow so, the problem is because of this pump. In the next step pumping controls for (117.1) are checked, pump controls determine how pumps and regulators in the drainage system will be adjusted during the simulation.



Junction 117

Property	Value
X-Coordinate	-797325.009
Y-Coordinate	213929.730
Description	
Tag	
Inflows	NO
Treatment	NO
Invert El.	21.18000
Max. Depth	3.670000
Initial Depth	0.00000
Surcharge Depth	0.00000
Ponded Area	0.00000

Optional category or classification

Figure.1.3.3 Node 117 properties.

Highest Continuity Errors

Node 117 (40.95%)
Node 319 (-12.72%)
Node 53 (9.36%)
Node 138 (6.74%)
Node 266 (-5.62%)

Figure 1.3.4

After adjusting the pump controls for node117 for rule 117.1 OFF head changed from <=21.28 to <=20.00 (fig.1.3.5)continuity error has been reduced as shown in (figure 1.3.6).

Runoff Continuity Error (%) = -2.135
Flow routing error = -0.973
Node 120 (11.35%)
Node 53 (9.44%)
Node 138 (6.75%)
Node 319 (-6.33%)
Node 121 (-5.15%)

Figure 1.3.6

RULE 117.1_ON
IF NODE 117 HEAD >= 21.530000
THEN PUMP 117.1 STATUS = ON

RULE 117.1_OFF
IF NODE 117 HEAD <= 20.00000
THEN PUMP 117.1 STATUS = OFF

Figure1.3.5 Pump controls

Solutions for continuity error for node 120 corrected by decreasing the conduit (120.1) size from 3316 to 3000 m. After running the simulation continuity error for node 120 is reduced.

<u>Unstable flow routing Results.</u> Due to numerical instability, the flows in some links or water depths at some nodes can fluctuate or oscillate significantly at certain periods of time in the solution. These instability indexes are shown in the following (fig.1.3.6)

Highest Flow Instability Indexes
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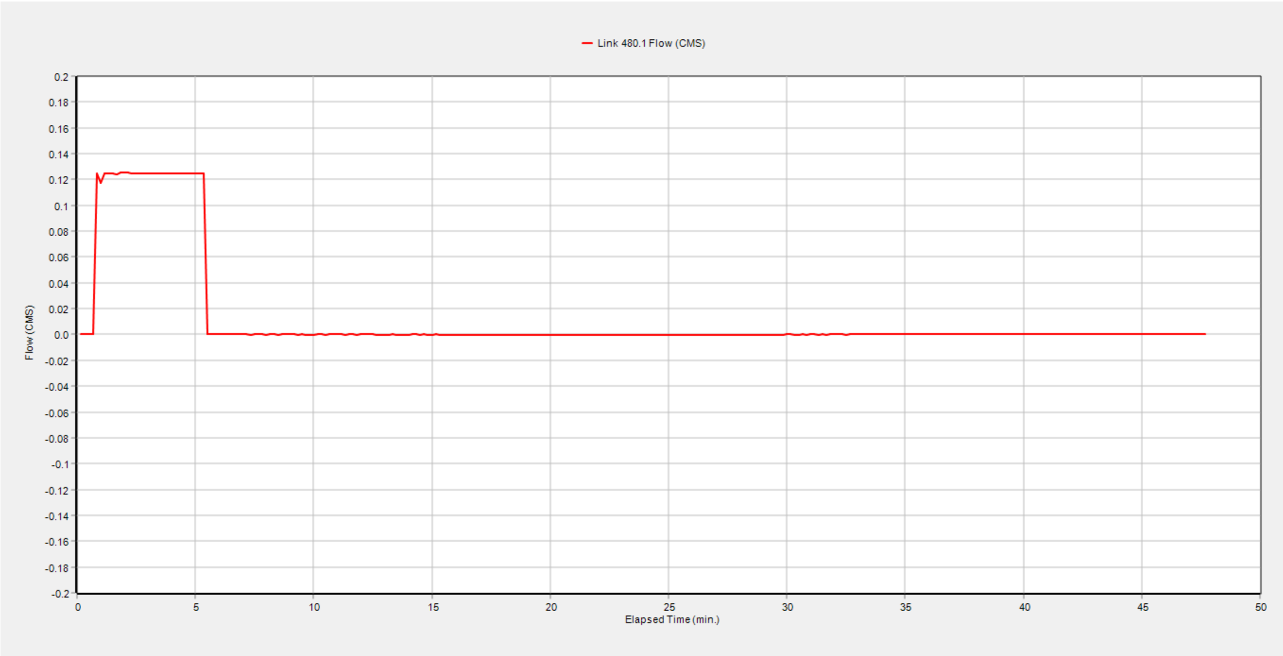
Link 480.1 (136)
Link 411.1 (65)
Link 380.1 (27)
Link 373.1 (27)
Link 5.1 (16)

Figure 1.3.6



Graph.1.1 Time series plot for link 480.1

There are fluctuations in the graph, so this problem needs to be solved as it is the result of the numerical instability. To solve this problem the length of the conduit 480.1 is reduced to 25m and thus the flow instability is reduced.

Flooding is not a matter of concern in this design storm as node flooding was checked and it can be considered reliable and acceptable.

Simulation 2: Running a model for 5 years of the return period

A similar process had been performed for 5 years of return period by considering 1 hour of composite design storm and 10 min increment time.

The time-series data for 5 years of return period is given to the model as following table 2.1

Time	Value
00:00	0.60
00:10	1.65
00:20	3.40
00:30	11.0
00:40	3.40
00:50	1.65
00:60	0.60

Table 2.1 Time series values

Simulation Results: In this design storm flow routing continuity error is less than 5% which is not a problem of concern but still continuity error for individual nodes is reduced by adjusting routing time and variable time steps. but surface runoff error is 6.87% which is more than 5% and thus needs to be solved (Fig. 2.1).

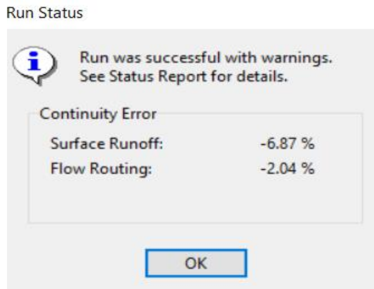


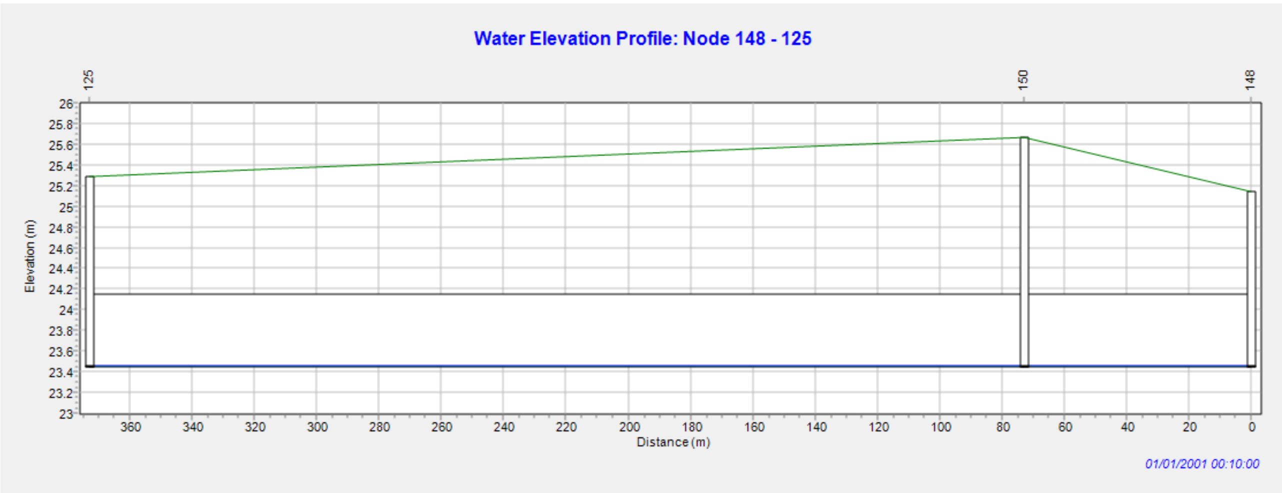
Figure2.1 Continuity error

Flooding Problem

Nodes	Flood Volume
125	1.206
112	1.110
226	1.034

Flooding problem is solved for few nodes such as 125,112 and 226. Other nodes had very less amount of flood volume so those were not considered to be solved in this design storm.

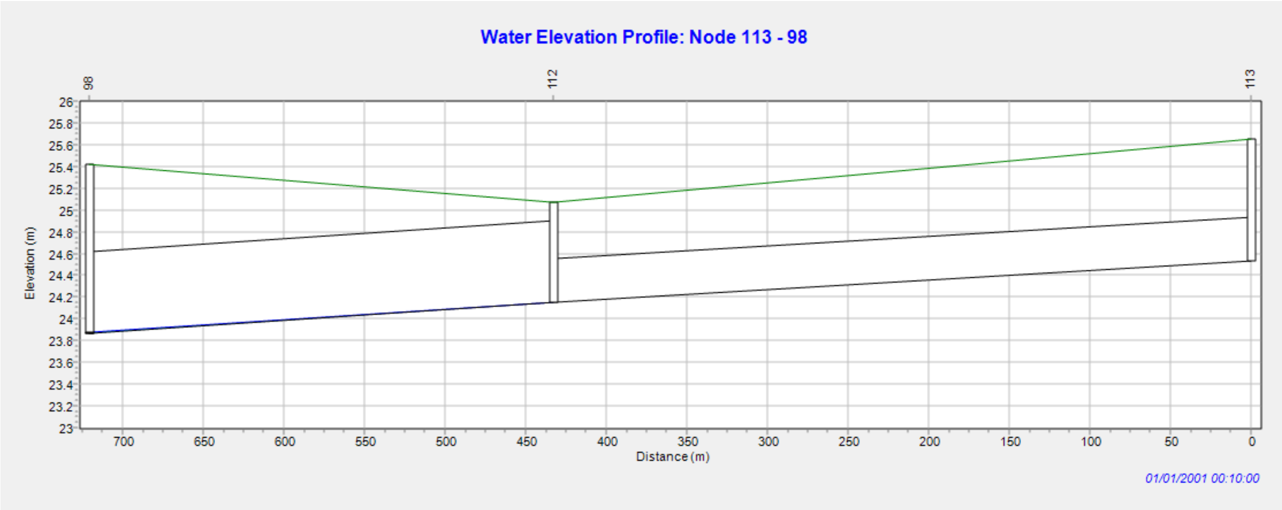
Node 125



Graph.2.1 Adjustments in structure

To solve the flooding problem at node 125, depth of the conduit 148.1 and elevation values had been adjusted to so that conduit 148.1 and 158.1 have the same elevation(graph.2.1). This adjustment reduced flooding at node 125 but it was not completely solved. Further adjustments like constructing a storage unit before the water reaches the node 125 helped to reduce flooding. Properties for a storage unit are considered such a way that the previous node 150 and node 125 have stable structure e.g. the elevation and depth to construct a new storage unit is very important to consider.

Node 112 Solution.



Graph 2.2 Representing the depth difference between conduits.

It seems like the reason behind the flooding at node 112 was the size of the conduit. Conduit 113.1 and 112.2 had different depths these have could be the reason for the flooding, so depths were adjusted.

Further, a pump is added [Grab your reader's attention with a great quote from the document or use this space to emphasize a key point. To place this text box anywhere on the page, just drag it.] between nodes 113 and 112 to solve the flooding problem.

Simulation 3: Running a model for 10 years of the return period

A similar process had been performed for 10 years of return period by considering 1 hour of design storm and 10 min increment time. The time-series data for 10 years of return period is given to the model as following table 3.1

Time	Value
00:00	0.60
00:10	1.65
00:20	3.40
00:30	11.0
00:40	3.40
00:50	1.65
00:60	0.60

Table.3.1 Time series values

Continuity Error. For 10 years of return period continuity error for surface, runoff is very high more than 10 % (Fig.3.1) which not acceptable as it indicates flooding problems in the sewer system. Flow routing continuity is not very high so it can be solved by adjusting flow routing time and variable time steps for individual nodes.

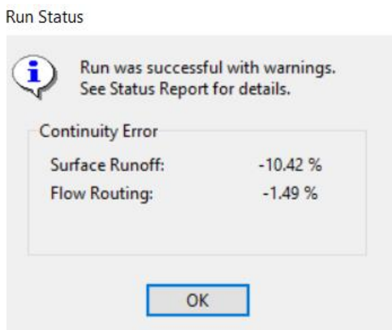
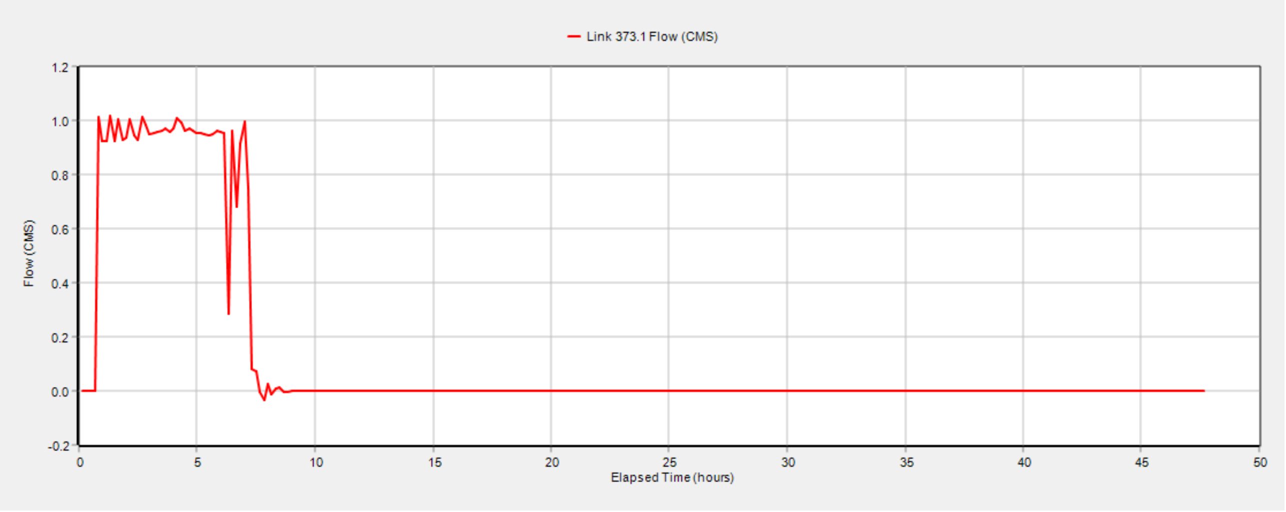


Figure3.1 Continuity error

Flow Instability Index



Solution: Highest flow instability index was found at link 373.1
To solve this problem the conduit size and elevation is adjusted to minimize numerical instability.

Flooding Problem

Node	Flood Volume
112	2.280
125	2.203
226	1.559
96	1.294
80	1.287
13	1.154
338	1.145
147	1.128
274	1.063
182	0.933

Table.3.2Node Flooding

After all these flooding problems similar solutions, for example, increasing the size of the conduit, adding reservoirs and pumps can be implied to the sewer system but for this simulation, the flooding problem is not very solved.

References

Rossman, L. (2015). *Storm Water Management Model User's Manual Version 5.1*. Retrieved from Cincinnati: