Global Scientific JOURNALS

GSJ: Volume 9, Issue 9, September 2021, Online: ISSN 2320-9186

www.globalscientificjournal.com

Hydraulic Performance Assessment of Storm Water Drainage Systems of Dejen Town Using Storm Water Management Model (SWMM), Ethiopia

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ABSTRACT: Stormwater drainage problem is a major challenge facing most of the Cities and Towns in Ethiopia including Dejen Town. This study was conducted to assess the current drainage performance of Dejen Town, to develop IDF curve, to estimate and predict flood amount, and to redesign drainage structures of the Town. Most of the existing drainage structures were inadequate to dispose runoff to the outfall area and most drainage structures in study area were poor. For instance the drainage condition 52% around CBE, 68% around Demis Hotel, 59% around Seble hotel, 46% around new bus station, 53% around Andinet College and 36% around St. George church were poor. The output from rational method and storm water management model (SWMM) also indicated that the discharge resulted from the sub-catchments was greater than the existing capacity. This implies in most of the canals, Junctions, and outfalls the flood level was greater than the designed water level, and over-flooding occurs at drainage canals and the junctions. Construction of additional drainage structures with proper dimension especially for secondary roadsides with no drainage structures, design and construction of well-connected structures, adopting the culture of clearing sediment and periodic repairing of drainage structures before total failure were the remedial measures to be taken to solve the problem.

Keywords: Dejen Town, Drainage, Runoff, Stormwater, SWMM

1. **INTRODUCTION**

Water is very essential for all life on the earth; it can also cause devastation through erosion and flooding if not managed properly. Due to the development of infrastructures as a result of urbanization, the surface runoff water greatly increased in the Town damaging the roads. The contributed runoff water thus needs to be safely disposed to the rivers or outlet channels so that the utility of the road infrastructure is maintained and thereby avoids the damages which otherwise occurred to the road and property [22]. An urban flood occurs due to a complex interplay of factors including intensity and duration of rainfall, the characteristics of the urban land surface, and engineering design of surface drainage and sewer systems [10]. The increment of urbanization also increases impermeability because of the increase in impervious surfaces. This increment of impervious surface changes the drainage pattern, increase overland flow resulting in flooding and related environmental problems. This impact is severe on road structures. Because, flooding and its related environmental problems like sheet flow and gulley erosion, surface inundation tends to affect road services and its life span [3]. Stormwater is any precipitation such as rain, and snow that falls on the surface of the earth. It is rainfall fallen from the built-up area. Stormwater drainage is the process of draining excess water from streets, roofs, sidewalks, buildings and other areas. The storm drain is the system used to drain stormwater [18]. Stormwater drainage networks in cities are designed to collect effectively and convey excess runoff to prevent urban flooding [9]. The provision of sufficient stormwater drainage structures is important during the design and construction of urban roads. Drainage facilities on the road should adequately be provided for the flow of water away from the surface of the pavement to properly designed channels. A properly designed and implemented drainage system should effectively intercept all surface and watershed runoff and direct this runoff into adequately designed channels for eventual discharge into proper outfall or the natural waterway [12]. Adequate drainage is very essential in the design of roads since it affects the road's serviceability and usable life. Drainage design involves providing facilities that collect, transport and remove stormwater from the highway. Stormwater on residential sites can be dealt with in a number of ways. The following techniques, which can be integrated into new construction and existing residential settings, help to manage stormwater: Increasing permeability, Directing water to more permeable areas, detaining water to allow infiltration, Intercepting and holding rainwater, and Utilizing water on-site as it is needed [11]. Storm water management is the control and use of storm water runoff. It indicates planning for runoff, maintaining storm water systems, and regulating the collection, storage, and movement of storm water. Storm water management also considers drainage in the design of cities and housing developments. The goal of storm water management includes protecting our environment; reducing flooding to protect people and property; reducing demand on public storm water drainage systems; supporting healthy streams and rivers. Effective storm water management provides environmental, social, and economic benefits to local communities. When storm water management is done well streams, rivers, and lakes are cleaner, food risks are reduced, costs due to flood damage decrease, and community quality of life increases [2].

2. Location of Study area

This study was conducted at Dejen Town Amhara National Regional State. Dejen is located in the East Gojam Zone of the Amhara National Regional State on the edge of the canyon of the Abay Basin. It is located in west-central Ethiopia about 241 km from Addis Ababa and located at the latitude and longitude ranging from 10° 9'30" to 10°11'0"N and 38° 7'30" to 38° 10'0"E and its elevation range between 2421 and 2490 meters above sea level. Dejen Town is the administrative center of Dejen Woreda and the checkpoint of traffic crossing regional boundaries. Locating the study area is the first task to conduct certain research and indicates where the study was performed. To locate the study area the location and map of Dejen Town was done with ArcGIS as shown below from Figure 2.1.

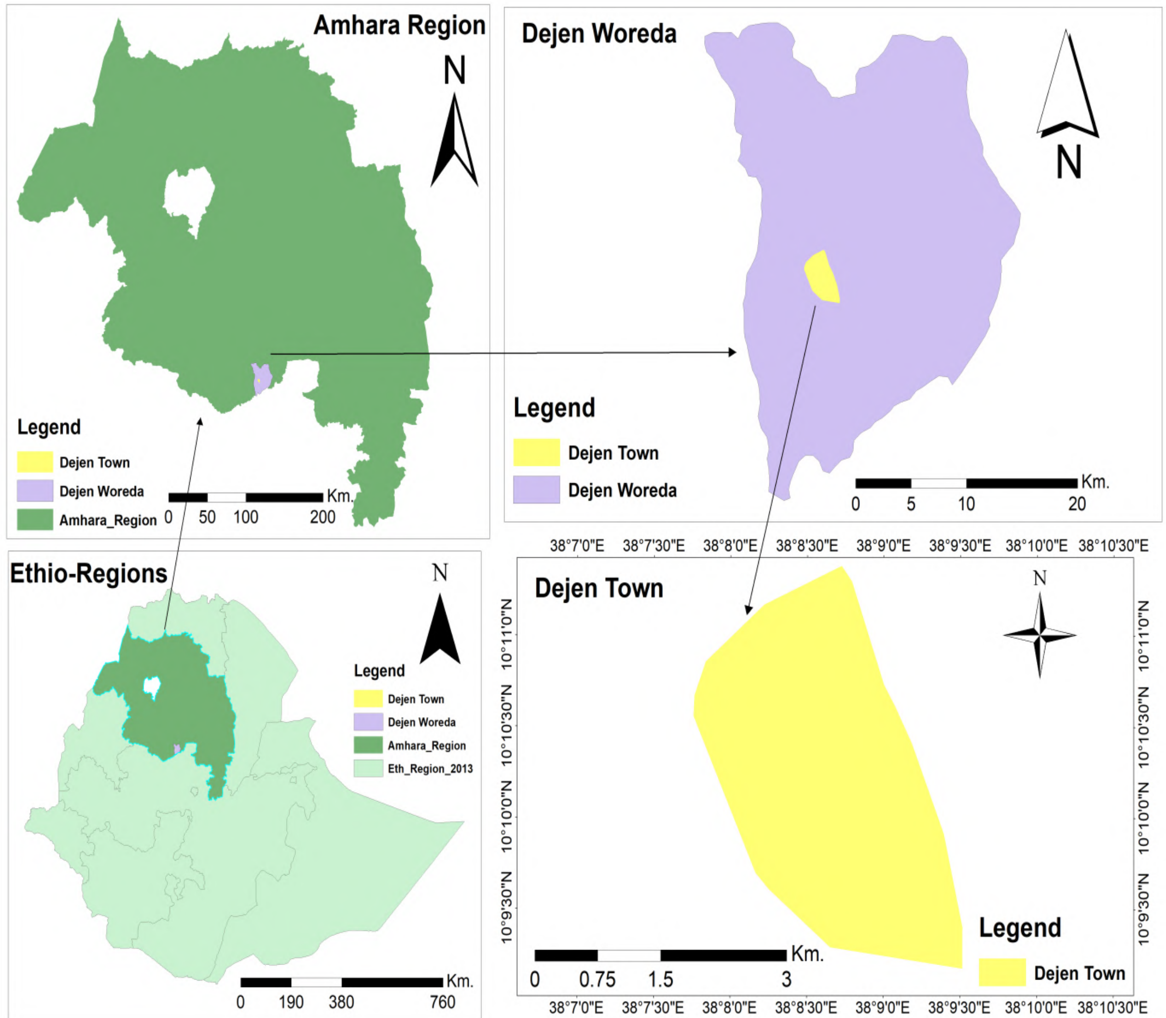


Figure 2.1: Location and map of the study area by ArcGIS

3. Material and methods

3.1. Data Collection and Analyses

To assess current situation of existing drainage systems of Dejen town, Primary and secondary data and different information was collected from concerning bodies. Interview was done for concerning bodies such as staff members and head of the municipality, and community in the Town. The primary data were also taken from the municipality and indicates improper design, aging, and improper utilization of drainage systems in the study area. For this study, site visit and capturing different pictures that shows drainage condition at the study area were taken to show the true status of the study area. The dimensions of the drainage structures were measured to know their capacity. Also, the size of existing drainage structures was measured and information was gathering about the overall performance of drainage structures. Then the rainfall data of

Dejen town was obtained from the National Meteorological Service Agency (NMSA) of Ethiopia to develop the Intensity-Duration-Frequency curve. Missing data was filled, data consistency was checked and method of probability distribution was selected and to develop IDF curved curve of Dejen town. As shown from Figure 2.2 below rainfall of Dejen Town and surrounding varies season to season, year to year, and the rainfall never distributed evenly due to many factors such as deforestation, topographic variability of catchment areas, and desertification.

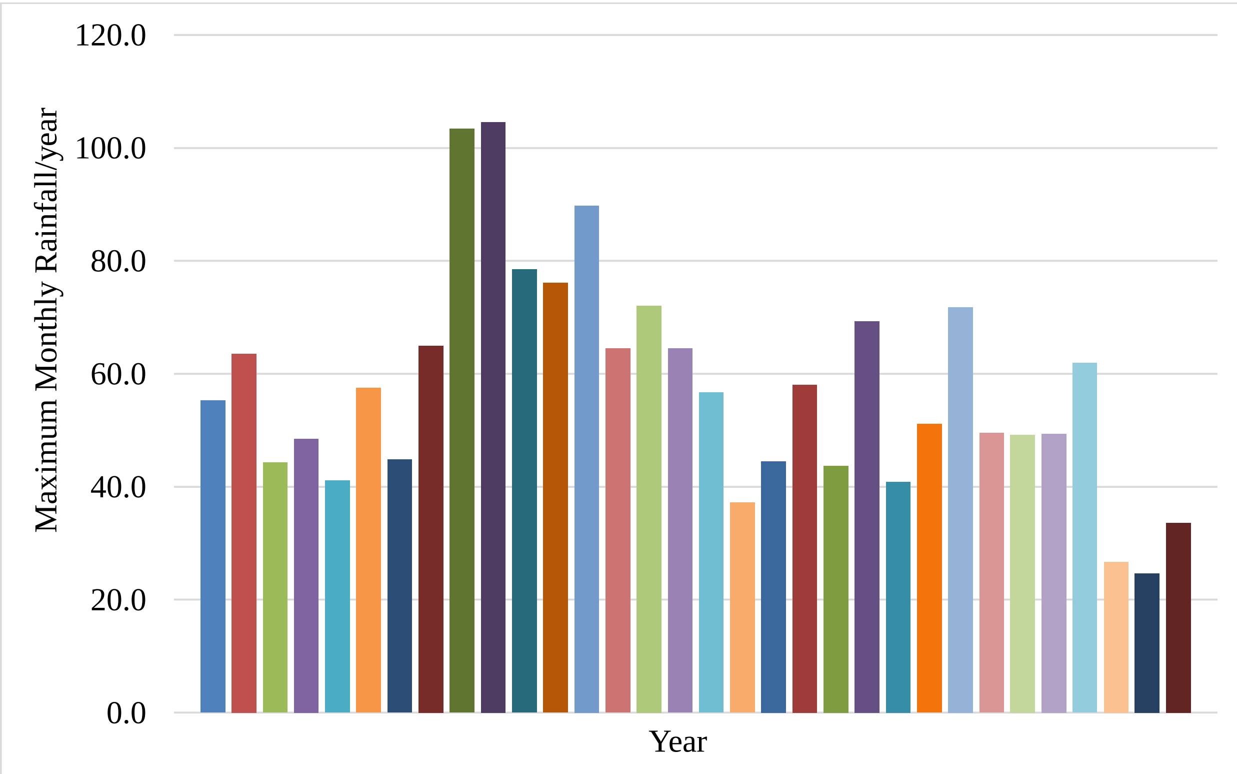


Figure 2.2: Maximum monthly rainfall/year of Dejen from1987-2018

Checking the consistency of meteorological records is an essential tool before taking data for analysis purposes. Double mass curve analysis was the method that is used to check the inconsistency of gaging records.

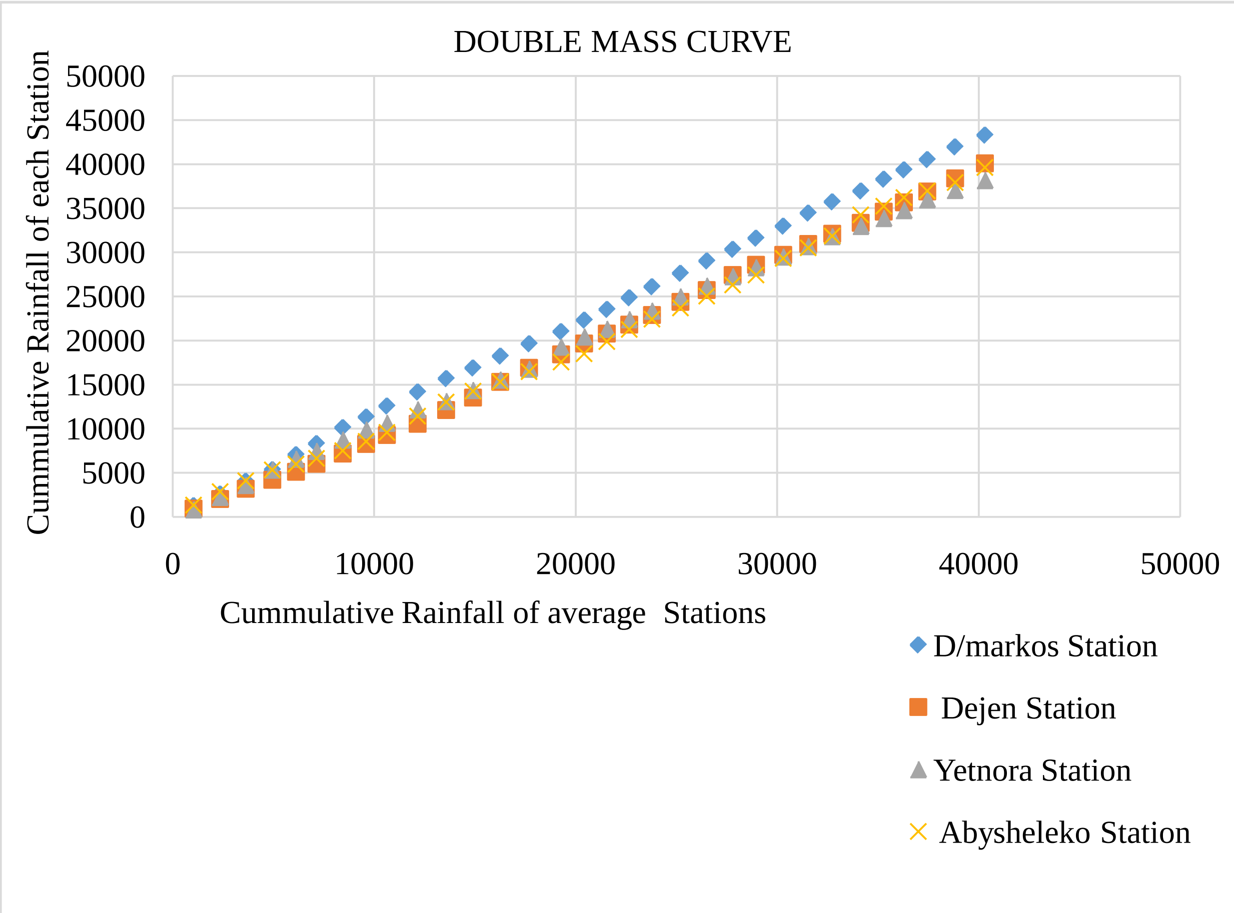


Figure 2.3: Double mass curve to check consistency of data of study area

The regional analysis of the Peak-Over-Threshold method series can be achieved through different means. Among these generalized least square regression model that explicitly accounts for interring site correlation to describe the variability of POT parameters using physiographic and climatic characteristics. The advantage of POT approach is more than one extreme value can be considered each year while only the most extreme value is kept using the annual maximum approach. The POT approach improves the sampling of extreme events [1]. The plot of mean residual life (MRL) is widely used method of determining the threshold value from a time series. The MRL plot displays the mean excess against a range of different threshold values [19]. This is done by arranging the data as the Pareto distribution fits and the goodness of fit test was done by Easy fit 5.6. From n observed data points of a variable X given as X1, X2….X_n new time series can be generated as;

$$Y=f(x/k, \sigma, \mu) = \left(\frac{1}{\sigma}\right) * \left(1 + k\left(\frac{x-\mu}{\sigma}\right)\right)^{-1-1/k}$$

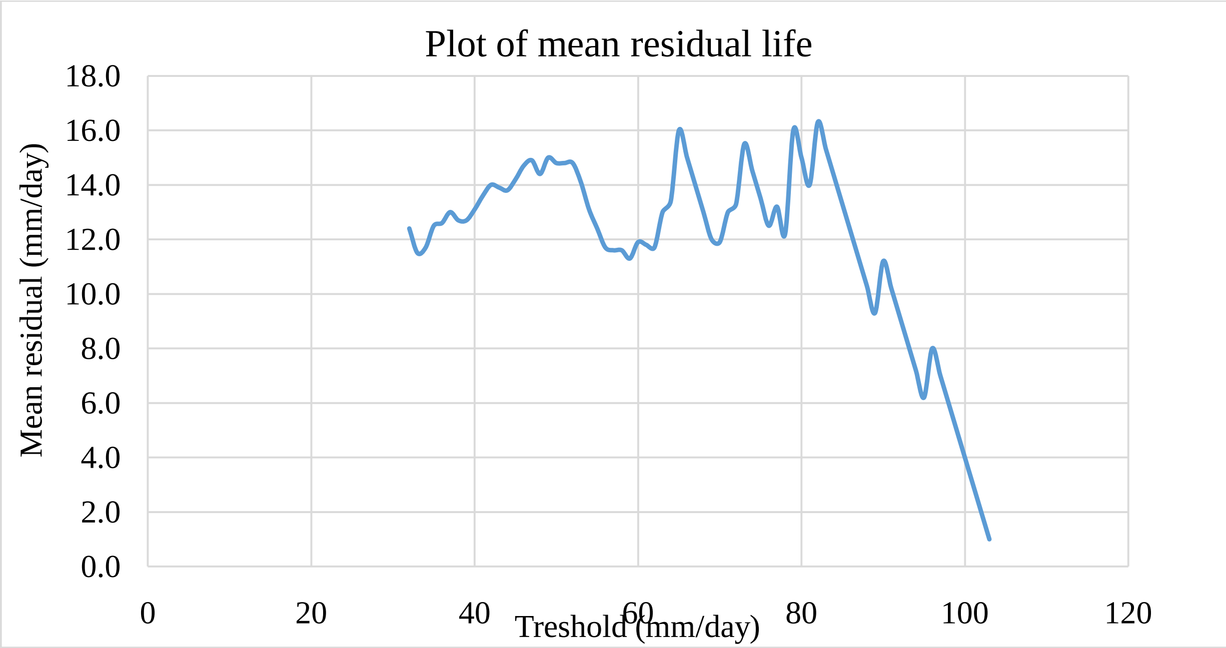


Figure 2.4: Plot of Mean Residual Life

There was a sort linear relationship between mean residual and threshold starting from 38mm. The selected data was minimum data of 38mm and selected at the point where mean residual vs threshold graph is linear. According to the Ethiopian Roads Authority [6], the following equations were used to calculate the shorter duration of rainfall from 24-hour duration.

RRt $=\frac{t}{24}\frac{(b+24)^n}{(b+t)^n}$

Where:

RRt = Rainfall depth ratio Rt: R24

Rt = Rainfall depth in a given duration t

R24 = 24-hr rainfall depth

Coefficients b = 0.3 and n = 0.78 to 1.09

Rearranging the above equation:

Rt $= \frac{t(b+24)^n}{24(b+t)^n} * R24$

Rainfall intensity in (mm/hr) is given by

I $= \frac{Rt}{t}$

I $= \frac{R24*(b+24)^n}{24(b+t)^n}$

Then the Rational formula was used to estimate peak rate of runoff in the catchment area as a function of the catchment area, runoff coefficient, and rainfall intensity for the duration equal to the time of concentration. The main input variables of the rational method are rainfall intensity, weighted runoff coefficient of the catchment, time of concentration, and catchment area.

3.2. Project setup and input parameters for simulation of SWMM

The first task to simulate the SWMM model is preparing sub-catchments of the project. The prepared sub-catchments were then opened in SWMM software and the default values were adjusted. After adjusting default values Junctions, outfall, Nodes, conduits, and Rain gage were added. Then the input parameters listed above were prepared and inserted into SWMM model. Some of the parameters required for simulation of SWMM were Manning's n, Per-DS, Imp-DS, N-Perv, N-Imperv, and soil infiltration. The other inputs of the SWMM model were width, slope, inverted elevation, depth of the canal, and Time series**.**

Table 3.1: Input parameters for the SWMM model

Parameter	Type	Symbol	Value
Manning's n	Overland flow	Imp-n	0.005-0.05
	Conduit flow	Per-n	0.05-0.5
	Open channel flow	Con-n	0.4
Depression storage	Per-DS		2.5-7.6(mm)
	Imp-DS		1.3-2.5(mm)
		Max.infi.rate	76.2(mm/hr)
		Min.infil.rate	3.18(mm/hr)
Soil infiltration	Horton infiltration	Decay constant	3.12 hr

Source: [12]

Table 3.2: Description of SWMM input parameters

Parameter	Description
N-Imperv	Manning's roughness coefficient for impervious areas
N-Perv	Manning's roughness coefficient for pervious areas
Dstore-Imperv	Depth of surface depression storage in impervious areas (mm)
Dstore-Perv	Depth of surface depression storage in pervious areas (mm)

4. RESULTS AND DISCUSSIONS

4.1. Existing drainage conditions of study Area

During performance assessment of stormwater drainage system, first current condition of drainage structures and their coverage or amount of drainage structures must be studied. According to the data collected during a site visit and the data taken from Dejen Town municipality the major problem in drainage structures of the study area include joint damage, the collapse of the wall, floor damage due to aging, sedimentation and deposition, and overall deterioration of the structures. The drainage condition of the existing drainage system of the study area was checked as shown from Figures blow.

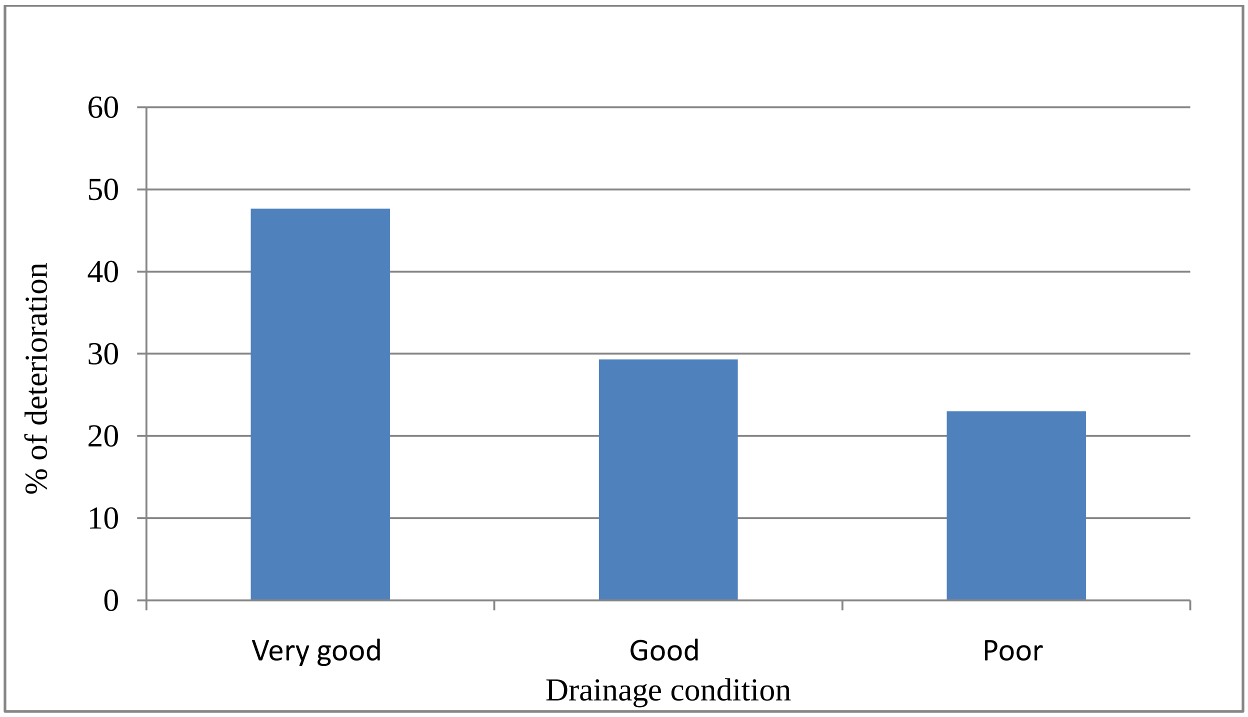


Figure 4.1: Drainage condition from CBE Abaysheleko branch to Fasiledes bridge outfall

As presented from Figure 4.1 above, 48% of drainage around CBE Abaysheleko branch to Fasileds Bridge is very good, 29% is good and 23% is poor. That shows the flood around this area cannot discharge nearby outlets safely in all drainage canals. Even if the percent of poor drainage is less in number it may cause damage on the road pavements during over flooding due to its poor drainage system.

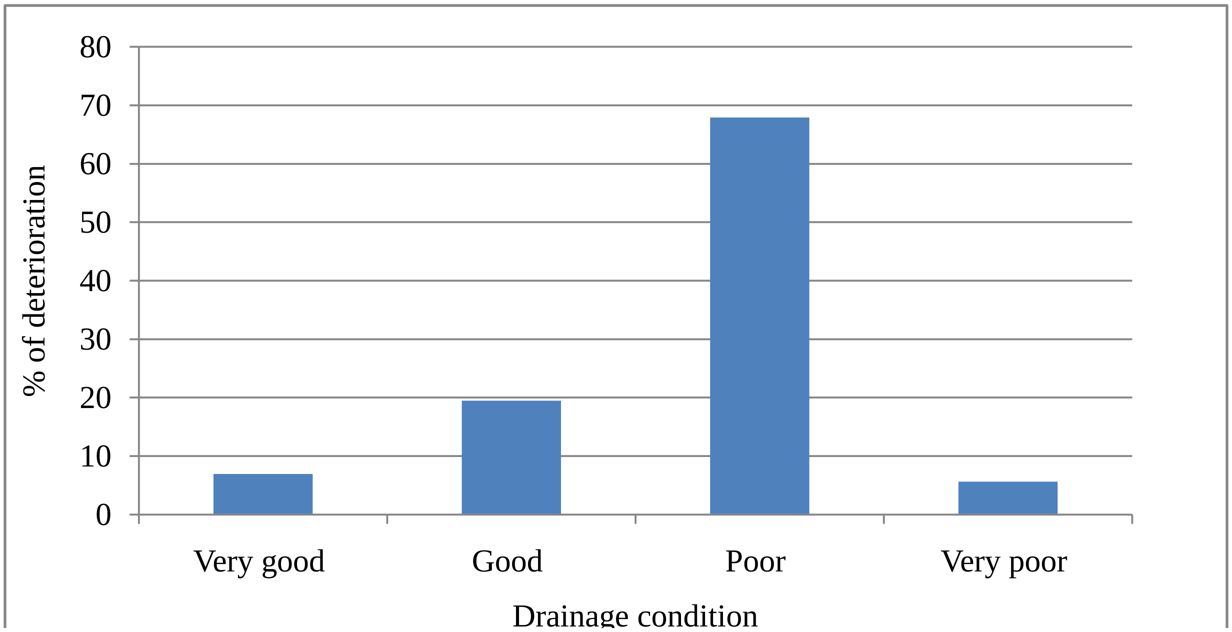


Figure 4.2: Drainage condition from Demis Hotel to Dejen 02 primary school

As shown from Figure 4.2 above, 68% of the drainage system is poor, 7% is very good, 20% is good and 6% is very poor. That means most of the drainage system is poor and cannot discharge a flood nearby outlets. Due to these poor drainage structures, the drainage canal cannot carry flood and over flooding occurred. These damages were due to collapse of wall, sedimentation and deposition, clogging of drainage structures due to disposal of plastic materials.

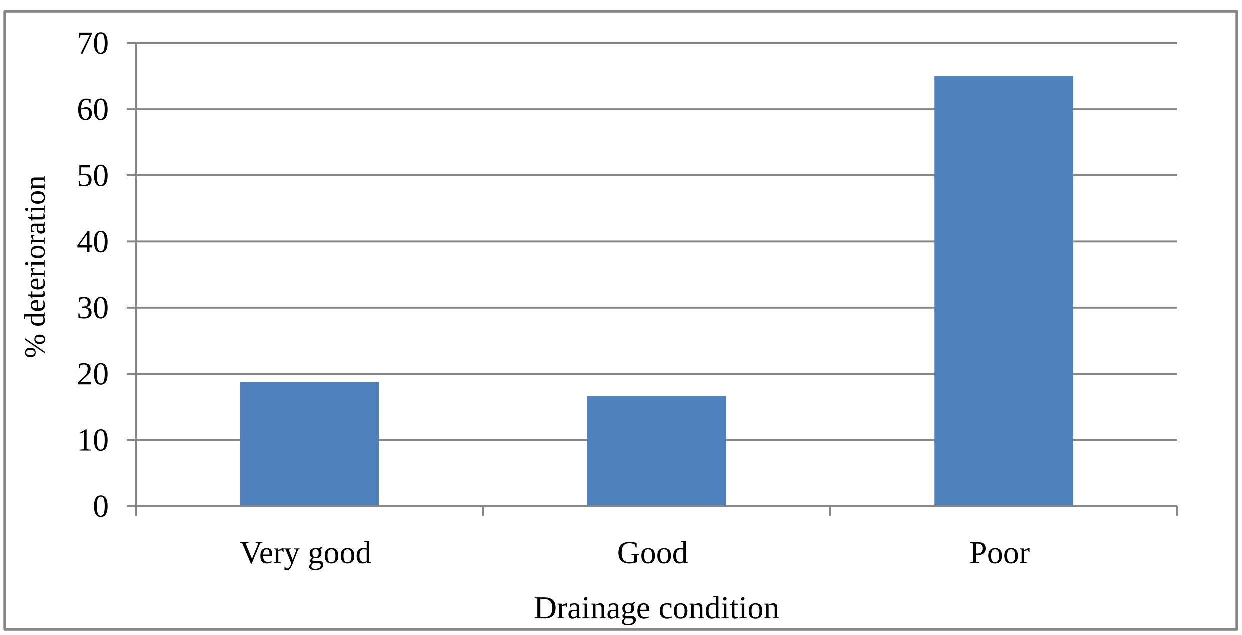


Figure 4.3: Drainage condition around Seble Hotel

According to Figure 4.3 above, from Seble hotel to Dejen kindergarten 19% of drainage structures are very good, 17% is good, 6% are moderate and 59% are poor. This shows flooding is more in this area because the drainage structure cannot carry flood and discharge into outlets. So the drainage system in this area cannot serve its function we and flooding will occur.

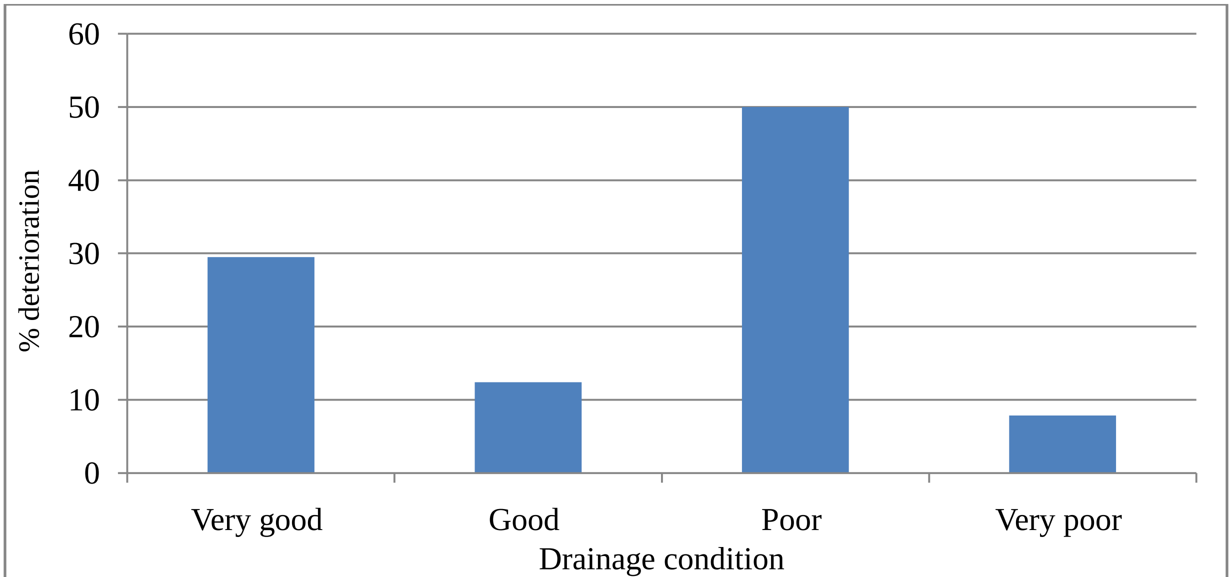


Figure 4.4: Drainage condition from CBE Dejen branch to new bus station

According to Figure 4.4 above, of most the performance of drainage systems in this area is poor. That is 29% of the drainage structure is very good, 12% of drainage structure is good, 4% is moderate, 46% poor and 8% is very poor or severe. On this, we can understand that most of the drainage system cannot perform its function well and cannot discharge flood into the outlet.

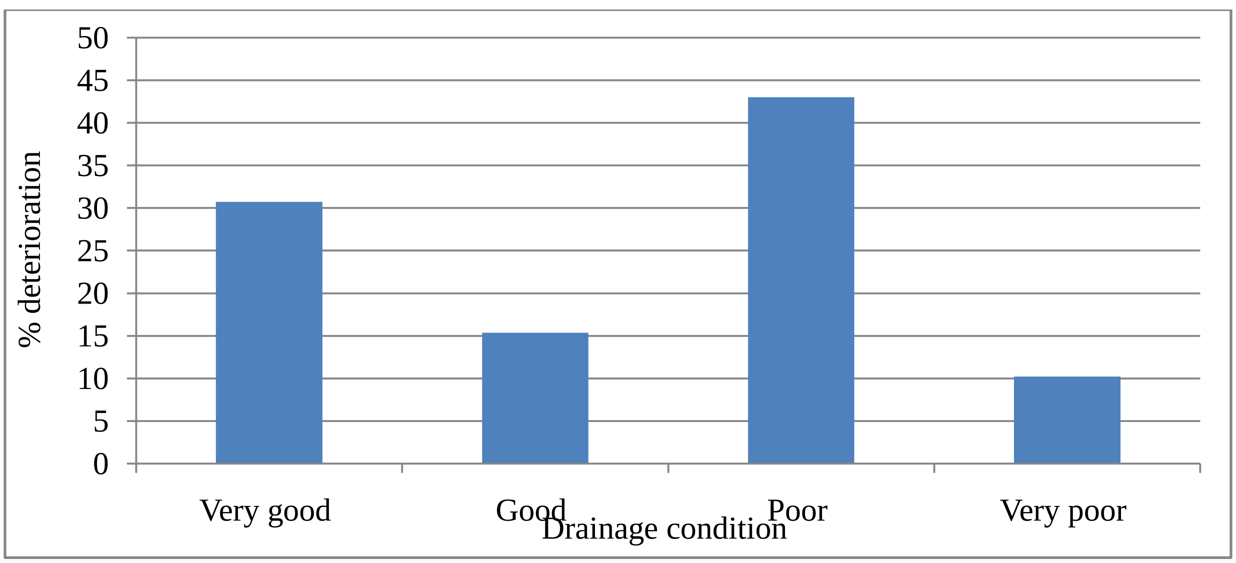


Figure 4.5: Drainage condition from Andinet College to Mulugojam hall

As shown from Figure 4.5 above, 32% is very good, 15% good, 15% is moderate, 28% is poor and 10% is very poor. In this area also the performance is poor and needs maintenance and redesign of the drainage system to serve its function properly.

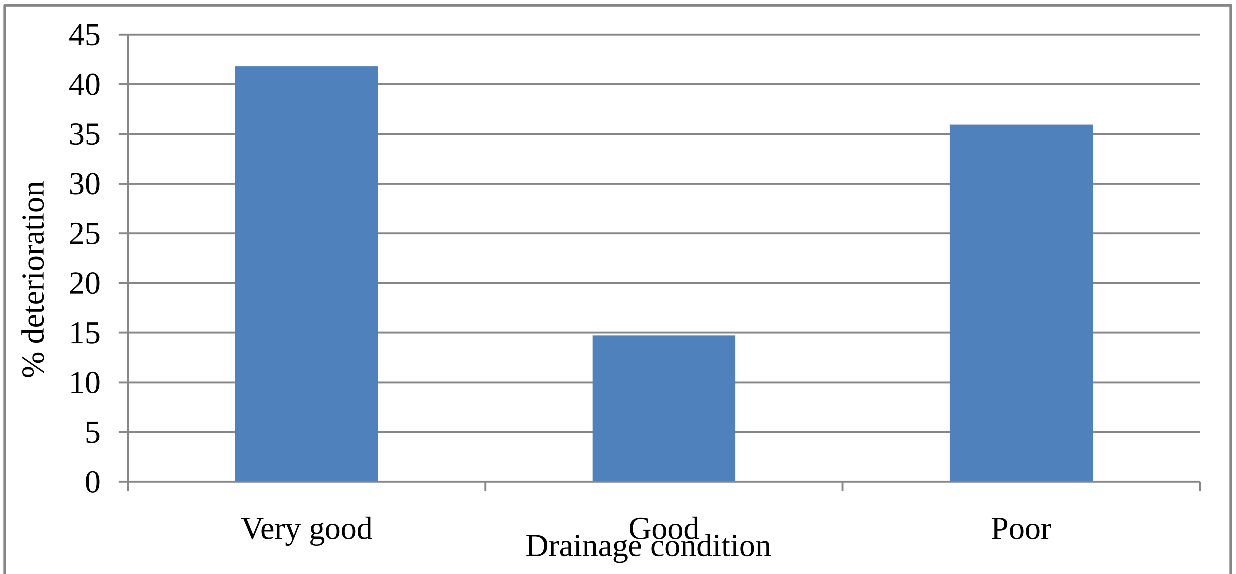


Figure 4.6: Drainage condition from St. George church to Litete gorge outfall

Also as shown from Figure 4.6 above, 42% is very good, 15% is good and 36% is poor. The major part of the drainage system in this area is very good but most of the drainage systems must be functional to reduce over flooding.

4.2. Intensity-Duration-Frequency curve of Dejen Town

For this thesis, Intensity-Duration-Frequency curve was developed from 24-hr rainfall data of a study area of 32 years obtained from the Meteorological Agency of Ethiopia. This Developed IDF curve was applicable specifically for the study area to interpolate rainfall intensity of the study area. Recorded daily rainfall data from 1987-2018 for 32 years was used for developing IDF curve of Dejen Town.

Table 4.1: Calculated Intensity vs Duration to develop IDF Curve of Dejen Town

Duration(min)	T-2	T-5	T-10	T-25	T-50	T-100
5	87.47	109.84	126.93	149.75	167.19	184.78
15	62.75	78.80	91.06	107.43	119.94	132.56
30	44.45	55.82	64.51	76.11	84.97	93.91
45	34.61	43.47	50.23	59.26	66.16	73.12
60	28.44	35.71	41.27	48.69	54.36	60.08
75	24.19	30.38	35.10	41.41	46.24	51.10
90	21.08	26.47	30.59	36.09	40.29	44.53
105	18.70	23.49	27.14	32.02	35.75	39.51
120	16.83	21.13	24.42	28.81	32.16	35.54
135	15.30	19.21	22.20	26.20	29.25	32.32
150	14.04	17.63	20.37	24.04	26.84	29.66
165	12.98	16.30	18.83	22.22	24.81	27.41
180	12.07	15.16	17.52	20.66	23.07	25.50

Figure 4.7: Intensity-Duration-Frequency curve of Dejen Town

Developed IDF curve from meteorological station of this study area shows less value of rainfall intensity than IDF curve developed by ERA for rainfall Region A-2 for each return periods 2, 5, 10, 25, 50 and 100 years with corresponding rainfall duration from 5min to180 minutes as described from Table 4.2 below. The change in rainfall characteristics, and changes in the hydrological cycle due to increase in greenhouse gases are projected to cause variations in Intensity-Duration-Frequency curve of a certain area. Percentage change of rainfall across different reference periods also causes significant changes on IDFC. For this thesis, IDF curve was developed from 32 years rainfall data of the study area and that increases accuracy of the intensity of Dejen Town.

Table: 4.2. Comparison of IDF curve of Dejen Town with IDF curve of ERA

	Mine	ERA	Mine	ERA	Mine	ERA	Mine	ERA	Mine	ERA	Mine	ERA
Duration (min)	T-2	T-2	T-5	T-5	T-10	T-10	T-25	T-25	T-50	T-50	T100	T-100
5	87	98	110	124	127	141	150	162	167	178	185	194
15	63	71	79	89	91	101	107	117	120	128	133	139
30	44	50	56	63	65	72	76	83	85	91	94	99
45	35	39	43	49	50	56	59	64	66	71	73	77
60	28	32	36	40	41	46	49	53	54	58	60	63
75	24	27	30	34	35	39	41	45	46	49	51	54
90	21	24	26	30	31	34	36	39	40	43	45	47
105	19	21	23	27	27	30	32	35	36	38	40	42
120	17	19	21	24	24	27	29	31	32	34	36	37
135	15	17	19	22	22	25	26	28	29	31	32	34
150	14	16	18	20	20	23	24	26	27	29	30	31
165	13	15	16	18	19	21	22	24	25	26	27	29
180	12	14	15	17	18	19	21	22	23	25	25	27

4.3. Land use Type of Study Area

The land use condition in Dejen Town and surrounding is covered with urban settlements or residential areas, manufacturing industries, green areas, social services, open spaces, and places reserved for the special purpose, different administration offices, and agricultural lands. Area covered with each land use type from total area of Dejen Town and surrounding is, Residential Areas covers about 25.2%, Mixed Residential 16.3%, commercial 15.9%, social services, and administration offices 5%, reserved area and Neighborhood playground 10.6%, colleges and schools 3.7%, Green area and forest 8.5%, Agricultural area is 10.1%, and Manufacturing and small industries 4.7%.

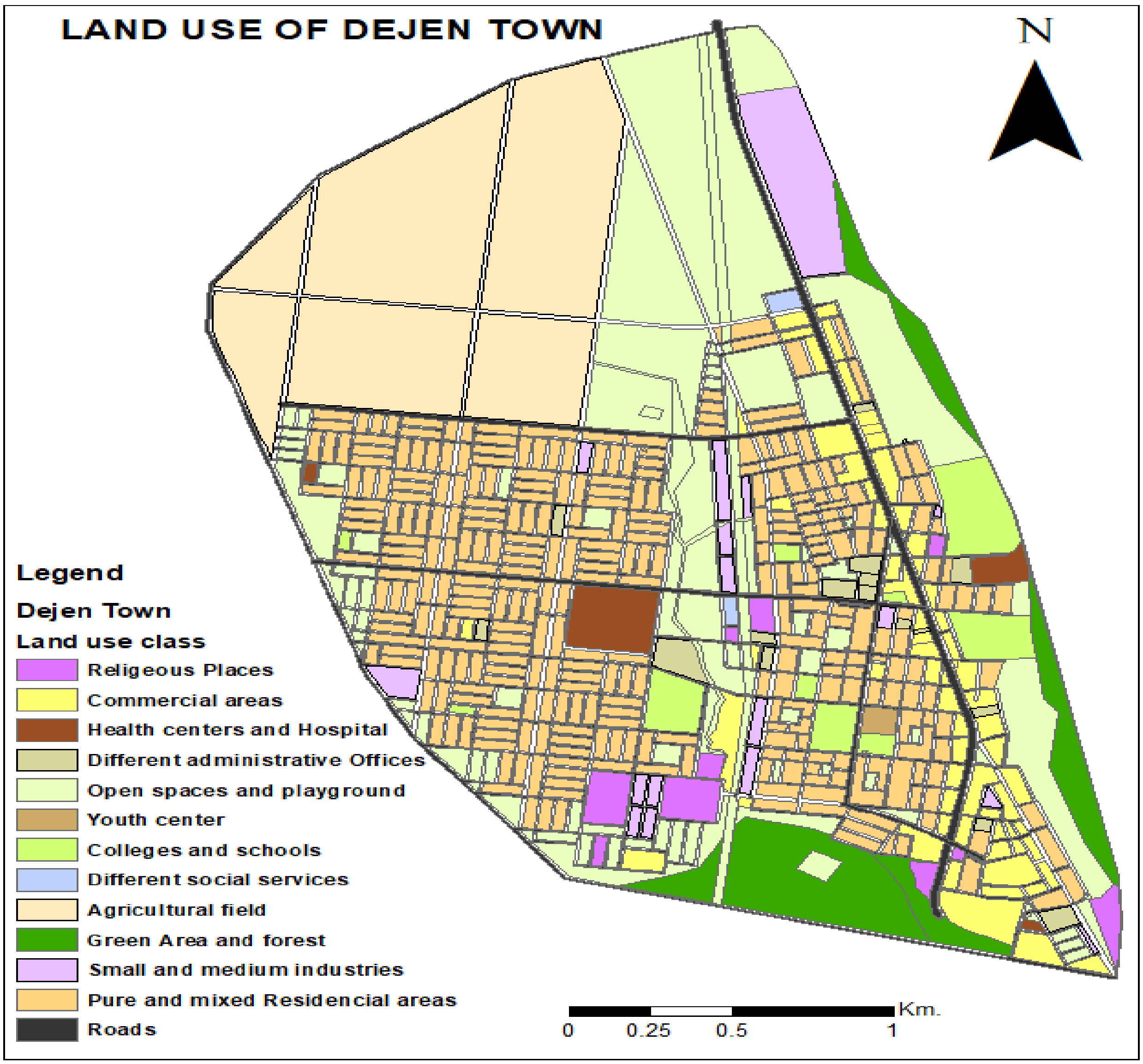


Figure 4.8: Land use of Dejen Town and surrounding by ArcGIS

Table 4.3: Peak runoff calculated by rational method for each sub-catchment

SC-ID	Area (ha)	TC-min	Cw	Intensity-10 yr	Intensity-25 yr	Intensity-50 yr	Intensity-100 yr	Q-10 Yr	Q-25 Yr
SC-1	7.92	10.12	0.64	105.56	124.24	139.04	153.67	1.48	1.92
SC-2	9.29	7.50	0.58	116.43	137.36	153.35	169.49	1.75	2.27
SC-3	7.71	8.43	0.67	112.64	132.89	148.37	163.98	1.62	2.10
SC-4	9.91	5.81	0.65	123.53	145.74	162.71	179.82	2.20	2.85
SC-5	7.15	10.00	0.66	105.92	124.96	139.51	154.19	1.39	1.80
SC-6	10.5	7.50	0.60	116.43	137.36	153.35	169.49	2.04	2.65
SC-7	4.17	6.16	0.71	122.06	144.00	160.77	177.68	1.00	1.30
SC-8	10.9	8.26	0.58	113.23	133.59	149.14	164.83	1.99	2.58
SC-9	34.1	11.30	0.65	102.05	120.40	134.42	148.57	6.30	8.18
SC-10	10.1	13.85	0.69	94.48	111.46	124.44	137.53	1.83	2.37
SC-11	3.09	9.34	0.82	108.69	128.23	143.17	158.23	0.77	1.00
SC-12	8.98	6.59	0.74	120.25	141.87	158.39	175.05	2.21	2.87
SC-13	1.63	5.42	0.70	125.17	147.61	164.87	182.21	0.40	0.52
SC-14	7.92	10.93	0.79	103.16	121.58	135.87	150.17	1.79	2.32

The peak discharge of this Thesis was estimated by using the rational method from the currently estimated amount of runoff for a design period of 10-years and for checking 25-years by considering the amount of runoff that will increase for each sub-catchment outfall. After calculating peak discharge of each sub-catchment with rational method, the existing hydraulic capacity in each sub-catchment was calculated by Manning's formula and compared with peak estimated runoff.

GSJ: Volume 9, Issue 9, September 2021
ISSN 2320-9186

Table 4.4: Comparing estimated and existing peak discharge of Sub-catchments using a rational method and Manning's Formula

SC-ID	Area (ha)	TC-(min)	Cw	Intensity-10 yr	Intensity-25 yr	Q (R)-10 Yrs	Q (R)-25 Yrs	Manning's (m^3/se)
SC-1	7.92	10.12	0.64	105.56	124.24	1.48	1.92	1.09
SC-2	9.29	7.50	0.58	116.43	137.36	1.75	2.27	1.33
SC-3	7.71	8.43	0.67	112.64	132.89	1.62	2.10	1.56
SC-4	9.91	5.81	0.65	123.53	145.74	2.20	2.85	1.24
SC-5	7.15	10.00	0.66	105.92	124.96	1.39	1.80	2.24
SC-6	10.49	7.50	0.60	116.43	137.36	2.04	2.65	1.77
SC-7	4.17	6.16	0.71	122.06	144.00	1.00	1.30	0.87
SC-8	10.92	8.26	0.58	113.23	133.59	1.99	2.58	2.75
SC-9	34.11	11.30	0.65	102.05	120.40	6.30	8.18	3.86
SC-10	10.07	13.85	0.69	94.48	111.46	1.83	2.37	1.50
SC-11	3.09	9.34	0.82	108.69	128.23	0.77	1.00	1.67
SC-12	8.98	6.59	0.74	120.25	141.87	2.21	2.87	1.64
SC-13	1.63	5.42	0.70	125.17	147.61	0.40	0.52	1.03
SC-14	7.92	10.93	0.79	103.16	121.58	1.79	2.32	1.49

From the above Table 4.4 indicates that existing drainage capacity near CBE Abaysheleko branch (SC-1), drainage around 02 playgrounds (SC-2), drainage around Demis Hotel (SC-3), drainage around Dejen 02 primary school (SC-4), around Dejen town kinder garden (SC-6), around CBE Dejen branch (SC-7), around Mulugojam hall (SC-9), around Andinet business technology college (SC-10), around Serkalem Hotel (SC-12) and around Kurar Amba Hotel (SC-14) were inadequate and estimated capacity was greater than Existing Capacity and existing drainage structure can't carry estimated discharge and that shows overflow had happened in these sub-catchments and redesign additional drainage structures are required. Whereas, around Seble restaurant (SC-5), around new bus station (SC-8), around Ambasel restaurant (SC-11), and around St. Gorge church (SC-13) existing capacity was greater than estimated capacity and that shows no overflow of runoff.

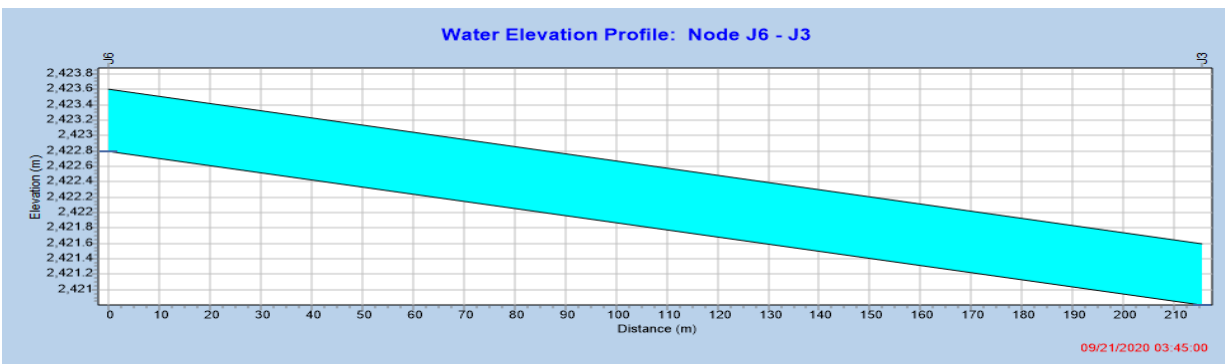
4.4. Simulation of Storm Water Management Model (SWMM)

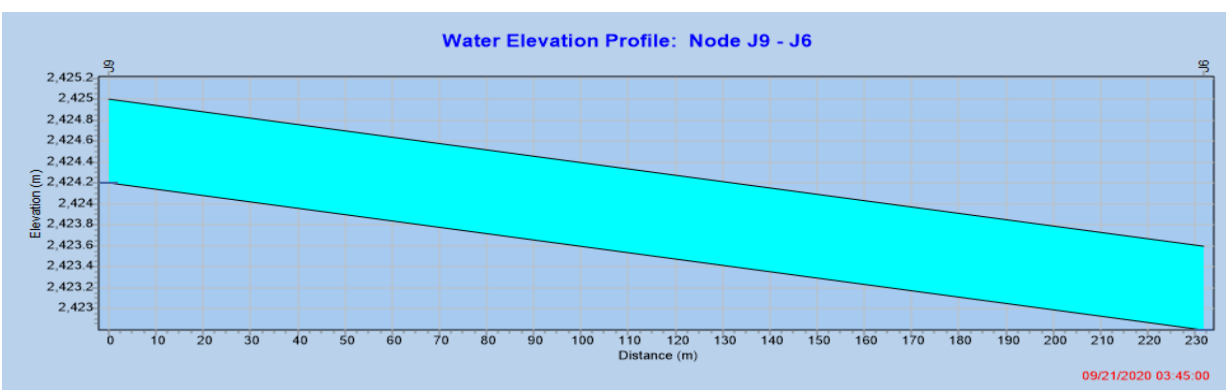
4.4.1. Water depth and flow in the Links

Outfall towards Fasileds Bridge

The figures blow shows the flow of flood through the conduit, amount of flood in the junction, and length of the conduit. It indicates how much the flood rises in the conduit and the amount of flood hazard in the study area.

As shown in Figures 4.9 below from the simulation results Junction J2, J3, J5, J6, J8, J9, J12, J27, and outlet 1 are over flooded as a result of the insufficient design of canal depth and width and outfall 1(conduit 3) is busy to remove flood coming from sub-catchments. But the drainage canals at Link 1, link 4, link 8, and link 12 can carry the generated runoff from sub-catchments.





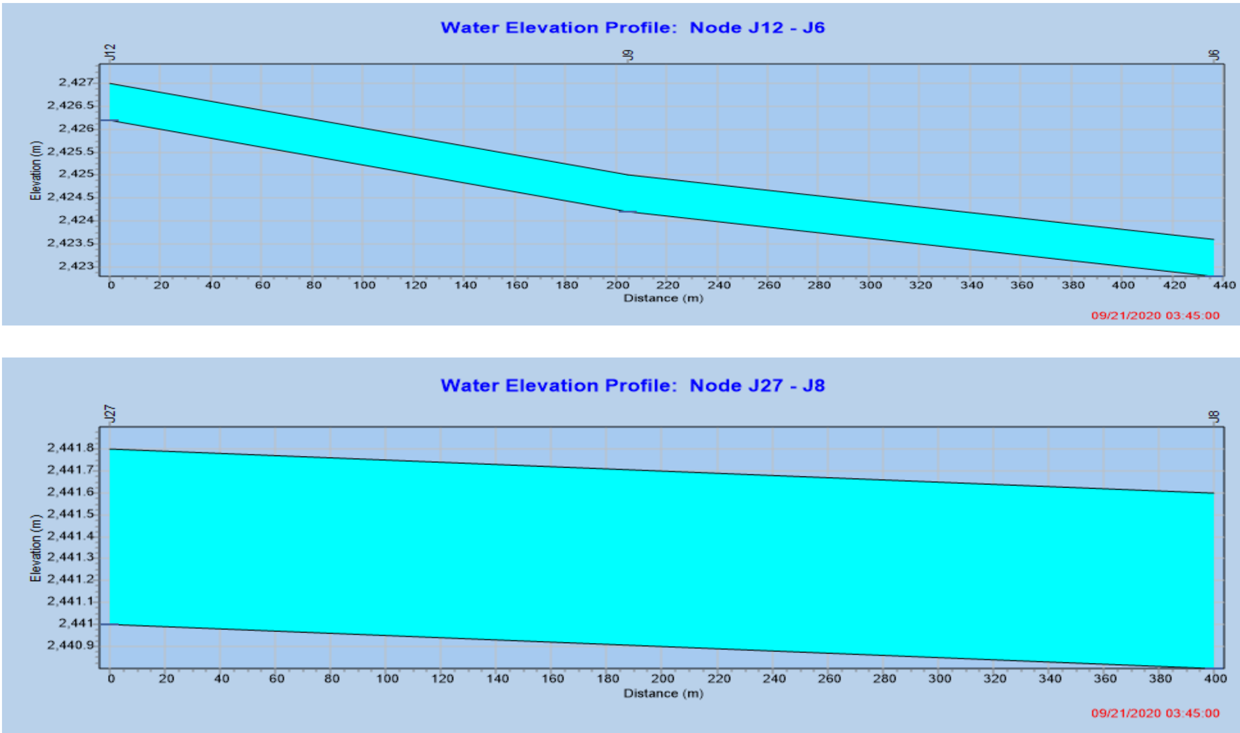
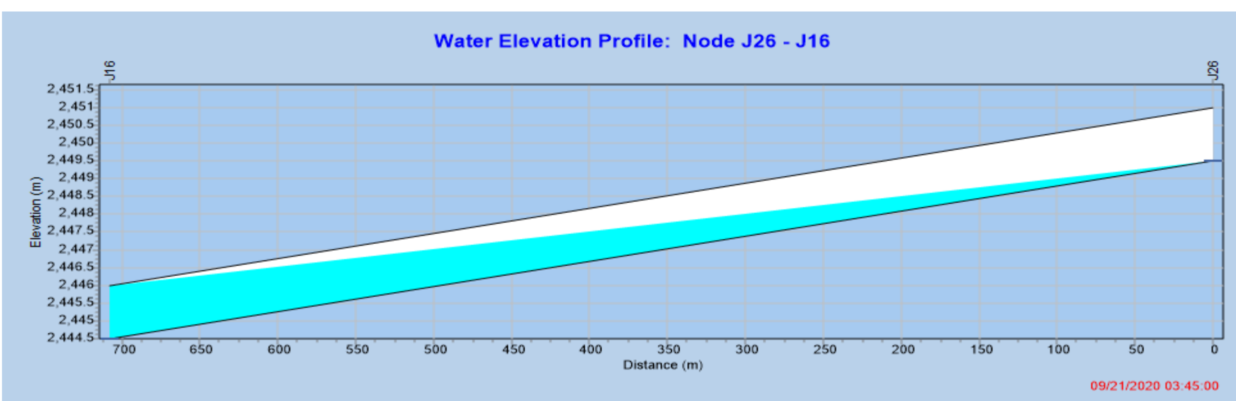


Figure 4.9: Water elevation profiles towards Fasileds bridge outfall

Outfall towards Abuadem gorge

As shown from Figures 4.10 below simulation results of SWMM Junctions 15, 16, 17 that is Links C 16, 17, 18, and Outfall 2 are over flooded and insufficient capacity to carry runoff generated from sub-catchments. But Junction 26 (Link C_{26}) can carry the generated flood.



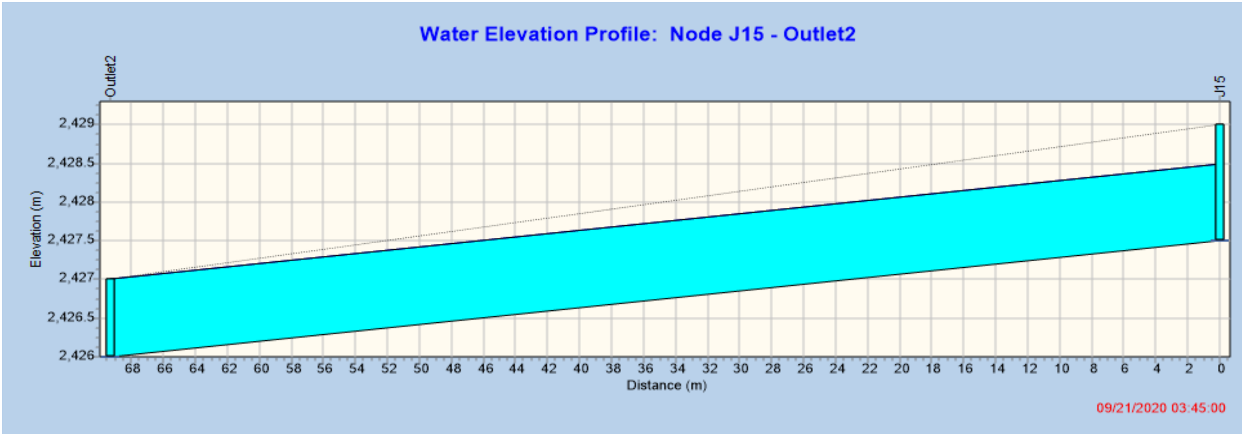
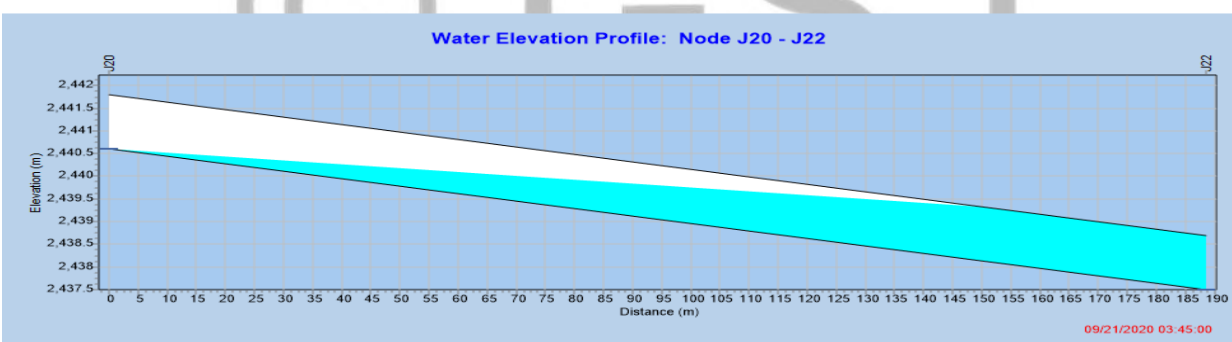
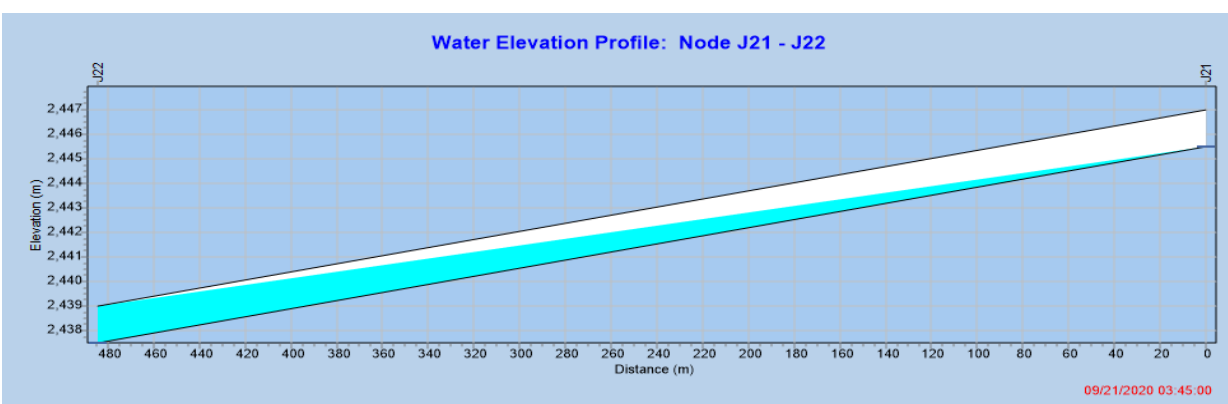


Figure 4.10: Water elevation profiles towards Aduadem gorge outfall

Outfall towards Litete gorge

As show from Figures 4.11 below from simulation result of Storm Water Management Model Junction 22 is over-flooded and has no the capacity to carry flood coming from sub-catchments, but outfall 3 have the capacity to carry flood coming from sub catchments and no over flooding in this outfall.





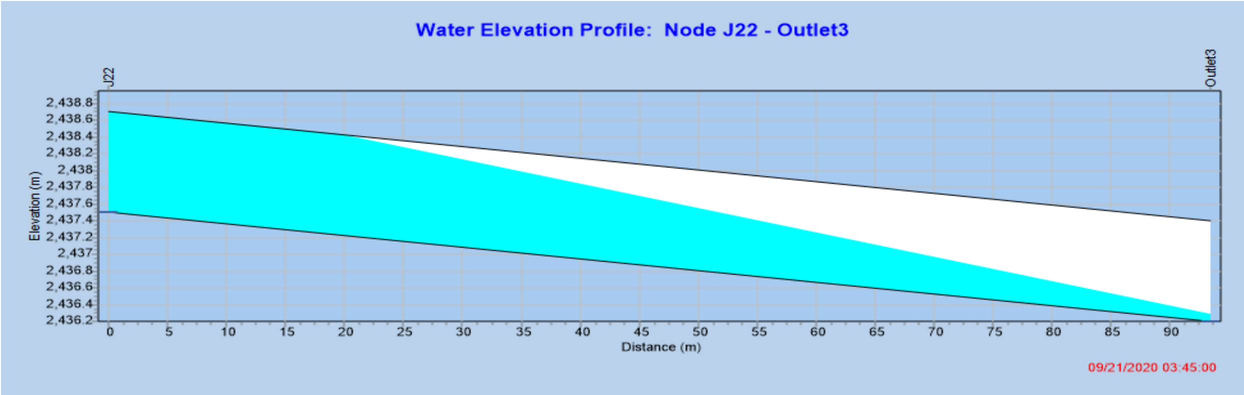


Figure 4.11: Water elevation profiles towards Litete gorge outfall

Storm Water Management Model shows that maximum flood occurs near CBE Abaysheleko branch, around 02 playgrounds, around Demis Hotel, around Dejen 02 primary school, around Dejen town kinder garden, around CBE Dejen branch, around Mulugojam hall, around Andinet business technology college, around Serkalem Hotel, and around Kurar Amba Hotel, and sub-catchments around Seble restaurant, around the new bus station, around Ambasel restaurant, and around St. George church the results indicated no over flooding.

Table 4.5: Comparison of runoff resulted from a rational method, SWMM, and Manning

SC-ID	Rational Q- 10 Yrs (m^3/se)	SWMM Q-10 Yrs (m^3/se)	Rational Q- 25Yrs (m^3/se)	SWMM Q-25Yrs (m^3/se)	Manning's Q-(m^3/se)	Velocity (m/s)
SC-1	1.48	1.34	1.92	1.63	1.09	2.1
SC-2	1.75	1.70	2.27	2.13	1.33	3.1
SC-3	1.62	1.4	2.10	1.7	1.56	2.12
SC-4	2.20	2.02	2.85	2.45	1.24	3.61
SC-5	1.39	1.21	1.80	1.47	2.24	2.17
SC-6	2.04	2.14	2.65	2.6	1.77	3.25
SC-7	1.00	0.79	1.30	0.96	0.87	3.21
SC-8	1.99	2.21	2.58	2.69	2.75	3.21
SC-9	6.30	5.21	8.18	6.34	3.86	3.23
SC-10	1.83	1.71	2.37	2.08	1.50	1.79
SC-11	0.77	0.54	1.00	0.66	1.67	1.48

SC-12	2.21	1.86	2.87	2.26	1.64	2.71
SC-13	0.40	0.34	0.52	0.42	1.03	2.39
SC-14	1.79	1.5	2.32	1.83	1.49	2.35

Figure 4.12 below shows discharge resulted from SWMM 5.1, rational method, and Manning's formula for a design period of 10 years and for checking 25 years design period. The result and the Figure shows the discharge result of SWMM model and Rational formula are closer but discharge resulted from Manning is smaller in most of sub-catchments. That indicates the current performance of drainage structures is low. Due to this, it is possible to conclude the design must be done according to the discharges resulted from Rational Formula and SWMM model. The results obtained from SWMM model shows flood occurs, from sub-catchments 1, 2, 4, 6, 9, 10, 12, and 14, but sub-catchment 3, 5, 7, 8, and 11 the existing structure can carry the incoming flood.

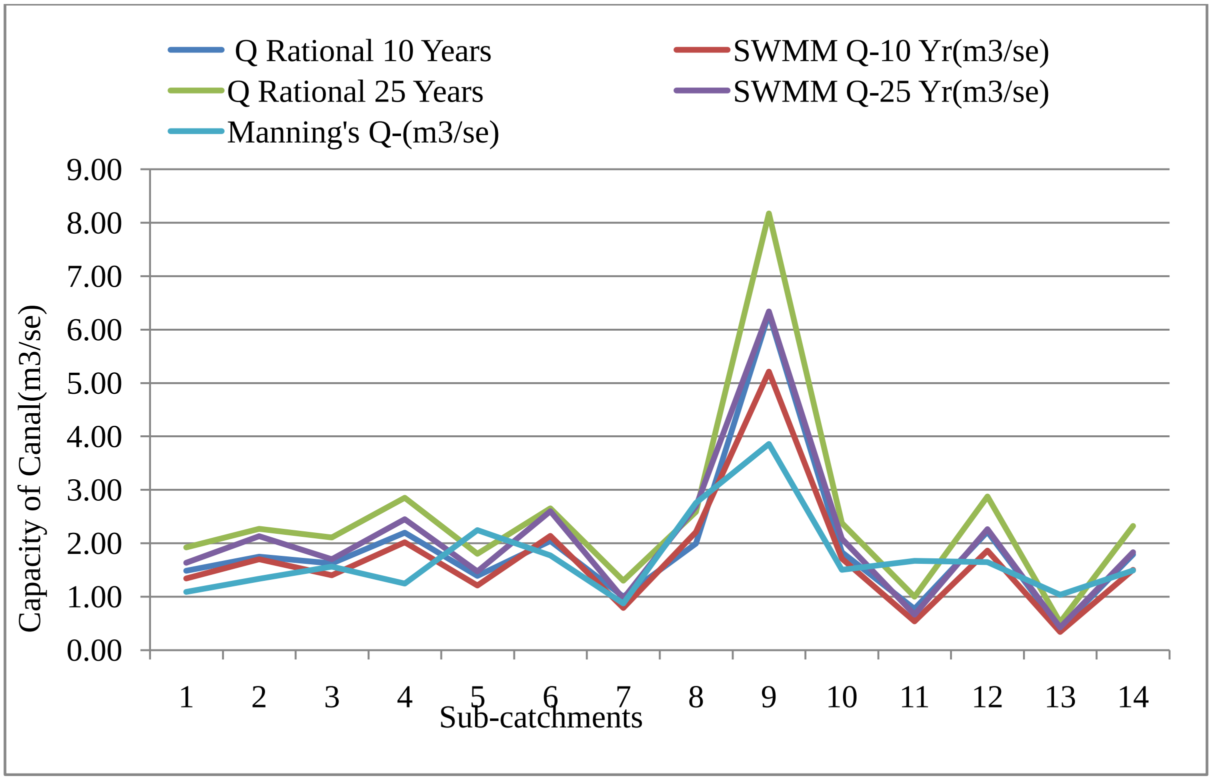


Figure 4.12: Discharge resulted from rational method, SWMM and Manning's Formula

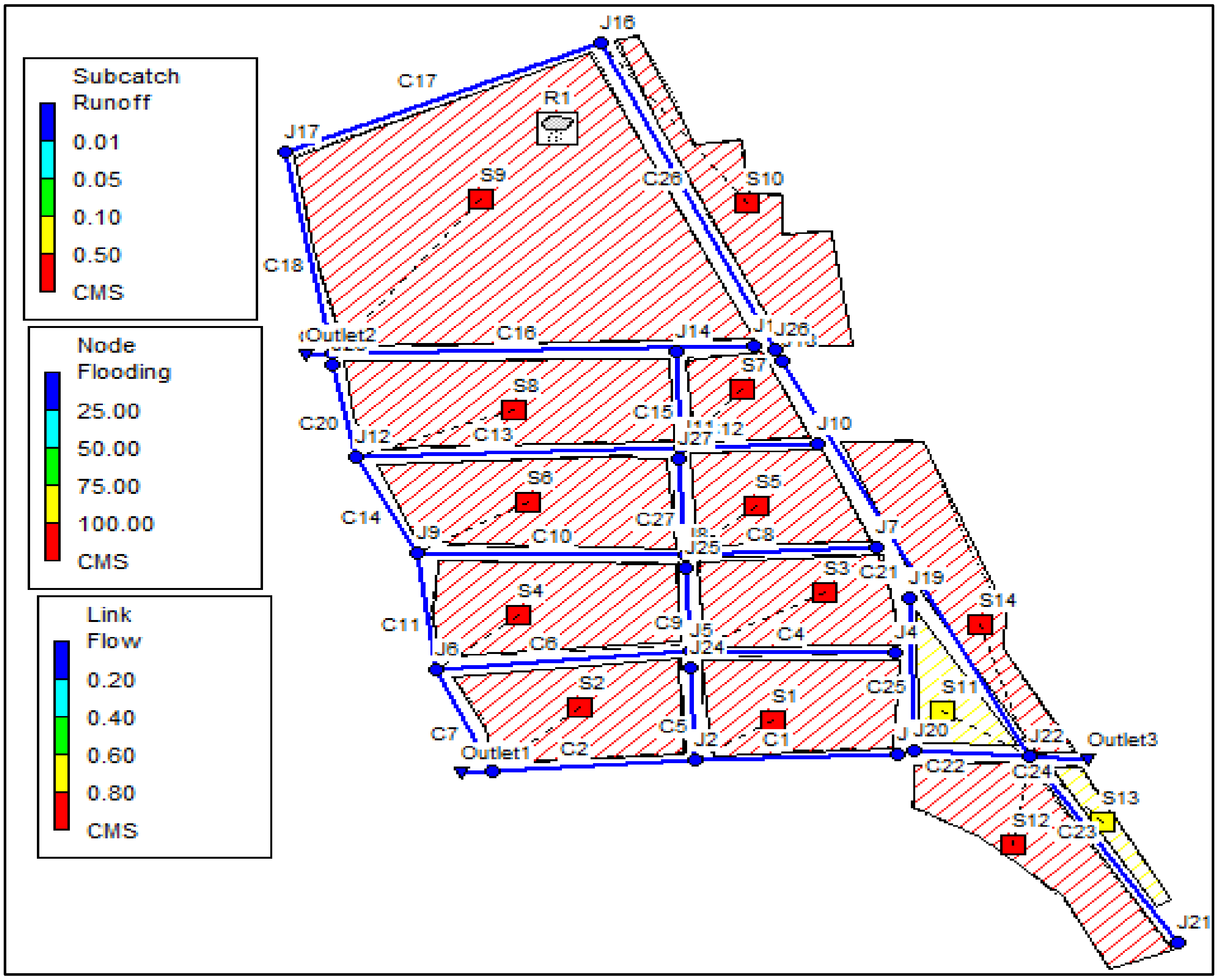


Figure 4.13: Map of Sub-catchments Modeled by SWMM

5. CONCLUSION

The results obtained from this thesis show the performance assessment of existing storm drainage systems of the Town was poor and the sewage systems were not proper to collect wastes originated from each household and most percent of the drainage systems were severe. This is because of lack of well-connected drainage networks, failure and breaking of drainage ditches, aging of drainage structures, and high traffic effect, unavailability of sufficient drainage structures in the proper place, most of the drainage structures were open drainage systems and exposed to failure as solid and liquid wastes were disposed into storm drainage systems. Another factor that leads Dejen Town to a drainage problem was the lack of waste management techniques to dispose of wastes extracted from each household.

According to the results obtained from engineering analysis of drainage structures of Dejen Town using rational formula and Storm Water Management Model as shown from Table 4.5, most of the storm drainage structures were inadequate and cannot carry existing runoff and have direct impact on road structures. The results obtained from rational method and Storm Water Management Model shows that maximum flood occurs near CBE Abaysheleko branch, around 02 playgrounds, around Demis Hotel, around Dejen 02 primary school, around Dejen town kinder garden, around CBE Dejen branch, around Mulugojam hall, around Andinet business technology college, around Serkalem Hotel, and around Kurar Amba Hotel, and sub-catchments around Seble restaurant, around the new bus station, around Ambasel restaurant, and around St. George church the results indicated no over flooding.

Acknowledgment

It is important to acknowledge who had contributed to this study directly and indirectly. This research is part of my MSc thesis. I would also like to thank Assosa University for giving sponsorship for my Master's study at Hawassa University. In addition, I extend my gratitude Hawassa University Faculty of Bio-systems and Water resources Engineering Department of Water resources and Irrigation Engineering and academic staff members for their support and encouragement. Finally, I would like to thank organizations who gave me necessary data for my study, like Ethiopian Meteorological Service Agency (EMSA) and Dejen Town municipality.

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