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Hydrological and Hydraulic Analyses of Storm Water Drainage System of Enjebara Town Under the Effect of Land Use and Land Cover Change

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Abstract: Urban drainage systems are desirable in all urban areas subsequently their interaction between human daily activity and natural water circulation. As the result of urban expansion and increasing surface impermeability, uncontrolled flooding from storm water drainage system has resulted in damage of small drainage channels, blockage of channels, deterioration of roads and land degradation. Hydrological analysis is thus critical to design road side drains for better management of storm water drainage. This study was conducted to evaluate hydrologic and hydraulic analyses of storm water drainage system for Enjebara town under the effect of land use land cover change. This research work included collection of both primary and secondary data. Landsat images of 1998, 2010 and 2019 for land use land cover classification were used. Geographical information system was used to prepare the classified maps and ground truth observations were also used to check the accuracy of classification. The result show that runoff volumes had increased due to land use land cover changes from 22.48% to 57.8%. In this study design of storm drainage system evaluated by using manning's and fixing new size of reinforced concrete pipe for existing and proposed area. Bentley Civil Storm V8i dynamic storm water modeling was used to calculates and analyzes hydraulic response of existing drainage system through dependent channel, manhole and outlet to visualize flooding problems. The results obtained from hydraulic condition for storm water is flooding on the street due to peak flow generation from the catchment. According to respondent's challenge for storm water management in Enjebara town is due to the lack of community awareness, shortage of disposing area, flooding occurrences in the street, blockage of drainage system and lack of clearance storm water drainage lines. Generally, the futures studies should conduct a more detailed study on identification of the flood causative factors to the specific location. Improve the drainage systems along Enjebara town highways, redesign storm water drainage system is essential.

Keywords: Bentley Civil Storm V8i, Hydraulic Performance, Enjebara Town, Storm Water Drainage System

1. Introduction

Urban drainage systems are needed in all urban areas because of their interaction between human daily activity and the natural water circulation.

In the developing countries, most the urban growth is unplanned, leading to rapid densification, and associated construction of buildings resulting in dramatic increase in impermeable areas due to paving and built-up areas [3]. As population grows, demand for housing and commercial amenities naturally follows and also urbanization adds roads, rooftops, parking lots, sidewalks, and other imperviousness to the landscape management [15].

Urban storm water drainage systems are part of the urban infrastructure basics and storm water is rain, snowmelt and rise water that temporarily runs off the ground surface. In towns with many impermeable surfaces, large quantities of storm water storage may be designed. Drainage problems in urban areas consist of flooding, deterioration of roads, land degradation, sedimentation, blockage of drainage facilities, waterlogging, etc. [6].

Storm water discharges are produced when the capacity of the land to retain precipitation is exceeded and run-off occurs. Run-off will be influenced by rain fall and intensity (millimeter of rainfall per hour) and duration, antecedent storms and a number of watersheds, and land use characteristics such as slope, soil type, and impervious surfaces [4].

Urban storm water modeling is important for constantly increasing three global trends: Urbanization, Population growth, and climate change. In the world has induce a rapid growth of cities, making storm water management ever more challenging while at the same time a rising number of people will affect by the harmful effects of storm water on the environment. In many areas, these effects are expected to be amplified in the future due to climate change and associated higher frequencies of extreme weather event [7].

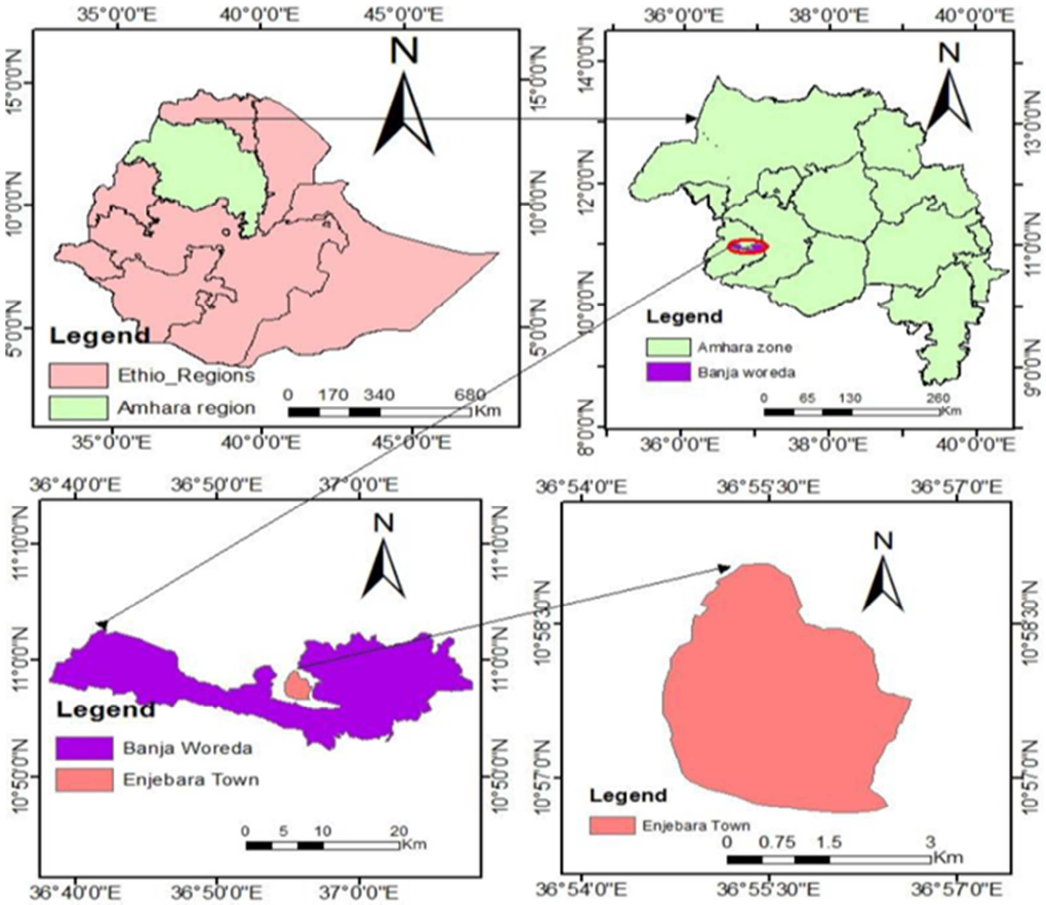

Figure 1. *Location of the study area.*

Ethiopian cities and towns at large, are troubled with storm water leading into floods especially during the rainy season due to inadequate installation of drainage infrastructure, poor maintenance of existing drains and the problem is more critical in cities of highland regions like Addis Ababa, though it also exist in cities with flat and plain geographies like Assosa, Adama, Bahir Dar and soon. The provision of sustainable drainage system for flat and highland areas is important from different point of views [13].

Drainage problems with in Enjebara town include flooding, deterioration of roads, land degradation, sedimentation, blockage of drainage facilities and water logging. The urbanization, impermeability increases with the increase in impervious surfaces (i.e., residential houses, commercial buildings, paved roads, parking lots). The drainage pattern changes, overland flow gets faster which leads flooding and environmental problems. It is a crucial problem facing the existing and future road and other infrastructure.

2. Materials and Methods

2.1. Study Area Description

2.1.1. Location

Enjebara town is located in the highlands of Ethiopia and the capital town of Banja Woreda and Awi Administrative Zone of the Amhara National Regional State. Geographically the town is located at 100 50’0” -110 00’00” North latitude and 360 50’00”-370 10’00” East longitude with an elevation 2520 m above sea level. It is located on the main road via Addis Ababa to Bahir dar, about 120 kilometers from Bahir dar and 445 kilometers from Addis Ababa. In 2019 the total population is 42,846 (male is 21,540 and female is 21,306) [8].

2.1.2. Coverage of Existing Drainage Services

The existing drainage facilities of the study area is composed of open drainage and covered drainage with precast concrete drainage cover, and either cross drains or culverts mainly constructed adjacent to the existing arterial asphalt and cobble stone surfaced roads.

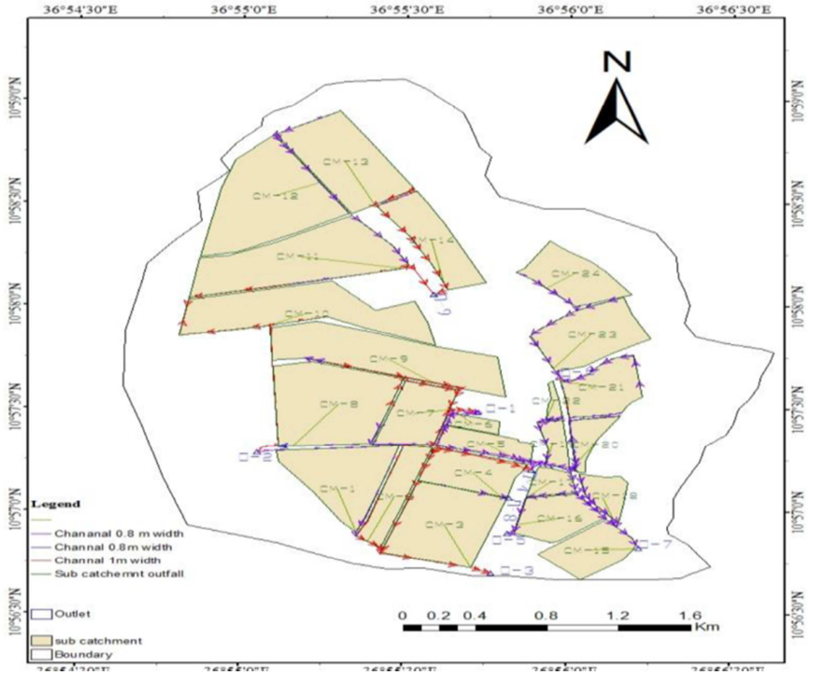

Figure 2. *Existing drainage alignment.*

The dimensions of the existing drainage systems are rectangular type with different width and depth (width varies from 0.8 up to 1m, depth 0.8 up to 1.2m) and the slope of the existing channel within the range of 0.01 up to 0.04 percent. The capacity of the existing storm drainage channel has significantly reduced due to the enormous amount of solid waste accumulation and under size.

2.1.3. Topography

The topography of Enjebara town is characterized by a highly flat relief with small hills. The highest elevation in Enjebara town is 2671 meters, while the lowest point in the study area is 2480 meters (DEM). The steeper areas are the northeast edge and the Southwest.

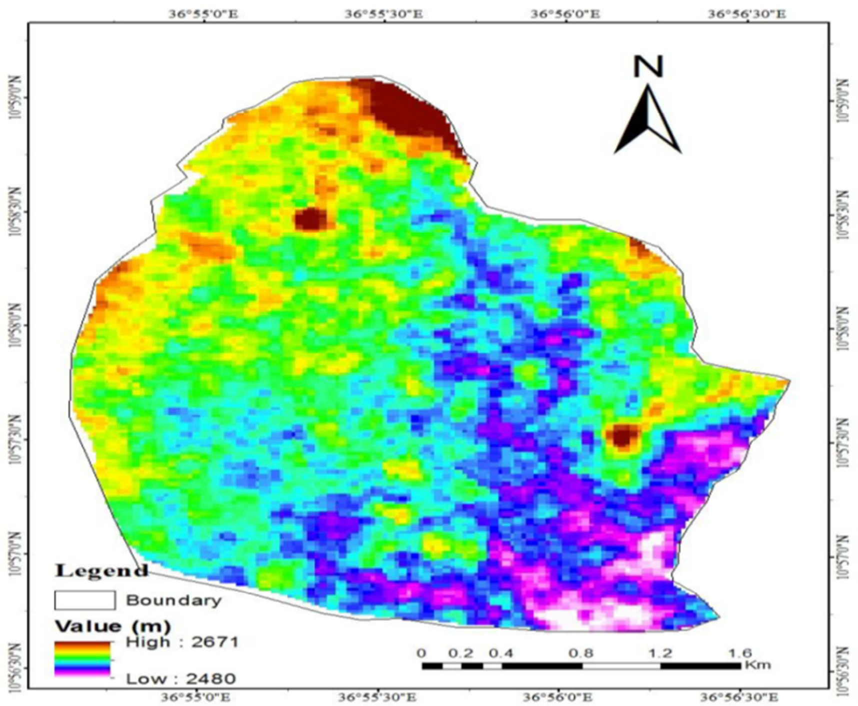

Figure 3. *Digital elevation model (DEM).*

2.2. Data Types and Sources

This part contains of the types and sources of data which were used in this study. Consequently, the qualitative as well as quantitative type of data has been used for this research. Data sources obtained for this research were both primary and secondary sources.

2.2.1. Primary Data Sources

Field survey or observation was employed to measure the existing drainage lines located in the study area, to gather information about the current condition of the drainage system with the help of field survey/observation and interview were the primary data sources which were engaged in this study.

In this research work contact with concerning body like head of municipality officer, Community, household, government civil servant water bureau concerning the effect of water drainage storm water management challenges as well as environmental challenges relating to the improper utilization of the drainage systems in the chosen locations.

The community in the study area were interviewed to get reliable data as they are the most vulnerable people in the past years and they have been observing the flooding problem, the challenge that has been faced over the year's survey/observation and interview were the primary data sources which were engaged in this study.

Figure 4. *Measuring of existing drainage channel geometry and its coordinates.*

2.2.2. Secondary Data Sources

Meteorological data from Bahir Dar branch meteorological service agency of Ethiopia, contour map, digital elevation model (DEM), land use and land cover data, (USGS) satellite image and other findings/literatures and reports were secondary data sources which were used for this particular research.

2.3. Meteorological Data Collection and Analysis

Four meteorological stations were collected for this study; are Enjibara, Gundil, Tilili and Kessa. The daily meteorological data exist from those station from 1998 to 2018 with missed certain monthly and daily data.

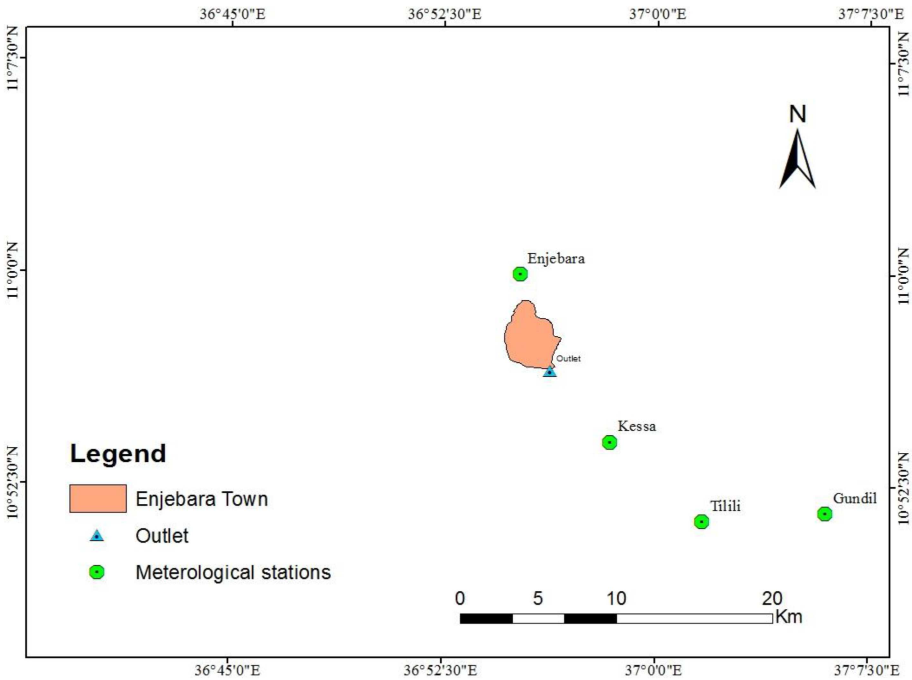

Figure 5. *Location of Meteorological station in and around Enjebara.*

2.3.1. Filling in Missing Rainfall Data

This study uses normal-ratio method for filling the missing rainfall data. Among different method normal ratio method is the one which is recommended to estimate missing rainfall data in regions where annual rainfall between stations differ by more than 10% [10]. Rainfall data at day one is missed from station Z having mean annual rainfall of Nz and there are three surrounding stations with mean annual rainfall of N1, N2, and N3 then the missing data Pz can be estimated [19].

$$\mathrm{Pz} = \frac{1}{2}(\mathrm{P1}\frac{\mathrm{Nz}}{\mathrm{N1}} + \mathrm{P2}\frac{\mathrm{Nz}}{\mathrm{N2}} + \mathrm{P3}\frac{\mathrm{Nz}}{\mathrm{N3}} \quad (1)$$

Where: Pz - missing rainfall data (daily, monthly or yearly)

P1, P2 and P3 – rainfall data at nearest different station (daily, monthly or yearly)

Nz - mean annual rainfall at missed station

N1, N2, and N3- mean annual rainfall at different nearest station.

2.3.2. Data Consistency Test

The daily maximum rainfall data of Enjebara meteorological station from 1998 to 2018 is taken for the design. Hence, 21 years of daily maximum rainfall data is available. These data should be checked for its consistency by higher and lower outlier testes.

Test for higher outlier

$$\mathrm{YH} = \overline{\mathrm{Y}} + \mathrm{Kn} * \delta\mathrm{n}^{-1} \quad (2)$$

where: Y^{-}= mean of data in log unity

Kn= from table for sample size N

∂n^{-1} = standard devotion [18].

Higher outlier test = 10YH

Test for lower outlier

$$\mathrm{YL} = \overline{\mathrm{Y}} - \mathrm{Kn} * \delta\mathrm{n}^{-1} \quad (3)$$

where: Y^{-}= mean of data in log unity

Kn= from table for sample size N

$\partial n - 1$ = standard devotion [18].

Lower outlier=10YL

2.3.3. Checking Data Reliability

Relative standard less than 10% the data series could be regarded as reliable and adequate [17].

N Number of data $\delta n - 1$ Standard deviation X^{-} Mean Standard

$$\text{error of mean, } \delta\mathrm{n} = \frac{\delta\mathrm{n}^{-1}}{\sqrt{n}} \quad (4)$$

$$\text{Relative standard} = \frac{\delta\mathrm{n}}{\overline{\mathrm{X}}} * 100 \quad (5)$$

2.4. Estimation of Average Depth of Rainfall over a Catchment

2.4.1. Depth

The most hydrological problems require knowledge of the average depth of rainfall over a significant area such as a basin. The rain catch at one station in a basin may be different from that of other stations in the same basin [2].

2.4.2. Point Rainfall

The extent of precipitation occurring at a single location in space is determined directly using a rain gauge. These point measurements are considered to be applicable only for areas up to $25km^2$. If the point on a hydrologic system does not have a gauge station, the precipitation at that point can be estimated by taking a weighted average of nearby points.

2.4.3. Area Rainfall

Due to the lack of information on the probability distribution of areal precipitation, point rainfall is used collectively to estimate areal average rainfall. In hydrologic design point of view, storm spatial characteristics become more important as the size of the watershed of interest increases [2].

2.5. Design Rain Fall Computation of Shorter Duration

After checking the consistency of the data for both higher and lower outlier, the 21 years' data was used for the analysis. These rainfall analyses and 30 processing is aimed at determination of appropriate Intensity-Duration Frequency relationship. Frequency analysis is performed using best fitted distribution i.e., Gumbel's distribution for different return periods and the frequency values are used for development of IDF (intensity-duration-frequency) curves [17].

Gumbel method analysis

$$XT = \overline{\mathrm{X}} + \mathrm{K} * \mathrm{SY} \quad (6)$$

$$\mathrm{SY} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(y - \overline{\mathrm{y}})^2} \quad (7)$$

SY: Stander deviations of sample size N

K= frequency factors expressed as

$$K = \frac{Yt - Yn}{Sn} \quad (8)$$

Yn and Sn reduced standard deviations, as sample N in the table [18].

2.6. Intensity-Duration-Frequency (IDF) Curves

The rainfall depths obtained from gauging station are of 24hr duration depth and Enjebara town is between Bahir Dar and Debre Markos. Design and analysis of drainage structures require rainfall intensity duration relationship of shorter duration. The IDF relationships give an idea about the frequency or return period of a mean rainfall intensity or rainfall volume that can be expected within a certain period. Because rainfall data of shorter duration is unavailable, appropriate IDF derivation for shorter duration is required as suggested below [9]

$$Rt = \frac{t}{24}\left(\frac{(b+24)^n}{(b+t)^n}\right) \quad (9)$$

where RRt=rainfall ratio=Rt: R24

Rt= rainfall in given duration"t"in hour

R24=rainfall in 24-hour t=time in hour n=0.9, b=0.3

$$Rt = \frac{t(b+24)^n}{(24(b+t)^{n*} R24} \quad (10)$$

2.7. Hydrological Estimation for Determining Peak Runoff

2.7.1. Rational Method

The main purpose of hydrologic analysis is to determine the maximum amount of run-off that can be accumulated at certain storm drainage outlet along a highway or access road alignment section for the design of storm water drainage system. The Rational Method considers the entire drainage area as a single unit and estimates the peak discharge at the most downstream point of that area. For this study area rational method is appropriate because of area for each sub catchment is less than 0.5Kilometer square. The peak runoff is given by the following expression: -

$$Q = \frac{CIA}{360} \quad (11)$$

where Q – Discharge at outlet (m^3/s)

C – Rainfall-Runoff Coefficient

I – Maximum probable rainfall Intensity (mm/hr)

A– Catchment Area in hectares

2.7.2. Runoff Coefficient Determination

This variable represents the ratio of runoff to rainfall. It represents the interaction of many factors, including the storage of water in surface depressions, infiltration, antecedent moisture, ground cover, ground slopes and soil types. Runoff coefficients are theoretically restricted to the range of 0 to 1.0.

Due to improper land use planning for the town, and there is no organized data regarding land use in Enjebara town then 1998 and 2010 and also to used overall the catchment. Which is essential to investigate the runoff Coefficient in detail in the following.

$$\text{Cwighted} = \frac{\sum Ai*Ci}{AT} \quad (12)$$

Where Ci- Runoff coefficient for a given hydrologic soil group area

Ai -Area under each hydrologic soil group

AT -Total catchment area considered of town [3].

2.7.3. Rainfall Intensity

The rainfall intensity (I) is the average rainfall rate in mm/hr. for duration equal to the time of concentration for a selected return period. Once a particular return period has been selected for design and a time of concentration calculated for the catchment area, the rainfall intensity can be determined from Rainfall-Intensity-Duration curves [11]. Calculation of Tc is discussed in detail in the next section.

2.7.4. Catchment Area

Like rational method, the catchment area can be determined from base maps and site observation. However, for large catchment areas Enjebara town is necessary to divide the area into sub-catchment areas using Auto CAD 2018 to account for common outlet of the town in natural drainage system.

2.7.5. Time of Concentration

The basin time of concentration is defined as the time required for water to flow from the most remote part of the drainage area to the point of interest for discharge calculations [12]. The time of concentration to any point in a storm drainage system is the sum of the inlet time to (the time it takes for flow from the remotest point to reach the sewer inlet), and the flow time tf in the upstream sewers connected to the outer point: The velocity of flow depends on the catchment characteristics and slope of the water course by using manning equation. Many empirical equations are available for calculating time of concentration for a watershed. For this study use the following equation [1].

$$Tt = \frac{0.091*(nL)}{P2^{0.5}S^{0.4}} \quad (13)$$

Where: Tt = travel time, hr

n = Manning's roughness coefficient

L = flow length, m

P2 = 2-year, 24-hour rainfall, mm

S = slope of hydraulic grade line (land slope), m/m based on topographic map

2.8. Hydraulic Equations

Manning's equation

The manning's equation can be used for uniform flow in a pipe, and stream channel, but the manning's roughness coefficient needs to be considered variable, dependent upon the depth of flow. The Manning's equation is used for calculating the cross-sectional area, wetted perimeter, and hydraulic radius for flow of a specified depth in pipe of known diameter and/or stream channel cross-section. Manning's equation is applicable for a constant flow rate of water through a channel with constant slope, size &shape, and roughness.

$$Q = \frac{AR^{2/3}S^{1/2}}{n} \quad (14)$$

Where,

Q = the volumetric flow rate passing through the channel reach in m^3/sec.

A = the cross-sectional area of flow normal to the flow direction in m^2

S = the bottom slope of the channel in m/m (dimensionless).

n = a dimensionless empirical constant called the Manning roughness coefficient.

R = the hydraulic radius = A/P.

P = the wetted perimeter of the cross-sectional area of flow in m [12].

2.9. The Use of Bentley Civil Storm V8i Software

The Bentley civil Storm V8i dynamic storm water modeling engine calculates runoff volume and analyzes the hydraulic response through dependent systems of inlets, pipes, channels, manhole, outlet, ponds. It is tools that make it easy to visualize flooding problems and how they can be eliminated. Animate profiles, plan views, and other presentations to observe water levels rising and falling over the course of a storm data [5].

Bentley civil Storm V8i features: -

1) Dynamic integration of rainfall, runoff, surface flow, storm sewers, open channels, culverts, and ponds.
2) Looped systems with diversions.
3) Pressure and gravity profiles.
4) Complex pond outlet structures.
5) Capture and carryover between inlets.
6) Hydraulic grade profile animation.
7) Customizable presentations and graphs Civil Storm V8i is an extremely efficient tool for laying out a storm sewer network. It is easy to prepare a schematic or scaled model schematic drawing is one in which pipe lengths are entered manually, in the user-defined length field [5].

2.10. Model Calibration and Validation

Model calibration is performed by carefully selecting values for model input by comparing model predictions (output) for a given set of assumed conditions with observed data for the same conditions [14]. Model validation is the process of demonstrating that a given site-specific model is capable of making sufficiently accurate simulations, although “sufficiently accurate” can vary based on project goals [16]. The verification of model efficiency and performance was done using the efficiency criteria: coefficient of determination R^2, Nash-Sutcliffe efficiency NSE and Root mean square error observation standard deviation ratio RSR.

Coefficient of determination (R^2): The value of R^2 ranges from 0 to 1. The more the value of R^2 approaches 1, the better is the performance of the model and the values of R^2 less than 0.5 indicate a poor performance of the model.

$$R^2 = \left(\frac{\sum_{i=1}^{n}(oi-oave)(pi-pave)}{(\sqrt{\sum_{i=1}^{n}(oi-oave)^2 \sum_{i=1}^{2}(pi-pave)^2})}\right) \tag{15}$$

where: O= Observed flow, P= Predicted/Simulated flow, Oave= Average observed flow, Pave= Average Simulated flow, n = number of observations.

Nash-Sutcliffe efficiency (NSE): NSE is the normalized statistics which measures the relative magnitude of the residual variance as compared to measured data variance. Similar to R^2, the more the NSE approaches 1, the better will be the model performance and vice versa.

$$NSE = 1 - \frac{\sum_{i=1}^{n}(oi-pi)^2}{\sum_{i=1}^{n}(oi-oave)^2} \tag{16}$$

Root mean square error observation standard deviation ratio (RSR): accuracy of the model performance. Values approaching 1 indicate a poor model performance. It is an error index indicator. RSR ranges from 0 to 1, with the lower value closer to zero indicating higher.

$$RSR = \frac{RMSE}{STDEV_{obs}} = \frac{\sqrt{\sum_{i=1}^{n}(oi-pi)^2}}{\sqrt{\sum_{i=1}^{n}(oi-pave)^2}} \tag{17}$$

3. Result and Discussions

3.1. Impact of Land use Land Cover Change on Storm Water Runoff with in the Study Areas

The output images of land use land cover and analysis was presented in this section. The land use land cover images were developed for the years 1998, 2010 and 2019 by using Arc- GIS.10.3.1. And for each land use and land cover, annual storm water run-off volume was calculated. It is understood that LULC change affects hydrological processes in the watershed. Annual runoff volume for different years was determined by using the Equation (2.1).

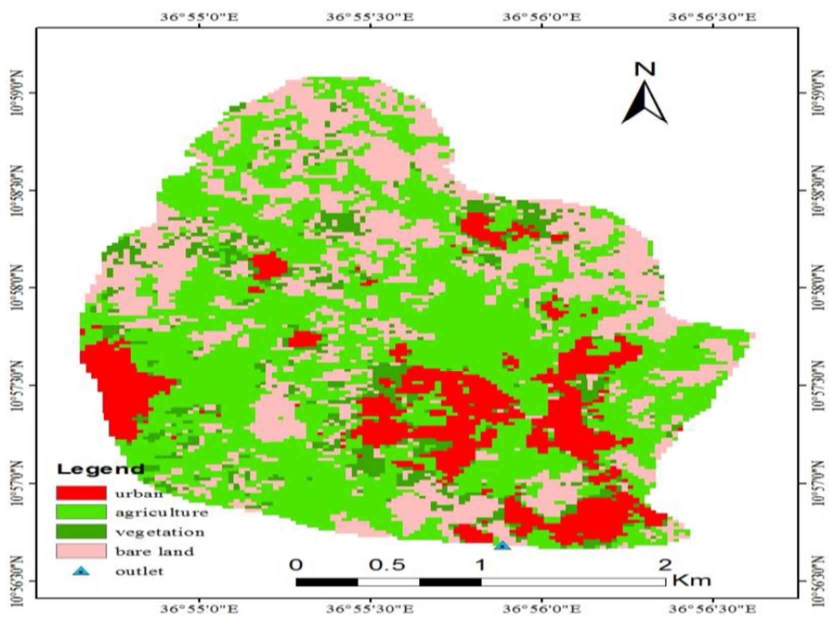

Figure 6. *Land use land cove change of 1998.*

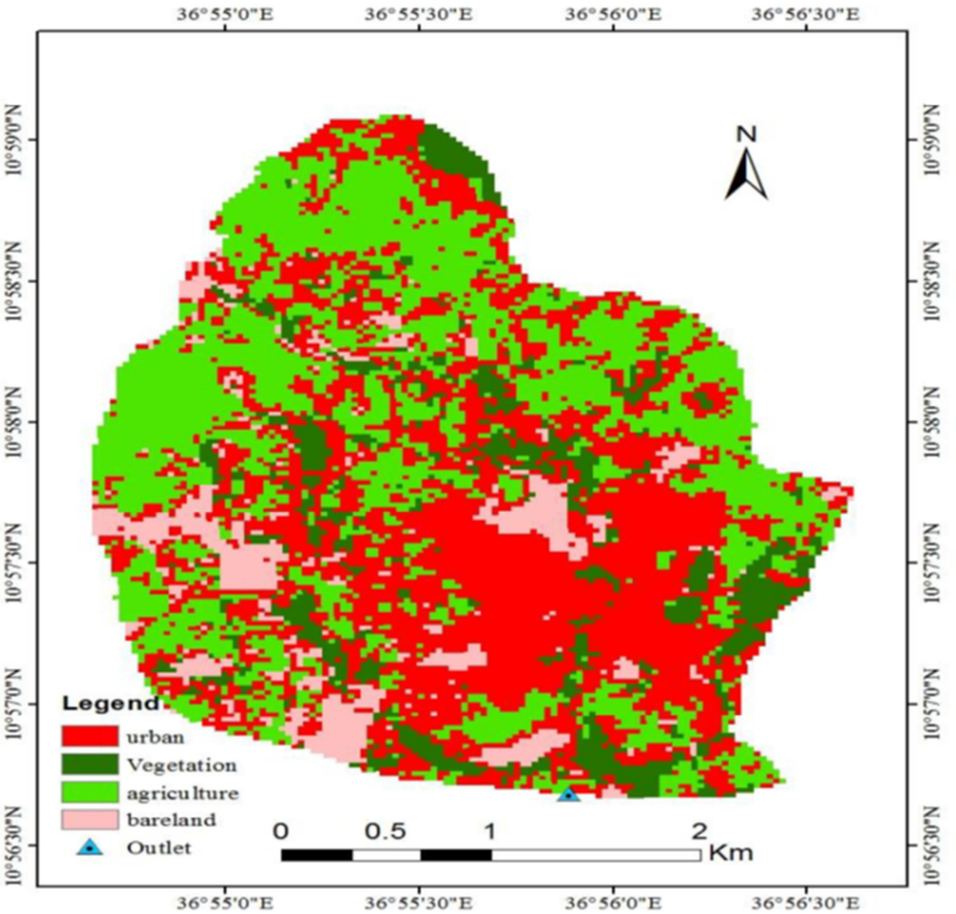

Figure 7. *Land use land cove change in 2010.*

Table 1. *Estimated annual runoff from land use land cover map in 1998 year.*

LUlc map of town	Runoff coefficient	Area (m^2)	Runoff volume (m^3)	Discharge (m^3/s)
Build-up area	0.8	2438200	2722982	0.086
Agricultural	0.2	4014700	1120904	0.036
Vegetation	0.25	2003500	699221	0.022
Bare land	0.48	2390400	1601759	0.051

Table 2. *Estimated annual runoff from land use land cover map in 2010 year.*

LUlc map of town	Runoff coefficient	Area (m^2)	Runoff volume (m^3)	Discharge (m^3/s)
Build-up area	0.83	4705300	5346492	0.169
Agricultural	0.2	2901400	810071	0.026
Vegetation	0.25	1622400	566217	0.018
Bare land	0.48	1617700	1083988	0.034

Table 3. *Estimated annual runoff from land use land cover map in 2019 year.*

LULC map the town	Runoff coefficient	Area (m^2)	Runoff volume (m^3)	Discharge (m^3/s)
Build up area	0.86	6223500	7327175	0.23
Agricultural	0.2	2270700	633979	0.021
Vegetation	0.25	1303200	454816	0.015
Bare land	0.48	1049400	703181	0.023

Table 4. *Change analysis of impact of LULC the years 1998, 2010 and 2019 in percentage.*

Lulc map of town	1998		2010		2019	
	Area (m^2)	Area (%)	Area (m^2)	Area (%)	Area (m^2)	Area (%)
Build-up area	2438200	22.48	4705300	43.38	6223500	57.38
Agricultural	4014700	37.01	2901400	26.75	2270700	20.93
Vegetation	2003500	18.47	1622400	14.96	1303200	12.02
Bare land	2390400	22.04	1617700	14.91	1049400	9.67

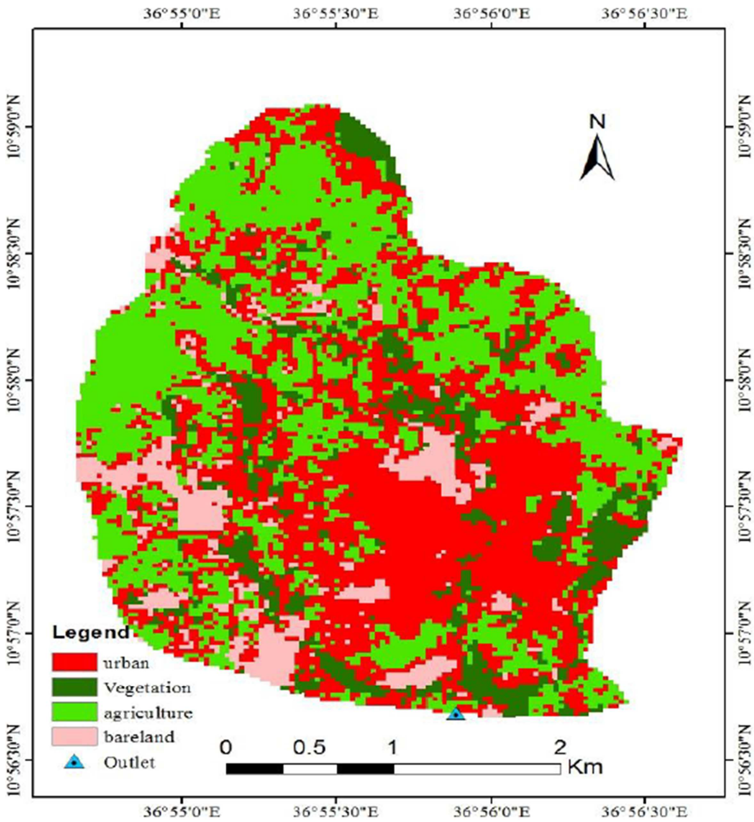

Figure 8. *Land use land cove change in 2019.*

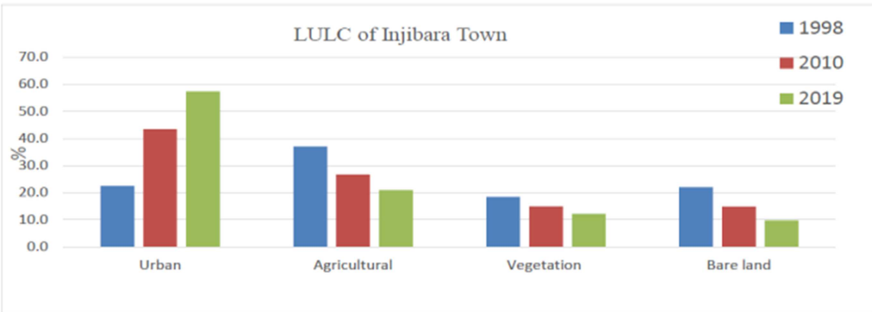

Figure 9. *The change analysis from 1998, 2010 and 2019 in percentage.*

The results indicate that the Built -up area in the study area has increased from cover areas 22.48% in 1998, 43.38% in 2010 to 57.38% in 2019 which accounts for the difference of 20.9%, 34.9% in 1998 to 2010 and 1998 to 2019 the total study area respectively. The agriculture has decreased 45 which accounts for 37.01%, 26.75% and 20.93% respectively.

The vegetation area has decreased which accounts for 18.47%, 14.96% and 12.02% respectively. The bare land area has decreased from which accounts for 22.04%, 14.91% and 9.67% respectively. In general, as the storm runoff will be affected by the changes i.e., production of runoff will increase in the area.

Table 5. *Change analysis impact of LULC between the years 1998 and 2010.*

Lulc map of town	Runoff coefficient	Area (m^2)	Area (%)	Runoff volume (%)
Build-up area	0.83	2267100	20.90	23.87
Agricultural	0.2	-1113300	-10.26	-7.74
Vegetation	0.25	-381100	-3.51	-4.04
Bare land	0.48	-772700	-7.12	-12.02

The results indicate that Annual runoff volume of Built -up area in the study area has increased which accounts for 23.81% of the total Annual runoff volume. The agriculture has decreased which accounts for 7.74%. The vegetation has decreased which accounts for 4.01%. The bare land area has decreased from 1601759 m^3 in 1998 to 1083988 m^3 in 2010 which accounts for 12.02%.

Table 6. *Change analysis impact of LULC between the years 1998 and 2019.*

Lulc map of town	Runoff coefficient	Annual rain falls (m)	Area (m^2)	Area (%)	Runoff volume (%)
Build-up area	0.86	1.396	3785300	34.90	35.57
Agricultural	0.2	1.396	-1744000	-16.08	-10.99
Vegetation	0.25	1.396	-700300	-6.46	-6.18
Bare land	0.48	1.396	-1341000	-12.36	-18.02

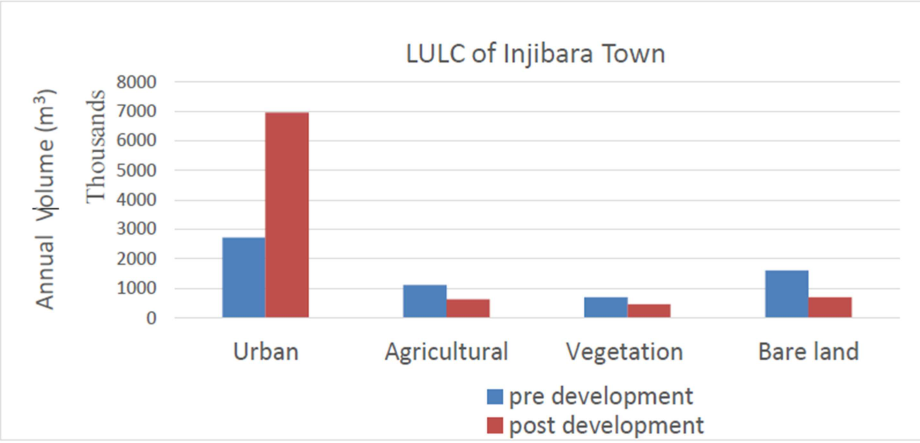

Figure 10. *Annual volume runoff comparison: Post vs Pre-development.*

The results indicate that Annual runoff volume of Built -up area in the study area has increased from 2722982 m^3 in 1998 to 6950405 m^3 in 2019 which accounts for 35.57% of the total annual runoff volume.

3.2. Hydrology and Hydraulics Analysis

3.2.1. Intensity–Duration–Frequency Curves (IDF)

The IDF curve is developed from 24-hour rainfall of 21 years data obtained from Bahir Dar branch of the national meteorological agency with rainfall gauge located in Enjebara town, Ethiopia. Appropriate reduction equation as described in the methodology section has been applied. For this study IDF curve for specific study area (Enjebara) is calculated. The Intensity-Duration-Frequency curve for Enjebara area is shown in Figure 12. In this study, the maximum daily rainfall of 1998 to 2018 was used for Enjebara-station.

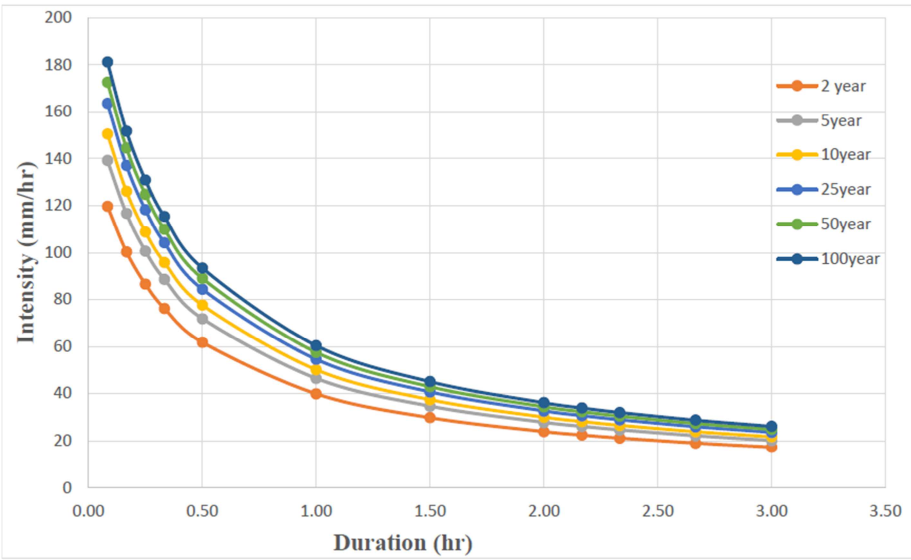

Figure 11. *Intensity –duration –frequency curve of Enjebara town.*

3.2.2. Results Using Rational Formula

As indicated in table 7 the discharge calculated by this method for area less than 0.5km^2. Land use composition of the in Enjebara town cover the total area is 1089 ha. The runoff coefficient is computed taking the average land use land cover in 2019 using the above formula in equation 3.14 and used for the calculation of each catchment weighted runoff coefficient.

Table 7. *Peak discharge estimation by using rational method.*

sub catchments	Area (ha)	IDF (10-year frequency) (mm/hr)	Runoff Coefficient	Tc (hours)	Discharge (m^3/s)
CM-1	43.389	56.2	0.72	0.81	4.88
CM-2	39.178	48.9	0.64	1.15	3.42
CM-3	49.01	54.6	0.72	0.82	5.36
CM-4	41.26	57.7	0.76	0.812	5.02
CM-5	34.62	65.5	0.67	0.55	4.22
CM-6	28.164	64.48	0.77	0.57	3.87
CM-7	42.42	58.76	0.69	0.61	4.80
CM-8	43.82	53.5	0.71	0.82	4.65
CM-9	43.21	49.94	0.63	1.08	3.77
CM-10	41.22	51.62	0.74	0.86	4.35
CM-11	45.66	49.03	0.58	0.89	3.61
CM-12	48.29	51.02	0.53	0.82	1.58
CM-13	49.25	57.13	0.29	0.63	2.32
CM-14	45.12	47.64	0.67	1.2	4.00
CM-15	40.182	76.32	0.62	0.62	5.14
CM-16	39.797	81.37	0.64	0.41	5.76
CM-17	30.261	80.73	0.83	0.44	5.43
CM-18	32.105	78.03	0.84	0.6	5.42
CM-19	29.98	58.31	0.77	0.8	3.72
CM-20	31.7	60.05	0.8	0.74	4.23
CM-21	41.98	51.75	0.79	0.96	4.77
CM-22	26.81	61.5	0.81	0.70	3.66
CM-23	40.33	52.04	0.72	0.93	4.21
CM-24	43.151	54.27	0.41	0.90	2.67

Based on the land use composition of in 2019 and by considering the ground truth of the study area has been determined the weighted runoff coefficient. This runoff coefficient obtained by using googles earth. Time of concentration should be calculated by considering different equations such as sheet, concentrated overland and channel flow as Ethiopian road and drainage manual recommendation [9]. The sub catchment has been divided depending the existing drainage and topography to manipulate discharge by using rational method.

3.3. Hydraulic Analysis

3.3.1. Assessing Capacity of Existing Drainage Structures

The storm water drainage channels were measured for all sub-catchments of the town and used to determine the existing drainage capacity using the Manning equation. The following are measured data based on the geometry of the channel and the slope varies from 0.01-0.04, its roughness and condition of occurrence. The other data are measured by the same procedure and presented in Table 7. Z = 1.2m, b = 1.1m, slope = 0.01 side slop: 1v:1h, (for catchment-1) and manning's roughness coefficient for all n = 0.013.

Based on the hydraulic calculation of the result drainage capacity of existing system were checked and presented in the above Table 7 to compare with proposed discharge this process also done first by determining the peak discharge for each existing catchment by used empirical equations (Rational method) as described in the methodology part of this study and then subtracted existing discharge this step is important to know over flow peak (excess discharge) for each catchments and the result also presented in the following table (Table 9).

Table 8. *Existing discharge estimation by using manning's.*

Sub catchment	Slope (%)	Depth (m)	Width (m)	R (m)	V (m/s)	Discharge (m^3/s)
CM-1	0.01	1.2	1.1	0.38	4.02	5.3
CM-2	0.01	0.9	0.8	0.28	3.27	2.35
CM-3	0.01	0.9	0.8	0.28	3.87	2.78
CM-4	0.01	1.2	1.1	0.38	4.0	5.27
CM-5	0.03	1.2	1.02	0.36	6.45	7.98
CM-6	0.02	0.9	0.8	0.28	4.62	3.33
CM-7	0.02	0.9	0.8	0.28	4.7	3.39
CM-8	0.01	1.2	1.1	0.38	4.36	5.76
CM-9	0.01	0.8	0.8	0.27	3.77	2.41
CM-10	0.01	0.9	0.8	0.28	3.8	2.75
CM-11	0.02	0.9	0.8	0.28	2.09	1.73
CM-12	0.02	0.8	0.8	0.27	1.96	1.5
CM-13	0.01	0.8	0.8	0.27	1.8	1.16
CM-14	0.01	0.8	0.8	0.27	3.1	1.99
CM-15	0.02	0.9	0.8	0.28	4.6	3.33
CM-16	0.04	0.9	0.8	0.28	5.59	4.71

Sub catchment	Slope (%)	Depth (m)	Width (m)	R (m)	V (m/s)	Discharge (m^3/s)
CM-17	0.02	0.9	0.8	0.28	4.08	2.94
CM-18	0.02	0.9	0.8	0.28	4.8	3.46
CM-19	0.01	0.9	0.8	0.28	3.55	2.55
CM-20	0.01	0.9	0.8	0.28	3.92	2.84
CM-21	0.01	0.9	0.8	0.28	2.64	1.9
CM-22	0.01	0.9	0.8	0.28	3.66	2.63
CM-23	0.01	0.8	0.8	0.27	3.52	2.25
CM-24	0.01	0.8	0.8	0.27	2.95	1.88

Table 9. *Existing and proposed discharges.*

sub catchment	Existing discharge capacity (m^3/s)	Discharge Capacity rational method (m^3/s)	Difference existing &rational discharge (m^3/s)
CM-1	5.3	4.88	-0.42
CM-2	2.35	3.42	+1.07
CM-3	2.78	5.36	+2.58
CM-4	5.27	5.02	-0.25
CM-5	7.98	4.22	-3.76
CM-6	3.33	3.87	+0.54
CM-7	3.39	4.8	+1.41
CM-8	5.76	4.65	-1.11
CM-9	2.41	3.77	+1.36
CM-10	2.75	4.35	+1.6
CM-11	1.73	3.61	+1.88
CM-12	1.5	1.58	+0.08
CM-13	1.16	2.32	+1.16
CM-14	1.99	4.00	+2.01
CM-15	3.33	5.14	+1.81
CM-16	4.71	5.76	+1.05
CM-17	2.94	5.43	+2.49
CM-18	3.46	5.42	+1.96
CM-19	2.55	3.72	+1.17
CM-20	2.84	4.23	+1.39
CM-21	1.9	4.77	+2.87
CM-22	2.63	3.66	+1.03
CM-23	2.25	4.21	+1.96
CM-24	1.88	2.67	+0.79

Based on the result of this study the drainage system is insufficient at different area. Most of the stations of the catchments were investigated that required construction of additional storm drainage system and its existing coverage based on assessing hydrologic and hydraulic calculation of this study. The existing drainage convening capacity is only 21% at different catchment safe and the other 79% of new drainage system is required for different catchment at existing to be upgrading. This suggest that the proper storm water management is important for avoiding the overflow problems on the road for which design of minimum required drainage size is critical that is based on hydrological analysis.

3.3.2. Flooding Occurrence of Storm Water Drainage System

The Bentley civil storm to show hydraulic grade and energy profile for storm water drainage system of town to identify which flooding risk of channel, cause of catchment and out fall of the town due to the effect of channel failure and sediment deposition of storm water drainage system.

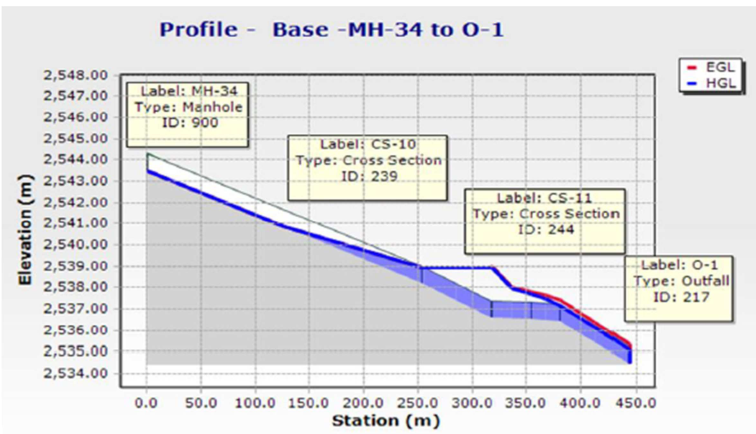

Figure 12. *Flow profile from MH-34 to O-1.*

Figure 12. shows a drainage system that is surcharged system, i.e., it receives greater volume of storm water than the system can convey at CS-10 and CS-11 to O-1 the hydraulic grade line is above the rim elevation of the cross section of the structure. When we came to the hydraulic performance the CH-11 conveying capacity is only 3.39 m^3/sec flow but the run off which is generated from the catchment is 3.87 m^3/sec. Flooding on the cross-sections, Cs-10 - 11 into an outlet- 1 on catchments of CM-7 occurs due to the existing channel size that does not compensate for the incoming flow of storm water from the catchments.

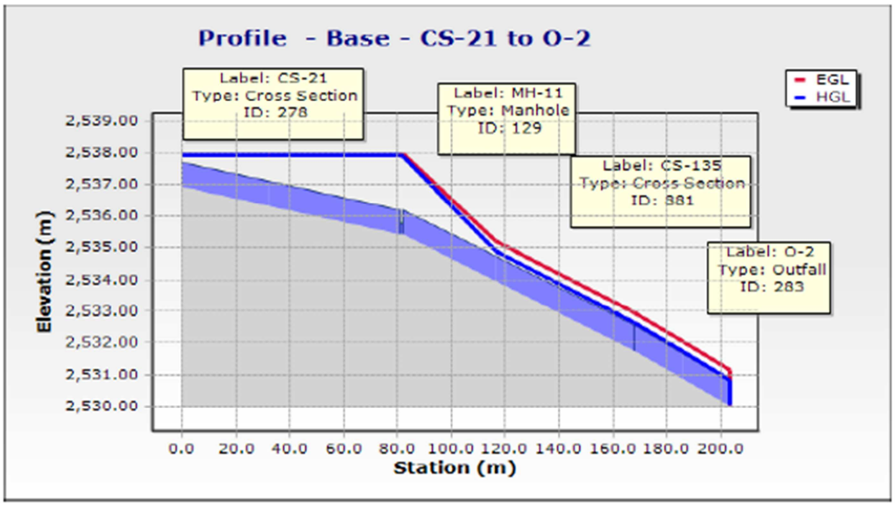

Figure 13. *Flow profile from CS-21 to O-2.*

The model shows that on CS-21 and CS-135 to outlet two on CM-8, and CM-7 hydraulic grade line exceeded the rim elevation of the structure that results surcharge flow hence flooding on the cross section happens due to limitation of channel size (the existing channel size does not carry the incoming flow of storm water from the catchments), slope and roughness factors. This means the maximum flood will occurs at the mentioned cross sections and catchment. It needs adjustment of slope.

3.4. Challenges of Storm Water Drainage in the Study Area

3.4.1. Planning Challenges

The process of drains planning is not led by a master plan, as Enjebara has no town-wide storm water network master plan. Consequently, drains planning is based on traditional and fragmented approaches. The option of integrating other sustainable storm water management systems (e.g., rainwater harvesting, retention and detention-based solutions) is absent. Enjebara has no integrated planning approaches from the context of storm water management. For example, integrating storm water management with urban land-use planning, GI development and other landscape plans is absent at any level. The landscape and urban planning instruments therefore don't offer possibilities to integrate storm water management concerns and to promote sustainable storm water management on a range of spatial scales.

3.4.2. Dumping of Solid Wastes in to Storm Water Drainage System

Dumping solid waste materials in to drainages is the challenge of storm water drainage system. Urban litter (alternatively called trash, waste, garbage, or solid waste) has become a major problem as result of dumping the solid wastes in to drains the drainage system has been clogged that causes flooding over streets and walk ways. Respondents Monitoring Survey (2019) about the solid waste in the town is disposed: shortage of disposal area 37.5%, lack of awareness 32.5% and carelessness 30% for storm water drains system. In this result indicated that the town drainage system will have blocked by the solid waste, poor maintenance practice of drainage system and lack strong integration among stakeholders in the provision of drainage infrastructure to ensure sustainability of drainage system. Within the town municipality weak technical capacities associated solid wastes disposal system because of lack budget, lack of integration among governmental organization with in community and shortage of community participation are factors for proper sustainability drainage system. The existing drainage channels were above 40% of the hydraulic capacity of the drainage channels full of silt accumulation due to this reason the existing drainage channels were functioning under limited conditions.

Figure 14. *Dumping of solid waste in the storm water drainag.*

3.4.3. Lack of Periodic Clearance in Storm Water Drainage System

Concerning drainage infrastructure provision, the main problems associated are like poor coordination and integration among stakeholders. Moreover, community participation is among the lowest in the study area. In the study area proved that there is no community participation in one way or another for drainage infrastructure provision. Due to lack of periodic clearance storm water drainage lines, they have become out of services. Sediment load, solid wastes blocked most of the drainage system. So without scheduled clearance the service life of those ditches and channels could be out of their life span.

Figure 15. *Storm water drainage system filling by solid waste and lack of clearance.*

3.4.4. Assessing Flooding and Diminished Street at the Study Area

Currently, road flooding and its related effects are common in the town. Most of the drains are in poor condition for proper functioning broken roads have their own challenge over the drainage systems because their damaged surface couldn't convey the runoff generated over the impervious area. This problem implies that flooding and diminishing road has been noticed in most of Keble 1, 3 and 4 suburban roads due to:

1) Inadequate integration between road and urban storm water drainage lines.
2) Inadequate drains are that causes of flooding in the study area.
3) Does not perform the intended carrying capacity drainage system due to the problem of solid waste dumping increasing with Sewerage connection.
4) Urban storm water drainage facilities not welled constructed with roads safely discharge to flood generated within the study area of storm water drainage facilities which is the challenge for the town.

Figure 16. *Diminished roads in Enjebara Town and lack of drainage construction.*

4. Conclusions

Based on the applied methodology and results obtained, the following conclusions are drawn: land use land cover practices of storm water runoff have significantly changed in 21 years. In this study land use land cover changes can affect urban drainage runoff, implying changes in the hydrological characteristics of the watershed.

The result show that watershed region the volume of runoff is significantly increased from 44.2% of pre development to 79.5% of post development respectively. The continuous change of built-up region has affected agricultural, vegetation and bare land class due to lack of land use planning, socioeconomic activities, natural phenomena.

The responses from Enjebara town municipality, civil servant, governmental and none governmental organization and residents, the problem lies in the drainage system. There was a general feeling that the type of drainage system is not adequate. Therefore, it needs for immediate remedies in order to achieve a good drainage system.

The performance and ill-functioning of the drains were not monitored timely. Furthermore, the town does not have legal instruments that promote on-site storm water management and prevent the dumping of wastes into drains.

As it was observed during field survey the findings of challenge of storm water management in Enjebara town the existing drains are not maintained properly, lack of awareness creation at the community level of drainage system. Municipality is poor since some people are intension of throwing solid waste into existing drains that caused flooding. The drainage connection filling by solid waste dumping that reduce the effective carrying capacity of drain.

5. Recommendations

Based on the finding of the research the following recommendations:

1) Adjusting hydrologic and hydraulic analysis for future change situations is very important in order to ensure safe drainage structures function in the long-term perspective.
2) Futures studies should conduct a more detailed study on identification of the flood causative factors to the specific location.
3) Improve the drainage systems along the Enjebara town highways, Redesign storm water drainage system and improvement of drainage facilities through maintenance.
4) I recommend the municipality to conduct periodic operations and maintenance to storm water drainage structures in order to achieve their intended purpose and stay functional until the expected design period.
5) Thus, future research should be conducted focusing on developing resilience indicators for urban storm water drainage system that consider social, economic and environmental aspects.

6) Research giving attention on the long-term effects of urban flooding should be conducted to understand its overall effect on urban environment.

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