Available Online at http://www.recentscientific.com

ISSN: 0976-3031

International Journal of Recent Scientific Research
Vol. 6, Issue, 1, pp.2530-2535, January, 2015

International Journal of Recent Scientific Research

RESEARCH ARTICLE

URBAN STORM WATER MANAGEMENT FOR GONDIA CITY FOR SUSTAINABLE DEVELOPMENT USING GIS AND MAT LAB

Devendra Pandey*[1], Pradeep Kundal[2] and Yaswant B. Katpatal[3]

[1]Department of Civil Engineering, Manoharbhai Patel Institute of Engineering and Technology, Gondia. India
[2] Department of Geology, RTM Nagpur University, Nagpur, India
[3]Department of Civil Engineering, VNIT, Nagpur. India

ARTICLE INFO

Article History:

Received 14th, December, 2014
Received in revised form 23th, December, 2014
Accepted 13th, January, 2015
Published online 28th, January, 2015

Key words:

Sustainable Drainage Systems(SuDs), Annually Flooded Area(AFA), Urban Storm Water Management (USWM), Natural Hazards Vulnerability Assessment (NZVA), World Geodetic System 84 (WGS 84), Gondia Municipal Council (GMC).

ABSTRACT

The presented study demonstrates that important improvements could and should be made in the way in which society manages its risk to natural disasters. The focus is on controlling the physical vulnerability of residences to flood disasters in Gondia city, Maharashtra, India. To balance the widespread data of damage from slow-rise flood depth, this study examines the lateral pressure from flood depth differential between the inside and outside of a residence and flood velocity. The main aims and objectives study is to identify Annually Flooded Area, sort and model a solution to Sustainable Drainage Systems for Storm water Management and minimize its impact on human lives as well as the Natural Hazards Vulnerability Assessment of Gondia City using GIS technique & MATLAB.

INTRODUCTION

Urbanization has brought forth several maladies and suffering to human kind, besides bringing economic and cultural development in its fold. Due to pressure of urbanization most of the cities are growing fast and sometimes they develop beyond the planned limits. Generally the unplanned areas of the city contain a quarter of the total population, where the spatial information is missing because of non-availability of up to date maps. The land use/cover study is of fundamental significance, as the land resources play a strategic role in the determination of man's economic, social, cultural and environmental progress. In fact the land use/cover of a region is always characterized by the spatial variations and is profoundly influenced by physio-socio-economic factors (Pandey, 2012). The last four decades have witnessed the scientific and technological developments which have brought about tremendous change in Land/cover use. The study of changes in land use/ land cover is important in the field of engineering. The exponential growth of population has been responsible for large-scale environmental degradation. The world population has already crossed 7 billion and is projected to reach 10 billion by 2025 (www.dhushara.com/book/diversit/bomb.htm) The serious repercussions that the growing impacts of human activities can have on the world's ecosystems can well be visualized. Cities are nodes of human's greatest impact on nature where he/she has altered the essential resources of land, air, organisms and water. A city is a perfect example of human's capacity to control changes in his habitat. In the newly created ecosystems the interactions of human, his/her works and nature is complex. The complexity grows as cities burgeon in the modern world.

Gondia is a developing city of Maharashtra State with future potential possibilities. Gondia has conventional and quite old open drainage system. It is comprised of storm water contained in drains along road sides which in turn transfers it to the larger drains carrying domestic, commercially, cottage-industrial waste and sewage. In absence of waste water treatment facility and poor maintenance of drains, there is a lot of infiltration of polluted storm water into groundwater (Bizier, 2007). Also the storm drains prove ineffectual in rainy seasons and incidents of flooding take place. There is a great need for a proper drainage system, but the system should be designed keeping in mind the future requirements and possibilities also. Here SuDs can play a vital role, providing a solution that will not only tackle the present drainage needs but also reduce future problems relating to pollution (Ellis, 1989). Thus the drainage system to be provided must be a combination of conventional drainage methods as well as modern SuDs techniques (www.essex.gov.uk/.../Environmental.../suds_design_adoption_guide.pdf)..

The prime objective of the present work is to prepare a sustainable drainage system for Storm water management plan for the Gondia Municipal Council and its environs by using GIS Technique and Mat Lab. The preparation of a scientific and environmentally compatible development plan requires consideration of all components of the environment that exist today and the environment to be created in future. Thus a comprehensive land use plan should inter-relate all elements

* Corresponding author: **Devendra Pandey**
Department of Civil Engineering, Manoharbhai Patel Institute of Engineering and Technology, Gondia. India

that form a community. Goals to formulate a sustainable urban land use plan is to focus on all physical, geographic, historic, socio-economic and cultural characteristics of the city and environ, harmonization of sector wise development portfolio on the basis of carrying capacity of the region. To carry out demographic analysis for identifying areas required for future urban development, the areas from the classified data were studied (Pandey, 2012).

The overall methodology adopted for this study of population data pertaining to 1981, 1991 and 2001 census have been collected and projected population for the year 2025 have been made by adopting standard statistical techniques such as ratio method, exponential and conversion methods. Population projections under each scenario are made by analyzing the observed trends from year 2001. The projections obtained by geometrical method have been adopted for the study.

The study area falls under 64C/3 Survey of India topographic maps on 1:50,000 scale. A standard registration procedure has been adopted. This is done by dividing the entire area into 5' x5' cardinal grids. On the basis of this spatial framework, a tile structure has been followed to capture the data with respect to different themes. Finally a composite map has been prepared showing the Composite Urban Land Development Units. IRS-1C LISS-III dated 11 march 2000 P100/R057 image registration has been used by identifying common ground control points (GCP's) from the image. Visual interpretation techniques were used to study digitally enhanced products on the basis of the image characteristics such as tone, texture, shape, size, shadow, pattern as well as the associated elements viz. location and association. These elements of interpretation helped in identifying and delineating various types of features present in the urban environment and judge their significance in delineating thematic information related to urban land use/cover, hydro-geomorphology, surface water bodies.

Study Area

Gondia is a city in the state of Maharashtra in Central India and is the administrative headquarters of the Gondia District. Gondia is very close to the state of Madhya Pradesh, and is considered the gateway to Maharashtra from Central and Eastern India as shown in Fig.1. GMC is situated on the cardinal points 21˚ 27' 26" N latitude and 80˚ 12' 53" E longitude an altitude of 318.82MSL. GMC covers an area of 18.60 Sq. Km. According to Census data of 2001 the population was 120902 but as on 2011 the population of GMC is approximately around 132888. In 2001 the number of household was27702 and as on 2009 the number of household is 30472. It is on the Railway junction on Nagpur-Kolkata broad gauge railway line of South-East Central Railway GMC is 'A' Class Municipal Council.

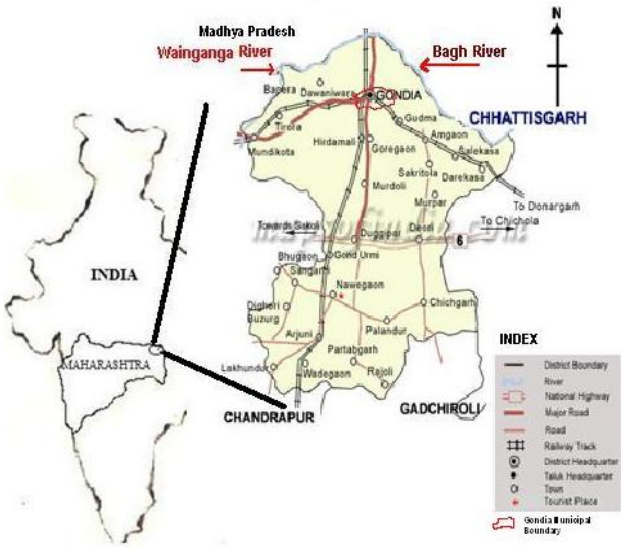

Fig1 Showing Geographical Boundary of Study Area (Courtesy: www.gondia.gov.in).

Landscape

The land with the town is plain. The east- west, Kolkata-Mumbai railway track passes along the ridge of the area. From Gondia railway station land is gently sloping towards north, north - east, and south, south- east respectively. The surrounding area of the town mainly consists of plain paddy with number of sub-drains and punctuated by number of irrigation tanks except to the western side, that somewhat consists of hillocks and forest lands**.** There are few water bodies within the developing area. Due to densely populated surrounding areas, these water bodies have become somewhat filthy. It is seen that the terrain is largely undulating plain and interspersed with more or less level ground in the western part. The hills forms a part of the southern-western branch known of the Kharra Hill, rising from an elevation of about 610 MSL. (Pandey & Choudhary, 2013).

Demography

As per Census year 1981, the population of GMC was 100423; in 1991 it was 109470 souls. The Census for year 2001 population of the GMC was 120902 souls. Outs of this 23364 were households. The Census of year 2011, population of Gondia was 140,000 souls having 30972 households (Pandey, 2012).

Growth of population

The population of Gondia was 4457 souls in 1901 where as it was 5847 in 1911, shows the increment about 32%. The increase in population in during 2nddecade was about 80%; it was because of further reasons:

a. Just prior to 1911, Nagpur – Calcutta broad gauge railway line and Jabalpur, Chandrapur narrow gauge lines were laid. It was brought Gondia town prominently on the map of India.
b. From 1917 onwards number of Rice – mills, Bidi factories and Shellac factories were established, providing employment to the large segment of population from surrounding areas.

Incremental rate of population for 3rd & 4th decade was just 42.21% & 35.86% respectively. In 5th decade it was increased by 80.54% due to, after independence number of Sindhi refugees were provided shelter at Birsi (about 14 km. away to the north of Gondia city), and later migrated to GMC that covers an area about 1286 hectors. As per Census year 1981, the population of the GMC was 100423. As per Census year 1991, the population of the GMC was 109470 and in 2001 it was 120902 souls. It shows, in 9th and 10th decade the rate of increment of population has come to the natural growth rate 9% and 10.42% respectively.

The Census of population for year 2011 shows the population of Gondia City at 140,000 souls, the rate of increment of population for 11th decade was 15.80% as shown in Fig.2. This shows that the population growth rate has increased in past decade due to increased commercial activities and coupled with development of surrounding areas. Currently, Gondia covers an area about 1808 hectors (Pandey, 2012).

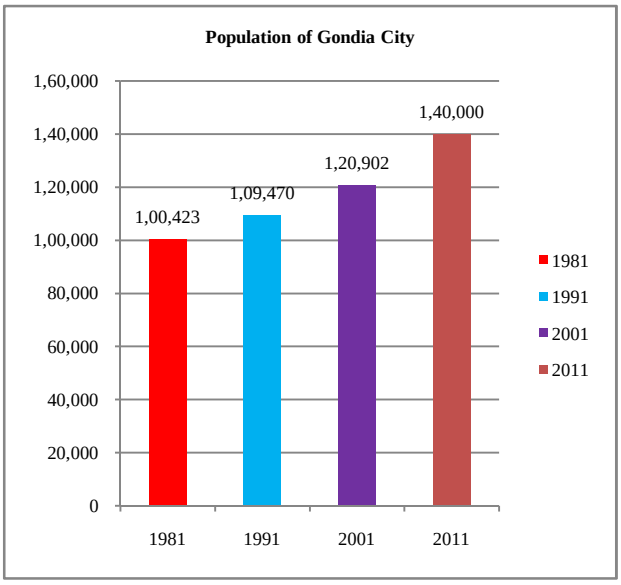

Fig.2 Showing Population of Gondia City

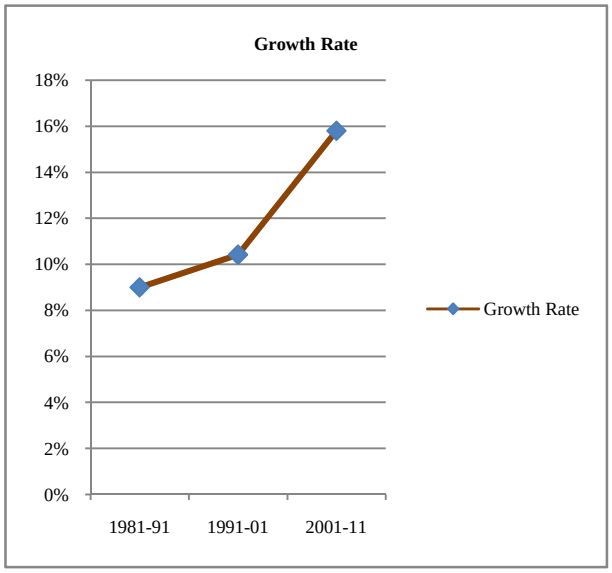

Fig.3 Showing Population Growth Rate of Gondia City

Population projection

In the Sectional Development Plan, population for the year 1991 and 2001 was estimated to 139,000 and 185,000 respectively. However, the actual population recorded by Census is 109,470in 1991 and 1, 20,878 in 2001. The percentage rise in the population in last two decades is 9% and 10.42% in the year 1991 and 2001 respectively. This is very low as compared to percentage growth in the previous 8 decades as shown in Fig.3. .This downward trend of percentage growth is due to following reasons.

Many rice mills established in the past are shifted in the territorial area outside the GMC limit. Most of the rice mills are closed due to shifting in the outer area. In the last three decades educational institutes like Engineering College, Homoeopathic College, Polytechnic, I.T.I., etc. have come up in the above stated period. The district administrative buildings, Police Headquarters and many such offices and business activities are come up in the rural areas outside the GMC boundary in Mouza-Fulchur and nearby Mouza Karanja which is situated on Amgaon and Goregaon state highway. Due to fast development in the outside area, many residential colonies have come up outside the GMC boundary. In that context, more and more population is projected to settle down outside the GMC boundary. This ultimately checked the population growth within the town itself .The another reason for fast development is due to fact that the land in the GMC area is costlier as compared to that outside area and the properties in the GMC area are heavily taxed. Due to social awareness and rise in education percent, small size family concept is developed which ultimately checked the population growth during last three decades in the town. In the above reference the percentage rises, from 9% to 10% in the past three decades. However since Gondia was declared as district headquarter from 1.5.1999, many more government offices and establishments have come up in the city and outside the city limit thereby resulting to change in percentage growth of population. Considering the average rise for the last three decades and also considering the change in status of the town, overall average percentage rise in population per decade could be 20% flat which seems to be reasonable while accessing the population for the year 2011 and 2051 as shown in Fig.4. Considering the flat percent rise of 20%per decade population for the year is worked out (Pandey, 2012).

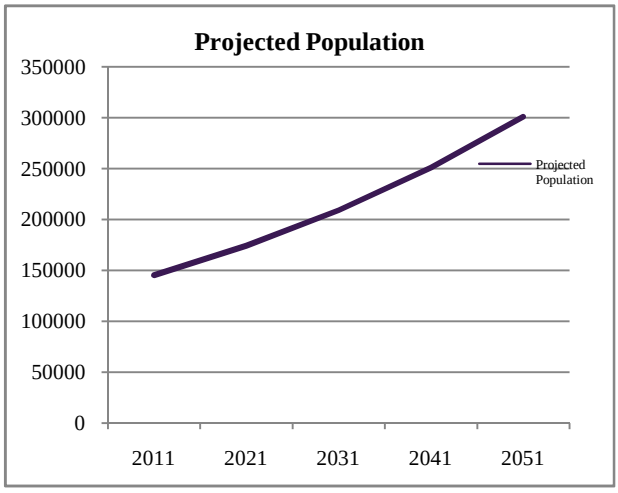

Fig.4 Showing Projected population (from Flat Rate Method) of Gondia

i. For year 2011-120878*1.20=145054 souls say 145100 souls.
ii. For year 2021-145054*1.20=174064 souls say 174100 souls.
iii. For year 2031-174064*1.20=208877 souls say 208900 souls.
iv. For year 2041-208900*1.20=250680 souls say 250700 souls.
v. For year 2051-250700*1.20=300840 souls say 300900 souls.

At present, the only drainage network present in GMC is open drainage system, Storm water drainage network covers about 30% of total area. The storm water drainage network chiefly consists of uncovered surface drains. The total length of

surface drains is approximate 9 Km (Pandey & Choudhary, 2013). During periods of rainfall this leads to incidents of water logging and flooding of streets which leads to problems of traffic and sociological problems (Pandey & Ali, 2013). There is no manual or centralized drainage database/map available with City Sanitation Department. The repairs and maintenance of drains are undertaken only during pre-monsoon season every year. The urban development body has no system in place to monitor incidents of flooding in terms of frequency.

MATERIALS AND METHODS

Site Selection

Site selection was done keeping in mind man-made types of flooding. The sites were selected along the drainage system keeping in mind the intensity of Storm in previous years. This is a part of the man-made flooding which causes the maximum losses. In Gajanan Colony, Gondia even the slightest of rains causes flooding. This site represents the best example of man induced flooding as a result of improper planning.

Ground Investigation

Interaction with the local people brought preliminary knowledge about the conditions of the area during and after rainfall every year. The study area was surveyed during the months of August and September, just after the rains.

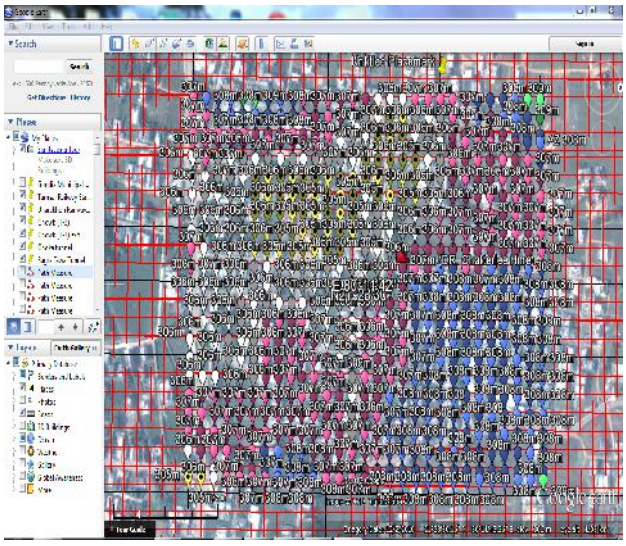

Fig.5 showing Grid plotting in Google Earth & marking the World Geodetic System (WGS 84) level at each point of grid.

The site was marked in Google Earth software with the latitudes and longitudes. Particular area was marked and square grids were plotted. Thus each site covered a particular area which could be found out by the number of square grids in the area, the grid size was 40x40m. Thus the intersection of the grid lines gave a point. A particular area yielded numerous intersection points which formed a mesh like surface. These points were marked for the WGS 84 level given by the Google earth software as shown in Fig.5.

Contouring & Digital Elevation Modeling in MATLAB

The starting point of the selected site grid was taken as (0, 0, 0) coordinates. From there the distance was taken in certain intervals in x and y direction, and the z coordinate was taken as the World Geodetic System (WGS 84) levels. Hence it formed a certain matrix in case of a certain area, giving each intersection of the grid points a unique set of coordinates. The data so processed was fed in MATLAB software through excel sheets. The contours line plots as well as the Digital Terrain Model (DTM) was obtained by various set of programs. This gave a very refined analysis of the topography of the site selected and the defects could be visibly identified. This made the research outcomes lucid and easy to understand (Pandey, *et.al*.2014).

The study area is bounded by the longitudes 80˚11'34.2.28"E and 80˚11'49.19"E and latitudes 21˚28'21.15"N and 21˚28'39.34"N. The Gajanan Colony is located in the Sector II of GMC's Proposed Sectional Development Plan along the Ring road. This sector includes 194 hectors land, partly from Mouza-Kudwa, Gondia (Buzurg) and Katangi Kala. In this sector, 108 hectors is developed land, which is more than 50% of the sector area. Out of total developed area 61 hectors land is under residential use, it is about 56% of total developed area. About 20 hectors area is under roads, which includes newly developed 30m wide by–pass road connected to Gondia–Balaghat highway. This sector also shows haphazard residential development. The projected population of this sector could be by 2025 is 22250 (Pandey, 2012). The Gajanan Colony covers an area of about 1 Sq.km as shown in Fig.6. This area is a habitat for many people living and working in the Gondia city. Gajanan colony is located in the GMC, along the Ring road that comes under potentially AFA area. This area has got developed very fast for the period post 2000. That time, it was not within the GMC limits. As a result random construction took place in that area.

Fig.1 Showing Satellite image of the Gajanan Colony in Gondia City, (Courtesy: Google Earth).

Contour Map & Digital Terrain Model Of The Area

RESULT AND DISCOUSION

Causes Of Flooding

Gajanan colony is frequently AFA due to moderate or heavy rains. The residents face lot of problems during the rainy season. Illegal construction, improper planning and reckless development in the area are the causes of flood. This is proto type of popular human induced disasters. Though it doesn't cause any harm to life, the roads get clogged, the first floor of the houses get submerged and it also can result in the outbreak

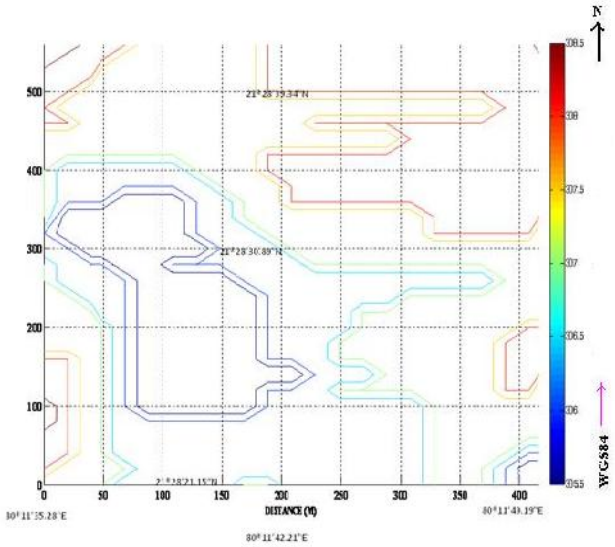

Fig.7 Showing Detailed WGS84 Contour Map of the Gajanan Colony.

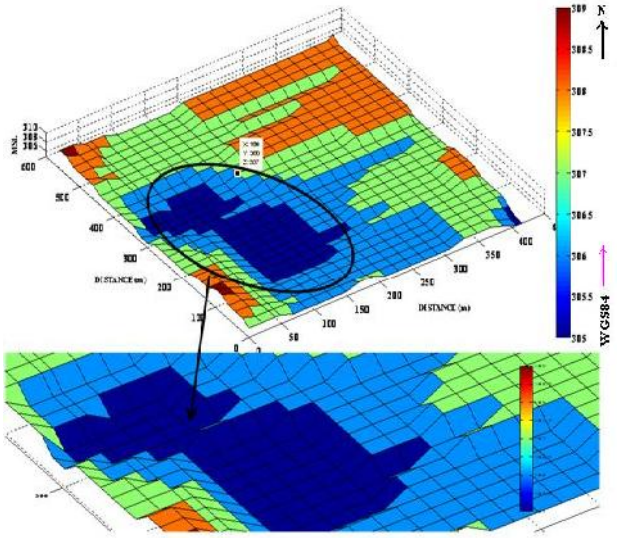

Fig. 8 Showing Digital Terrain Model of the Gajanan Colony.

of epidemic diseases. The main reasons of flooding in this area are:

- A synclinal structure is formed in the area due to which the water stays accumulated in one place and does not move out as shown in Fig.7.
- There is no municipal drainage system present in the area.
- Excessive constructions in the synclinal region have led to encroachment of the unlined open drains around the houses. This has reduced their ability to drain the excess runoff water.
- Illegal constructions have mushroomed in the in the synclinal region as shown in Fig.8. This has resulted in blockage of natural drainage of the area leading to stagnation of the runoff water.

An artificial central drainage system parallel to the Ring road should be constructed. This will in turn help in drainage of bulk amount of water from the surrounding areas on both the sides of the road. The network sub drains should be constructed in the area from different houses. Thus these sub-drains should meet this central drainage as marked with black colored line in Fig.9. Illegal constructions should be banned. The unlined open drainages system as marked with red colored line should be lined and cleaned regularly to prevent blockage. As the area of Ring road falls under Public Works Department and Gajanan colony comes under GMC, a proper coordination between the Public Works Department and the GMC is required to plan and implement such type of schemes. Thus the problem of flooding and water logging can be eradicated from the area.

Fig.9 Showing Proposed Drainage Network System of Gajanan Colony is showed in Red and Black color (Courtesy: Google Earth).

The present study suggests that conventional drainage systems (combined and separate) are unsustainable. They lead to the pollution of watercourses through combined system and through separate system. More notably, developed land allows runoff to travel faster and reach watercourses quicker, leading to increased volumes of runoff over short periods which in turn overloads connecting watercourses. The threat of increased intensity and duration of rainfall events caused by climate change is further underlining the view that conventional drainage systems are not sustainable and cannot adapt to increasing volumes of runoff as shown in Fig.9. Therefore, infrastructure that utilizes conventional drainage systems poses a significant flood risk to receive watercourses, where the damage is caused by flood events that can have high financial burdens (FHWA-NHI-10-009, 2009). The theoretical and practical competence of SuDs in calculating the storage and discharge capacity of runoff to the underlying soil or receiving watercourse is generally understood. However, constant monitoring after their inception must be carried out in order to reduce the likelihood of blockage or failure of the system, which could invariably lead to an increase in the infrastructures potential to flood local watercourses (Stewart and Hytiris, 2008).

CONCLUSION

The drainage pattern of Gondia city has to be upgraded. Proper planning according to growing population is required for the construction and maintenance of an underground drainage system. This will enable a better sewage clearance and drainage of heavy runoff of rainwater. This will also minimize the effects of water logging in certain areas like Gajanan

Colony and keep the city away from the menace of floods. Also, it should be kept in mind that the solid waste is not disposed in these closed drains to prevent them from clogging. This will make the city a better place to live in.

It is very difficult to establish Suds in an urbanized city but GMC can be easily incorporated in a proper Suds system. After studying land-use pattern for the city using GIS and remote sensing it was found out that there is space available in the city to develop a new drainage system. Suds techniques such as permeable pavements can be used in areas where other methods are not effective or are difficult to provide. Therefore, it is imperative to follow an integrated approach where engineers and planners must develop Suds along with the existing drainage patterns in the city.

References

Begon, M., J.L.Harper, and C.R. Townsend. Ecology: Individuals, Populations and Communities. 2nd ed. London: Blackwell Sci. Pub., 32-129,(1990).

Bizier, P. (Editor) 2007, Gravity Sanitary Sewer Design and Construction. Second Edition (= ASCE Manuals and Reports on Engineering Practice No. 60, WEF MOP No. FD-5), New York: American Society of Civil Engineers (ASCE), pp.21-46.

Ellis, J.B. (1989). The Management and Control of Urban Runoff Quality. Jour.Inst. Water & Env. Management, Vol 3 No 2, :177-192.

Pandey , Devendra, Katpatal, Yaswant B, Kundal , Pradeep P., (2014). Natural Disasters Vulnerability Assessment of Gondia District, Maharashtra, India Using DTM & GIS Techniques**,** International Journal of Research in Engineering and Technology, eISSN: 2319-1163/pISSN: 2321-7308, Volume: 03 Issue, 09, 165-170.

Pandey Devendra , Mir Mubashir Ali, (2013). Water Quality Index of the Wainganga River, Bhandara Maharashtra, India, International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD); ISSN(Online):2249-6866; Volume:3; Issue:2, :115-124.

Pandey Devendra, (2012). Land Use and Land Cover Planning of Gondia Municipal City, Maharashtra State, India Using Remote Sensing & GIS Techniques, Int. J. LifeSc. Bt & Pharm. Res. Vol. 1, No. 4, October, :51-62.

Pandey Devendra, Choudhary,B. (2013). Route Optimization for Municipal Solid Waste Disposal Sites in Gondia, Maharashtra State, India, International Journal of Bioassays, ISSN: 2278-778X, Vol.2 No.4, :661-666.

Stewart,R. , Hytiris, N, (2008). The role of Sustainable Urban Drainage Systems in reducing the flood risk associated with infrastructure A93 Craighall Gorge to Middle Mause Farm - Road Realignment, Perth, Scotland – Case Study , 11th International Conference on Urban Drainage, Edinburgh, Scotland, UK, 2008, :1-15.

Urban Drainage Design Manual, Hydraulic Engineering Circular No. 22, Third Edition, U.S. Department of Transportation, Publication No. FHWA-NHI-10-009 September 2009 (Revised August 2013)

www.dhushara.com/book/diversit/bomb.htm assesses on 22 Dec.2014.

www.essex.gov.uk/.../Environmental.../suds_design_adoption_guide.pdf assesses on 23 Dec.2014.

www.gondia.gov.in assesses on 23 Dec.2014.

www.googleearth.com assesses on 22 Dec.2014.

www.googlemaps.com assesses on 22 Dec.2014.

****