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RUN OFF ESTIMATION BY USING LOW IPMACT DEVELOPMENT (LID) APPROACH FROM A SMALL WATERSHED

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ABSTRACT

Development of land transforms the landscape and impacts in stream ecosystems as it changes the natural flow area. An increase in impervious areas where the water doesn't percolate in the ground results in higher volumes of storm water runoff, which in turn reduce time to peak, and more frequent flooding. Low Impact development (LID) is a measure which can be used to reduce the impact of urbanization by controlling runoff at the source. Peak flow, rainfall and runoff volume are few of the conventional terms which are used to evaluate the impact and performance of storm water management techniques on the watershed. In this study it is focused to simulate runoff with LID approach and compare it with conventional approach. There are many LID techniques available to estimate runoff; here it has used pavements and bio-retention technique only. With LID, curve number has been estimated and by using the curve number method, runoff has been estimated. It has been found that with LID approach, the runoff amount is increased by 0.8 to 1.7 % than conventional approach.

Keywords*: Low Impact Development (LID), Curve Number, Bioretention, Pavement, Runoff*

I. INTRODUCTION

Proper development and management of watershed will increases the peak flows and runoff volume. This alters the natural flow system of the stream and disturbs the in-stream ecosystem. Watershed management is an amalgamation of technologies within the natural margins of a drainage area for optimum development of lands and water resources. Simply, Watershed management implies the wise use of all land and water resources and for the betterment of people. Low Impact Development (LID) practices are different methods for controlling storm water at the source like rooftops, parking lots and sidewalks.

LID technologies include permeable pavements, roof gardens, infiltration swales, rainwater harvesting bio retention areas, disconnected impervious areas [1]. LID goals at reproducing the natural hydrologic landscape and create flow conditions that mimic the pre-development flow system through the mechanisms of micro-scale storm water storage, increased infiltration, and lengthening flow paths and runoff time. Permeable pavements are regarded as an effective tool in managing stormwater. When compared to traditional, impervious asphalt, permeable pavements can reduce runoff quantity, lower peak runoff rates, and delay peak flows due to their high surface infiltration rates [2, 3, 4]. A set of studies have examined the impact of LID on the hydrologic stream regime and found that LID is able to reduce the peak flow for regular, less intense storms. For other rainfall measures, LID may not be effective in depressing the peak flow, but can increase the time to peak or decrease the period of sustained high currents.

However it was witnessed that, reduction was higher for less frequent rainfall events, and this less frequent rainfall events leads to flood, which needs the proper management. Therefore, the LID approach helps in flood management and also in improving hydrologic sustainability of the watershed. By using LID approach at a field site in Goldsboro, North Carolina, water quality samples from PICP subsurface drainage were evaluated [5].

The goal of watershed management is to choose LID, or a combination of technologies to mitigate the hydrologic effects of expansion in a watershed. The modifications in the timing of flows and duration of flooding can considerably impact the condition in the downstream ecosystem communities, which have to be incorporated when evaluating and picking sustainable watershed management plans.

Hence, in this study, a small watershed Batanwada has been taken to study the impact of LID to the hydrologic behaviour of watershed. The LID practices, including permeable pavements and bioretention, were considered to investigate the impact of LID on the small watershed. These LID strategies are simulated within a hydrologic model to facilitate watershed management for a small watershed where storm water runoff and erosion problems have been documented. The Curve Number method has been used and integrated into the watershed model to represent each of the LID technologies.

The Bioretention units are being constructed in the upland areas which improves the aesthetic appeal as well as the use of the land. Porous pavements will only help in improving the transportation facilities. And as a whole these LID practices will help in the development of the watershed

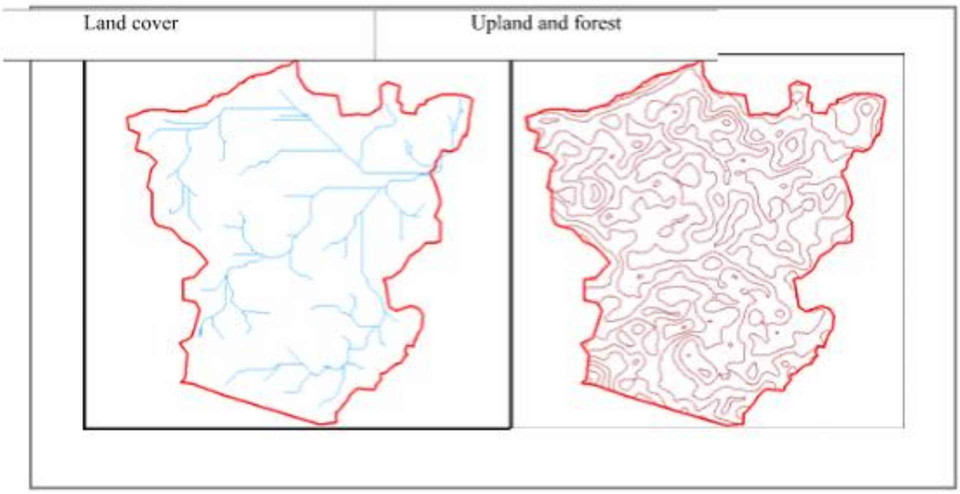
II. STUDY AREA AND DATA COLLECTION

Table 1 depicts the characteristics of the study area. The monthly rainfall data has been collected for 2013 for this study area. The watershed DEM has been downloaded from USGS and the watershed has been delineated by using GIS software. The drainage network and contour maps are shown in Fig. 1. The land use and land cover has been shown in Fig. 2.

Table No. 1: The characteristics of the study area

Name of the watershed	**Batanwada**
Latitude	18° 15' 39.60"
Longitude	81° 33' 28.8"
Name of the village	Batanwada
Name of the Block	Podia
Name of the District	Malkangiri
Name of the State	Odisha
Total geographical area	377.06 Hectares
Agro climatic zone	North central plateau zone
Land cover	Upland and forest

Figure No. 1: Drainage network and contour map of Batanwada watershed



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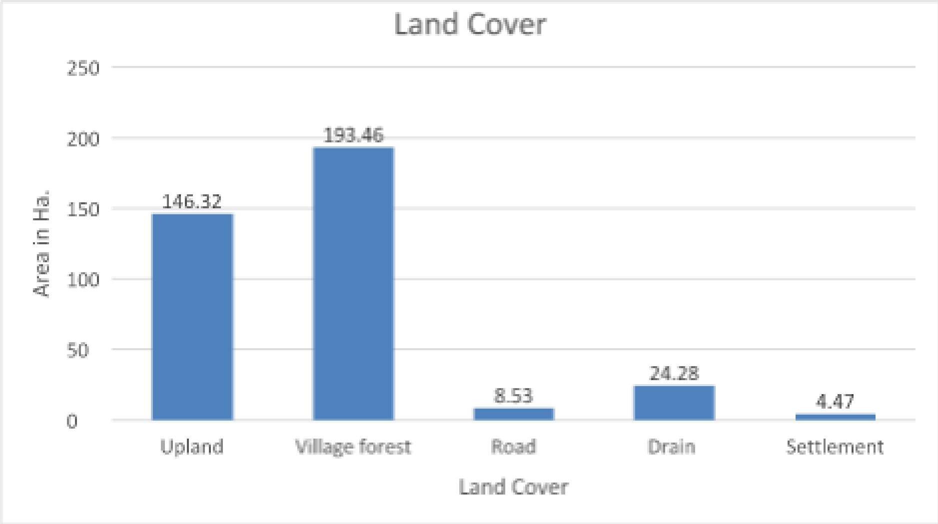

Figure No. 2: Land cover with its coverage area

III. METHODOLOGY

3.1 Estimation of Runoff

The runoff was estimated by soil conservation services or SCS curve number method. The curve number has been used to determine the runoff in this method. The curve number depends on hydrologic soil group, land use and hydrologic condition. Curve number has been taken from the information of land use and land cover and soil types .The equation for runoff estimation in SCS method is:

$$Q = 0 \qquad \text{for } P \leq IaP-Ia2P-Ia+S \text{ for } P>Ia \qquad (1)$$

Where,

Q = Runoff in inches

P = Rainfall in inches

S = Maximum watershed storage

I_a = Initial loss

The initial equation is based on the trends observed in the data collected from various sites. And after further evaluation of empirical datasets the value I_a can be expressed in terms of S;

$$I_a = 0.2S \qquad (2)$$

Substituting this in the previous equation gives;

$$Q = 0 \quad \text{for } P \leq IaP-0.2S2P-0.8S \text{ for } P>Ia \qquad (3)$$

The runoff curve number CN is then related to S as;

$$S=1000CN-10 \qquad \text{for Q,P,S in inches} \qquad (4)$$

And, S=25400CN-254 for Q, P, S in mm (5)

3.2 Runoff estimation by using LID

3.2.1 Permeable Pavement

HydroCAD software solutions provided a method for calculating the appropriate CN for pavements in watersheds where there is no hydrologic data available for the same. The maximum watershed storage (S) and effective storage (S_e) are equated, which is defined as the product of depth (d) and porosity (n) of the pavement.

$$S_e = d \times n \qquad (6)$$

The required data for different pavements have been taken from available literature [5] and presented in Table 2. The values of curve numbers were calculated by substituting the values in (5)

Table No. 2: Values of CN for different pavements

Permeable Pavement Design	Effective storage (S_e)	Curve Number (CN)
Porous pavement	40 mm	85.4
Concrete grid paver	70mm	77.5
Porous pavement with underdrain	9mm	95.4

3.2.2 Bioretention

Bioretention are typical storm water control measures that stores and manages water quality control volume (WQ_v). The change in curve number by the implementation of bioretention was calculated by a method developed by schueler's which calculates water quality control volume (WQ_v) by multiplying 1 inches (2.54 cm) of rainfall by volumetric runoff coefficient (R_v) [6].

Volumetric Runoff Coefficient (R_v) is defined as;

$$R_v = 0.05 + 0.009 I_a \qquad (7)$$

Where I_a is defined as % of impervious cover for the drainage basin.

Water quality volume in inches is calculated as follows;

$$WQ_v = 1.0(R_v) \qquad (8)$$

Using WQ_v, a modified curve number (CN_m) is calculated by utilizing the following equation;

CNm=100010+5P+10WQV-10WQV2+1.25WQVP0.5 (9)

Where: P = Rainfall, in inches (use 1.0 inches)

WQ_v = Water quality volume, in inches (1.0 R_v)

For Batanwada watershed

Total Impervious Area = 37.28 Hectares

Volumetric Runoff Coefficient (R_v) = 0.05 + 0.009 (37.28377.06×100)

= 0.14

Water Quality Volume (WQ_v) in inches = 1.0(R_v)

= 0.14 inches

The Modified Curve Number; CNm = 100010+5P+10WQV-10WQV2+1.25WQVP0.5

= 1000100+5×1.0+10×0.14-100.142+1.25×0.14×1.00.5

= 83.33

IV. RESULTS AND DISCUSSION

The Runoff was calculated for Batanwada watershed for the year 2013 based on available rainfall data (Fig. 3 & 4) by using SCS curve number as conventional way. It is observed that there is no runoff generated for a period of five months with the highest runoff being generated in the month of July. The amount of runoff varies in between 30% to 50% of the total rainfall in that particular month. Variation in curve number was calculated for three types of permeable pavement and bioretention. And appropriate locations are being selected for placement of bioretention. Results are being simulated for the same and the difference in the amount of runoff generated was calculated.

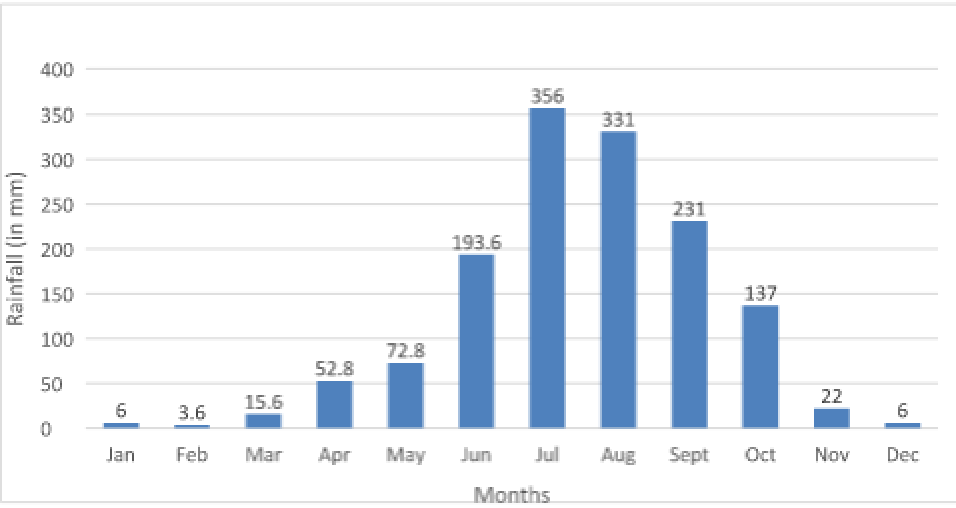

Figure No.3: Monthly rainfall in the year 2013

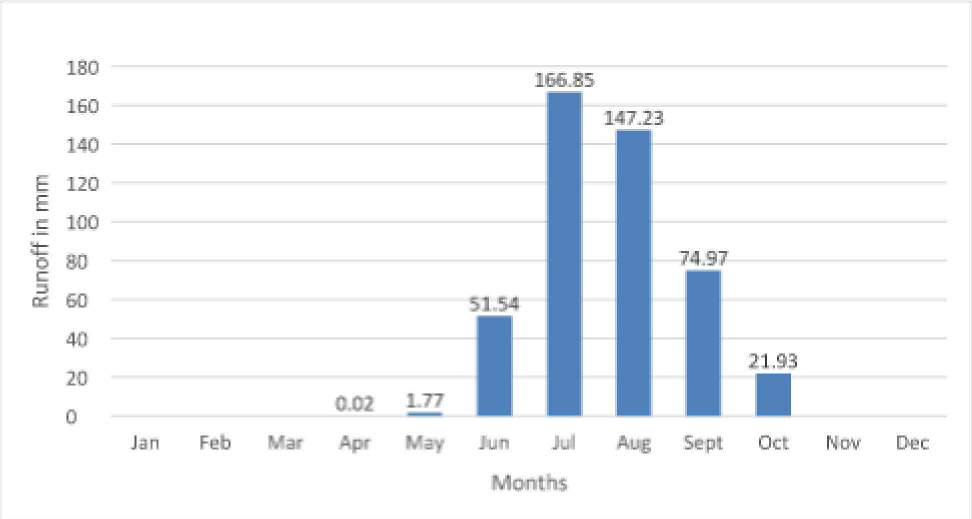

Figure No. 4: Runoff generated in Batanwada watershed

4. 3 Estimation of Runoff for different pavements

Runoff was estimated after replacing traditional pavements with porous pavements using modified curve number from Table 2. It was observed that the runoff volume increases by 15082.4 m^3 or 0.86%. than the conventional method. Runoff was estimated after replacing traditional pavements with concrete grid paver using the modified curve number from Table 2.

It was observed that the runoff increases by 7541.2 m^3 or 0.4% than the conventional method. Runoff was estimated after replacing traditional pavements with porous pavements with underdrain using the modified curve number from Table 2. In this case also runoff increased by 30164.8 m^3 or 1.7% than conventional method. The increment volumes of runoff by using different pavements are presented in Table 3.

4.4 Estimation of Runoff for Bioretention

Runoff was estimated by placing Bioretention on the appropriate location and using (9) the modified curve number. I t was observed that the runoff increases by 15082.4m^3 or 0.8%.

5. 5 Estimation of Runoff for Bioretention with different pavements

Runoff was estimated by simultaneously placing Bioretention with different pavements i.e. porous, concrete and porous with underdrain. The results are presented in Table 3. The percentages of volume increased are 1.7%, 1.1% and 2.6 % respectively.

TABLE NO. 3: Comparison of change in volume of runoff for different LID approaches with conventional approaches

Approach	Volume of runoff	Difference in Vol. with conventional approach
Conventional	1749558.4 m^3	
Porous Pavement	1764640.8 m^3	15082.4 m^3
Concrete Grid Paver	1757099.6 m^3	7541.2 m^3
Porous Pavement with Underdrain	1779723.2 m^3	30164.8 m^3
Bioretention	1764640.8 m^3	15082.4 m^3
Bioretention with porous pavements	1779723.2 m^3	30164.8 m^3
Bioretention with concrete paver	1768411.4 m^3	18853 m^3
Bioretention with porous underdrain	1794805.6 m^3	45247.2 m^3

V. CONCLUSION

LID was simulated using a modelling approach for a watershed to evaluate the implementation of storm water management strategies and its impact on hydrology of watershed when compared to the existing scenario without any mitigating strategies. A variety of rainfall events needs to be consider for sustainable development of the watershed. The simulation here indicates that a variety of LID events needs to be used based on the suitability of the geographical condition. And the results demonstrated a considerable improvement in managing the runoff by implementing multiple LID events when compared to strategies individually.

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It was observed that the runoff with only porous pavement was 15082.4 m^3 and when porous pavement and bioretention were used simultaneously a 100% increase to 30164.8 m^3 was observed. And similar changes were also seen when bioretention was used simultaneously with concrete paver and porous pavement with underdrain. Future research can investigate alternative solutions. With these alternatives different set of solutions can be obtained which are different with respect to the decision variables but which results in a similar performance. This would be helpful for the storm water management decision makers to explore different solutions which results of same implementation cost and similar hydrologic impact reduction. Finally, the framework can be extended to include different types of LIDs and BMP.

REFERENCES

[1] United State Environmental Protecting Agency (US, EPA), Reducing storm water cost by through low impact development strategies and practice, 2007. EPA-841-F-07-006

[2] C. J. Pratt, J. D. G. Mantle, P. A. Schofield, Urban stormwater reduction and quality improvement through the use of permeable pavements, Water Science and Technology, 21(8), 1989, 769-778.

[3] B. O. Brattebo, D. B. Booth, Long-term stormwater quantity and quality performance of permeable pavement systems. Water Research. 37(18), 2003, 4369-4376.

[4] E. Z. Bean, W. F. Hunt, D. A. Bidelspach, Field survey of permeable pavement surface infiltration rates, Journal of Irrigation and Drainage Engineering, 133 (3), 2007 247-255.

[5] E. Z. Bean, W.F. Hunt, D.A. Bidelspach, Evaluation of four permeable pavement sites in eastern North Carolina for runoff reduction and water quality impacts, Journal of Irrigation and Drainage Engineering, 133(6), 2007, 583-592

[6] W. Schluter, C. Jefferies, Modelling the outflow from a porous pavement, Urban Water 4, 2002, 245-253.