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Challenges due to Change in Land use & Rain Fall Pattern for Storm water Collection Treatment & Disposal

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Abstract

There is urgent need to consider Storm water management as a part of Town planning and development. Urban storm water is surface run off from roofs, roads, footpaths, car parks & all open spaces like gardens, parks etc. Storm water has been traditionally collected by storm water drains and transported through pipes and channels to creeks, rivers, the harbor and ocean. In the earlier days there used to be a combined sewerage system that carries sanitary wastewater & storm water together. For Municipal Authorities provision of storm water sewers is always the last priority. In most of the urbanized area Storm water flows on the road, through the open gutter or the storm water sewer if provided. Due to Urbanization Land use pattern changes & natural drainage system is vanished, altered, encroached & being used as dumping site during non-rainy days. Rain water gushes directly because natural obstructions and percolation are drastically reduced in urbanized area. Despite of the best efforts by the municipal authority, chaos takes place during rainy season e.g. flood like situation in Mumbai, Chennai etc. The statistic shows that the rain fall pattern is not changed much. However it is definite that duration of rain fall is becoming shorter. The excess rain fall always becomes excuse for failure of storm water drainage system. Therefore there is need of understanding different aspects of Storm water management & its integration with Water supply & Sewerage system. Geological & topographical conditions, Land use pattern, Hydrogeology and the rain fall are not same all over therefore approach & guidelines are to be developed for site specific conditions. Urbanization changes the original landscape & increases the surface run off rate. Excess water if it does not find way, it creates the problems of manmade flood like situation. Therefore storm water needs a proper design & planning. Carefully engineered and dedicated storm water system is required. The storm water is highly contaminated because it carries all the discharges of liquid & solid waste on and above the ground along with it, to the receiving water bodies. Attention is to be given to the impact & mitigation measures. Runoff into storm sewers can be minimized by including sustainable or low impact development or green infrastructure practices into municipal plans. Direct use of rain water will increase Green water Foot Print of Urbanized population. The wetland can be developed to reduce the peak flow of Strom water & to have green cover over the land & enhance ground water recharge. Rain water harvesting in urbanized area needs critical evaluation. SOP is to be prepared for storm water management system during rainy and dry days. Finally people involvement & participation needs to be built up to take care & maintain natural & manmade drainage system for their safety. Hence Smart Technologies & engineering solutions are required to take up the challenges due to Change in Land use & Rain Fall Pattern for Storm water Collection Treatment & Disposal.

Key Words – Urbanization. Land Use Pattern, Rain Fall, Storm water Management

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Introduction

After independence there is shift of population from rural to urban area. According to 1901, 2001 & 2011 census population residing in urban area in India was 11.4%, 28.53% & 31.16% respectively. Growth rate of urban population was 2.76% per annum during 2001-2011. It is anticipated that more than 50% population will be urban by 2050. (1,2). Under the urban sprawl change is from **Village -> Out Growth -> Urban Agglomeration -> Census Towns -> Statutory Towns -> Municipal Corporation .** In Annual report 2015-16 Ministry of Urban Development acknowledged that this transition to urban society, has not been accompanied by a appropriate increase in the supply of basic urban services like water supply, sewerage and drainage network, garbage disposal facilities, citywide roads, public transport, and public safety systems like street lighting and pedestrian pathways. The supply of land and housing has not kept pace with the increase in urban population. Water supply and sanitation is a State subject and the State Governments/Union Territories and Urban Local Bodies are responsible for providing water supply and sanitation services through planning, design, implementation, operation and maintenance. (3) However more thrust is given on Water Supply. Sewerage system is not yet provided in most of the urban areas. Storm water management is yet waiting to get in the list of priorities. It is commonly observed that, these expanding urban areas receive increased water supply through network of pipelines, but do not have a well defined sewerage systems or storm water drainage systems. Proper storm water drainage system is always put on the last priority while planning new developments.

Urban storm water is surface run off from roofs, roads, footpaths, car parks & all open spaces like gardens, parks etc. Storm water has been traditionally collected by storm water drains and transported through pipes and channels to creeks, rivers, the harbor and ocean. In the earlier days there used to be a combined sewerage system that carries sanitary wastewater & storm water together. For Municipal Authorities provision of storm water sewers is always the last priority. In most of the urbanized area Storm water flows on the road, through the open gutter or the storm water sewer if provided.

Change in Land use pattern due to Urbanization & its impact on storm water

Surface runoff is the flow of water that occurs when excess storm water, melt water, or other sources flows over the Earth's surface. This might occur because soil is saturated to full capacity, rain arrives more quickly than soil can absorb it or impervious areas (roofs and pavement) send their runoff to surrounding soil that cannot absorb all of it. Surface runoff is a major component of the water cycle. Soil characteristics, plants and animals, and slope angle are among the natural factors controlling the proportion of precipitation that is converted to runoff in a given landscape, and the time it takes for runoff to enter a stream. Human changes to these landscape features has greatly influence runoff.

Before the urbanization the land is agricultural where surface run off rarely exceed 25%. Due to urbanization, large magnitude of virgin land is being converted into residential & commercial centers. It changes the surface and topographic characteristics of the area by ‘grading and re-grading. The roads & buildings increase the impervious surfaces that subsequently increase the storm water runoff rate and volume. Natural l drainage patterns are encroached, altered or redirected. This leads to Localized flash flooding, increased frequency of flooding on the downstream, scouring of banks of natural streams, silting, loss of ground water recharge, lower dry weather flows in the streams, habitat destruction and pollution of natural streams. When land-use changes Routing factor increases i.e. time taken for the runoff to reach the water inlet decreases thus resulting in higher peak flows. The increase in runoff coefficient causes larger volume of flow in the drains and lower volume percolate into the ground.

Change in Rain Fall pattern & its impact on storm water

The Indian summer monsoon (June – September) rainfall is very crucial for the economic development, disaster management & hydrological planning of the country. The July rainfall has shown decreasing trends over most parts of central India. However, June and August rainfall has shown increasing trend over the central and south western parts of the country. Contribution of July rainfall is decreasing in central and west peninsular India. But contribution of August rainfall is increasing in all these areas. Significant increasing trend is also observed in the annual rainfall for the subdivisions Konkan and Goa, Madhya Maharashtra, North Interior Karnataka, Rayalseema, coastal Andhra Pradesh, Gangetic West Bengal, Assam and Meghalaya and Jammu and Kashmir (4). Nearly 75 to 90 % of the total average annual rainfall in India occurs during the four months from June to September. As such storms of heavy to moderate rain are common phenomena during this period in most parts of India. The extreme rainfall event of 994 mm on 26 July 2005 has been a lesson for Mumbai and it has indicated the perils of rapid development in highly concentrated urban areas. Hyderabad in August 2008 received over 150 mm of

rainfall in less than 14 hours within a span of two days. It is second highest in four decades. On 15 to 16th of Nov 2015, Chennai city and neighboring areas got 246.5 mm of rain precipitation. These examples indicate that change in rain fall pattern is making the scenario worst. Urban floods are becoming common since 2005.

Intergovernmental Panel on climate Change (IPCC) in its report released in January 2001 has concluded that most of the warming observed over the last 50 years is attributable to human activities (especially emissions of heat trapping gases from fossil fuels which is likely to double the risks). Further, deforestation, urbanization, industrialization, increase in automobiles, etc. add to the fury. These changes are having a lot of influence on meteorological parameters. Rao, Jaswal & Kumar (2004) studied the effects of urbanization on meteorological parameters over fifteen cities (with a population of more than one million) and concluded that in general bright sunshine hours, wind speed, total cloud amount and radiation values were showing a decreasing trend while relative humidity and rainfall had an increasing trend (7,8). It is observed that average rain fall remains almost same. However the duration of rain fall is decreasing. Probability of having +50 mm rain fall in one hour duration is more. It happened in Pune, Mumbai and Nagpur etc. Conditions become worst due to increase surface runoff rate due to change in land use pattern.

Alone in Chennai due to urban flood the losses are accumulating from Rupees 50,000 crores to 100,000 crores. The automobile sector's losses alone were estimated between 8,000 crore. (5) Thus floods in urbanized area caused the damages to the tune of thousands of million rupees in India & will continue to happen till storm water management is considered seriously. Thus an integral approach is required for storm water design for reduction in peak flow and total flow of storm water runoff.

Direct & Indirect causes of urban floods are summarized in Figure -1

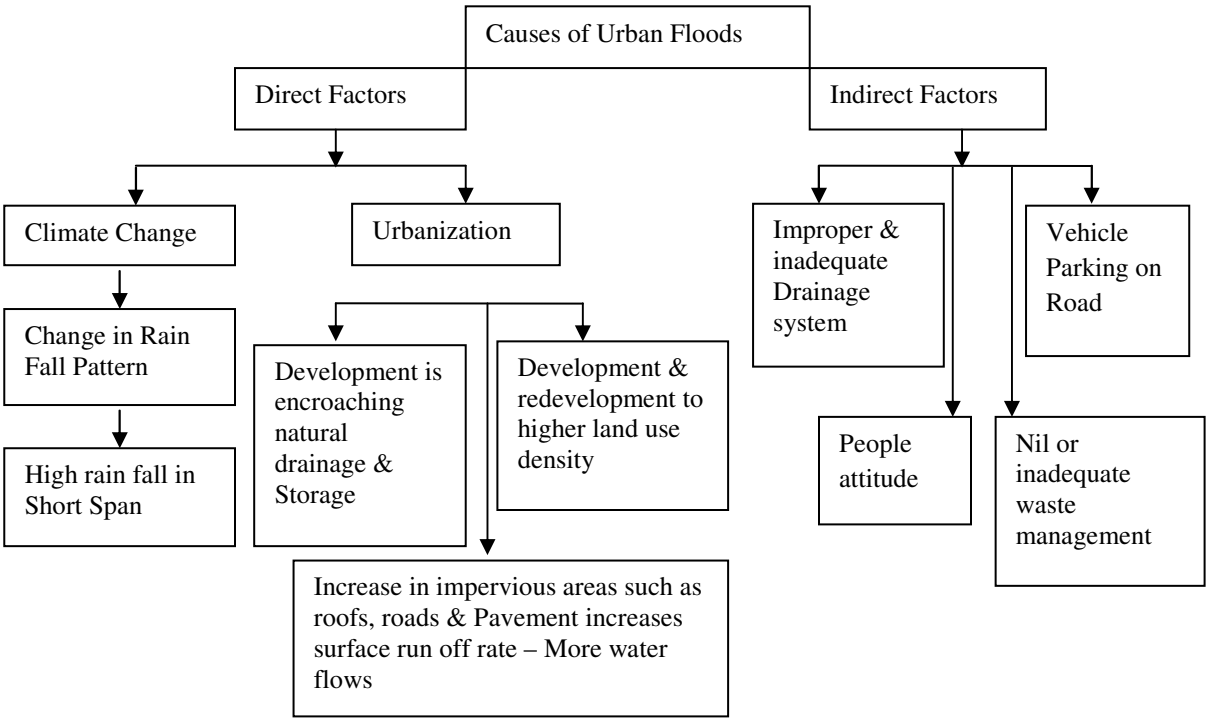

Figure -1 Cause of Urban Floods

Need of Storm Water Management

Increased urban population obliviously creates pressure on available urban infrastructure for land, water, shelter and put forth higher demands for housing, transportation, industrial and commercial developments. Unplanned urban growth causes illegal encroachments on natural drainages. Water management in urban area always play vital role in city development. In addition to water supply and sewerage distribution network, management of storm

water is getting a prime importance. By default we assume that storm water will find its way. It was true prior to the change in land use by urbanization. Improper storm water management increases flood and water logging potential of city, create serious threats to underground & surface water resources available. Therefore storm water needs a proper carefully engineered design appropriate planning &dedicated storm water management. Sustainable urban drainage systems ensure planning of storm water drainage network with environmental considerations and use of green technologies for storm water management. It has potential for economic use of costly water resources and also to reduce the cost of water pollution control and abatement. It will also reduce the associated health hazards, increase green cover and improve air quality and increases aesthetic values of the city. Essential planning considerations, technology options and innovations in storm water management to be considered for "Smart City" concept.

Strom water quality its impact & mitigation measures

The storm water carries all the discharges of liquid & solid waste on and above the ground along with it to the receiving water bodies. It is highly contaminated. Yet attention is not given to the impact & mitigation measures. Urban storm water contains pollutants that deteriorate water quality and adversely impact aquatic habitat. Pollutants found in storm water include suspended solids, heavy metals and a broad spectrum of organic compounds including pesticides, nutrients, petroleum compounds, pathogen indicators and other by-products of urban activities. Urban storm water has also been shown to alter water quality parameters such as pH, oxygen demand, specific conductance, temperature and turbidity. Urbanization modifies the hydrologic properties of a land that generally leads to increase volumes of runoff from a given amount of precipitation, and a more rapidly developing runoff peak. These pollutants and hydro-modifications can directly result in negative impacts to biota and degrade ecosystems. The samples of Storm water joining Mutha River were collected during heavy rains in August 2016. The results are given in Table 1. Similar are the findings by Nivedita & Rawal (6) for the sample collected from Kothrud Basin in Pune. It can be concluded from the Table -1 that Storm water quality in natural drains is very poor and is comparable to that of dilute to medium strength sewage. It means the Storm water shall be treated before the disposal in to water bodies.

Table -1 Storm Water Quality.

Parameters	1	2	3	4	5
Suspended Solids, Mg/l	240	320	235	198	210
COD Mg/l	315	192	145	295	188
BOD, Mg/l	122	90	78	145	102

Rain Water Harvesting

Fate of rain water is given in Figure -1. Four products of rain water are humidity, natural storage (ponds, Lake etc), surface runoff, ground water recharge & bound water. As discussed earlier after construction the due to increase in impervious areas surface runs of increases from 25% to 85%. To increase ground water recharge Pune, Chennai and many other cities have made Rain water harvesting compulsory. However practically it is difficult to put entire rain water or water equivalent to difference of surface run off before & after the construction. At present storm water gushes out on roads or through the storm water drainage system. Storm water drainage system can be integrated with Rain water harvesting by providing the recharge pits and the obstructions to the flow. As per the studies carried out by R. V. Saraf (9) rainwater before touching the ground is devoid of soluble solids & has tendency to leach out calcium and solids from all the rocks commonly found in aquifers. It indicates that Magnesium & other solids based on and heavy metal present in rock can be leached out with rainwater.

Enhance rate of percolation and recharge can cause drastic change in ground water quality. It is observed that excessive pumping of ground water has lowered down the ground water table. This is due to imbalance between natural recharge and draw of ground water. Vice versa if the recharge of ground water is enhance by rainwater harvesting then it may increase the ground water table and cause the serious problem of increase in salinity of soil and change in soil flora and fauna. Similarly if rainwater directly comes in contact with lower strata of soil and rock it can change water quality and weather the rock at faster rate. Over period of time it may change the geochemistry. (9)

Organic and inorganic chemicals emitted due to vehicular traffic and other domestic and industrial activities can get deposited on rooftop and leach out with rooftop water. These chemicals may present in micro level can contaminate the underground water over period of time. Therefore rainwater harvesting is to be critically evaluated and carefully implemented to avoid any adverse impact due to collision of human activities with the nature to have more water. (9,10). No doubt at present Rainwater harvesting offers a small-scale best management practice to reduce storm water runoff and the problems associated with it.

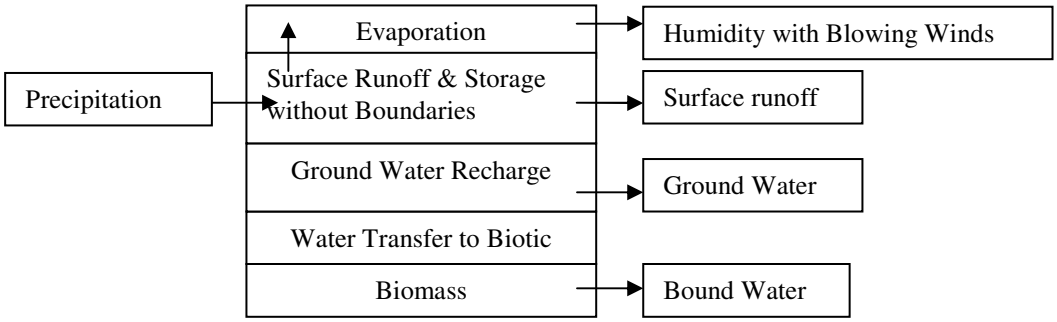

Figure – 1 Fate of Rain Water

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Retention basins

Retention basins offer a viable solution to the problem of urban storm water runoff in developing countries. In rural India, retention basins have been used for centuries for holding rainfall to augment drinking water and irrigation supply. Percolation tanks are among the most common runoff harvesting structures in India. It is an artificially created surface water body submerging a highly permeable land area so that the surface runoff is made to percolate and recharge the ground water storage.

Retention basins filter pollutants such as metals, nutrients, sediments, or organics by sedimentation. Further removal of pollutants is achieved through algal and wetland plant uptake as well as bacterial decomposition Case studies have been reported from various parts of India including Hyderabad, Surat and Karnataka (11). Due to financial constraints and lack of infrastructure, wastewater management systems are not well equipped to treat sudden increase in hydraulic load due to rain or floods. Retention basins offer an inexpensive and sustainable drainage solution to this problem. Instead of Retention basins ponds can be used for storage of storm water for longer time. This allows natural processes, using bacteria and sunlight, to break down pollutants before the water eventually flows into downstream watercourses. Ponds can also be a welcome addition to urban areas, encouraging plants and wildlife. Studies show that incorporating retention basins to conventional drainage networks can prevent flooding in receiving bodies and transport of oil, organics and toxic metals through storm water runoff (CIDCO 2013). Retention basins or holding ponds have been constructed in coastal Navi Mumbai to avoid water logging of low lying areas and prevent pollutants to flow into the creek. In Mumbai, retention basin was effective in storm water flooding and reducing the total suspended solids (10, 11, and 12). Silting of Pond and mangroves growth is the main problem observed with Retention Basin constructed in Navi Mumbai. Ponds act as retention basin in normal condition & storage tank during high tide. It helps in avoiding water logging.

Sustainable urban drainage systems

Sustainable urban drainage systems (SUDS) mimic nature and typically manage rainfall close to where it falls. It involves sequence of followings management practices.

- Transport of surface water with reduction in surface run off before it joins the natural water body to ensure reduction in urban floods & protection of natural flow regimes in watercourses
- Encourage natural groundwater/aquifer recharge
- Provide opportunities for natural evaporation from surface water & evapo-transpiration from vegetation.
- Reduction of pollution from storm water to protect water quality
- Ensures minimal or no long-term detrimental damage on manmade structures & natural environment.
- Provide storage for storm water for natural treatment to enhance percolation for ground water recharge & usage of water in non rainy days. It will be also an attractive habitat for wildlife in urban watercourses
- Create safe & better places to live, work and play.

A SUDS is done in three stages as shown in Figure - 2. It begins with Source control at Individual Buildings, Site control for larger area of residential complex, roads & parks & finally Regional Control at downstream of Site control and before it joins the natural water conveyance (Streams, Nala & river) Rainwater that passes through small SUDS can feed into larger SUDS which deal with the gathered run-off from a wide area. It is best to connect the flows between SUDS components with swales, filter drains or ditches and avoid the use of pipes.

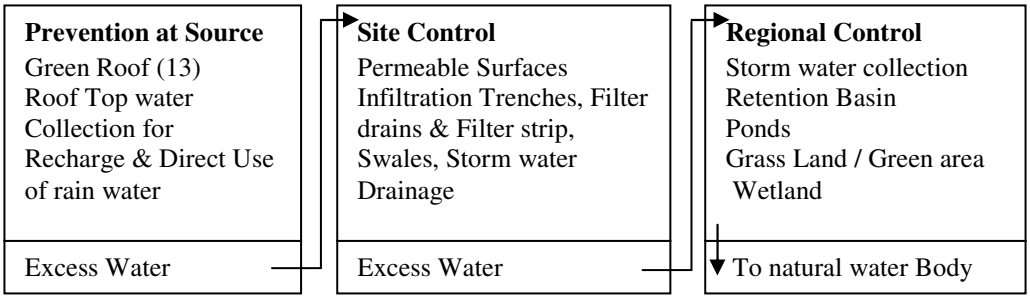

Figure -2 – Three Stages of Sustainable urban drainage systems.

Integration of Storm water for Wetland development

Storm water can be stored on the open land before it joins the natural drainage. The wetland can be developed to reduce the peak flow Strom water & developed the green cover over the land. It will also add to the ground water recharge. It also satisfy urban design objectives, such as providing passive recreational and landscape value, wildlife habitat, flood control and control of the physical changes in a stream due to urban development. Existing ponds or wetlands to treat run-off shall never be used. Always create new ponds to avoid damaging or disturbing the wildlife that is already in the area. Contrary to common practice, vegetation should be established perpendicular to the direction of flow to optimize interaction between wetland vegetation and polluted water. Most pollutants from urban area are transported during storm events. Therefore physical processes are more important in trapping pollutants at these times. Biological processes become important under low flow conditions, when previously trapped materials are transformed and recycled. Small suspended particles adhere to plant surfaces, which act as filters. Plants also provide a surface on which photosynthetic organisms such as algae can grow. These epiphytic algae remove both fine particles and dissolved pollutants from the water column. The proper design of constructed wetlands for treatment of urban storm water is a multi-disciplinary task. Early planning, identification and prioritizing of the various beneficial uses are vital in ensuring a sustainable urban storm water management and urban design system. The creation of constructed wetlands requires the coordination of civil works and wetland vegetation establishment. (14) The functions of vegetation during storm-event flow and base flow conditions in wetlands are summarized in Table - 2.

Table – 2 Function of Wetland during Base Flow & Storm event flow

During Base Flow	During Storm event flow
Provides surface area for epiphytes Eepiphytes take up materials from the water and introduce them to sediments, as cells dislodge from plant surfaces and settle. This is a short-term process occurring over hours to weeks	• Increases hydraulic roughness • Promotes uniform flow • Enhances sedimentation of particles • Provides surface area for small-particle adhesion • Protects sediments from erosion
Takes up nutrients from the sediments Nutrients in the sediment are transformed into plant biomass. This is a medium-term process occurring over weeks to years	
Control of surface sediment redox Plant root-zones generally help maintain an oxidized sediment surface layer preventing chemical transformation of settled pollutant	

Operation & maintenance of Storm water drainage

The storm water system is to be operated only during rainy season & rest of the year it remain idle. As such there is no SOP available for storm water management system during rainy and dry days. There is need of Storm water quality monitoring to ensure the treatment and protect the receiving water body.

Guidelines or Standards for Storm Water Management

Detail Guidelines standards are not yet available in India. There is one standard called as Guidelines on Urban Drainage Published by Indian Roads Congress. (15). There is need to prepare Guidelines & standards for Storm Water Management general and specific to site condition.

Public involvement & participation

Natural drainage system is encroached by or changed for human habitation. It is observed that storm water manholes are used for dumping the solid waste. Sewage is connected to the storm water line. This results into the unsafe conditions. People involvement & participation needs to be built up to take care & maintain natural & manmade drainage system for their safety.

Conclusion

Sustainable Strom Water Management is to be considered on top priority to avoid urban floods & loss of money due to damages. There is definite impact of change in land use and rainfall pattern on storm water generation. It is to be integrated with site specific geological and metrological factors. There is a need of planning of storm water drainage network with environmental consideration and use of green technology. Prevention at resource, reduction and control at site followed by control at region will reduce the impact of pollution, peak flow and gushing water in the storm water drain. The rain water harvesting, retention pond and wetland development are to be incorporated in planning. The wetland will reduce the pollution, peak load impact and will increase percolation of water. The water in the tank can be used during non rainy season and will also attract the wild life. Public involvement and participation is must to protect the natural drainage and avoid the encroachment or dumping of solids. Specifications and guidelines are to be prepared for sustainable storm water drainage system. It will reduce the cost of water pollution control and abatement, associated health hazards & urban flood. It will increase green cover & aesthetic values of the city. Essential planning considerations, technology options and innovations in storm water Management are required for “Smart City” concept.

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