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Hydrological Modelling of Geological Behaviours in Environmental Planning for Urban Areas

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Abstract**—**Runoff,decreasing water levels and recharge in urban areas have been a complex issue now a days pointing defective urban design and increasing demography as cause. Very less has been discussed or analysed for water sensitive Urban Master Plans or local area plans. Land use planning deals with land transformation from natural areas into developed ones, which lead to changes in natural environment. Elaborated knowledge of relationship between the existing patterns of land use-land cover and recharge with respect to prevailing soil below is less as compared to speed of development. The parameters of incompatibility between urban functions and the functions of the natural environment are becoming various. Changes in land patterns due to built up, pavements, roads and similar land cover affects surface water flow seriously. It also changes permeability and absorption characteristics of the soil. Urban planners need to know natural processes along with modern means and best technologies available,as there is a huge gap between basic knowledge of natural processes and its requirement for balanced development planning leading to minimum impact on water recharge. The present paper analyzes the variations in land use land cover and their impacts on surface flows and sub-surface recharge in study area. The methodology adopted was to analyse the changes in land use and land cover using GIS and Civil 3d auto cad. The variations were used in computer modeling using Storm-water Management Model to find out the runoff for various soil groups and resulting recharge observing water levels in POW data for last 40 years of the study area. Results were anlayzed again to find best correlations for sustainable recharge in urban areas.

Keywords**—**Geology, runoff, urban planning, land use-land cover.

I. Introductİon:

NATURAL systems are already responding increasingly making their presence by extreme weather events in the recent decades like floods, droughts, tsunamis, earthquakes along with world's rivers, lakes, wildlife, glaciers, permafrost, coastal zones, disease carriers and many other elements of the natural and physical environment leading to imbalance and natural hazards. Many activities like UNESCO, UNEP, IPCC and UNHSP at international level during last decade have been developing a basis for the rational use and conservation of the resources of biosphere, to overcome the impacts of climate change for the improvement of the relationship between man and environment within the natural and social [1]. The assessment reports of IPCC2007 and 2013 have stated that warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased. Gradually each decade is getting warmer from the previous one. Confidence in precipitation change averaged over global land areas since 1901 is low prior to 1951 and medium afterwards [2], [3].

The most notable changes observed are related to the urban and hydrological system where urban areas have increased from 100000 to 5000000 and as per United Nations projections half of the urban population would live in urban areas with 85.9% around in 2050 for developing and developed countries. Built up associated with urban areas have also had noticeable change of 145.68% as compared to 54.05 % change in Population Growth from 1971 to 1999. Also UN report of 2013 the urban population will increase from 29.1 in 1950 to 66.6 in 2050. As per the State of resource, UNESCO report [4] water is predicted to be the primary medium through which early climate change impacts will be felt by people, ecosystems and economies [5].Hydrology has suffered drastic changes in its components felt changes in recharge that dropped from 45-50% in 1961 to -10to-30% in 2050 as per the UNEP and IGRAC.

Many changes in hydrological cycle are both positive and negative in different aspects of urban and water systems. Increased annual runoff may produce benefits for a variety of both in-stream and out-of-stream water users by increasing renewable water resources, but may simultaneously generate harm by increasing flood risk [6]. Water scarcity on the other hand is already becoming a burning issue in most of the cities and countries . Precipitation pattern is also showing a temporal variation in its behavior in many of the urban and rural areas. [7]. Secondly, rising temperatures are accelerating the hydrological cycle and causing rivers and lakes to freeze later in the autumn. Predictions are already being made for irregular , variant and extreme possibiity of weather events . As per .IPCC 2007, human activities and urbanization is likely to affect climate change which in result will impose extreme weather events [1], [8].

Both observational records and climate projections provide strong evidence that freshwater resources are vulnerable, and have the potential to be strongly impacted by the increasing urban areas. The variations in climate change are having impacts on many natural cycles like extreme precipitation-related weather and climate events, observations and reports indicate areas with heavy precipitation increasing intensities, increase in areas affected by droughts, and intense tropical cyclone increase, damaging to crops, soil erosion, land degradation, lower yields, damage to ability of land to

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cultivate. More intense rainfall events will increase runoff percentages and will overload the capacity of sewer systems and water and wastewater treatment plants more often. One reason is that precipitation variability is *very likely* to increase, and more frequent floods and droughts are anticipated.

Thus changes in land use and land cover due to urbanization are likely to impact water requirement as some places leading to water scarcity and some with flash floods. Dynamic land use changes and soil transitions bring challenges not only for Social, Hydrological, Geological and Urban Systems but also for over all ecological systems and decision making processes creating an urgent need for planning and developing parallel solutions to changing world.

II. Literature Review

A. Relation between Soil, Urban, and Hydrological System

As per the US Drought Mitigation Centre-"The processes of evaporation and transpiration (evapotranspiration) are closely linked to the water found in soil moisture;these processes act as driving forces on water transferred in the hydrological cycle [9] that are difficult to measure and require demanding analyses in order to calculate an acceptable level of accuracy. Evaporation from surface water bodies such as lakes, rivers, wetlands and reservoirs is also an important component of the hydrological cycle and integral to basin development and regional water management."The soil moisture content in any area mark the availability of underground water as well as influence up to great extent the occurance of precipitation and its nature. The water bodies also define the water level in the soil column. Hence it essential for planners to have knowledge for the soil below and water availability before development as future implications of climate and hydrological information can be predicted and water future can be forecasted. Also this will be helpful to maintain the water table during development..But urban planning is still not using this parameter as a tool for land use-land cover planning though many square kilometer of land and soil moisture gets directly affected by the urban development.

1. Effects of Impervious Area to Water Recharge and Drainage Flow:

a. Impervious Surface Area:

Impervious surfaces associated with urbanization include roads, sidewalks, parking lots, and buildings- any artificial, hardened surface that reduces permeability and infiltration of water into the soil.

b. Natural Drainage:

In Natural Drainage, the pathway which upgrades the entire drainage system in such a way that surface runoff is conveyed with increased capacity to natural channels or subsurface channels running to storage areas. Natural drainage was viewed as a living organism by Mars bug [10] on observing the working condition and characteristics of the drainages.

c. Water Holding Capacity of Soils:

TABLE I
WATER HOLDING CAPACITY FOR DIFFERENT SOILS

Soil	Soil type	Water holding capacity (when pressure not applied)
Alluvial	Clay	70-80%
Sandstone	Loamy	80-90%
Sandstone	Loamy sand	30-40%
Basalt	Silt loam	70-75%
Basalt	Silty clay loam	70-80%

Source: (Agvise Laboratories, 2001)[11]

2. Observations of Hydrological Changes as Per Case Studies:

The management of surface water flooding is hindered by the characteristics of urban Drainage. The presence of impervious non-porous surfaces in urban area (such as Buildings Roads, Car Parks) raises the volume of surface water runoff, lowers the underground water percolation from paved coverings [12].

Urbanization is the process of converting natural soil to a sealed one with almost non porours open spaces wich are responsible for holding and transfering water to the soil beneath. Imiting this natural cycle increases the runoff factor in such sealed spaces and hence imbalancing the natural phenomenon of infiltration, evaporation, runoff and evapotranspiration. Manu research have been modeled surface water runoff from different types of land uses and found that runoff increases with proportion of built-up areas [12].

a. Western Scenario:

Therefore it is apparent from Table I that land use, land cover and the evapotranspiring surfaces have a significant influence on behavior of water in urban water cycle and related urban flooding. Similarly Induction of Built-upareas around natural water routes make these readings more focused on placement of Land use –land cover as per accordance to the natural landscaping behavior.

Indian Scenario:

Study of some Indian Major Urban Centre's for variations in Components of Hydrological Cycle and land cover depicting to impervious areas reveal that built up areas and water withdrawal has resulted in declining of water levels in areas [12] as shown in Fig. 1.

The Indian Urban centers (Fig. 1) as ranked worldwide as per their urbanization extent and as per their Urban land area (footprints) were observed in reference of the specific water supply and demand for these urban cities and also the density and source of available water resources are compared to achieve a correlation of urban centers and availability of water or shortage of water. Urban centers like Delhi, Nagpur, Bhopal, Jaipur are having severe shortage of water supply and water is being transported from various sources, 25 kms away from cities. Among these many cities have water availability potential which is deteriorating at fast rate. Instant urbanization is considered as the cause for difference in supply and demand.

TABLE II
READING AND OBSERVATIONS FOR VARIATIONS IN INFILTRATION RUNOFF AND EVAPOTRANSPIRATION FROM CASE STUDIES

Case studies	% vegetated	% infiltration	% runoff	Evapo-transpiration
Natural condition	natural	50	10	10
Modified	modified	6	50	
Northwest England	66	1	32	1
	20	4	74	2
California, Thompson creek	natural	50 (25 shallow + 25 Deep)	10	40
	80-90	42(21+21)	20	38
	50-65	35(20+15)	30	35
	0-50	15(10+5)	55	30
Harzliya , Israel	30-40(residential		45	
	60-75(Industrial)		90	
Vegetated cover in Low density areas	66		32	
Very less vegetated town centre's	20		74	

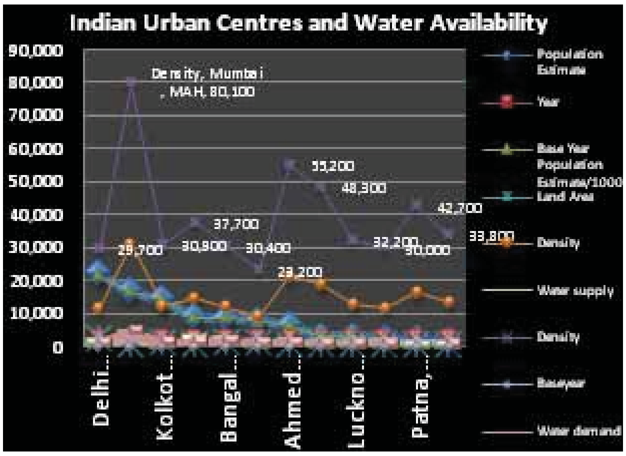


Fig. 1 Indian Urban centers with population, land area and water availability [12]

III. NEED

Urbanization is a major issue in now a day's scenario and water scarcity and flash floods too are directly linked with urban areas correlating the increasing built up areas. However constant increase in urban areas is lacking and ignoring the effects of urbanization and thus hampering the working natural courses of environmental systems like water cycle and continuously harming the environment as well through on surface and sub-surface water variations. Though efforts have been constant for creating balance between two, still urbanization being at its fast pace is keeping thoughts and actions behind. Thus spatial planning needs a fast, improved and scientific as well as technical thought for planning and implementation of these balancing ideas in accordance with due consideration to maintaining natural regime along with development.

To maintain balance between ever dynamic population increase and decrease of underground water availability, the gap between increases in population resulting more built up areas and rate of water availability has to be reduced.

Urban planners have to be updated with natural cycle and modern means as well as best technologies for maintaining the balance between urban system and natural system, but there is a huge gap between basic main-streaming of knowledge of natural processes with physical planning studies and its requirement for balanced development.

IV. METHODOLOGY

A.Methodology Adopted for Hydrological Modeling:

Fig. 2 depicts the broad methodology adopted to observe the correlations between soil, development and water. The study was carried out by observing individual systems first and then their interactions with other systems with most affecting variables. Urbanization, soil properties and water moisture content with water table variations were most observed parameters for a span of 40 years to get correlations among systems.

a. Maps Prepared

The digitization was carried out in following stages:

i. GIS Maps for watershed imageries.
ii. GIS and Geology map, ward map, road, built up and contour map for sub-catchments.
iii. Colony maps by town& Country Planning , Bhopal.
iv. Contour Map, Digital Elevation Model. DEM
v. The SCS Curve numbers and the curve number (CN) were allotted as per GSI Map . Standard formats used by EPA SWMM were used as default inputs.
vi. The land covers were separated into two categories ie impervious & pervious. After dividing them in two heads each land cover was assigned by a mannings for the type and category as mentioned above by USGS.

Accordingly, a basic model of the study area in Bhopal city was built using the Arc GIS with integration of different layers for different time periods. The precipitation data obtained from the meteorological department and the report of [13] WRD 2008 the normal rainfall series and the critical rainfall series were decided. Auto cad Civil 3D software was used to categories sub-catchments on basis of water drop flows and contours of Google surface to facilitate analysis of surface flows. Then, the natural drainage paths and the manmadeconduits along with the junctions and nodes were formed in the SWMM model. The sub-catchments were assigned the related properties and detailing for length, width, slope, impervious %, flow routing, inflows, dry weather inflows, etc were addressed. The outlets and conduits were assigned properties such as circular pipe, trapezoidal, natural etc. Manning N for the concrete pipes and the natural rains were assigned. The storage units and the aquifers were assigned data as per Hydrogeology reports.

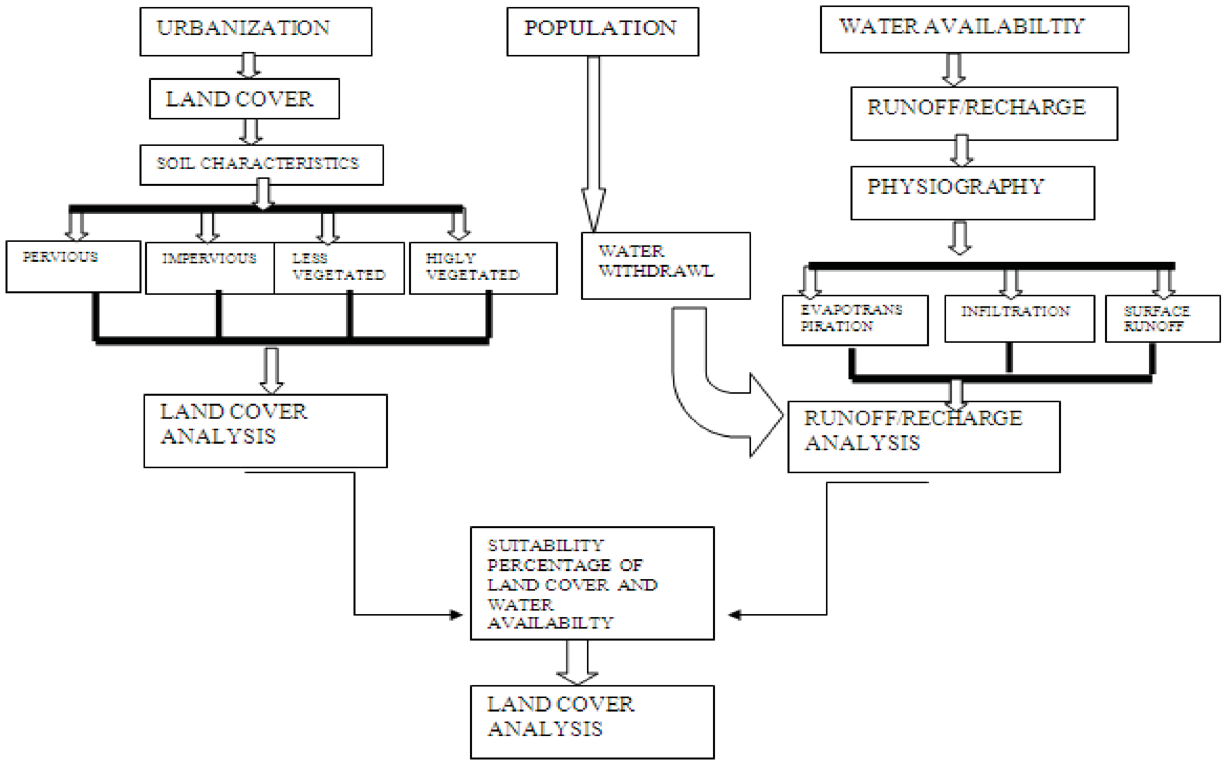


Fig. 2 Methodology for hydrological modeling

Thus a whole set of parameters was formed to set a model where simulation for various runoff, peak runoffetc can be observed.

B.Simulation

The two methods for simulation used were:

- By keeping precipitation and slope, width constant for respective years and
- By changing precipitation on hourly and daily basis to observe long term runoff changes and short term peak flow changes.

Model results obtained were tested for accuracy by regression model and the difference between observed and simulated Hydrographs were checked for least error.

The runoff changes for constant precipitation with changing built up were analyzed first. The combinations of inter-location runoff and the intra-location runoff were used to form the Correlation Equation and the constants ($y=Ax^2+bx+c$) where y is runoff and x is built up.

The correlation observations for each catchment for each decade was plotted to see the trend line and the resulting equation. To calibrate the hydrologic model the LULC data was prepared in a 8m grid. The time series data was made for hourly rainfall event.

Finally, the simulation was run for different years as per conditions prevailing for that specified times and the continuity errors as well as flow routing errors were minimized to get accurate results. The obtained report of the rainfall runoff was then observed and compared for viewing results and changes in the parameters. The correlation analysis was performed to obtain a correlation and best fit method was used to get minimum error value.

The correlation thus formed was observed for various catchments individually ieinter location and then with others with same characteristics over all the study area ie-intra location.

The simulation was run with following time series:

i. Critical rainfall-runoffanalysis from June to September
ii. Critical rainfall-runoffanalysis for peak hour (24 hours)
iii. Rainfall-Runoff analysis with varying precipitation.
iv. Rainfall- Runoff analysis for Built up as per rule and built up as per actual.

V. Study Area-Bhopal(India)

The study area selected covers two Urban Areas constituting several wards of Bhopal District, State Madhya Pradesh, and Country India. (Fig. 3) The areas selected have two different urban Catchment forms. One with developing character with specific geological setup and other with developed character and different geological set-up. Both areas have recently being facing water level drop; one has a recharge zone character and other have discharge zone character. The wards coming within these natural boundaries have been taken for observation and analysis. It consists of Area Colony, Shahpura, ChunaBhatti and Manit. The study area comprises of Natural Drainage of Kaliasot River along with Kaliasot Dam, Bhadbhada area (Soil way of Upper lake), Southern Portion of Upper Lake, Hills like Samasgarh, Forest Areas near Chichli, Nayagoan, The study area spreads over 117800 sq.kms. Covering major portion of urban areas some developed according to physical planning aspects whereas some developed drastically in short span, of the Bhopal district (M.P.). It refers to Survey of India Toposheet No. 55 E/8 and bounded by latitudes 23^0 10’ to $23^0$15’ N and longitudes $77^0$23’30 to $77^0$27’ E, Bhopal- India.

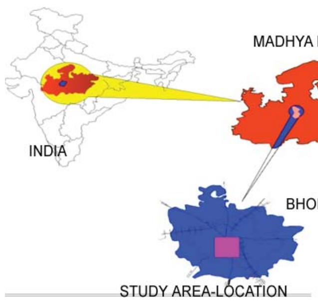


Fig. V Bhopal City

A. Watershed of Study Area

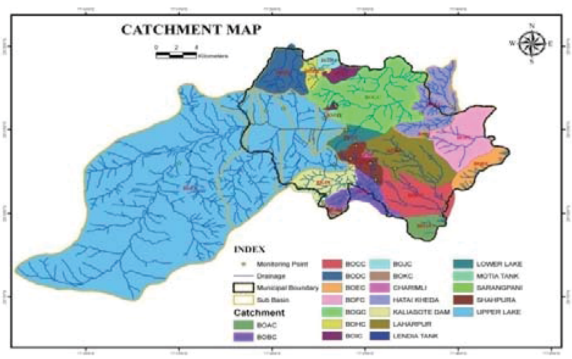


Fig. 4 Catchment Map for Bhopal District, Source : CGWB Bhopal [14]

The watershed map of Bhopal (1990) , in which different catchment were identified for analysis of water prospect map and hydrogeology wells (Fig. 4) of the city for maximum recharge potential and areas experiencing sudden decline in water table (Fig. 5). Some areas which had been showing satisfactory reactions to urbanization processes were also selected to observe the basic factor underlying their performance in natural as well as urban cycle. Also the ward map (localities demarcated as wards by Bhopal Municipal Corporation at local level plan) for the same area was obtained to ascertain the areas already developed and areas still developing.

B. Basic Characteristics

Along with this CGWB report for critical water tables in city were identified. As per the secondary data it was found after analysis that some areas have been critical for water table fluctuation and some had shown improvement. The areas were marked as per the hydrogeology wells location. Water prospects of the study areas which were sensitive to water development and the areas which have great natural potential or carrying capacity were highlighted such as catchments named BSHC, BOBC, BOCC (catchment names as per nomenclature use by CGWB) and catchments with poor water prospects such as BSHC (upper part), BOBC-lower part and BLPC.

1. Area is underlain by Vindhyan sandstone and basalts of the Deccan Trap.
2. Promising aquifer zones cited in the Vindhyan within a depth range of 60-70 mbgl especially at the base of Vindhyan hillocks or under a cover of weathered basalt.
3. Weathered and vesicular basalts also form potential aquifers.
4. Areas identified for construction of tubewells.
5. Need for rooftop rainwater harvesting stressed to make the aquifer more sustainable.
6. Chemically the ground water contains high nitrate at a few places.

C. State Ground Water Report for Declining Water Levels

SGWB has marked Bhopal District as Semicritical Zone for declining water levels in recent years .whereas Bhopal is called the city of lakes where 17 lakes had been existing since historical times. Only in recent time it had been facing sudden decline in water levels. The year 2009 was considered worse for Bhopal as its famous Lake dried to 3% of its catchment area from 36 sqkm to 5 sqkm.

As per the report of the Ground water levels in District Bhopal, Madhya Pradesh (in meters BGL) for Phanda, Berasia Blocks. 1999, the phanda block of the city has been identified as semi critical zone for the ground water development in 2009-12 [15]. Along with this CGWB report for critical water tables in city were identified. And catchment map was obtained from SGWB (State ground water department).

As per the secondary data it was found after analysis that some areas have been critical for water table fluctuation and some had shown improvement. The areas were marked as per the hydrogeology wells location.

As per the Peizometric and POW data (SGWB) 1984 to 2008 the following wells had variation:

- Satisfactory recharge:
- Well no. 2,3,4,8,9, 12,15,16, 24
- Not satisfactory recharge:
- Well no.5,6, 7,9,10,11,13,14,15,20,23

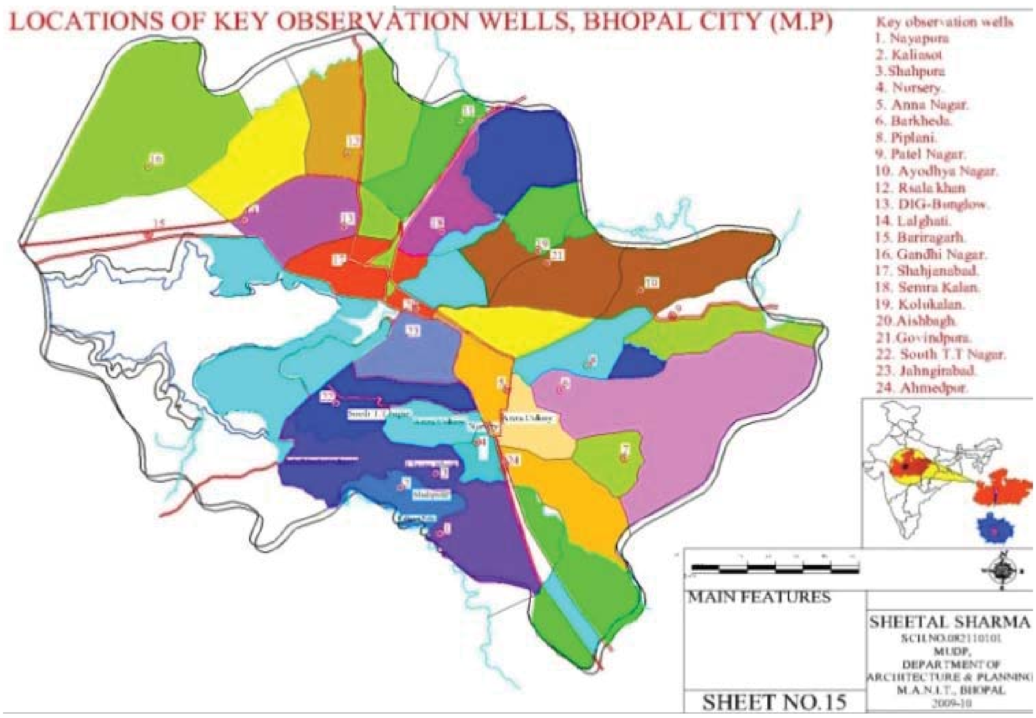


Fig. 5 Hydrogeology wells Bhopal, Source: Hydrogeology Map [14]

D. Geoglogy of Study Area

The Geological Map obtained from the geological survey of India was observed for geology of these catchments and the different soil layers under these catchments. The hydrogeology characteristics of the area were determined. The site has been divided into different sub-catchments depending upon the Hydrogeology and the water flow pattern.

Fig. 6 Sub-catchment division (demarcating) of study area as per geology

E. The Details of Hydrogeology and Lithology of the Area

Soil properties were analysed by obtaining Geology map for Bhopal from Geological Survey of India Bhopal and study area was divided as per soil categories along with the physical and chemical properties of the soil.

TABLE III
GEOLOGICAL CHARACTERISTICS OF BHOPAL. GSI MAP OF BHOPAL 1986

SN	Age	Lithology	Ground water Potential
1.	Quaternary to recent	Alluvium	≤2 unconsolidated, Primary Porosity (areas- ChunaBhatti)
2.	Upper Cretaceous to Eocene	Deccan trap (porosity 0.65%) Absorption %=0..33-2.43	1-5, Secondary Porosity, Fractured Horizons, interflow contacts & vascular Basalt. (areas-Shahpura, Arera region)
3	Upper Prtozoic	Sandstone (Absorption- 0.004-0.12)	1-3, Secondary porosity, jointed & fractured horizon. (areas- South T T Nagar, North T.T Nagar, Shivaji Nagar, Part of Arera Colony)

A grid of approximately 8mX8m resolution of the two selected sample areas is analyzed. The characteristics observed for the selection of the Study Area is Physiography, Geology, Drainage Pattern, Catchment Area, Rain Gauge, Planned and unplanned development and within natural environmental conditions or Altered ones.

To study the variations in surface flow, the observations of the catchment area and development is necessary simultaneously. The catchment area is thus defined by the boundaries and water flow within an catchment area. Thus different types and scale of catchment area are used for detail studies. Thus a micro level observation can be done with catchment of micro scale with 5-10sqkm

F. Main Geological Features

- Black cotton soil occurs in the valleys in between the sandstone ridges. Good erasures of sandstone are found on the banks of Kaliasot River.
- Typical trapping topography is found near villages Chan, Misrod, Bangroda, Diprietc
- The contact of Vindhyan and Deccan traps is found in the quarries near Panchsheel (Charimli) .
- Black cotton soil covers rest of the plain and low lying area under consideration.
- In study area Black cotton soil is grayish Black to Dark Black in colour. The average thickness of black cotton soil is about 3m to 4m.

G. Water Bearing Properties of Different Rocks in the Area

In the PhandaBlock the valleys sandstone and Deccan traps occur. Only weathered portion of basalt is eroded easily.

Most of the surveyed area is covered by Deccan traps. Some Flows of Deccan traps form Good Aquifers due to the presence of the numerous joints and presence of weathered portion along the contact of two flows. ie:near Misrod , Bagli and Ranadia etc. The Ground water of traps rocks occur both under confined and water table conditions. If well site, the water is normally under pressure conditions. During the rainy season the pressure are highest and during the summer seasons, they are nearly impermeable. The pressuring conditions become more pronounced in the case of a flow which occurs below one or more flows.

Where the vascular zone of the flows, along with the overlying weathered material, forms the porous zone, the water occurs under the water table conditions. The tops of some of some of the flows are vascular and fractured, which are found to hold a fair quantity of water.

The Vindhyan sandstone being well cemented acts as aquifuge, except where they are highly fractured and pointed . Black Cotton soils provide small domestic water supplies from shallow wells.

One important feature of the area is that most of the villages are situated near the banks of rivers and these rivers are responsible for recharging of aquifers.

VI. Analysis

A. Land Cover Changes from 1974 to 2013

a. Built Up Changes in Chronological Order for the Study Area

Another maps related to study were also mapped for present Geology, contours, DEM, Land use, roads, Drainages etc.

b.Changes in Water Levels throughtout the Time Period in Specific Hydrogeology Wells

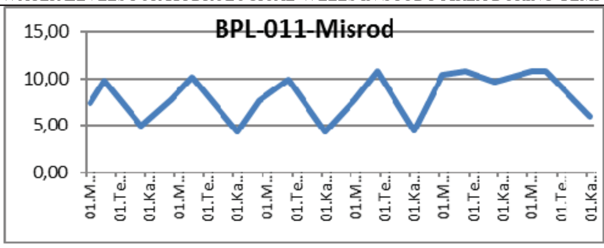
The observed changes in water levels obtained from State ground water department were compared with the catchment results of runoff and the relative recharge and discharge levels of these were studied. Also the catchments were observed with colony level water flows by photographs and videos.

The observations of comparative charts were analyzed by simulation results obtained from SWMM model.Observations were based on comparative charts, regression analysis and minimum error check for the results.

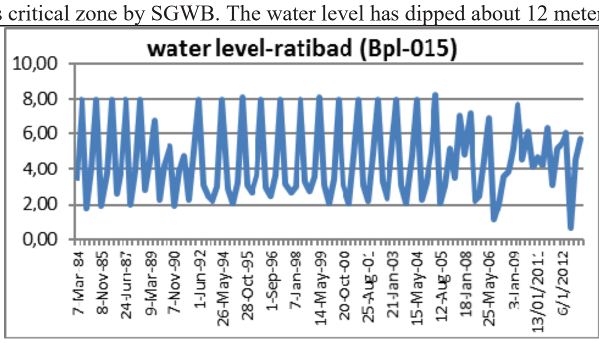
TABLE IV
BUILT UP VARIATIONS

SN	Subcatchment	Total Area (Sqmt)	1974%	1981%	1991%	2001%	2011%	2013%
1	BOBC-S1	1446194.00	4.85	5.21	10.93	8.46	54.10	55.31
2	BOBC-S2	3267546.00	0.00	5.08	30.26	32.51	51.43	51.87
3	BOBC-S3	443747.00	100.00	12.38	31.15	45.21	45.21	47.62
4	BCIC-S1	241845.10	0.00	0.00	0.00	0.00	9.45	9.45
5	BLPC-S1	1850300.00	0.71	58.51	75.51	84.29	85.23	86.91
6	BLPC-S2	425139.30	0.00	11.88	11.88	49.91	51.61	51.61
7	BSHC-S1	70351.56	41.08	69.59	77.86	83.71	83.93	83.93
8	BSHC-S2	796863.00	9.45	12.59	55.84	55.07	91.42	99.97
9	BSHC-S3	667820.60	46.79	48.61	87.02	99.98	100.00	100.00
10	BSHC-S4	467654.20	1.92	66.09	75.36	92.44	92.44	92.44
11	BSHC-S5	847028.40	7.11	56.48	64.54	67.15	81.43	82.72
12	BSHC-S6	3455035.00	2.36	17.19	42.38	46.94	77.90	87.18
13	BSHC-S7	292338.30	0.00	0.00	66.80	90.26	92.75	92.75
14	BSHC-S8	336526.10	2.54	18.88	34.15	51.87	59.09	59.09
15	BSHC-S9	1077419.00	0.49	12.81	18.66	38.83	43.73	46.25
16	BSHC-S10	253820.20	0.00	16.67	24.46	36.79	51.12	51.12
18	BOCC-S1	926885.20	2.00	65.17	90.92	93.15	94.49	94.49
19	BOCC-S2	1342964.00	0.00	23.84	33.04	42.66	42.66	45.50
20	BOCCS3	2056776.00	0.00	19.20	68.17	79.93	80.69	80.69

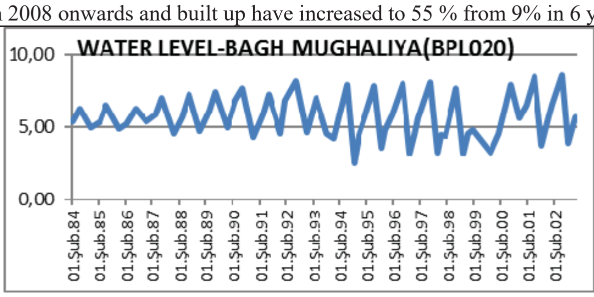
TABLE V
CHANGES IN WATER LEVELS FOR HYDROLOGICAL WELLS IN STUDY AREA DURING TEMPORAL PERIOD



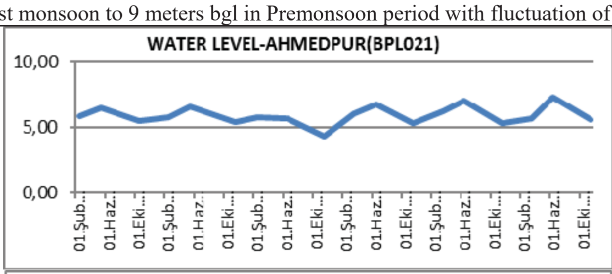
Situated in outskirts of study area and on Hoshangabad highway this area has shown continuous decline in water levels since 1990 onwards and have been declared as critical zone by SGWB. The water level has dipped about 12 meters below ground level.

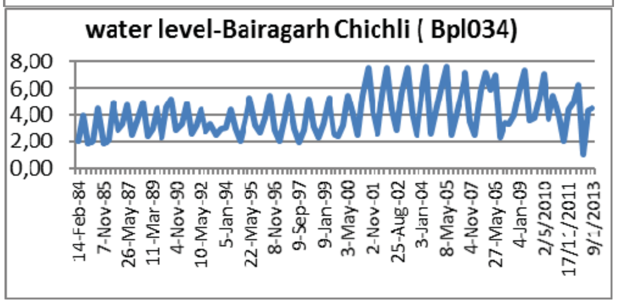


This well has revealed the fact that though it lay within the catchment area of upper lake, its recharge value has been constantly affected since 2009 onwards. The well had been functioning well before 2009. On survey it was found that about 18 colonies have been developed in this area from 2008 onwards and built up have increased to 55 % from 9% in 6 years.

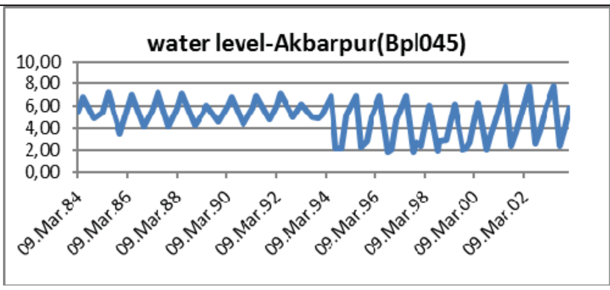


The well is located in the flood zone of South Bhopal, and has shown better water results since 1994, when second master plan was implemented with Land use change as flood plain and restricted construction around natural water ways. The well have experienced water level of 4 meters bgl post monsoon to 9 meters bgl in Premonsoon period with fluctuation of 5 meters in a year.





This well is located in a rocky area of south Bhopal where Deccan trap soil is available in compact layer. The slope is towards the canal flowing nearby with barren land around. The well has poor performance with only 4 to 6 meters of levels bgl for the year.



This well is just to another well in Akbarpur by CGWB and is in the area reserved as flood affected area by the Bhopal Master plan 1991. It has shown improvement in recharge but also same time has been experiencing declining water levels in pre monsoon period up to 8 meters bgl.

c.Intra Location Analysis:

The well water levels for last 40 years were compared to the infiltration and runoff results, assuming the recharge from other sources as constant. Only the infiltration from rainfall was considered to be prime factor for increase in level. This helped in comparing years and water levels in catchments with real time water level and simulated infiltration in accordance to runoff and land cover roughness.

The observations were tabulated to form groups of well recharges areas and less recharge areas.

VII. Infiltration

The Observations were made for different catchments by considering the prevailing geological and hydrological characteristics along with the increasing built up character on the land surfaces.

The Time interval chosen was from 1971 to 2011 and also 2012 and 2013 data was included wherever necessary.

The area selection was purposely done for catchments that come under urban areas and also which experienced sudden urban growth as well as steady and planned growth. The most critical areas were selected for observations which consist of three different geologies ie Basalt, sandstone and Alluvial and pre- and post developmentconditions existing within some, which enabled to observe and identify the surface flow changes for both conditions. The land cover was divided into four categories.

1. Asphalt Concrete with low to medium grass
2. Asphalt Concrete with dense bushes and forest
3. Low to medium Grass with Mud Concrete
4. Dense bushes forest with Mud Concrete.

The Observation is based on analysis of the primary data, secondary data and the simulation results that were obtained for temporal and spatial changes in Runoff for study area.

A. *Fluctuation in Water Levels*

Fluctuation of groundwater in different seasons can be divided into two sections.

1.Premonsoon Depth to Water Level from Ground Surface

It is observed that the most of the wells located I the eastern portion are having water level between 4.50 to 5.5 m. the wells located in the south west are having water level from ground surface ranging between 3m to 4m. The villages located near the bank of the Kaliasot and kerwan river have water level between 3m to 6m. One patch having water has been observed in the southwest bounded by the villages Bairagarh (Longitude 77^{0}24’0” Latitude 23^{0}9’0”) Nayapura, Bawariklan and Shahpura.

A big patch which starts from South-west and extends in western, northwestern and eastern have water level between 6m to 9m. Recharge percentage in Ground water level:

- 65% -0 to 3m
- 37.50%- 3m to 6m
- 52.10 % 6m to 9m
- 9.75% above 9m

2. Post Monsoon Water Levels

A study of post monsoon water levels shows that are two big and nine small patches having depth to water level between 0 to 3m.

The big patch located in the south west was at Longitude 77023’0” Latitude 2308’0”, Near Chichli

The water level is below 3m in some villages because the villages are located very close to the rivers or located in the valleys.

Percentage of depth to water level in meters:

- 0-3m – 37.85%
- 3 to 6m- 47.60%
- 6m to 9m 13.20%
- Above 9m – 1.85%

The weighted average fluctuation of the water level in the phanda block has been calculated and found to be 2.65 m .

VIII. Observations

A.Change Detection in Natural Working System

The Following changes were observed in the Data analysis for variations in infiltration, evaporation, evapotranspiration and runoff along with peak runoff which results in flash floods in urban areas for certain rainfall.

Variations in hydrological components with variations in built up in context of Geological characteristics.

TABLE VI
GROUPING OF CATCHMENTS AS PER IMPERVIOUS AND PERVIOUS CHARACTERISTICS AND RESULTING INFILTRATION FOR DIFFERENT SOIL GROUPS

Catchment	Geology	Impervious (concrete)	Pervious (grass cover)	Soil Characteristics Water holding capacity (infiltration)	Results for infiltration	
					A . moderate rainfall	B . intense rainfall
BCIC-S1	Sand Stone (Loamy Sand)	0.01	0.14	High , shallow	Low (5%)	High (17.2)
BCIC-S1	Sand Stone (Loamy Sand)	0.011	0.14	High ,shallow	Low(8.6%)	High (12%)
BCIC-S1	Sand Stone (Loamy Sand)	0.012	0.41	High ,deep	Low(12.2)	High (28.7)
BLPC-S1	Basalt (Loamy)	0.012	0.24	Moderate ,deep	High (26.8%)	Low(23%)
BLPC-S1	Basalt (Loamy)	0.011	0.24	Moderate infiltration,	High (32.5%)	Low(20%)
BLPC-S1	Basalt (Loamy)	0.012	0.8	Moderate shallow	High (71.3%)	Low (19.2%)
BLPC-S2	Sand Stone (Loamy Sand)	0.012	0.24	Very less	Low (5%)	moderate(8.6)
BLPC-S2	Sand Stone (Loamy Sand)	0.011	0.24	less	Low(8.6%)	Moderate (12%)
BLPC-S2	Sand Stone (Loamy Sand)	0.01	0.24	less	Low(12.2)	Low (5.2%
BOBC-S1	Alluvial (Clay, silt)	0.012	0.81	Very less ,deep	Moderate(69.7)	Less(28.2)
BOBC-S1	Alluvial (Clay, silt)	0.011	0.81	Very less, deep	Moderate(42.8)	Less (20.7)
BOBC-S1	Alluvial (Clay, silt)	0.01	0.81	Very less	High(34.5)	Moderate(20.1)
BOBC-S2	Deccan (Sand Stone)	0.012	0.41	moderate	Moderate (28.1)	High (38.7)
BOBC-S2	Deccan (Sand Stone)	0.011	0.41	moderate	High (36.8%)	Low(23%)
BOBC-S3	Deccan Basalt (Loamy)	0.012	0.41	Good, deep	High (71.3)	Moderate (32.5)
BOBC-S3	Deccan Basalt (Loamy)	0.011	0.41	Good , Deep	High (38.3)	Less(19.0)
BOCC-S1	Deccan Basalt (Loamy)	0.011	0.17	moderate	Low (9.2)	Very low (5.2)
BOCC-S1	Deccan Basalt (Loamy)	0.012	0.41	moderate	Low (17.2)	Low (12.4)
BOCC-S1	Deccan Basalt (Loamy)	0.012	0.8	moderate	Moderate (23.6)	Moderate(20.0)
BOCC-S3	Deccan (Sand Stone)	0.011	0.17	low	Moderate (28.1)	High (38.7)
BOCC-S3	Deccan (Sand Stone)	0.011	0.05	low	Low (6.8%)	Low(3%)
BOCC-S3	Deccan (Sand Stone)	0.012	0.17	moderate	Moderate (18.1)	Low (8.7)
BSHC-S1	Sand Stone (Loamy Sand)	0.012	0.17	moderate	High (36.8%)	Low(23%)
BSHC-S1	Sand Stone (Loamy Sand)	0.011	0.24	Low	Low((8.6)	(5.2)
BSHC-S10	Deccan Basalt (Loamy)	0.011	0.17	Good, deep	High (71.3)	Moderate (32.5)
BSHC-S10	Deccan Basalt (Loamy)	0.012	0.41	Good , Deep	High (38.3)	Less(19.0)
BSHC-S2	Sand Stone (Loamy Sand)	0.011	0.13	Moderate	Moderate(30.5)	Moderate(23.5)
BSHC-S2	Sand Stone (Loamy Sand)	0.011	0.17	Good	Good(40.1)	Good(30.5)
BSHC-S2	Sand Stone (Loamy Sand)	0.012	0.13	Good	Good(69.9)	Good (50.4)
BSHC-S3	Deccan Basalt (Loamy)	0.011	0.17	Good, deep	High (71.3)	Moderate (32.5)
BSHC-S3	Deccan Basalt (Loamy)	0.012	0.17	Good , Deep	High (38.3)	Less(29.0)
BSHC-S4	Sand Stone (Loamy Sand)	0.011	0.41	Good	Good(40.1)	Good(30.5)
BSHC-S4	Sand Stone (Loamy Sand)	0.012	0.41	Good	Good(69.9)	Good (50.4)
BSHC-S5	Deccan Basalt (Loamy)	0.011	0.17	moderate	Low (9.2)	Very low (5.2)
BSHC-S5	Deccan Basalt (Loamy)	0.012	0.13	moderate	Low (17.2)	Low (12.4)
BSHC-S6	Alluvial (Clay, silt)	0.012	0.41	less ,deep	Moderate(69.7)	Less(28.2)
BSHC-S6	Alluvial (Clay, silt)	0.011	0.41	less, deep	Moderate(42.8)	Less (20.7)
BSHC-S7	Deccan Basalt (Loamy)	0.012	0.8	Good, deep	High (71.3)	Moderate (32.5)
BSHC-S7	Deccan Basalt (Loamy)	0.011	0.8	Good , Deep	High (38.3)	Less(19.0)
BSHC-S8	Deccan Basalt (Loamy)	0.012	0.8	moderate	Low (19.2)	Very low (11.2)
BSHC-S8	Deccan Basalt (Loamy)	0.011	0.8	moderate	Low (22.2)	Low (12.4)
BSHC-S9	Deccan Basalt (Loamy)	0.012	0.41	moderate	Moderate (28.1)	High (38.7)
BSHC-S9	Deccan Basalt (Loamy)	0.011	0.41	moderate	High (36.8%)	Low(23%)

B.Alluvium

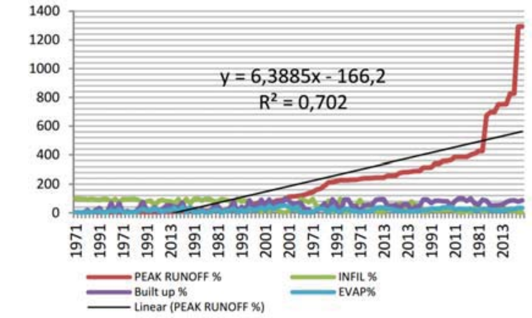


Fig. 7 Peak runoff and Infiltration results for Alluvium soil from 1971 to 2013 in study area

C.Sandstone

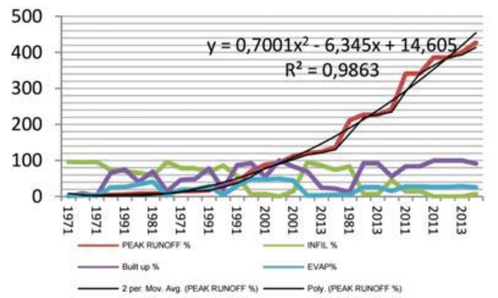


Fig. 8 Peak runoff and Infiltration results for sandstone soil from 1971 to 2013 in study area

D.Basalt

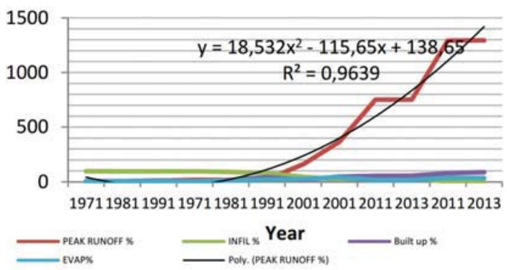


Fig. 9 Peak runoff and Infiltration results for Basalt soil from 1971 to 2013 in study area

D.Charts Showing Variations in Peak Runoff and Components of Hydrological System

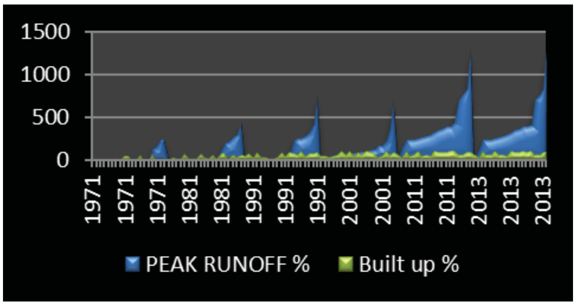


Fig. 10 Correlation Chart (Alluvium): Peak runoff and Infiltration results with Built up for Alluvium soil from 1971 to 2013 in study area

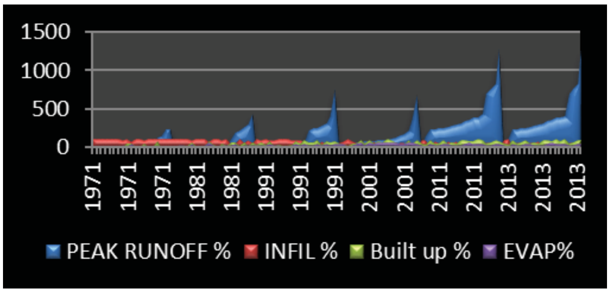


Fig. 11 Chart (Basalt): Peak runoff and Infiltration results with Built up for Basalt soil from 1971 to 2013 in study area

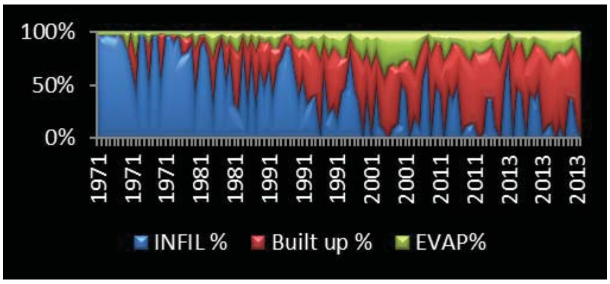


Fig. 12 Chart (Sandstone) Peak runoff and Infiltration with Built up results for sandstone soil from 1971 to 2013 in study area

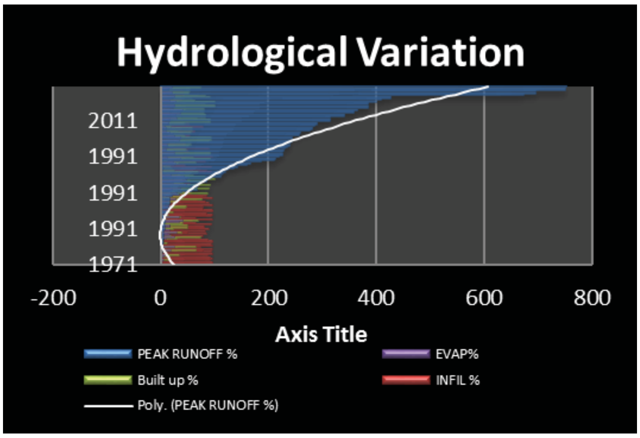


Fig. 13 Chart (Hydrological variation): Hydrological Cycle for infiltration, runff, evaporation and built up for study area

IX. Conclusion

Peak k runoff in almost all catchments have shown changes out of which areas with basalt and sandstone covered with less rough areas had maximum peak discharges. Infiltration has been constantly reducing in years as evaporation and peak flows

A.Ground Water Potential of Geology along with Development

The excellent groundwater potentials areas in the Natural Drainage are intersection points of lineaments and valley fills marked on the map especially in Deccan Trap area, where slope is nearly level to gentle and built up is satisfactory for urban development and natural working. These are contributing to form aquifer zones, this is also realized by well inventory and field observation at villages ChunaBhatti and BairagarhChichli, where artesian condition of some of the wells has been noticed. The area is characterized by presence of loose and unconsolidated material.

AREA A -VERY GOOD TO GOOD

This zone is specially considered for buried pediments of Deccan Trap having gentle slope and medium Built up area. Wells observed in this unit are having less water table fluctuation. The area is characterized by vesicular and basalt with considerable depth of weathering.

(Catchment BSHC-S6, S7, S8, S9, BOCC-S3)
AREA-B GOOD TO MODERATE

This zone is found mainly in the central portion of the study area covered by weathered vesicular basalt filled with secondary fillings having gentle slope. Geomorphologically the area is marked as buried pediment, which is almost flat with little undulations and maximum cultivation.

TABLE VII
FINAL CORRELATION OF BUILTUP, ROUGHNESS AND RUNOFF

Area	Soil	roughness	Vegetation	Runoff	Runoff %	Maximum built up	Balanced Runoff %achieved
Basaltic Sandstone	Sandstone (Clay,Sand, Black Cotton Soil)	0.05-0.17	Bushy, Scanty	Slow	45-50	60-80%	20
Loamy Basalt	Loamy	0.011-0.17	Scanty	Medium	55-60	60-70%	30
Deccan basalt	Loamy Sand	0.24-0.41	Heavy	Very slow	65-70	30-40%	15
Deccan	Silty Loam	0.05-0.24	Interval	Average	30-40	15-20%	25
Alluvial	Silt , Clay	0.17-0.24	Moderate	Low	10-20	80-90%	35

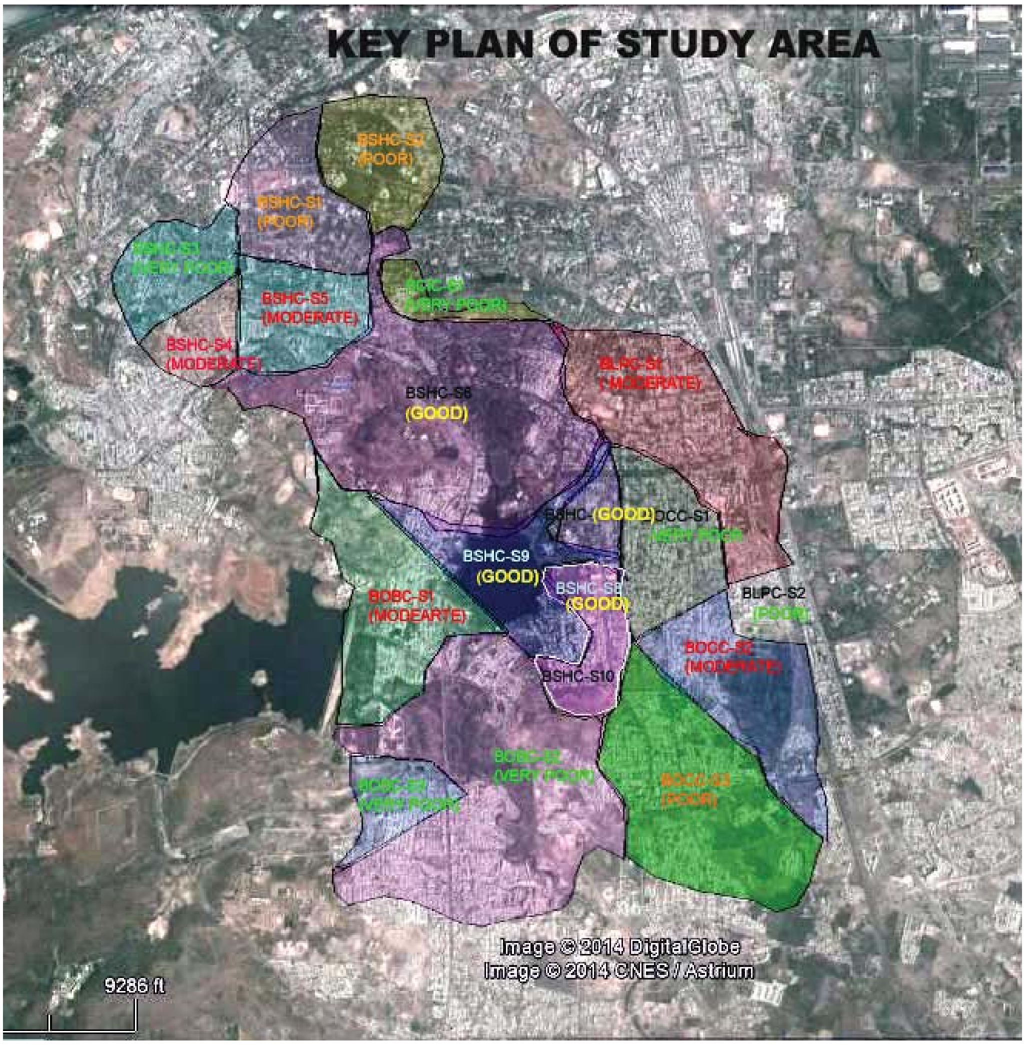


Fig. 14 Areas demarcated as good and poor zone

(BSHC- S5, S4, BLPC-S1, BOCC-S2, BOBC-S1)
AREA-C MODERATE TO POOR

This zone is mainly confined to areas having moderate slopes and minor lineaments, which are playing major role to develop the semi confined conditions. Mesa tops, Vindhyan sandstones are coming under this category and water is moderately available only along lineaments. Scanty cultivation is seen over the area.

(BSHC-S2, BSHC-S1, BLPC-S2, BOCC-S3)
AREA-D POOR

Northern and Southwestern boundary of Natural Drainage is emerged as poor zone for groundwater potential. Residual hills and structural hills of Vidhyan's sandstone come under poor potential. All these hills are covered by dense forest and scanty scrubs.

(BSHC-S3, BOBC-S2, BOBC-S3, BOCC-S1)

X. Conclusions

1. Runoff is directly proportional to land cover and precipitation. The quantity of runoff is very difficult to be minimized or stopped due to the varying precipitation pattern in recent climate changes. But it can be reduced to 40% by proper physical planning.
2. Balanced combination of built up, open space, Geology and Drainage analysis can improve the flash floods and help in recharging the ground.
3. The old approach of moving surface water quickly out through drains needs to be changed as manmade drains are unsuccessful if not designed as Sustainable Urban Drainage. (SUD), instead principle of “catch water where it falls “ should be practiced.
4. Geological characteristics like Deccan trap, alluvial soil and sandstone plays an important role in resulting runoff and recharge depending upon the land cover provided.
5. Urban planning needs special areas to act as interception channels and storage places for surface runoff, along with provision of effective open spaces from plot level to zonal level.
6. Wise land use planning is needed for allocation of resulting land cover and clear regulation are needed for Marginal open spaces in various land uses.
7. Definition of open needs to be revised. Old rules of Ground coverage, FAR should be revised in order to achieve effective open spaces in urban areas.
8. Natural drainages need to be preserved to carry peak discharges.
9. Each parcel of land is drainage itself and hence needs alternative route to play it role when modified.
10. Larger colonies have more scope for recharge pits and open space for holding water compared to small colonies.

References

[1] SienceDaily-IPCC. (2007). Responding To The Impacts Of Human-caused Climate Change. UNEP: http://www.sciencedaily.com.accessed 13.03.2008)
[2] E.B, W. (2004). Thestate of Resource, Chapter 4. Retrieved Sept 11, 2011, from unesco.org: www.unesco.org/bpi/wwap/press/pdf/wwdr2_chapter_4.pdf
[3] H.Hengeveld, C. V. (1982). Role of water in urban ecology. Amsterdam: Elsevier Scientific Publishing Company.
[4] White, E. W. (2006). Chapter 4-The state of Resource. UNESCO,WMO, IAEA, WWDR2. Mexico: 2nd United Nations World Water Development Report: Water, A Shared Responsibility
[5] E.B, W. (2004). Thestate of Resource, Chapter 4. Retrieved Sept 11, 2011, from unesco.org: www.unesco.org/bpi/wwap/press/pdf/wwdr2_chapter_4.pdf
[6] IPCC. (2007). Linking climate change and water resources. www.ipcc.ch/pdf/technical-wpapers/ccw/chapter3.pdf. (accessed 03 23, 2008).
[7] CLimate, I. (2007-2010). Climate change and water resources. Washington: http://www.climate.org/topics/water.html. (accessed 11 08, 2011).
[8] M.Stephenson, B. (2004). Extreme Climatic Events and their evolution under changing climatic conditions. Global Planet Change, pp. 1-9.
[9] WMO, U. &. (2006). The United Nations World Water Development Report 2. Paris: www.unesco.org/water/wwap/wwdr2/pdf/wwdr2_ch_4.pdf. (accessed july 28, 2011).
[10] Marsbug. (2007, December). Natural Drainage Systems as simple inorganic life. Retrieved July 26, 2011, from http://cosmoquest.org/forum/showthread.php: http://cosmoquest.org/forum/showthread.php?90734-Natural-Drainage-Systems-as-simple-inorganic-life
[11] Agvise Laboratories, A. (2001). Agvise.com, soil testing and laboratory services. Retrieved July 2009, from www.Agvise.com: http://www.agvise.com/educational-articles/water-holding-capacity/
[12] Sharma, D. (2015). “Correlating urban system and hydrological system in context of physical planning”. International Journal of Scientific & Engineering Research, Volume 6, Issue 4, April-2015, 1334-1348.
[13] S.Sharma. (2013). Statistical change detection in water cycle over two decadesand assessment of Impact of Urbanization. Open Journal of Modern Hydrology, Scientific Research, 165-171.
[14] CWC, W. (1988). Flood Estimate report for Chambal Subzone-1(B). New delhi: Hydrology (Small Catchment), Directorate,Central water commission.
[15] CGWB. (2014). Bhopal water Prospects. Bhopal: Centra Ground water Board.