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Integrating Micro Watershed Management for the Evolution of Physical Development Plan

Case Study: Central University of Rajasthan Bandarsindri

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Abstract: Water is an important and limited abiotic resource on our planet earth, thus the judicious use and conservation of this life giving resource has become avital aspect of sustainable development. By 2011 census, India's decadal growth rate of population was17.64% along with the cumulative urbanisation of 31.16%. It has critically increased the consumption of fresh water and concurrently depleting and polluting many of the water sources. The current scenario is leading towards the water-scant future which is against the very objective of the sustainable development. To ensure the availability of water to each individual as per the prescribed quality and quantity standards, the physical planning process should assimilate the macro and micro level watershed management strategies as essential base layer. The selected case study, Central University of Rajasthan, Bandarsindri in Ajmer district of Rajasthan, is one of the live models of this kind of practise.

Key *words: Water, Micro-Watershed, Surface Runoff, Campus Master Plan*

1. Introduction

Like land water has also been the essential natural resource from the beginning of the human civilization. On our planet this is available as surface and ground water,of which 97% is saline seawater and only 3% is available as fresh water. Out of this 3% of fresh water over 2.5% is frozen, locked up in Antarctica, the Arctic and glaciers, and not available to man, Thus only 0.5% is available for whole of mankind and the fresh water dependent ecosystem. The continuous growth in Indian population i.e. 1210.19 million by year 2011 with 17.64% decadal growth rate and 31.16% urbanization has diabolically increased the demand of fresh water for various activities. The fresh water available in the surface water bodies and the ground are not only getting polluted through various solid and liquid wastes but also getting rapidly depleted.

In addition to the existing settlements which are already in shortage of water, many new physical developments like townships, industrial units, academic campuses etc are emerging with all new modern infrastructure and amenities. Such developments are radically dependent on nearby available natural water resources. In many cases these developments are creating conflict amongst all the concerned stakeholders. As per the Millennium Development Goal, the adequate availability of fresh water as per prescribed standards is essential for sustainable development. To fulfil this objective there is need to ensure the availability of surface and ground water by pragmatic and location specific solutions on macro as well micro watersheds. Watershed is a natural system which functions in a manner to collect, store, and release water to a common outlet, such as a larger stream, lake, or ocean. The quality and quantity of surface runoff and the ground water in a particular watershed depends on the climate, geographical and geological profile of the land and the vegetation. Watershed is the integral entity of any geographical region thus any physical development or land use planning should be in concurrence to enhance the capacity of holding water for sustainable ecosystem and human habitation. To have such development it is important to adopt the practice of integrated watershed planning on macro as well micro level. Traditional Indian settlements in all the regions were developed specifically in conformity with the existing water resources. Unfortunately in modern planning system this fundamental practice has been overlooked, resulting in both water scarcity and quality degradation in various regions of the country. Many scientific studies of urban disasters are now endorsing this fact and it is time we should plan in accordance with the watershed.

2. Aim of the study

i. Developing a model **of** Micro Watershed Management at the neighbourhood scale **using** the method of micro level drainage analysis, quantification of surface run off and conceptualisation of surface water bodies and drainage infrastructure to harvest the optimum surface runoff.

ii. Optimization of the neighbourhood population by using the recycled water and simultaneously minimizing the net use of available fresh water.

iii. Formulation of water perceptive campus master plan by assimilating the micro watershed management plan as thematic base layer at neighbourhood level.

3. Study area: Central University of Rajasthan Bandarsindri, Ajmer, Rajasthan

3.1. Physical setting

Government of India has proposed fifteen new Central universities by an act of parliament in 2009. Among these the Central University of Rajasthan has also been proposed, to promote research and higher education in Rajasthan. To establish the university campus, 518 acre (209.63 Ha) of land was acquired at Bandarsindri panchayat in Kishangarh Tehsil of Ajmer district. The geographical co-ordinate of the campus is 260 37' 35" N & 750 01' 40" E. The campus falls under the Delhi Mumbai Industrial corridor and it is 1.3 km away from the Delhi Mumbai NH no. 8. The nearest railway station is at Kishangarh, which is 23 km away and the nearest airport is at Jaipur which is 90 km away

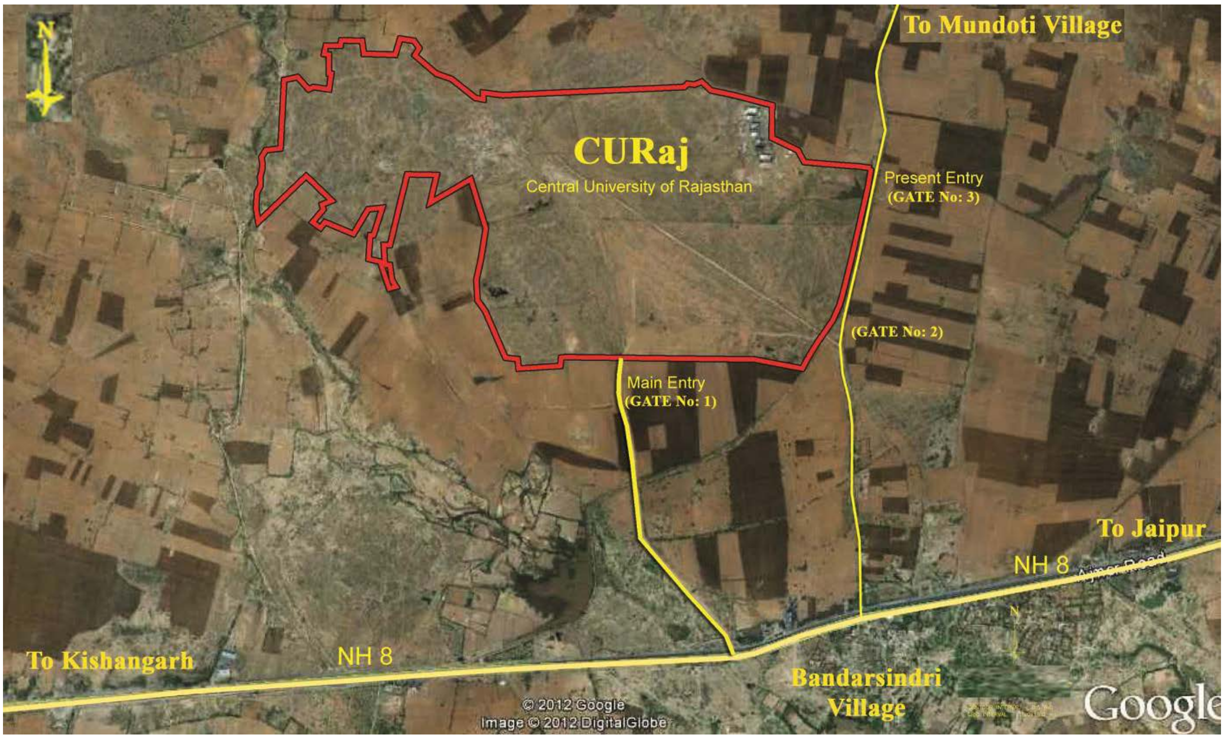

Figure 1: Location Map of CURaj Bandarsindri Campus

3.2. Climate

The site falls under hot and dry climate zone of India. It experiences high diurnal temperature difference during summer and less rainfall in monsoon. The average precipitation is 529 mm which is significantly less than the national average rainfall of 1100 mm per annum. The number of rainy days in a year is sixteen, amongst these nine to ten events are of high intensity rain falls, which pours almost 80% of rain in this area which has significant importance for surface runoff generation. The evapo-transpiration losses are very high i.e. 2420 mm per annum. Especially during non-rainy months, because of high temperature and low humidity the evapo-transpiration losses are very high which means high evaporation losses from the surface water bodies and transpiration losses from vegetative cover. Following is the 100 year (1901-2000) climatic data summary of Ajmer district sourced from the Indian Meteorological Department (IMD) and National Remote Sensing Centre (NRSC).

Month	Mean Temperature ^{0}C		Mean Rainfall in mm	Evapo-Transpiration (mm/ day)	Evapo-Transpiration (mm/ month)
	Max	Min			
January	22.9	7.6	7.3	5.1	158.1
February	25.7	10.3	6	5.8	162.4
March	31.3	16	5	7	217
April	36.5	22.2	4	8.1	243
May	39.7	26.8	15.7	8.6	266.6
June	38.4	27.5	58.1	8.15	244.5
July	33.6	25.6	181.5	6.6	204.6
August	31.3	24.4	157.5	5.6	173.6
September	32.6	23.7	73	6.4	192
October	33.5	18.8	13.1	7	217
November	29.2	12.3	4	6	180
December	24.7	8.4	3.8	5.2	161.2
Total			**529 mm**		**2420 mm**

Table 1: Climate Data (Ajmer District)

Source: Indian Meteorological Department & National Remote Sensing Centre

3.3. Land form (Topography)

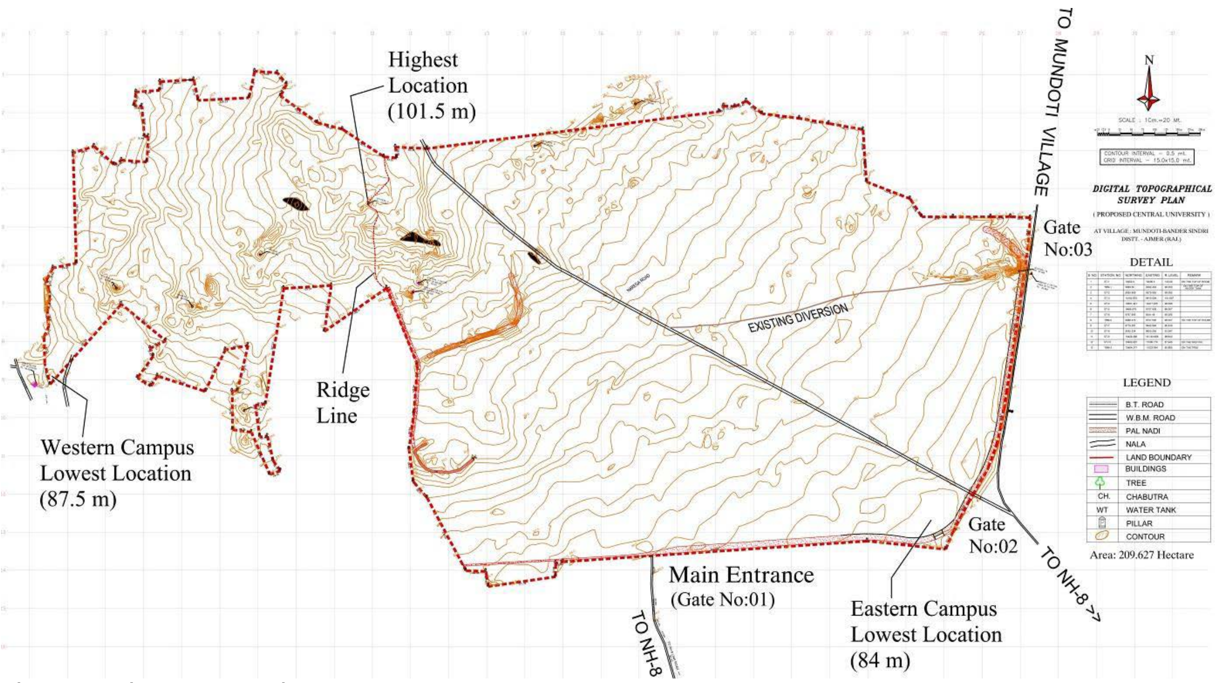

Figure 2: Site Topography

Site is broadly distributed in two watersheds. The eastern part of the site is having slope towards south east direction. The highest point in this pocket is 101 m and the lowest point is 86 m as per contour sheet made available by CPWD. There is a drop of 1 m in every 150 m in this particular pocket. The western pocket of site is sloping towards western side. There is a drop of 1 m in every 100 m in this particular pocket. There are some identified drainage channels and three natural depressions (as marked in map) on the site, which becomes important in terms of channelization and collection of surface runoff within the site premises.

3.4. Natural and manmade site features

The acquired land was the part of pasture land. The village people had free access to this land for cattle grazing purpose. To access the site a kutcha road was constructed under MGNAREGA scheme. An earthen bund next to the mining pit and central highland was also constructed to collect the surface runoff under this scheme. Village people also constructed a diversion structure to divert the surface runoff to the depression located at third gate. Considering the importance of these structures for surface runoff collection the University has decided to conserve it.

3.5. Site Geology& Soil

Geological strata of site consist of weathered rock, of five meter depth from surface and then formation of hard rock strata which are Granite (Igneous rock) and Schist (Metamorphic rock). At some places the weathered rocks are also exposed to natural conditions over the ground.

In every rain the weathered rock erodes and get converted to the bajri and then further into soil. The soil depth on this site is minimal which varies from 0.4m to 2.4m. The soil is loose sandy soil with little clay whose water holding capacity is not good

3.6. Ground water

Because of weathered and hard rock strata the possibilities of homogenously distributed unconfined aquifer system is minimal. Only some non-perennial confine shallow aquifers are available below the weathered rock which can be rejuvenated by continuous recharge through the collection of surface runoff for two to three years. By recharging such confined dry aquifers we can create sufficient water bank for the dry months of the year. This process will also reduce the salinity and hardness of ground water. The pH value of ground water is within prescribed limits of IS code 10500.

3.7. Vegetation

The campus had minimal canopy vegetation due to scarcity of water and poor soil quality. In beginning the campus had only three trees, those were one Neem tree and two Khejdi trees. The entire landscape is covered with drought resistance shrubs like vilayati babool, cactus (Opuntia ficus-indica) and varieties of native desert shrubs.

3.8. Expected Demography

Since Rajasthan is a water scarce state, thus considering the less gross density of 60 person per hectare, the expected population of the university would be approximately 12,500 by 2025, of which 8,500 will be students and rest 4,000 will be university employees (teaching and nonteaching both) and their family members.

4. Runoff Potential Characteristics

The site has dynamic runoff potential which generates enormous surface runoff during rain. This characteristic is analysed in the following manner.

i. The site has a slope of 150:1 in eastern pocket and 100:1 in western pocket. With very less vegetative cover and less soil depth such slopes create very high surface runoff in both the pockets. Detail drainage analysis is done to calculate the surface runoff potential of natural ground. In this study the site was divided into nine micro catchments and then the micro channel behaviour was studied on the basis of rainfall events, natural topography and manmade structures. In this micro catchment analysis the eight possible depressions were also finalized to collect the maximum surface runoff.


Figure 3: High runoff during rain


Figure 4: Surface runoff carrying huge silt

ii. The less depth of soil, which is sandy with little clay has poor water holding capacity, it saturates comparatively in short time span and then allows all the rain to flow as surface runoff. Because of this specific property of the soil the high intensity rainfall with longer span results into the high surface runoff.

iii. As the vegetation on site is minimal the speed of surface runoff is very high. This increases the soil erosion and huge soil deposition in low lying areas.

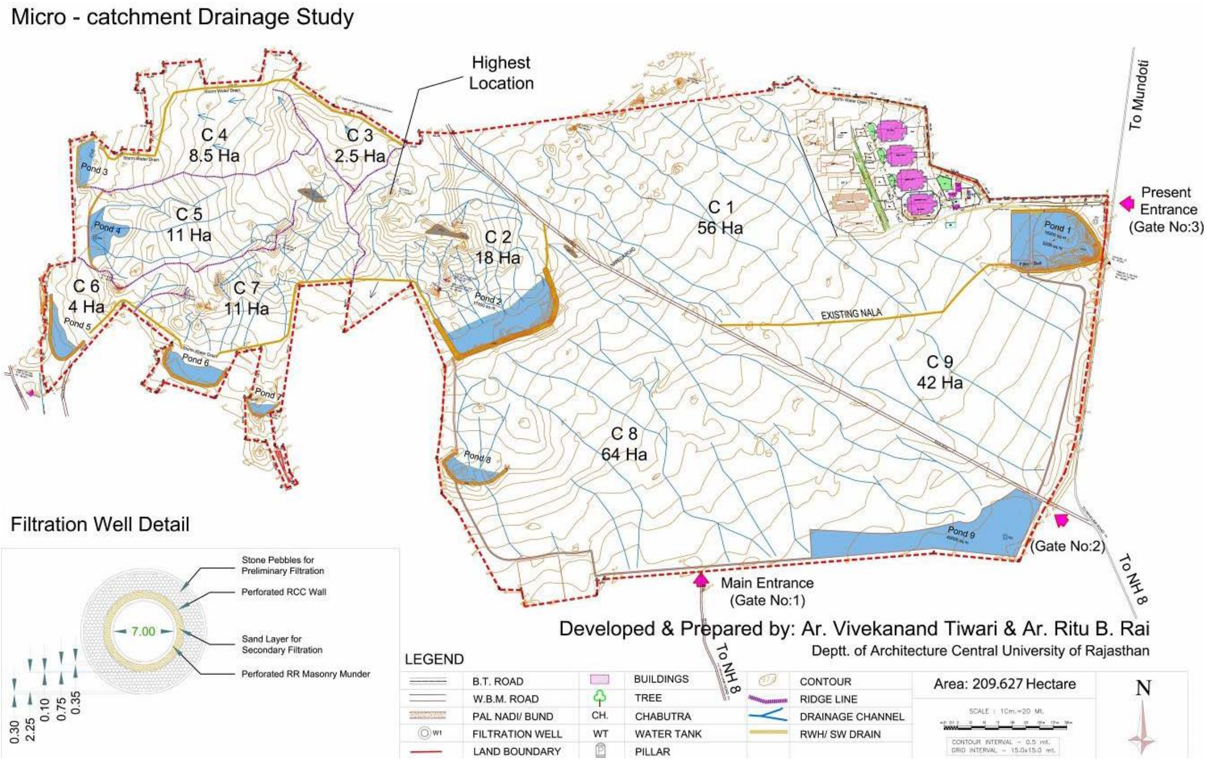

Figure 5: Micro Catchment Drainage Study

iv. As per the field study conducted during rain events, the runoff coefficient of the eastern campus (C1, C8 & C9) is estimated 0.40 and in the western campus (C3, C4, C5, **and C6**& C7) is 0.60. The central highland, next to the mining pit (C2) is having the runoff coefficient of 0.50. The runoff coefficient of western campus and area close to the central highland is high because of high degree of slope, very minimum soil cover, hard geological formation and less vegetative cover.

5. Surface Runoff, ground water recharge and ET losses at Micro Watershed Level

For the catchment wise water harvesting the detail drainage study was conducted at micro catchment level to explore the major and minor flow channels along with the probable runoff collection pockets. The table 2 shows the catchment wise runoff generation, ground water recharge and evapo-transpiration (ET) losses based on following criteria:

a. Only 80% of annual average rainfall will generate surface runoff
b. The surface water bodies as well as the vegetative cover will lose 60% of surface water as evaporation and transpiration respectively.

Catchment	Area (Ha)	Runoff Coefficient	Surface Runoff (Cum)	GW Recharge during rain (Cu m)	Evaporation + Transpiration Loss (Expected 60 %)
	A	C	R = A x 80% RF x C	GW_R = A x 80% RF x (1-C)	ET = R x 60/100
C1	56	0.40	94796.80	142195.20	56878.08
C2	18	0.50	38088	38088	22852.80

C3	3	0.60	7617.6	5078.40	4570.56
C4	9.5	0.60	24122.4	16081.60	14473.44
C5	9.5	0.60	24122.4	16081.60	14473.44
C6	5	0.60	12696	8464	7617.60
C7	14	0.60	35548.8	23699.20	21329.28
C8	70	0.40	118496	177744	71097.60
C9	24	0.40	40627.2	60940.80	24376.32
Total	**209**		**396115.2**	**488372.8**	**237669.12**
Net Harvesting			**$R + GW_r - ET$ = 646818.88 Cum**		

Table 2: Catchment wise surface runoff, ground water recharge & evapotranspiration losses

6. Net water availability and optimal population size

Water harvested in surface water bodies and as ground water will be supplied through a well-planned system for various usages considering the following practicality.

a. Only 80% of the ground water can be possible yield
b. The system losses in the supply of water from the surface water bodies and ground water exploration wells are 20%.

Thus the net available water (fresh water) = 80% of ($R + 0.8GW_R - ET$) = 439315.45 Cum

Being a limited natural resource in Rajasthan, the water should be used in very judicious manner. By conserving and recycling the available water we may accommodate more population as demonstrated in following scenarios:

6.1. **Scenario1: Using 100% fresh water**

As per National Building Code 2005 the per capita per day consumption of water is 135 litters. Ensuring this standard and on the basis of net availability of water the optimum population of the campus will be,

Optimum population$_{(1)}$ = Availablewaterx1000/ (135lpcd x 365) = 8915person

6.2. **Scenario2: Using fresh water &Recycled water**

The optimum population of the campus can be increased by using the treated water which will be supplied through the separate line from the waste water treatment plant. To meet the National Building Code 2005 standards, conventionally 45 litres per capita per day fresh water has been used in flushing if water is supplied at 135 litres per capita per day (lpcd). If recycled water is being used in flushing then the fresh water demand can be reduced to 90 lpcd from 135 lpcd. Thus the optimum population of the campus will be

Optimum population$_{(2)}$ = Available waterx1000/ (90lpcd x 365) = 13373 person

Thus by recycling and reusing the treated water we can accommodate more population than the projected figure of 12,500. The total waste water to be generated after various uses will be 80% of total supplied water which will be

Waste water per day **=** 0.8x90 lpcdx13373 Person = 9,62,856 lpd

Considering the output efficiency of wastewater treatment plant is 80% the treated water volume will be 7,70,284.80 lpd. As per the construction manual developed by the Ministry of Environment and Forest (MoEF), the latest water conserving toilet fixtures are recommended to use only 21 lpcd water for flushing. Hence for the population size of 13373, the required treated water for flushing will be only 2,80,833 lpd, the rest volume of water (4,89,451.80 lpd) can be used in housekeeping, floor cleaning and landscaping activities by laying the separate supply line.

7. Water Perceptive Campus Master Plan

To instrument the concept of integrated micro-watershed management plan as a base layer of development plan of the University the three large and five small surface water bodies were conceptualized to ensure the maximum surface runoff collection during the rain. Three of these eight water bodies proposed in zone C1, C2 and C8 were planned to develop with the help of earthen embankment. One of the reservoirs in zone C8 was conceptualized to develop by deepening the already existing depression. Rest four comparatively small surface water bodies were proposed in zone C4, C5, C6 and C7. The water bodies have been planned and developed with the cost effective practices.

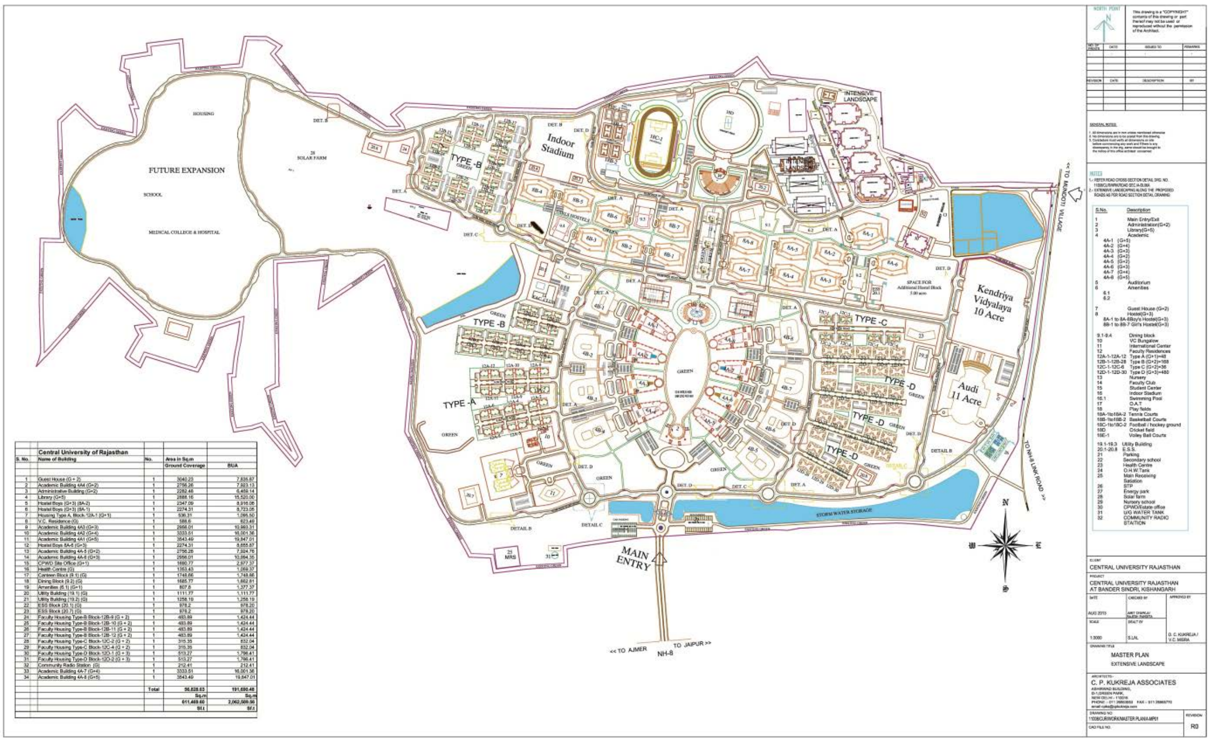

Figure 6: Water Perceptive Campus Master Plan

i. On the basis of Micro Catchment Drainage Analysis the storm water drainage plan has been developed to channelize the inland drainage to capture the maximum possible surface runoff during the rains.

ii. Initially the existing water channels were enhanced, channelized and directed to feed the water bodies. Later on these channels were replaced by the underground storm water drainage system.

iii. The water bodies are designed with filtration bed to ensure the quality of surface runoff reaching to the main reservoir.

iv. The average depth of three major water bodies is 3.0 to 3.5 m to increase the holding capacity and minimise the evaporation losses of these water bodies with less surface area.

v. In principle all the water bodies are developed without base lining. The logic behind this is to ensure the continuous ground water recharge.

vi. As inspired by traditional practice in Rajasthan the Bentonite or the similar quality soil which is locally known as **Murud** has been identified as unique material to avoid any seepage from these water bodies.

8. Results & Conclusion

i. In comparison to earlier proposals of the Master Plan the final revised Campus Master Plan in principle acknowledges the importance of natural site drainage. The Integrated Micro Watershed Management Plan has been used as a tool to develop the Water Perceptive Campus Master plan. Water bodies are incorporated to hold the surface runoff, augment the ground water table and enhance the overall ecological and environmental condition of the campus. The exercise enhanced the carrying capacity of the earmarked campus and also ensures the water availability for upcoming generations.

ii. In first phase, the half portion of the first water body which is located at gate no: 3 was developed with the lining of HDPE layer. Later the remaining portion of that was developed without lining. The lined portion of the water body dries by the month of April, whereas the non-lined portion uses to be perennial. The comparable result of both portions endorse that the continuous ground water recharge from the non-lined portion has successfully revived the confined aquifers of that particular pocket.

iii. Deepening the water bodies has increased the ground water recharge rate as well as reduced the direct evaporative losses due to reduction in the surface area of the stored water.


Figure 7: View of pond at gate no:3 from the Estate Office of the University


Figure 8: Evolution of physical form around the pond at gate no:3

iv. The traditional knowledge in the form of age long successful practices should be adopted for the construction of medium scale water bodies. Traditionally the earthen embankments have been used for the construction of the water bodies. To line these water bodies the Bentonite like soil which is known as Murud (localy) is used in various parts of Rajasthan. The correct application of Murud or Bentonite fills the large and fine voids in base surface of the water bodies. Murud or Bentonite shows unique swelling property and sticky behavior in presence of moisture, which allows it to remain fixed for long time. Even after filling the major gaps, voids and cracks it never stops the ground water recharge process which is remarkable.

v. The absence of vegetation increases the run off velocity, which erodes the top soil and increases siltation in various pockets, which may choke the storm water drainage system as well as decrease the holding capacity of water bodies. Thus Soil Management through native species should be implemented as an important strategy for such integrated micro watershed management.

vi. The revival of confined aquifers is positively helping the vegetation to grow and also ensures the availability of ground water during the dry months. Because of such revival the water bodies have attracted many bird species of this region.

vii. Maintaining water quality as per IS 10500 standard is essentially important for overall Micro Watershed Management. Treatment of waste water is required to reuse the waste water in various activities like flushing, landscaping, street cleaning etc. The high efficiency treatment facility is capable of enhancing the carrying capacity of the water.

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