A Report of

Watershed management initiatives in the campus of School of Planning and Architecture at Bhauri, Bhopal

Submitted to:
School of Planning and Architecture

Prepared by:

NCHSE

National Centre for Human Settlements and Environment

E-5/A, Girish Kunj, Arera Colony, Bhopal.
Ph. No.: 0755-2465306, 2463731, Fax No.: 0755-2465651
Email: nchsebpl@gmail.com; Web-site: www.nchse.com

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1	S.P.A. Bore no -1	30	193
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A Report of Watershed management initiatives in the campus of School of Planning and Architecture at Bhauri, Bhopal

1. Introduction:

Watershed management needs no explanation to combat water crisis. In fact, its application is more useful in limited area with constraints of the scanty or irregular rain fall, inadequacy of underground water availability, prevalence of impervious rocks resulting into area being waterlogged.

NCHSE, the premier institution of watershed management and ecological development, started working on watershed in the districts of Madhya Pradesh since 1993. NCHSE's project in Jhabua on "Environmental and Soil Degradation Control" was awarded for the United Nations Environment Programme's International Award in the year 1995. Where ever, NCHSE carried out the activities of natural resource management, the local community has taken full advantage of the initiatives and as a result of which, there is change in the socio-economic conditions of the people especially of marginalized sections of the society. The other important part aspect of these interventions is that there is transformation in barren hillocks to lush green areas, increase in underground water level of water bodies, availability of fodder and advancement in agricultural practices. Most importantly, the precious natural resource `water' has helped to find out sustainable livelihood to the people in the countryside.

Watershed is not confined to the rural areas, its application is equally important in upcoming towns and cities which are under constant threat of urbanization and population increase. To get desired results, in urban areas is more challenging task. NCHSE in the year 2003-04 had planned watershed based activities in Rajiv Gandhi Technical University, as a result of these initiatives, the water crisis of RGTU, Bhopal was mitigated. In fact, in the campus of RGTU, ridge to valley approach adoption provided a meaningful solution in increasing under ground water level of the existing bore wells and collection of water in a pond located on the down side of the campus.

In urban areas, roof top water harvesting has been taken up as a good source to augment underground water. NCHSE has carried out roof top water harvesting in Ujjain and Jhabua. These experiments have provided much desired results to meet water requirement during the period of crisis. NCHSE developed a model project for Pratibhavan Shashkiya Vidyalaya, Ujjain for the students with the support of Gas Authority of (India) Limited. The entire campus of Vidyalaya is now in a position to meet water requirement of its students as well as of plants and vegetation.

School of Planning and Architecture, Bhopal, an Institute of National importance, is established by Government of India in the year 2008. Its new campus would come up at Bhauri which is located in Phanda block of Bhopal district and at a distance of 27 kms. from Habibganj railway station. The campus of the institute is spread in an area of 77 acres which is to be covered under built up area for the requirement of academic and administrative complex, hostels, bungalows, commercial complex, roads network, open area for sports, greenery, etc.

One of the immediate concerns of the SPA area is that water availability at the site is deficient and in the coming time the situation would be more alarming for the rising demand coming from the students and staff of the institute if adequate or alternative measures to cope up the situation are not taken up. The task is difficult with the prevalence of impervious rocks. A solution to this can be searched with the help of possible interventions of watershed management in the available open area in unison with the planned area.

2. Possible interventions:

The following points have been viewed while exploring interventions:

a. The area of campus, by and large, is covered by imperious rocks which results into minimum recharge of underground water during rains.

b. Area gets waterlogged in the rainy season (one of the reasons area being waterlogged is that the fine grade black clay soil of 2 to 3 mts. from upper lake of Bhopal is being dumped at Bhauri site).

c. With the minimal recharge of underground water, the water availability from the ground is inadequate.

d. With the coming up of construction activities (buildings, road, park, play grounds, parking space, etc.) in all parts of the campus, the space is limited to watershed management and ecological development.

Based on above facts, the following activities have been taken up to determine the watershed management initiatives:

- Geophysical survey.

  To point out fractures, liniments and aquifer for water conservation in the open area of SPA campus.

  To estimate the groundwater potential based on hydro-geological investigation in the SPA area.

- Planning of watershed activities.

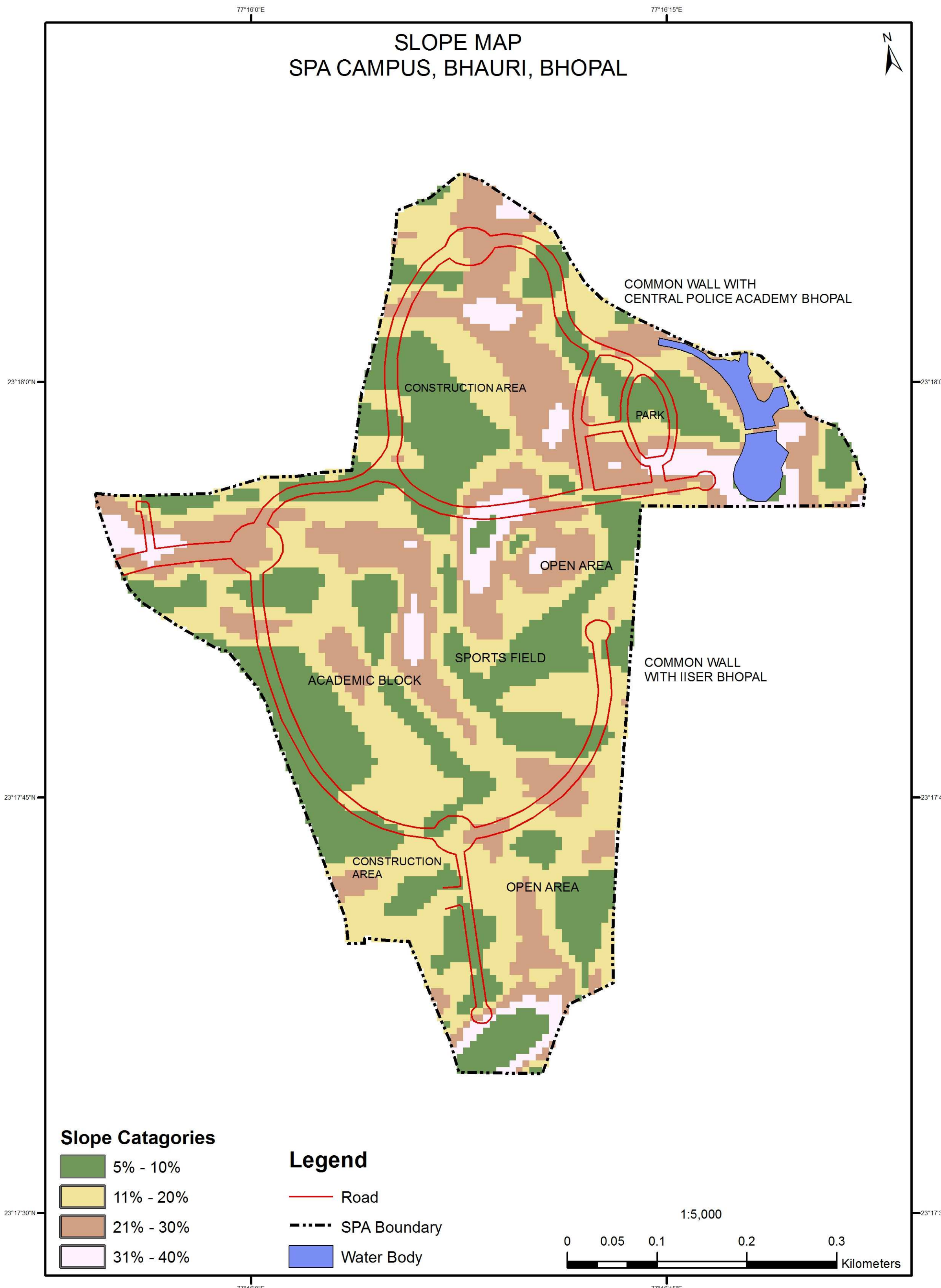
  Watershed activities to eradicate soil erosion, moisture conservation, impounding of water in ponds, ground water recharge, vegetation and plantation.

- Action plan and GIS mapping.

  Development of an action plan based on geo-physical survey and field visits.

  Completion of GIS mapping in respect of the following themes:

  - Slope map of SPA campus to know the direction of flowing water in the area.
  - Map indicating existing and proposed bore wells to be taken up for the purpose of underground water recharge.
  - Distribution net work for the planning of under ground water recharge of the existing and proposed bore wells through roof top water harvesting.
  - Action Plan map indicating watershed activities including bunding, loose boulder structures, gabion structures, farm ponds, vegetation, plantation, etc.
  - Complete map of all proposed activities.


SLOPE MAP
SPA CAMPUS, BHAURI, BHOPAL
N
COMMON WALL WITH
CENTRAL POLICE ACADEMY BHOPAL
CONSTRUCTION AREA
PARK
OPEN AREA
SPORTS FIELD
ACADEMIC BLOCK
COMMON WALL
WITH IISER BHOPAL
CONSTRUCTION
AREA
OPEN AREA
Slope Catagories
5% - 10%
11% - 20%
21% - 30%
31% - 40%
Legend
Road
SPA Boundary
Water Body
1:5,000
0 0.05 0.1 0.2 0.3
Kilometers

3. Geo-physical survey:

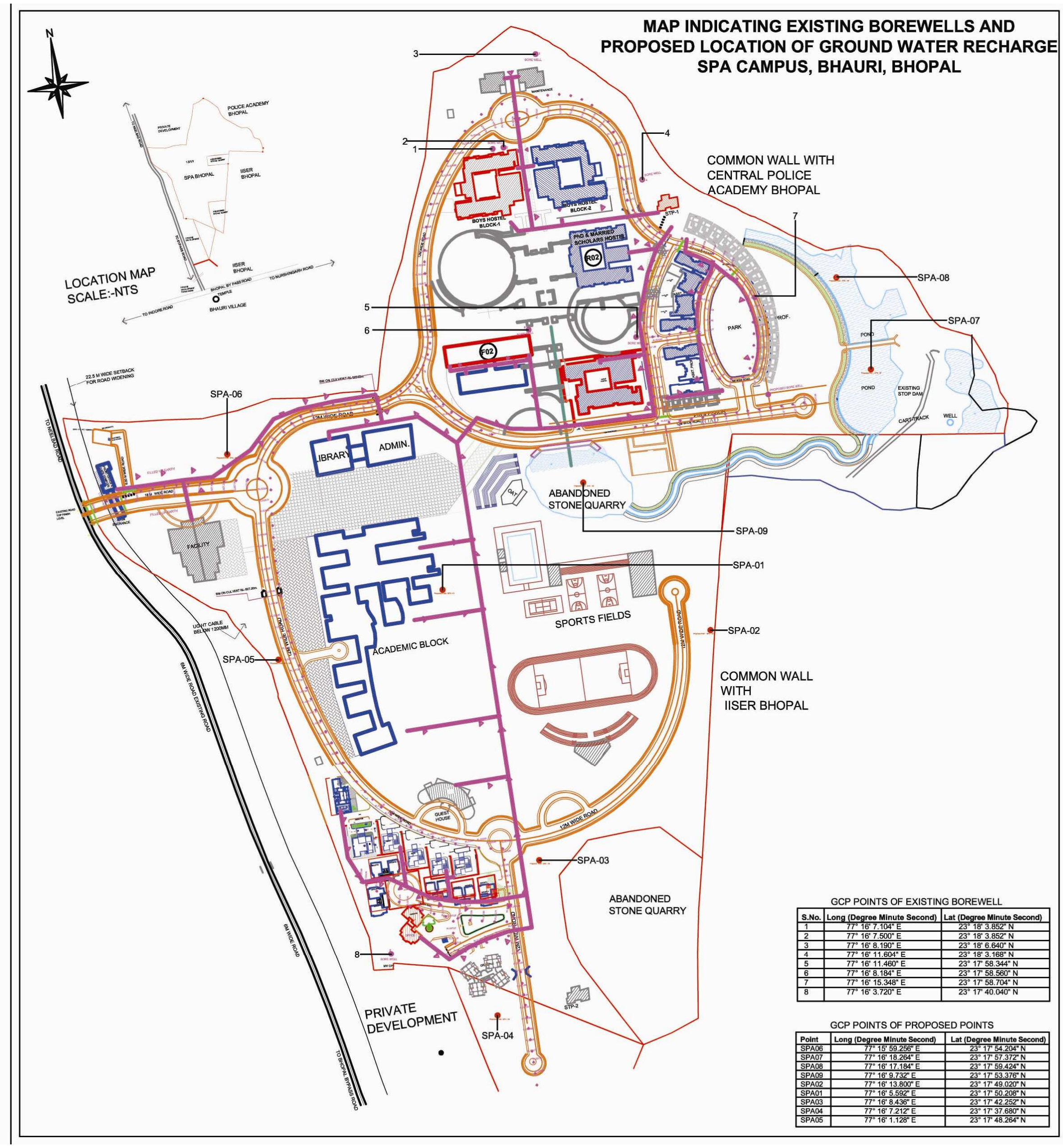
NCHSE combined its team of technical experts, subject matter specialists and field staff to conduct geo-physical survey at SPA Bhauri site. The survey was conducted by the team during the period commencing from 19th March, 2013 to 26th March, 2013. In carrying out the field work, the team members got full cooperation and support from Dr. Ajay Vinodiya, Mr. Maksood Alam Ansari, Mr. Ramendra Singh Sisodiya, Mr. Hemant Joshi and others.

In order to acquire quantitative data on aquifer thickness and aquifer resistivity survey techniques - (a) Horizontal Electrical Profiling (HEP) to determine lateral variations in earth resistivities and (b) Vertical Electrical Sounding (VES) to determine resistivity variations with depth have been applied in nine locations. The technical details of the survey are given in annexure-A.

The nine locations which have been tested have been shown on the map as SPA1, SPA2, SPA3, SPA4, SPA5, SPA6, SPA7, SPA8, SPA9. Based on technical analysis of VES data, low resistivity zones encountered at sounding location SPA1, SPA3, SPA4, SPA5, SPA7 and SPA8 may act as aquifer. These recommended locations may be drilled down to a depth of about 150 to 180 mts.

Out of these recommended six locations (SPA1, SPA3, SPA4, SPA5, SPA7 and SPA8), two of the locations SPA7 and SPA8 are adjoining with pond no.2 on the down side of the campus. Interestingly, as per technical findings, sediment immediately below at pond no. 2 (SPA7 and SPA8) sampled from ground surface down to 27m do not show any remarkable change in lithologic character. The low electrical resistivity value of the sediment indicates they are predominantly weathered / fractured basalt rock.

As evident from technical survey, two recharge shaft may be dug at location SPA7 and SPA8 (pond no. 2) down to 15 mts. from ground level (pond bed) with a diameter of 2.5 mts. The top of the shaft is kept above the pond bed level. Shafts will be back filled with boulders, gravels and coarse sand (Annexure-B).



GCP POINTS OF EXISTING BOREWELL

S.No.	Long (Degree Minute Second)	Lat (Degree Minute Second)
1	77° 16' 7.104" E	23° 18' 3.852" N
2	77° 16' 7.500" E	23° 18' 3.852" N
3	77° 16' 8.190" E	23° 18' 6.640" N
4	77° 16' 11.604" E	23° 18' 3.168" N
5	77° 16' 11.460" E	23° 17' 58.344" N
6	77° 16' 8.184" E	23° 17' 58.560" N
7	77° 16' 15.348" E	23° 17' 58.704" N
8	77° 16' 3.720" E	23° 17' 40.040" N

GCP POINTS OF PROPOSED POINTS

Point	Long (Degree Minute Second)	Lat (Degree Minute Second)
SPA06	77° 15' 59.256" E	23° 17' 54.204" N
SPA07	77° 16' 18.264" E	23° 17' 57.372" N
SPA08	77° 16' 17.184" E	23° 17' 59.424" N
SPA09	77° 16' 9.732" E	23° 17' 53.376" N
SPA02	77° 16' 13.800" E	23° 17' 49.020" N
SPA01	77° 16' 5.592" E	23° 17' 50.208" N
SPA03	77° 16' 8.436" E	23° 17' 42.252" N
SPA04	77° 16' 7.212" E	23° 17' 37.680" N
SPA05	77° 16' 1.128" E	23° 17' 48.264" N

4. Ground Water Recharge:

(a) Roof top rain water harvesting:

Ground water recharge by roof top rainwater harvesting is the process by which the rainwater is collected from roof of buildings and used for recharge of ground water. This is an important aspect of water conservation and management as it provides a cost effective means of collecting and storing water for use during the dry period.

SPA area Bhauri has eight bore wells of 150 to 180 mbgl. which are drilled for water supply. The water bearing zones are ranging from 79 to 81 mbgl. and from 140 to 165 mbgl. The aquifer is fractured basalt and vesicular basalt. These bore wells already existing in the campus can be utilized with other possible locations identified during the course of geophysical survey.

Augmentation of the ground water recharge from roof top rain water harvesting may provide appropriate solution to the prevailing conditions of the SPA Bhauri campus (Annexure-C).

As reported, the roof top area of the respective buildings is:

S. No.	Building Name	No. of units	Area of built up roof top (Sq.m.)	Total roof top area (Sq.m.)
1	Main Academic Complex		9911	9911
2	Administrative complex		1360	1360
3	Library and computer center		900	900
4	UG boys hostel		2138	2138
5	PG Boys hostel		2138	2138
6	UG/PG girls hostel		2047	2047
7	PHD & married scholars hostel		1862	1862
8	Director bungalow		310	310
9	Registrar bungalow		190	190
10	Dean bungalow	03	190	570
11	Professor	06	113	678
12	Group-A officers duplex	06	137.5	825
13	Associate Professor duplex	20	110	2200

S. No.	Building Name	No. of units	Area of built up roof top (Sq.m.)	Total roof top area (Sq.m.)
14	Assistant Professor		1920	1920
15	Group-B Officer/ staff		956.85	956.85
16	Group-C Officer/ staff		650	650
17	Guest house		560	560
18	Swimming pool complex		200	200
19	Sports		800	800
20	Auditorium		2000	2000
21	Student activity centre		1325	1325
22	Commercial complex, Bank, PO, Shopping, dispensary, etc.		950	950
23	Gate complex security		250	250
24	Senate building		350	350
25	Maintenance Blocks (A & B)		560	560
	Total roof top area of proposed building (as available)			**35650.85**

Say total roof top area of buildings – 35650 sq.m.

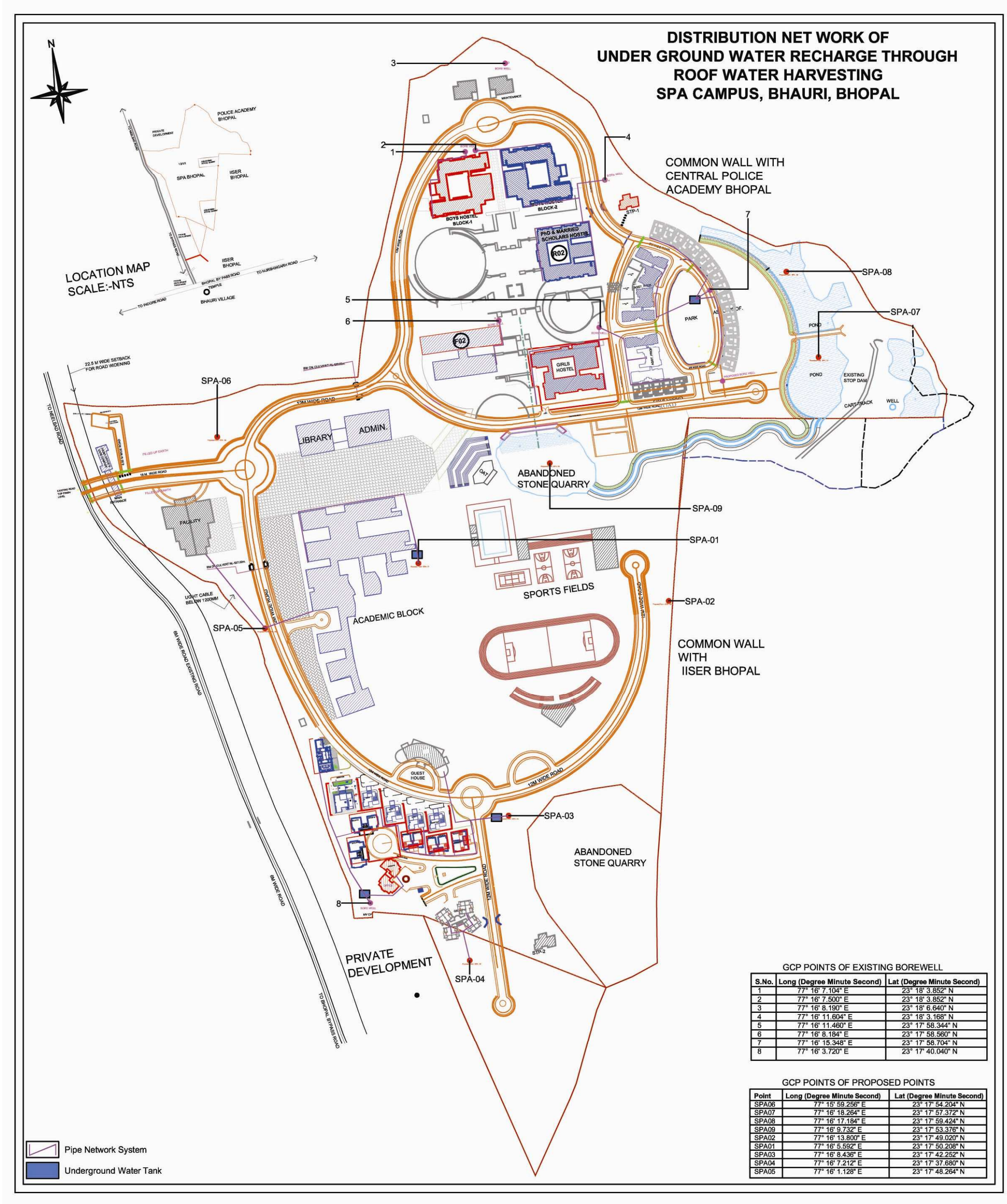
The introduction of a *Roof top rain water harvesting* connected through the outlet system of the Rainwater received from the Roof top of the respective buildings in the campus of SPA is proposed.

No. of Bore well for recharge		Feasible & proposed
Proposed	**Existing**	
04	07	Roof top rainwater harvesting through bore well

A closed system will collect the water from the roof top through a filter to an under ground collection tank. The excess water from the collection tank would then be directed towards the proposed bore well meant to recharge the strata below and thus benefit the existing and the proposed bore wells.

The pipeline system layout is being planned under ground to a depth of more than 2.5 ft. with proper slope (from underground tank to bore well).

The roof top rainwater is channelized through PVC Pipes of 5–inch dia. connected to roof drains to collect rainwater. The first 2-3 showers is set off through the bottom of drain pipe coming from roof after closing the bottom of pipe, the rainwater of subsequent showers is taken through T to an On – line Filter (PVC Filter).



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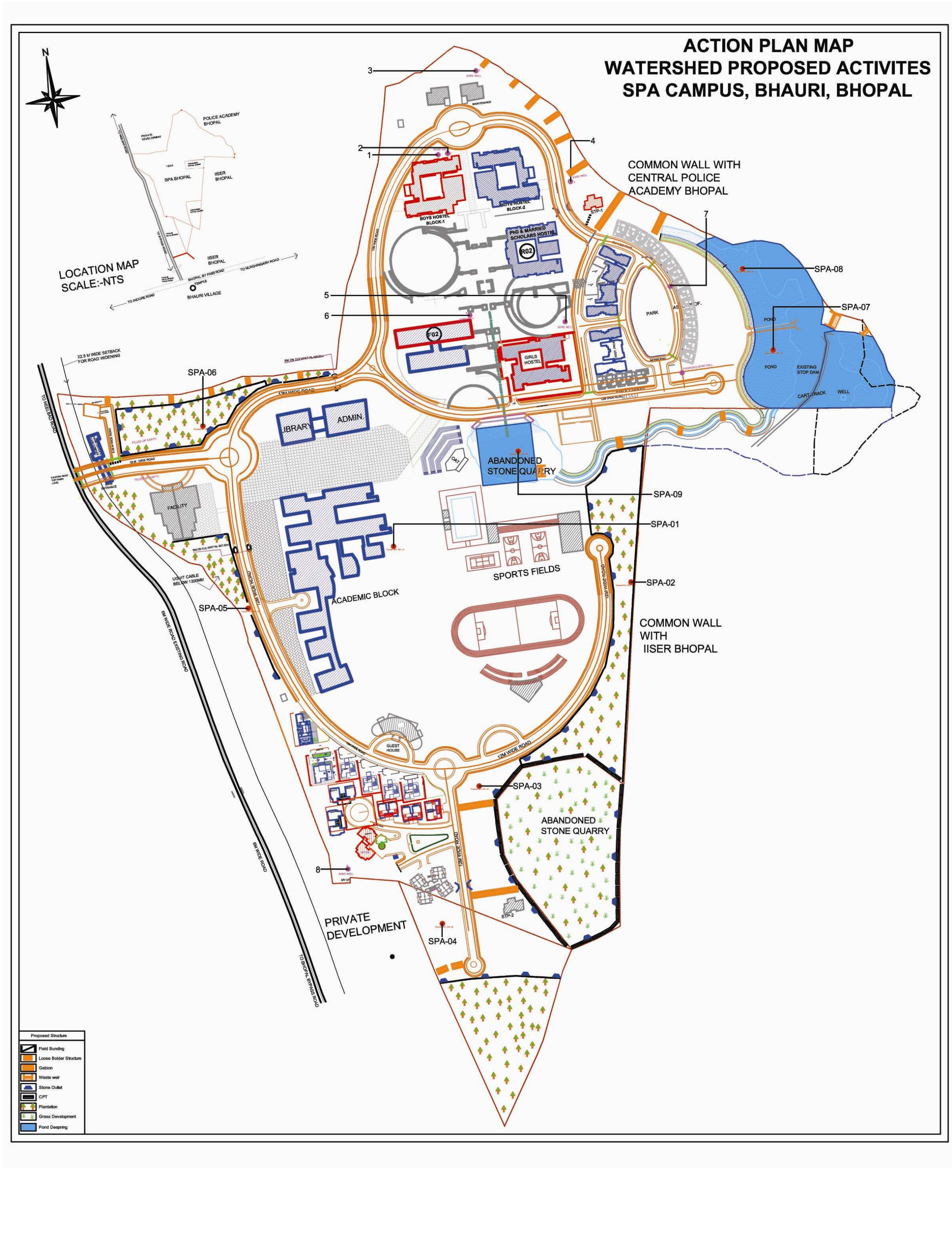
SPA02	77° 16' 13.800" E	23° 17' 49.020" N
SPA01	77° 16' 5.592" E	23° 17' 50.208" N
SPA03	77° 16' 8.436" E	23° 17' 42.252" N
SPA04	77° 16' 7.212" E	23° 17' 37.680" N
SPA05	77° 16' 1.128" E	23° 17' 48.264" N

(b) Planning of watershed activities:

Watershed interventions are useful both in the context of impounding surface water as well as increasing under ground water level. A look into area details of the SPA campus under various usages – proposed built up area, roads, parking, playgrounds, swimming pool complex, etc. shows that some of the very useful watershed initiatives would be extremely useful to provide solution to the demand of water in the campus. Based on field observation, the following set of activities can be taken up:

S. No.	Name of activity	No.	Utility
1.	Bunding	1485 rms.	Checking of soil erosion and moisture conservation.
2.	Stone-out let	27	Checking of soil erosion and moisture conservation.
3.	Loose Boulder Structures	12	To retard the velocity of rain water and to arrest soil erosion.
4.	Gabion structures	8	To retard the velocity of rain water and to arrest soil erosion.
5.	Soil protection trench	520	From the building construction sites, the soil has been dumped to a common point. Soil protection trench would provide a barrier to the flowing of soil in rainy season.
6.	Plantation & vegetation	4.525 ha. (at four sites)	**1.** This will add to environment protection, greenery development and ecological balance. **2.** The dumped site of soil can be developed as a good plantation site with green bed at a later stage when dumping operations are over after the completion of construction works.
7.	Farm ponds	3	**1.** The water available during the rainy season would be collected in the farm ponds and, thus, can be made use for the requirements of SPA. **2.** The ground water recharging at proposed locations SPA7 and SPA8 would raise the underground water level through recharge shafts.
8.	Roof water harvesting	11	Collection of rain water for underground recharge and excess water to be used in farm ponds.
9.	Recharge Shaft	2	Augmentation of underground water recharge.
10.	R.C.C. underground water tank	4	Collection of roof top rain water to meet water requirement.


ACTION PLAN MAP
WATERSHED PROPOSED ACTIVITES
SPA CAMPUS, BHAURI, BHOPAL
N
LOCATION MAP
SCALE:-NTS
COMMON WALL WITH
CENTRAL POLICE
ACADEMY BHOPAL
COMMON WALL
WITH
IISER BHOPAL
BOYS HOSTEL BLOCK-1
GIRLS HOSTEL
LIBRARY
ADMIN
ABANDONED
STONE QUARRY
ACADEMIC BLOCK
SPORTS FIELDS
PARK
POND
EXISTING STOP DAM
WELL
GUEST HOUSE
PRIVATE
DEVELOPMENT
SPA-01
SPA-02
SPA-03
SPA-04
SPA-05
SPA-06
SPA-07
SPA-08
SPA-09
Proposed Structure
Field Bunding
Loose Bolder Structure
Gabion
Waste weir
Stone Outlet
CPT
Plantation
Grass Development
Pond Deepning

5. Action Plan:

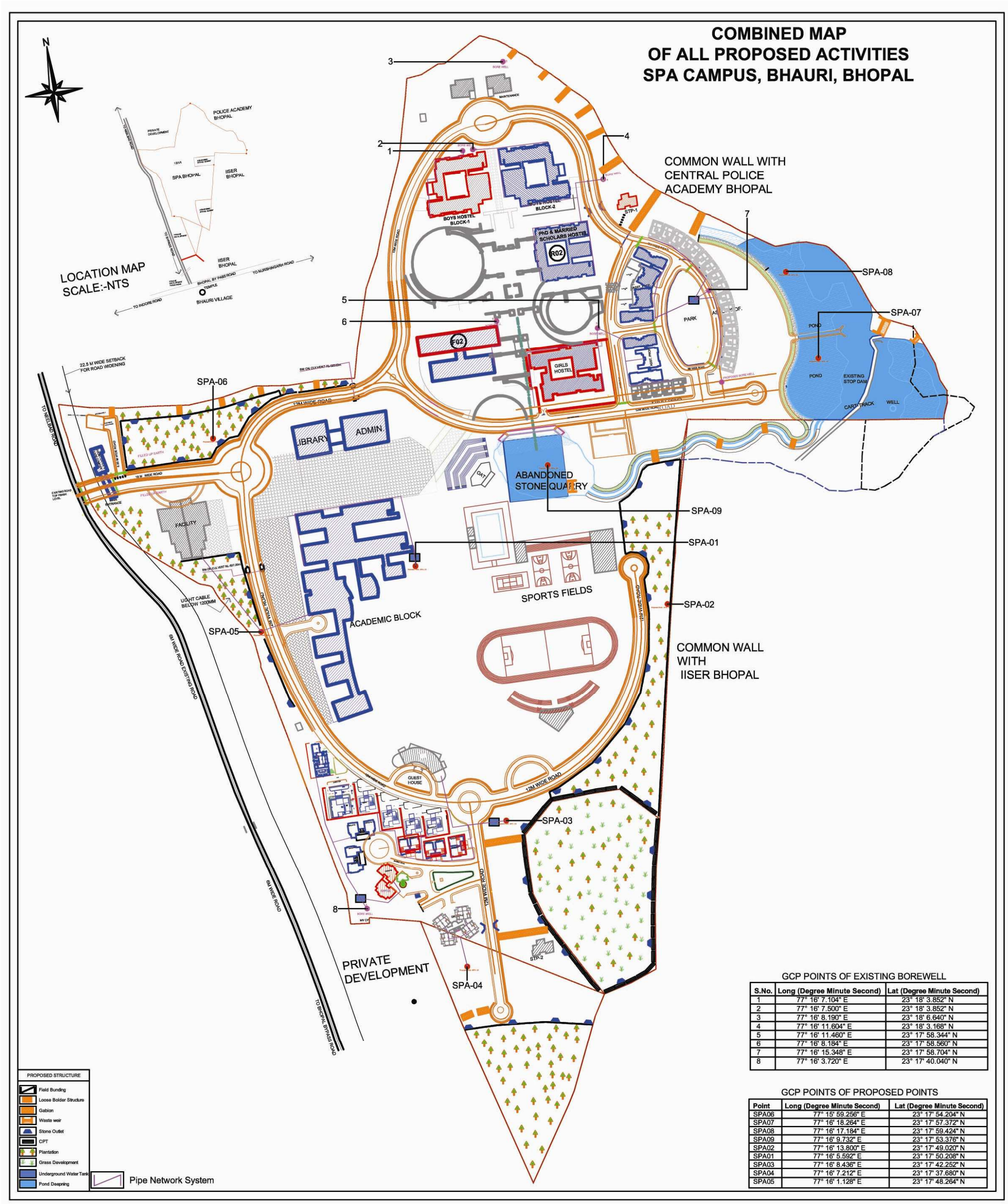
Based on the geophysical survey and subsequent field visits of SPA campus, the area can be taken up for planning of watershed activities and roof top water harvesting to recharge bore wells which are already existing in the campus and are proposed to be taken up as a result of technical study of fractured rock and lineaments. One of the important observations is to take up recharge shaft in the pond of the campus lying on the extreme down side. The details of proposed activities are given below:

S. No.	Type of intervention	Unit	No.	As per DSR		As per RES, CSR	
				Rates per unit (in Rs.)	Proposed cost (in Rs.)	Rates per unit (in Rs.)	Proposed cost (in Rs.)
A.	**Watershed activities**						
1	Bunding -1m(h)Type-1	Rm.	335	243	81405	140	46900
	Bunding -1.50m(h)Type-2	Rm.	1150	391	449650	198	227700
2	Stone outlet structure (1 m.)	No.	27	1811	48897	753	20331
3	Loose boulder structure 7mx0.80mh	No.	2	19435	38870	7168	14336
	Loose boulder structure 5mx1mh	No.	2	18745	37490	6770	13540
	boulder structure 4mx1mh	No.	3	14950	44850	5417	16251
	Loose boulder structure 12mx1.50mh	No.	3	51750	155250	18317	54951
	Loose boulder structure 15mx1.50mh	No.	2	65550	131100	22750	45500
4	Gabion Structure(15.00M x1.5mh)	No.	1	169050	169050	164000	164000
	Gabion Structure (20.00M x 1.00mh)	No.	1	174800	174800	186000	186000
	Gabion Structure (20.00Mx1.80mh)	No.	1	220800	220800	213000	213000
	Gabion Structure(25.00M x2.0mh)	No.	1	346150	346150	317000	317000
	Gabion Structure(40.00M x1.0mh)	No.	1	386400	386400	410000	410000
	Gabion Structure(40.00M x1.5mh)	No.	1	464600	464600	448000	448000
	Gabion Structure(45.00M x2.0mh	No.	1	580750	580750	536000	536000
	Gabion Structure (55.00Mx1.20mh)	No.	1	543950	543950	565000	565000

S. No.	Type of intervention	Unit	No.	As per DSR		As per RES, CSR	
				Rates per unit (in Rs.)	Proposed cost (in Rs.)	Rates per unit (in Rs.)	Proposed cost (in Rs.)
5	Plantation	Ha.	2.75	343850	945587	356000	979000
	Plantation & grass vegetation	Ha.	1.775	347300	616457	359000	637225
6	Soil protection trench	Rm.	520	387	201240	193	100360
7	Farm Pond no-1 (150mx65mx2.0md)	No.	1	6083500	6083500	2369000	2369000
	Farm Pond no-2 (200mx80mx2.0md)	No.	1	8099450	8099450	3200000	3200000
	Farm Pond no-3 (100mx60mx2.0md)	No.	1	3375250	3375250	1400000	1400000
	Sub Total-A				**23195497**		**11964094**
B.	**Drilling of bore wells at proposed sites**	No.	4 (SPA1, SPA3, SPA 4 & 5)	To be carried out by SPA			
C.	**Roof top water harvesting of bore wells**						
a.	Existing bore wells						
1	Existing Bore no -1	No.	1	158700	158700	98000	98000
2	Existing Bore no -2	No.	1	150650	150650	96000	96000
4	Existing Bore no -4	No.	1	312800	312800	197000	197000
5	Existing Bore no -5	No.	1	431250	431250	280000	280000
6	Existing Bore no -6	No.	1	100000	100000	64000	64000
7	Existing Bore no -7	No.	1	422000	422000	300000	300000
8	Existing Bore no -8	No.	1	240350	240350	153000	153000
b.	Proposed locations for bore wells				0		0
1	S.P.A. Bore no -1	No.	1	261000	261000	159000	159000
2	S.P.A. Bore no -3	No.	1	384000	384000	234000	234000
3	S.P.A. Bore no -4	No.	1	143750	143750	95000	95000
4	S.P.A. Bore no -5	No.	1	372600	372600	227000	227000
	Sub Total-C				**2977100**		**1903000**
D.	**Recharge shaft**						
1	S.P.A. Bore no -7	No.	1	299000	299000	173000	173000
2	S.P.A. Bore no -8	No.	1	299000	299000	173000	173000
	Sub Total-D				**598000**		**346000**

S. No.	Type of intervention	Unit	No.	As per DSR		As per RES, CSR	
				Rates per unit (in Rs.)	Proposed cost (in Rs.)	Rates per unit (in Rs.)	Proposed cost (in Rs.)
E.	**Under ground water storage tanks**						
1	R.C.C. tank capacity of tank - 100000 liters (10x5x2.30m.) Existing. Bore no -7 & 8 and SPA Bore no -1 & 3	No.	4	883200	3532800	644000	2576000
	Sub Total-E				**3532800**		**2576000**
	Total (A+C+D+E)				**30303397**		**16789094**
	15% Administrative & Other expenses				**4545510**		**2518364**
	Grand Total				**34848907**		**19307458**

The estimates of the suggested initiatives are given in Annexures-D & E.



GCP POINTS OF EXISTING BOREWELL

S.No.	Long (Degree Minute Second)	Lat (Degree Minute Second)
1	77° 16' 7.104" E	23° 18' 3.852" N
2	77° 16' 7.500" E	23° 18' 3.852" N
3	77° 16' 8.190" E	23° 18' 6.640" N
4	77° 16' 11.604" E	23° 18' 3.168" N
5	77° 16' 11.460" E	23° 17' 58.344" N
6	77° 16' 8.184" E	23° 17' 58.560" N
7	77° 16' 15.348" E	23° 17' 58.704" N
8	77° 16' 3.720" E	23° 17' 40.040" N

GCP POINTS OF PROPOSED POINTS

Point	Long (Degree Minute Second)	Lat (Degree Minute Second)
SPA06	77° 15' 59.256" E	23° 17' 54.204" N
SPA07	77° 16' 18.264" E	23° 17' 57.372" N
SPA08	77° 16' 17.184" E	23° 17' 59.424" N
SPA09	77° 16' 9.732" E	23° 17' 53.376" N
SPA02	77° 16' 13.800" E	23° 17' 49.020" N
SPA01	77° 16' 5.592" E	23° 17' 50.208" N
SPA03	77° 16' 8.436" E	23° 17' 42.252" N
SPA04	77° 16' 7.212" E	23° 17' 37.680" N
SPA05	77° 16' 1.128" E	23° 17' 48.264" N

Annexure -A

Geophysical Survey

Introduction

In hard rock terrain, one has to depend on ground water on a sufficiently thick weathered zone at the top followed by the jointed portion of the rock. In addition, in the Deccan Trap terrains, intertrappeans, act as potential aquifers where they are present in considerable thickness provided the recharge conditions are favourable. These zone fifer in their electrical behaviour and as such are reflected in the resistivity picture. Electrical Resistivity surveys can be successfully employed in most of the trap areas to delineate these zones viz., the highly weathered portion, fractured zone and the massive compact rock and also intertrappeans. It is observed that, in general, the resistivity contrast between weathered and unweathered portion of the trap rock is very low and that the resistivity of the hard trap might some times overlap, at the lower end of the range, the resistivity of jointed zone.

The electrical resistivity method is based on the principle of measurement of the physical parameter of the electrical resistivity. The electrical resistivity may be defined as the resistance offered by a unit cube of material for the passage of current when the voltage is applied at the opposite ends (expressed in Ohm-meters in MKS system). The resistivities of natural accruing formations has a wide range of resistivities depending on several parameters such as mineral composition of the rock, porosity, degree of fluid saturation, and the quality of fluid. In general, the resistivity of a geological formation may be considered as a function of formation resistivity, porosity, water content in the pores and the salinity of the saturating water.

To record the resistivities of the subsurface formations a known electric current is sent into the ground and the potential drip resulting from the resistance of the ground is measured. There are several electrode arrangements (configurations) of current and potential electrodes. Among these SCHLUMBERGER configuration is more popular in hard rock terrain.

In Schlumberger configuration, all the four electrodes are kept in a line but the potential electrodes are kept close symmetrically about the centre of the system as shown in fig.-1. Current is sent through the extreme electrodes (C1C2) and the potential gradient is measured at these closely spaced potential electrodes (P1P2).

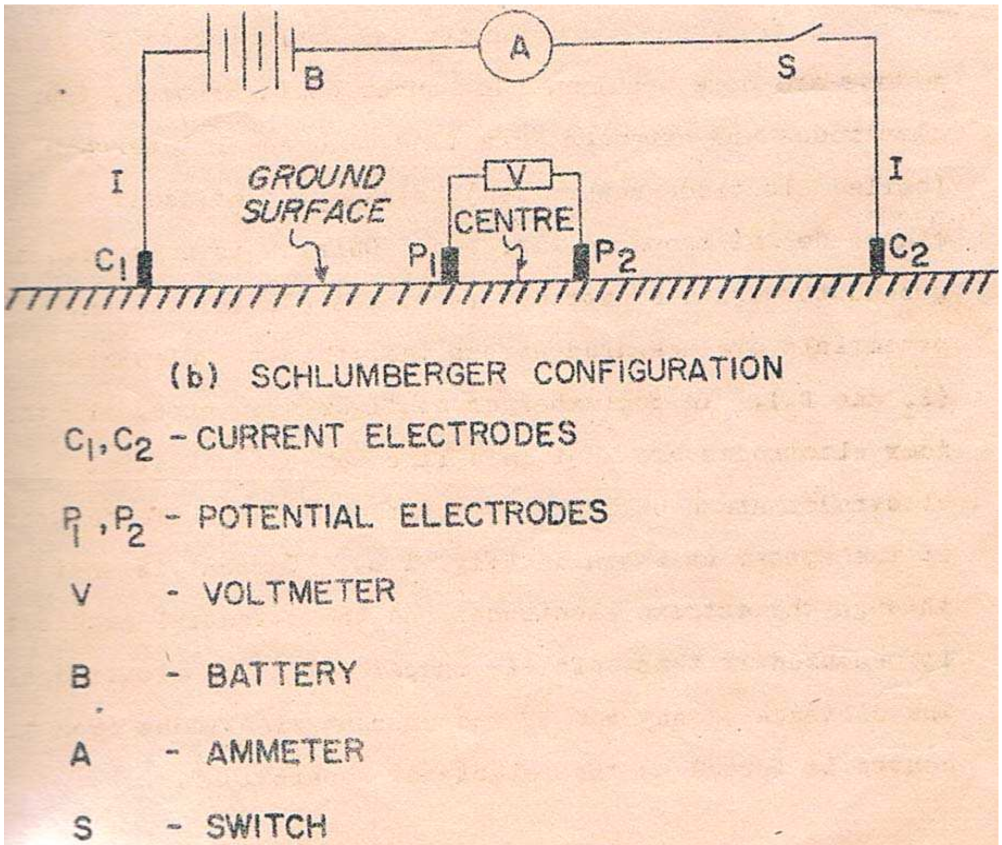


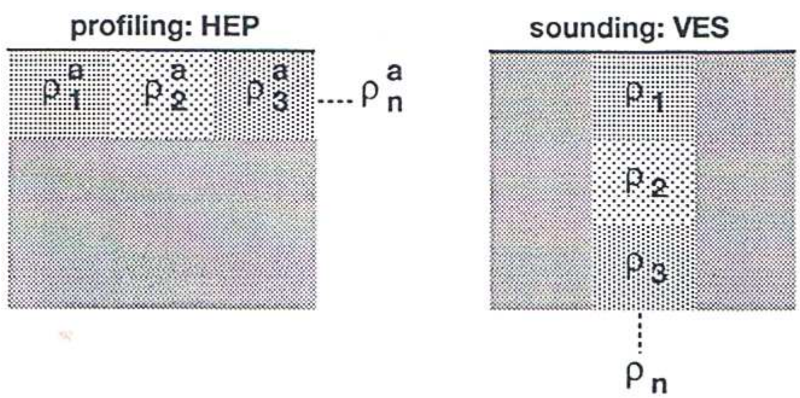
Fig-1

There are two types of application of the resistivity methods: horizontal electrical profiling (HEP) and vertical electrical sounding (VES). In the former (HEP), the spacing of electrodes is kept constant and configuration moves as a whole along the traverse. This measures the resistivity of a slice of earth, whose thickness depends on the electrode separation. In the second Resistivity sounding method VES, the measurements are made at one location (keeping the centre of the system fixed) for various values electrode separation starting from a small value say 2 meter to several tens or hundreds of meters. The increase of electrode separation increases the depth of investigation and the resistances, thus, measured are used to interpret the resistivities and depth of the subsurface formations.

The Geo-Electric Survey

In order to acquire quantitative data on aquifer thickness and aquifer resistivity, 09 vertical electrical soundings (VES) and two horizontal electrical profilings (HEP) were carried out at selected locations of SPA campus. The geo-electric measurements were made with Aqua meter CRM AUTO C Model (Computerised Resistivity Meter) which is modern version of Earth Resistivity Meters, make use of microprocessor technology. For obtaining subsurface litho-logical information, the largest available current electrode separation was utilised for taking vertical electrical soundings at the selected/suitable points. The apparent resistivity values recorded in the field were plotted and interpreted with the help of computer using different software program. Final results were corroborated with existing hydro-geological conditions of the area. The computerised resistivity curves obtained from the field survey sites are given in SPA1, SPA2, SPA3, SPA4, SPA5, SPA6, SPA7, SPA8 and SPA9.

Electrical resistivity profiles with WENNER configuration were carried out on the down stream of the campus in pond no.2 located in East of the SPA area (Details given in Profile No. 1 depicting eastern part of the pond No. 2 and Profile No. 2 gives details taken at the beginning (western side) of the pond's area that is upstream at 15 meter distance and stations interval of 10 mts.). Electrode separations of 1m, 2m, 5m, 7m, 10m, 15m & 20 m were considered two understand the horizontal variations in the substratum of the ponds. Two electrical resistivity soundings at SPA7 and SPA8 with Schlumberger configuration were taken on the ponds bed to known the vertical distribution of the aquifer geometry.



Electrical resistivity survey techniques: (a) Horizontal Electrical Profiling (HEP) to determine lateral variations in earth resistivities and (b) Vertical Electrical Sounding (VES) to determine resistivity variations with depth.

Results

The resistivity sounding results are presented in Table1 and profiling results are presented in Table2. The interpreted data indicated the true electrical resistivity and thickness of different subsurface horizons.

The topmost layer with thickness from 1.3 mts. to 3mts. having resistivity 17 to 80 Ohm-m represents black cotton soil and combination of black cotton soil and yellow soil. The electrical resistivity value from 275 Ohm-m to 750 Ohm corresponds to massive/compact basalt bed. A bed with the resistivity of about 55 Ohm-m to 155 Ohm-m is indicative of a combination of fractured & compact/hard basalt. Weathered and hard rock basalt indicated by the resistivity value of about 50-65 Ohm-m. Highly weathered to weathered rock has been indicated by the resistivity value of the order of 22 Ohm-m to 40 Ohm-m in the survey area.

A careful comparison of profiling data reveals that the delineation remains nearly the same for all the spacing. This indicates that deeper strata in the eastern part of the pond no.2 development of ground water tapping are encouraging i.e. at SPA8. It is also seen from the results that these low resistivity zones are continuing from ground level to the depth of at least 20 meters depth/suitable for recharge of the ground water with appropriate technology.

Conclusions:

Sediments immediately below at pond no. 2 sampled from ground surface down to 27m do not show any remarkable change in litho logic character. The low electrical resistivity values indicate that sediments are predominantly weathered/fractured basalt rock.

It is seen from the VES data results that low resistivity zones encountered at sounding location SPA1, SPA3, SPA4, SPA5, SPA7 & SPA8 may act as aquifer as indicated by survey. Recommended locations may be drilled down to a depth of about 150-180m.

Table 1

Results of electrical resistivity soundings

S. No.	Sounding Locations	Resistivity in ohm-m								Depth in meters (below ground level)						
		ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6	ρ_7	ρ_8	h_1	h_2	h_3	h_4	h_5	h_6	h_7
1	SPA1	80	306	112	63	36	98			1.3	13.4	26	40	69.5		
2	SPA2	21	48	2679	high	588	68	36			3.1	3.3	6.7	8.7	34	
3	SPA3	58	375	210	85	43	40	60		1.4	6.4	14	26	57	80	
4	SPA4	48	125	278	155	99	64	26		1.3	3.7	10.3	20	26.7	34	80
5	SPA5	29	48	134	219	109	56	44	59	1.3	4.9	7	21	34	53	67
6	SPA6	28	71	122	54	28	57(?)			2.6	3	11	25	53		
7	SPA7	17	10	18	29	30	51	110		1.9	5.4	12	21.5	26	39	
8	SPA8	34	8	22	42	83				1.3	9	13	27			
9	SPA9	750	400	139	38	23	106			2.0	3	5.5	6	33		

Table-2

(Wenner Profiling)

Profile No.1:

Location: SPA Bhauri, Bhopal (Pond no.2-Extreme Eastwards)

Station interval: 10m, Orientation- N-South

Electrode spacing (a=1,2,5,7,10,15 & 20 mtr.)

Station No. I Lat/long: N23^0 29' 8.97", E77^0 27' 19.5", Survey No.(610)

S. No.	a(m)	Resistance (Ohm)	K(Geometric factor)	ρa (Ohm-m) Apparent Resistivity
1	1	2.82	6.28	17.7
2	2	1.97	12.57	24.8
3	5	0.765	31.42	24.0
4	7	0.437	44.0	19.2
5	10	0.303	62.85	19.0
6	15	0.230	94.28	28.7
7	20	0.134	125.71	16.8

Station No.II: Lat/Long N23^0 29' 9.06", E77^0 27' 19.6", Survey No.(611)

S. No.	a(m)	Resistance (Ohm)	K(Geometric factor)	ρa (Ohm-m) Apparent Resistivity
1	1	1.88	6.28	11.8
2	2	1.002	12.57	12.6
3	5	0.397	31.42	12.5
4	7	0.261	44.0	11.5
5	10	0.177	62.85	11.1
6	15	0.139	94.28	13.1
7	20	0.125	125.71	15.7

Station No.III: Lat/Long N23^0 29' 9.14", E77^0 27' 20.3", Survey No.(612)

S. No.	a(m)	Resistance (Ohm)	K(Geometric factor)	ρa (Ohm-m) Apparent Resistivity
1	1	3.55	6.28	22.3
2	2	0.985	12.57	12.4
3	5	0.375	31.42	11.8
4	7	0.261	44.0	11.5
5	10	0.196	62.85	12.3
6	15	0.148	94.28	13.95
7	20	0.122	125.71	15.3

Profile No. II

Location: SPA, Bhauri, Bhopal (Pond no.2-Westward 15,mtrs.)

Station interval:10m, Orientation- N-South

Electrode spacing (a=1,2,5,7,10,15 & 20 mtr.)

Station No.I Lat/long: N23^0 29' 9.56", E77^0 27' 18.3", Survey No.(613)

S. No.	a(m)	Resistance (Ohm)	K(Geometric factor)	ρa (Ohm-m) Apparent Resistivity
1	1	3.97	6.28	24.9
2	2	1.65	12.57	20.7
3	5	0.495	31.42	15.6
4	7	0.204	44.0	9.0
5	10	0.158	62.85	9.9
6	15	0.127	94.28	12.0
7	20	0.117	125.71	14.7

Station No.II Lat/long: N23^0 29' 9.49", E77^0 27' 18.0", Survey No.(614)

S. No.	a(m)	Resistance (Ohm)	K(Geometric factor)	ρa (Ohm-m) Apparent Resistivity
1	1	8.13	6.28	51.0
2	2	1.58	12.57	19.9
3	5	0.410	31.42	12.9
4	7	0.220	44.0	9.7
5	10	0.199	62.85	12.5
6	15	0.121	94.28	11.4
7	20	0.106	125.71	13.3

Station No.III Lat/long: N23^0 29' 9.40", E77^0 27' 17.9", Survey No.(615)

S. No.	a(m)	Resistance (Ohm)	K(Geometric factor)	ρa (Ohm-m) Apparent Resistivity
1	1	6.61	6.28	41.5
2	2	2.08	12.57	26.1
3	5	0.331	31.42	10.4
4	7	0.222	44.0	9.8
5	10	0.173	62.85	10.9
6	15	0.146	94.28	13.8
7	20	0.120	125.71	15.1

Station No.IV Lat/long: N23^0 29' 9.27", E77^0 27' 17.9", Survey No.(616)

S. No.	a(m)	Resistance (Ohm)	K(Geometric factor)	ρa (Ohm-m) Apparent Resistivity
1	1	1.91	6.28	12.0
2	2	1.107	12.57	13.9
3	5	0.332	31.42	10.4
4.	7	0.223	44.0	10.3
5	10	0.186	62.85	11.7
6	15	0.145	94.28	13.7
7	20	0.128	125.71	16.1

Station No.V Lat/long: N23^0 29' 9.17", E77^0 27' 16.9", Survey No.(617)

S. No.	a(m)	Resistance (Ohm)	K(Geometric factor)	ρa (Ohm-m) Apparent Resistivity
1	1	4.84	6.28	30.4
2.	2	1.83	12.57	23.0
3	5	0.376	31.42	11.8
4	7	0.259	44.0	11.4
5	10	0.188	62.85	11.8
6	15	0.140	94.28	13.2
7	20	0.143	125.71	18

Station No.VI Lat/long: N23^0 29' 9.10", E77^0 27' 17.0", Survey No.(618)

S. No.	a(m)	Resistance (Ohm)	K(Geometric factor)	ρa (Ohm-m) Apparent Resistivity
1	1	7.15	6.28	44.9
2	2	0.702	12.57	8.8
3	5	0.347	31.42	10.9
4	7	0.265	44.0	11.7
5	10	0.178	62.85	11.2
6	15	0.147	94.28	13.9
7	20	0.125	125.71	15.7

Station No.VII Lat/long: N23^0 29' 9.0", E77^0 27' 17.0", Survey No.(619)

S. No.	a(m)	Resistance (Ohm)	K(Geometric factor)	ρa (Ohm-m) Apparent Resistivity
1	1	5.61	6.28	35.2
2	2	1.94	12.57	24.4
3	5	0.35	31.42	11.0
4	7	0.243	44.0	10.7
5	10	0.207	62.85	13.0
6	15	0.157	94.28	14.8
7	20	0.130	125.71	16.3

Station No.VIII Lat/long: N23^0 29' 8.09", E77^0 27' 17.3", Survey No.(620)

S. No.	a(m)	Resistance (Ohm)	K(Geometric factor)	ρa (Ohm-m) Apparent Resistivity
1	1	4.83	6.28	30.3
2	2	3.09	12.57	38.8
3	5	0.357	31.42	11.2
4	7	0.235	44.0	10.3
5	10	0.173	62.85	10.9
6	15	0.148	94.28	14.0
7	20	0.090	125.71	11.3

Table-3

Litho- Resistivity relationship

Location: SPA1

[Lat (N) 23˚ 17' 50.208" Long (E) 77˚ 16' 5.592", Survey No. 600]

Geo-Electric Layer No.	Resistivity (Ohm-m)	Depth range (m)	Probable Lithology
1	80	ground level-1.3 m	Loose yellow soil
2	306	upto 13m	Hard trap
3	112	upto 26m	combination of fractured and hard basalt
4	63	upto 40m	weathered and hard basalt
5	36	69.5m	massive basalt with intermittent weathering
6	98	upto investigated depth	fractured basalt with hard trap

Location: SPA2

[Lat (N) 23˚ 17' 49.020"Long (E) 77˚ 16' 13.800", Survey No. 603]

Geo-Electric Layer No.	Resistivity (Ohm-m)	Depth range (m)	Probable Lithology
1	21	ground level-3.1 m	black cotton soil and yellow soil
2	48	upto 3.3m	black cotton soil and yellow soil
3	high	upto 9m	Massive basalt
4	68	upto 34m	Combination of fractured and hard rock
5	36	upto investigated depth	massive basalt with intermittent weathering

Location: SPA3
[Lat (N) 23˚ 17' 42.252" Long (E) 77˚ 16' 8.436", Survey No. 606]

Geo-Electric Layer No.	Resistivity (Ohm-m)	Depth range (m)	Probable Lithology
1	58	ground level-1.4 m	black cotton soil and yellow soil
2	375	upto 6.4m	hard trap
3	210	upto 14m	hard trap
4	85	upto 26m	Combination of fractured hard basalt
5	40-43	upto 80m	Vesicular & massive basalt
6	60	up to investigated depth	Combination of fractured basalt and hard basalt

Location: SPA4
[Lat (N) 23˚ 17' 37.680"Long (E) 77˚ 16' 7.212", Survey No.607]

Geo-Electric Layer No.	Resistivity (Ohm-m)	Depth range (m)	Probable Lithology
1	48	ground level-1.3 m	yellow soil
2	125	upto 3.7m	fractured and hard rock
3	278	upto 10.3m	massive basalt
4	155	upto 20m	Combination of fractured and hard basalt
5	99	upto 26.7m	fractured basalt with hard rock
6	64	upto 34.5	fractured basalt
7	25	upto 80	highly weathered trap
8	45	upto investigated depth	Vesicular & massive basalt

Location: SPA5

[Lat (N) 23˚ 17' 48.264" Long (E) 77˚ 16' 1.128", Survey No. 608]

Geo-Electric Layer No.	Resistivity (Ohm-m)	Depth range (m)	Probable Lithology
1	29	ground level-1.3 m	yellow soil
2	48	upto 4.9m	weathered rock
3	134	upto 7m	combination of fractured and hard rock
4	219	upto 21m	hard trap
5	109	upto 34m	combination of fractured and hard rock
6	56	upto 53m	weathered basalt
7	44	upto 67m	vesicular & massive basalt
8	59	upto investigated depth	combination of fractured and hard basalt

Location: SPA6

[Lat (N) 23˚ 17' 54.204" Long (E) 77˚ 15' 59.256",Survey No. 609]

Geo-Electric Layer No.	Resistivity (Ohm-m)	Depth range (m)	Probable Lithology
1	28	ground level-2.6 m	yellow soil
2	71	upto 3.0m	weathered/fractured rock
3	122	upto 11m	combination of fractured and hard basalt
4	54	upto 25m	weathered basalt with hard trap
5	28	upto 53m	highly weathered basalt
6	57	upto investigated depth	combination of fractured and hard basalt

Location: SPA7

[Lat (N) 23˚ 17' 57.372"Long (E) 77˚ 16' 18.264", Survey No. 621]

Geo-Electric Layer No.	Resistivity (Ohm-m)	Depth range (m)	Probable Lithology
1	17	ground level-1.9 m	B.C. soil
2	10	upto 5.4m	B.C. soil
3	18	upto 12m	yellow soil
4	29	upto 21.5m	highly weathered basalt
5	30	upto 26m	highly weathered basalt
6	51	upto 39m	combination of weathered and hard rock
7	110	upto investigated depth	combination of fractured and hard rock

Location: SPA8

[Lat (N) 23˚ 17' 59.424"Long (E) 77˚ 16' 17.184",Survey No. 622]

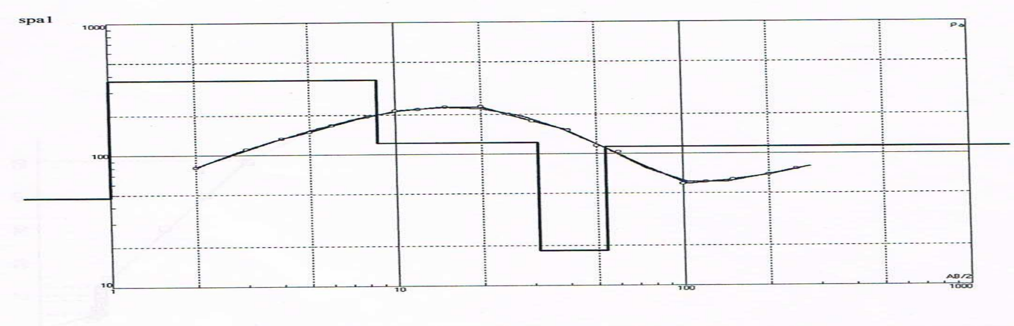
Geo-Electric Layer No.	Resistivity (Ohm-m)	Depth range (m)	Probable Lithology
1	34	ground level-1.3 m	yellow soil and silk
2	8	upto 9m	B.C. soil
3	22	upto 13m	highly weathered trap
4	42	upto 27m	combination of vesicular and massive basalt
5	83	upto investigated depth	fractured basalt with compact rock

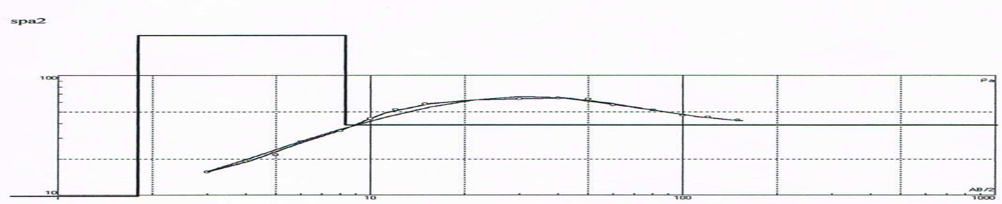
Location: SPA9

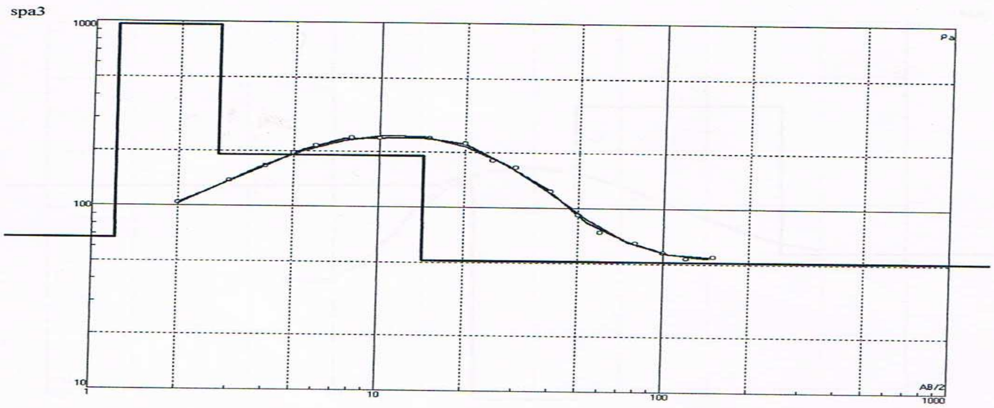
[Lat (N) 23˚ 17' 53.376" Long (E) 77˚ 16' 9.732", Survey No.624]

Geo-Electric Layer No.	Resistivity (Ohm-m)	Depth range (m)	Probable Lithology
1	750	ground level-2.0m	massive basalt
2	400	upto 2.8m	compact basalt
3	139	upto 6m	fractured and hard rock
4	38	upto 6m	weathered and hard rock
5	23	upto 33m	weathered basalt
6	106	upto investigated depth	fractured and hard rock

Vertical Electrical Soundings (VES) Field cures



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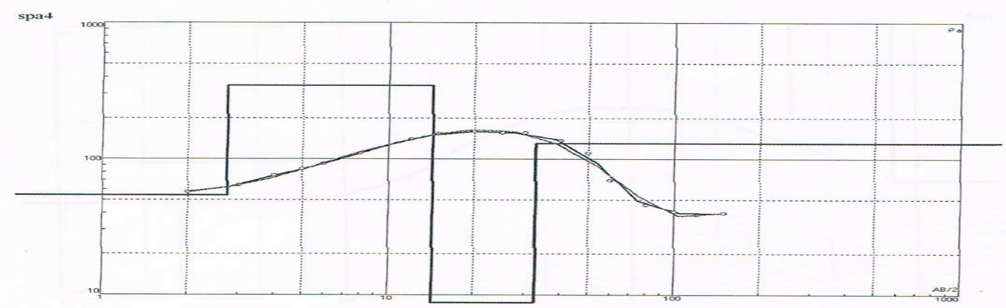

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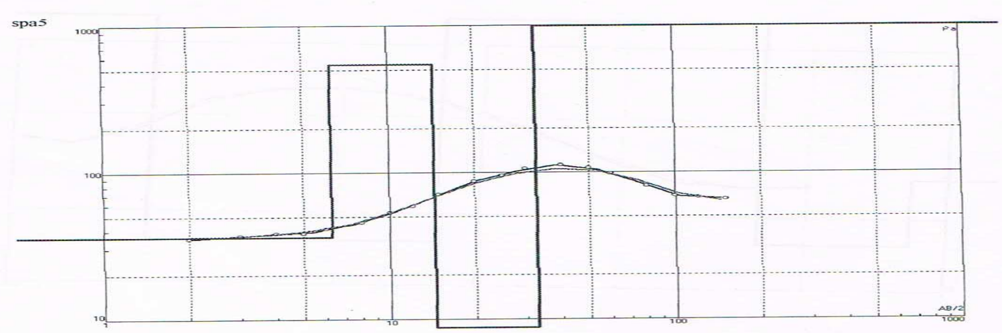

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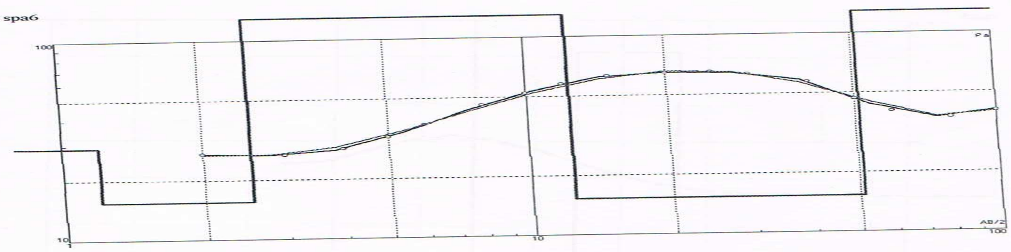
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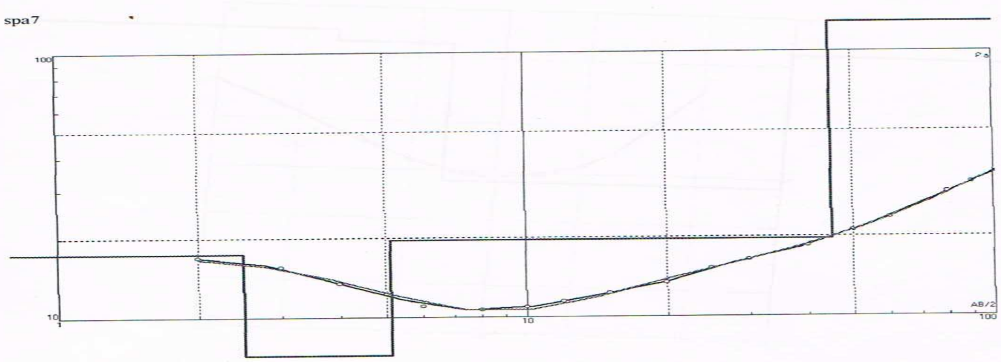
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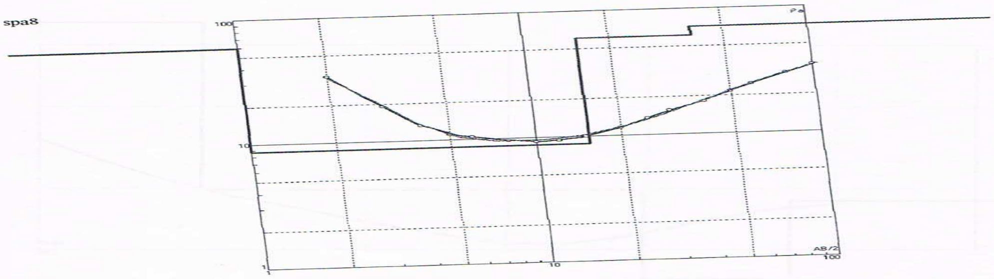
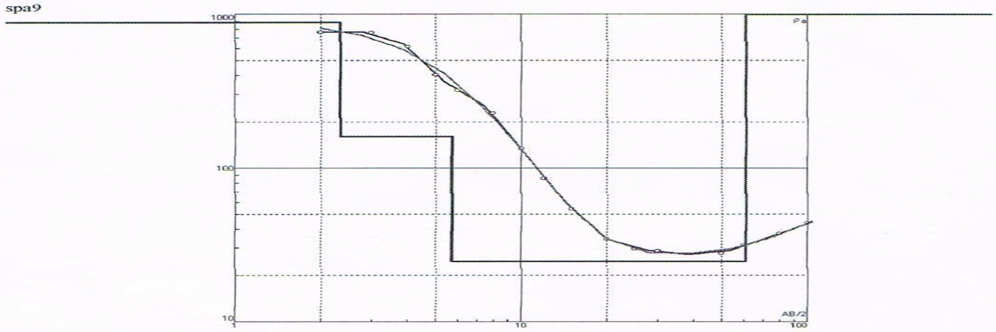
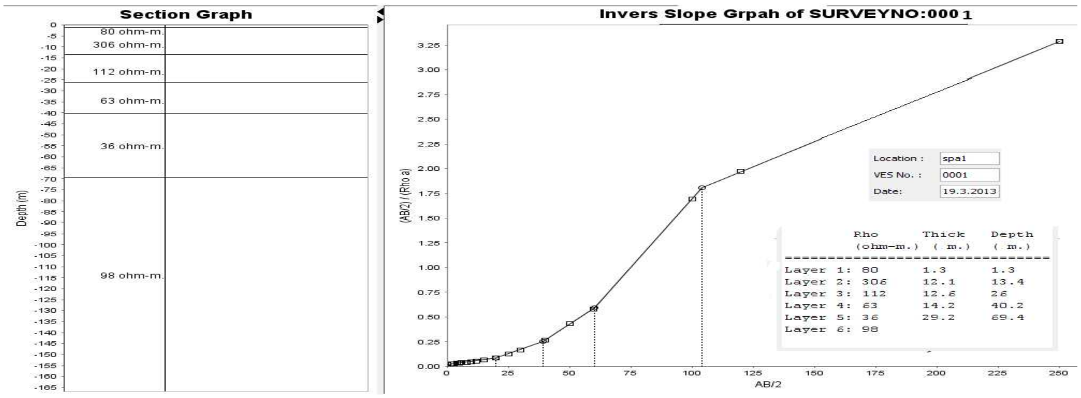
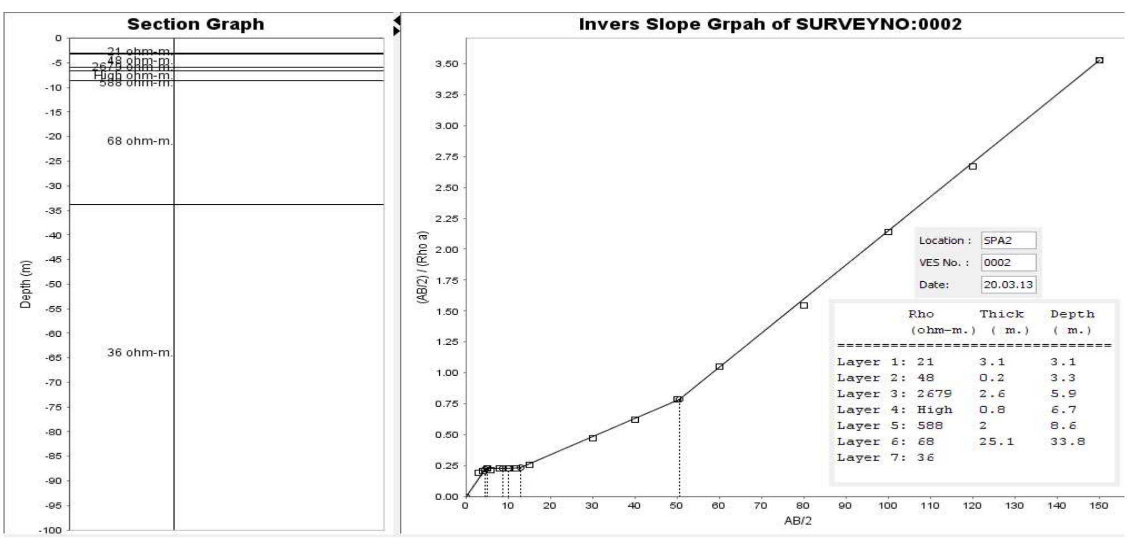


spa9

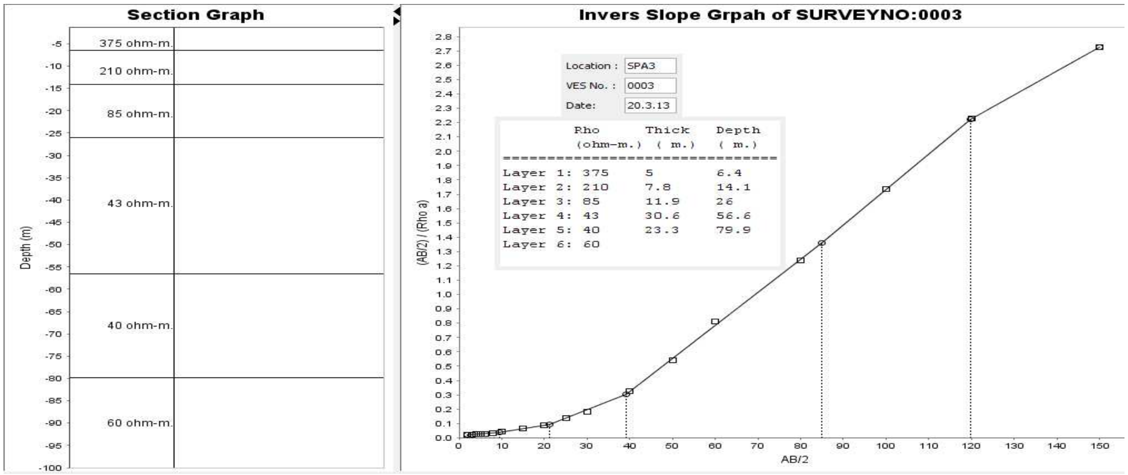


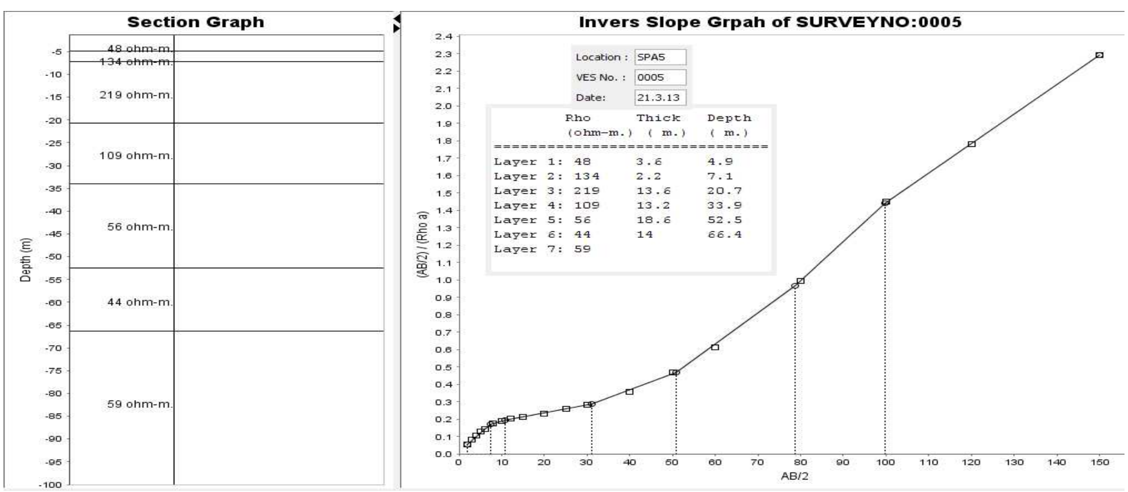


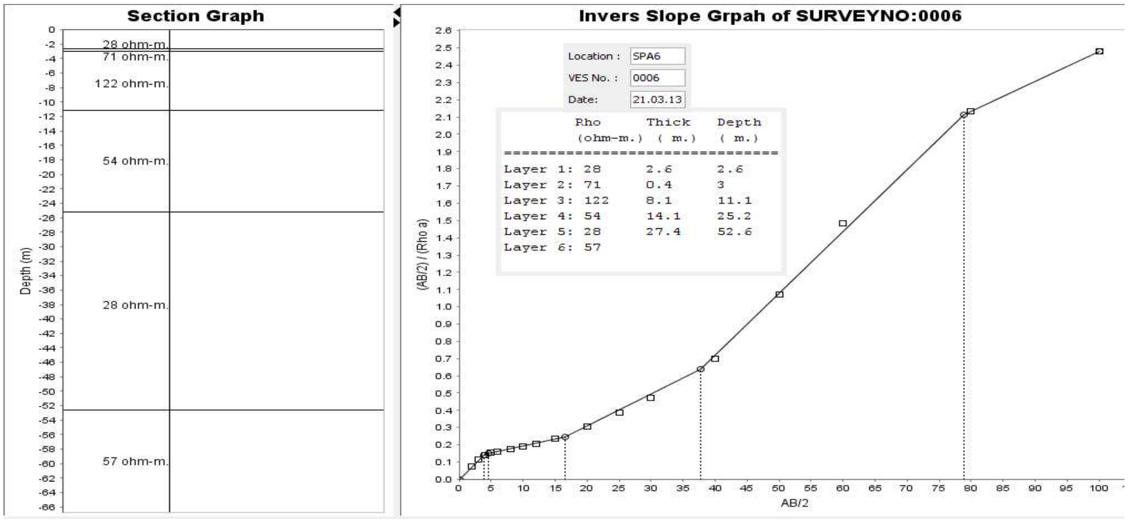
Section Graph
80 ohm-m.
306 ohm-m.
112 ohm-m.
63 ohm-m.
36 ohm-m.
98 ohm-m.
Depth (m)
Invers Slope Grpah of SURVEYNO:0001
(AB/2) / (Rho a)
AB/2
Location : spa1
VES No. : 0001
Date: 19.3.2013
Rho (ohm-m.) Thick (m.) Depth (m.)
Layer 1: 80 1.3 1.3
Layer 2: 306 12.1 13.4
Layer 3: 112 12.6 26
Layer 4: 63 14.2 40.2
Layer 5: 36 29.2 69.4
Layer 6: 98

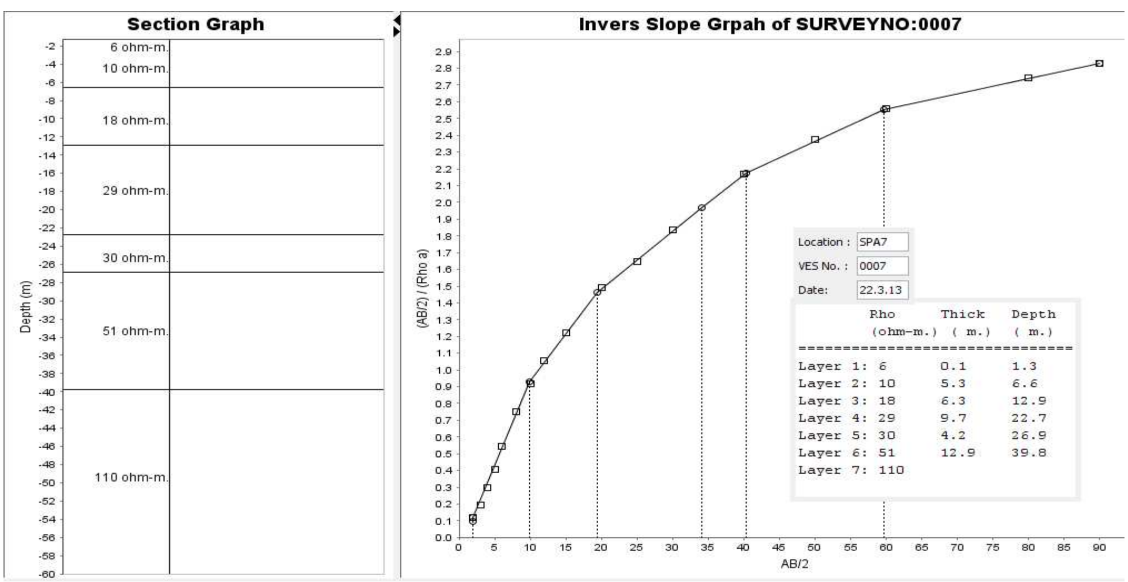


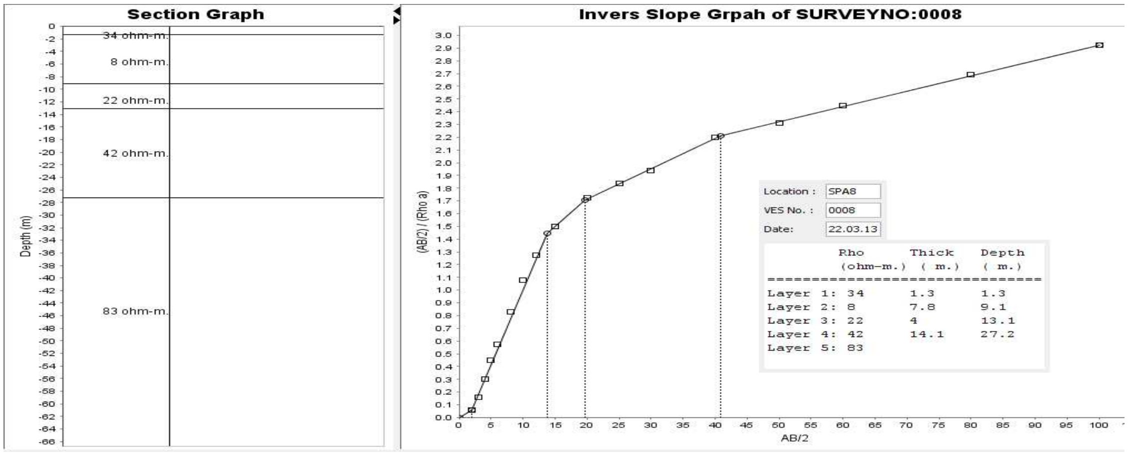
Section Graph
21 ohm-m.
48 ohm-m.
2679 ohm-m.
High ohm-m.
588 ohm-m.
68 ohm-m.
36 ohm-m.
Depth (m)
Invers Slope Grpah of SURVEYNO:0002
(AB/2) / (Rho a)
AB/2
Location : SPA2
VES No. : 0002
Date: 20.03.13
Rho (ohm-m.) Thick (m.) Depth (m.)
Layer 1: 21 3.1 3.1
Layer 2: 48 0.2 3.3
Layer 3: 2679 2.6 5.9
Layer 4: High 0.8 6.7
Layer 5: 588 2 8.6
Layer 6: 68 25.1 33.8
Layer 7: 36

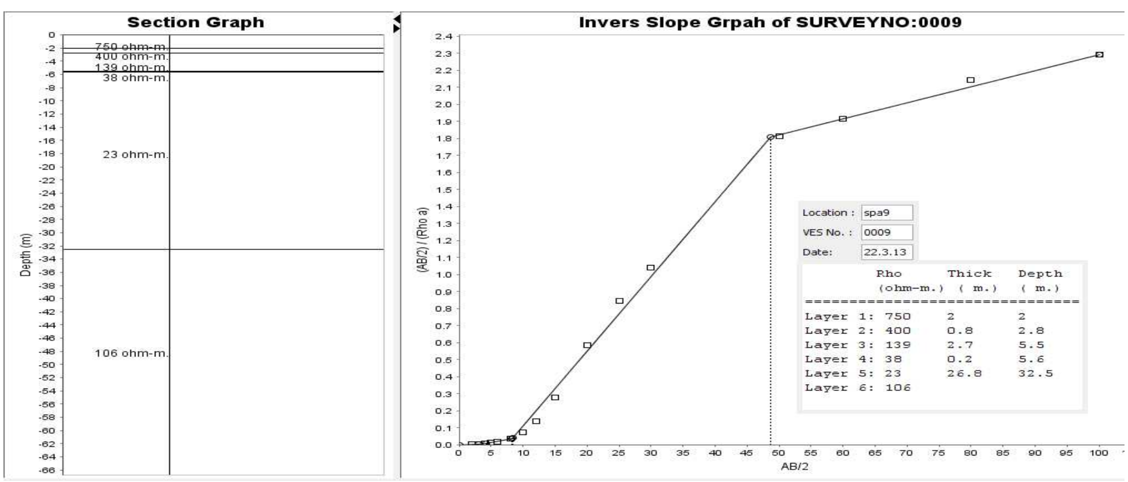

Section Graph
375 ohm-m.
210 ohm-m.
85 ohm-m.
43 ohm-m.
40 ohm-m.
60 ohm-m.
Depth (m)
Invers Slope Grpah of SURVEYNO:0003
Location : SPA3
VES No. : 0003
Date: 20.3.13
Rho (ohm-m.) Thick (m.) Depth (m.)
Layer 1: 375 5 6.4
Layer 2: 210 7.8 14.1
Layer 3: 85 11.9 26
Layer 4: 43 30.6 56.6
Layer 5: 40 23.3 79.9
Layer 6: 60
(AB/2) / (Rho a)
AB/2


Section Graph
48 ohm-m.
134 ohm-m.
219 ohm-m.
109 ohm-m.
56 ohm-m.
44 ohm-m.
59 ohm-m.
Depth (m)
Invers Slope Grpah of SURVEYNO:0005
Location : SPA5
VES No. : 0005
Date: 21.3.13
Rho (ohm-m.) Thick (m.) Depth (m.)
Layer 1: 48 3.6 4.9
Layer 2: 134 2.2 7.1
Layer 3: 219 13.6 20.7
Layer 4: 109 13.2 33.9
Layer 5: 56 18.6 52.5
Layer 6: 44 14 66.4
Layer 7: 59
(AB/2) / (Rho a)
AB/2


Section Graph
28 ohm-m.
71 ohm-m.
122 ohm-m.
54 ohm-m.
28 ohm-m.
57 ohm-m.
Depth (m)
Invers Slope Grpah of SURVEYNO:0006
Location : SPA6
VES No. : 0006
Date: 21.03.13
Rho (ohm-m.) Thick (m.) Depth (m.)
Layer 1: 28 2.6 2.6
Layer 2: 71 0.4 3
Layer 3: 122 8.1 11.1
Layer 4: 54 14.1 25.2
Layer 5: 28 27.4 52.6
Layer 6: 57
(AB/2) / (Rho a)
AB/2


Section Graph
6 ohm-m.
10 ohm-m.
18 ohm-m.
29 ohm-m.
30 ohm-m.
51 ohm-m.
110 ohm-m.
Depth (m)
Invers Slope Grpah of SURVEYNO:0007
Location : SPA7
VES No. : 0007
Date: 22.3.13
Rho (ohm-m.) Thick (m.) Depth (m.)
Layer 1: 6 0.1 1.3
Layer 2: 10 5.3 6.6
Layer 3: 18 6.3 12.9
Layer 4: 29 9.7 22.7
Layer 5: 30 4.2 26.9
Layer 6: 51 12.9 39.8
Layer 7: 110
(AB/2) / (Rho a)
AB/2


Section Graph
34 ohm-m.
8 ohm-m.
22 ohm-m.
42 ohm-m.
83 ohm-m.
Depth (m)
Invers Slope Grpah of SURVEYNO:0008
(AB/2) / (Rho a)
AB/2
Location : SPA8
VES No. : 0008
Date: 22.03.13
Rho (ohm-m.) Thick (m.) Depth (m.)
Layer 1: 34 1.3 1.3
Layer 2: 8 7.8 9.1
Layer 3: 22 4 13.1
Layer 4: 42 14.1 27.2
Layer 5: 83


Section Graph
750 ohm-m.
400 ohm-m.
139 ohm-m.
38 ohm-m.
23 ohm-m.
106 ohm-m.
Depth (m)
Invers Slope Grpah of SURVEYNO:0009
(AB/2) / (Rho a)
AB/2
Location : spa9
VES No. : 0009
Date: 22.3.13
Rho (ohm-m.) Thick (m.) Depth (m.)
Layer 1: 750 2 2
Layer 2: 400 0.8 2.8
Layer 3: 139 2.7 5.5
Layer 4: 38 0.2 5.6
Layer 5: 23 26.8 32.5
Layer 6: 106

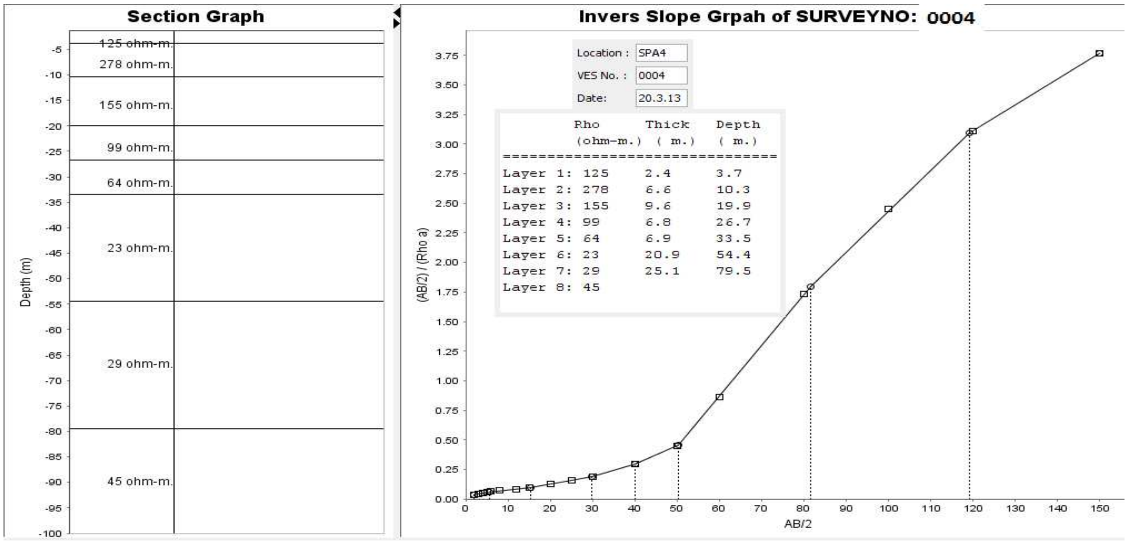

Section Graph
125 ohm-m.
278 ohm-m.
155 ohm-m.
99 ohm-m.
64 ohm-m.
23 ohm-m.
29 ohm-m.
45 ohm-m.
Depth (m)
Invers Slope Grpah of SURVEYNO: 0004
Location : SPA4
VES No. : 0004
Date: 20.3.13
Rho (ohm-m.) Thick (m.) Depth (m.)
Layer 1: 125 2.4 3.7
Layer 2: 278 6.6 10.3
Layer 3: 155 9.6 19.9
Layer 4: 99 6.8 26.7
Layer 5: 64 6.9 33.5
Layer 6: 23 20.9 54.4
Layer 7: 29 25.1 79.5
Layer 8: 45
(AB/2) / (Rho a)
AB/2

Table-4

Location of Existing Tubewells in the SPA area, Bhauri, Bhopal.

S. No.	Longitude (E)	Latitude (N)
1	77˚ 16' 7.104" E	23˚ 18' 3.852" N
2	77˚ 16' 7.500" E	23˚ 18' 3.852" N
3	77˚ 16' 11.604" E	23˚ 18' 3.168" N
4	77˚ 16' 11.460" E	23˚ 17' 58.344" N
5	77˚ 16' 15.348" E	23˚ 17' 58.704" N
6	77˚ 16' 8.184" E	23˚ 17' 58.560" N

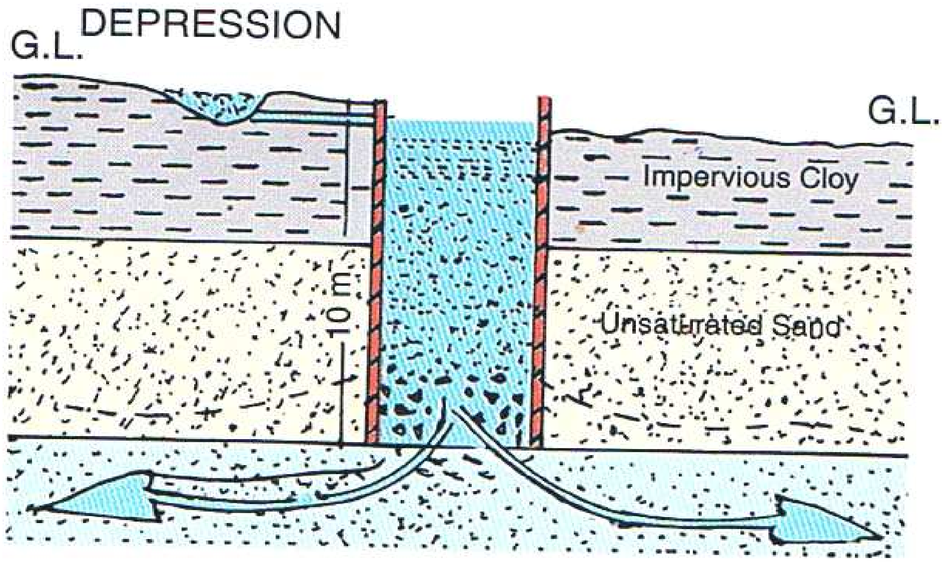
Annexure-B

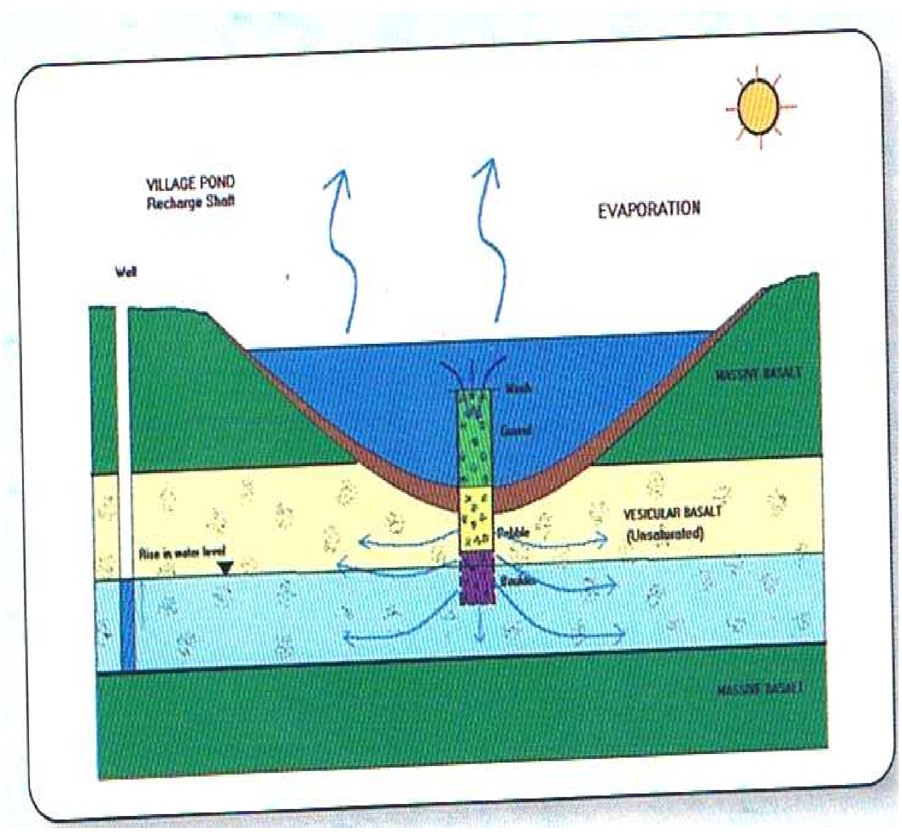
Rain Water Harvesting Through Recharge Shaft

This is the most efficient and cost effective technique to recharge unconfined aquifer overlain by poorly permeable strata. The Recharge shaft is dug manually or with machine and the diameter of the shaft is normally more than 2m. The shaft should end in more permeable strata below the top impermeable strata. It may not touch water level. The shaft should be back filled, initially with boulder/cobbles followed by gravel and coarse sand. These recharge structures are very useful for village ponds where shallow clay layer impedes infiltration of water to the aquifer. It is seen that in rainy season ponds are fully filled up but water from these ponds does not percolate down and tube well and dug wells located nearby remains dried up. The water from ponds gets evaporated and is not available for the beneficial use.

By constructing recharge shaft in ponds, surplus water will be recharged to ground water. Recharge shaft of 0.5m to 3m diameter and 10 to 15m deep are constructed depending upon availability of quantum of water. The top of shaft is kept above the tank bed level preferably at half of full supply level. These are back filled with boulders, gravels and coarse sand. In the upper portion of 1 or 2m depth, the brick masonry work in carried out for the stability of the structure. The site selected for rainwater harvesting should have sufficient thickness of permeable bed or weathered formation to facilitate recharge of stored water within short span of time. Behind the recharge shaft check dams are constructed across small streams on the flowing course of accumulated water to harness the maximum run of in the stream also to make pond water for a longer time in contact with the proposed shaft for the recharge of water to the ground.

RAIN WATER HARVESTING THROUGH RECHARGE SHAFT





Annexure –C

Roof top rain water harvesting

Design Consideration:

The important aspects to be looked in to for designing a Roof Top Rainwater Harvesting system to augment ground water resources are:

- Hydrogeology including nature and extent of aquifer, soil cover, topography, depth to water levels, Rainfall and Roof Top area.
- The Quantification of source of water availability as surface run off and Roof Top.
- To prevent from pollution, Silting, etc. (1) On-Line filter (2) Tank filter designing.

The existing scenario of the Phanda Block

The climate of area is characterized by three well defined seasons - hot summer, mild winter and well distributed rainfall during south west monsoon. (1) winter, December to February, (2)Summer-March to mid of June and (3) Rainy season from June to October.

The average annual rainfall of Bhopal is 1146 mm.

Hydrogeology:

Basalt formation at The School of planning & Architecture, Bhauri area – *Area is underlain* by basalt, which shows wide variation in their nature and extent. Thickness of weathered basalt forms the upper part of the area, which is about 1.20 m. The black hard, compact and massive fractured basalt rock is outcropped in the upper part of the area.

Quality of surplus water

Recharge water should be clean, free from contamination and should have compatibility with quality of native ground water in aquifer. Silt from the main runoff should also be checked at different stages of its augmentation for conservation & recharge.

Basis of the technical assessments:

In the SPA area, Bhauri, wells are drilled to meet water requirement. The details of existing bore wells are:

No of tube wells	Depth range of well (mbgl)	Discharge Variation (lps)	Aquifer
07	106.68-109.73	1.5 to 3.24	Basalt

- **Proposed bore wells to be drilled at SPA Bhauri.**

No. of proposed Bore wells	Well depth (mbgl)	Water bearing Zones (mbgl)	Aquifer	Discharge m3 /h
06 (SPA1, SPA3, SPA4, SPA5, SPA7, SPA8)	**150 - 180**	**79.-81.0 140-165**	***Fractured basalt & vesicular basalt***	**5400 -9000**

<u>Run – Off estimations for the area</u>

1. The surface runoff of area may be estimated by considering the catchments area, physiographic factor and plantation area. An annual rainfall run off relationship through ***STANG FORMULA*** is as follows:

    - **Run Off (mm)** = 0.3 x Rain fall (mm) - 60
      = 0.3 x 1146- 60
      = 283.8 mm

With the annual rainfall (Bhopal rain gauge station) being 1146 mm the annual runoff of the area is estimated to be 284 mm. It allows good scope for the recharge structure.

- Regular occurring Max rainfall in a day = 27 mm/day (as per rainfall analysis)
- Maximum runoff estimated from 27 mm rainfall = 08 mm (@ 30% of 27 mm)
- Runoff estimated over 1 ha of land = 100m X 100 m X 0.008 m=80 m^3

*Therefore, an estimated Run – off in the area of**, the School of planning & Architecture Open*** area (12.950 Ha) *was assessed as 1036 m^3 to augment the ground water recharge and water conservation measures.*

- **Assessed Run off, at the campus of SAP to design the RWH structures = *1036* M^3**

2. Volume of water available for rain water harvesting through entire SPA area

Description of Area	Area (Sqm)	Run-off Factor	Yearly Rainfall (m)	Volume of Water Available for Rain Water Harvesting Yearly (cum.)
Total Area	302100	0.35	1.146	121172

Considering 80 % of water is actually available for rain water harvesting = 96938 Cubic meter yearly.

3. Volume of water available for rain water harvesting through roof top

Description of Area	Area (Sqm)	Run-off Factor	Yearly Rainfall in (mt.)	Volume of Water Available for Rain Water Harvesting Yearly (cum.)
Roof Top	35,650	0.9	1.146	36769
Total				

Considering only 80 % of water is actually available for rain water harvesting = 29415 cum. yearly.

4. Enumeration of the RWH of the Bore wells through the Roof top

Roof of proposed building complex location	Effective roof top area (sq m)	Harvested water from roof top (cum)
TOTAL	**35,650**	

- Total Roof Top area = $35650\ m^2$
- Annual rainfall of 50 % dependability = 1146 mm x 0.50
  = ***573 mm or 0.573m***

► **Rainfall quantity on the total roof top =35650 m^2 x 0.573= 20427 m^3 OR 20427000 liters.**

► **Rain water to be harvested from roof = 20427^3 x 0.80 = 16342 m^3 or 16342000 liters.**

► **From roof top of Building complex, rainwater harvesting will augment the quantity of 16342000 liters.**

5. Proposed scheme for rainwater harvesting of bore wells through roof top at the premises

The introduction of a *Roof top rain water harvesting* connected through the outlet system of the Rainwater received from the Roof top of the respective buildings in the campus of SPA is proposed.

No. of Bore well for recharge		Feasible & proposed
Proposed	**Existing**	
04	07	Roof top rainwater harvesting through bore well

A closed system will collect the water from the roof top through a filter to an under ground collection tank. The excess water from the collection tank would then be directed towards the proposed bore well meant to recharge the strata below and thus benefit the existing and the proposed bore wells.

The pipeline system layout is being planned under ground to a depth of more than 2.5 ft. with proper slope (from underground tank to bore well).

The roof top rainwater is channelized through PVC Pipes of 5 –inch dia. connected to roof drains to collect rainwater. The first 2-3 showers is set off through the bottom of drain pipe coming from roof after closing the bottom of pipe, the rainwater of subsequent showers is taken through T to an On – line Filter (PVC Filter).

Salient feature of proposed rainwater harvesting structure

The area receives a large quantity of surface run off (free from contamination as well as roof) during the rainy season. Rainwater harvesting through existing and proposed bore wells can be adopted to recharge the deeper aquifers.

Number of tube wells for recharging	-	07 + 04 = 11 (Direct)
Geology	-	fractured Basalt
Advantage	-	Direct recharge to bore wells

Rainwater harvesting through proposed bore wells is feasible.