PRESERVE GROUND WATER. ENRICH FUTURE.

Groundwater Surveys & Development Agency
Govt. of Maharashtra

REFERENCE BOOK

GROUNDWATER SURVEYS AND DEVELOPMENT AGENCY-GSDA

(WATER SUPPLY AND SANITATION DEPARTMENT) **GOVERNMENT OF MAHARASHTRA**

Preface

Groundwater is considered as the ideal source of water for mitigating domestic, industrial and agricultural requirements. Due to its longer residence time in the subsurface, low level of contamination, wide distribution and availability within reach of the consumer. Hence development of groundwater gets first priority both at individual as well as government level for different uses. However the occurrence and distribution of groundwater is not uniform through out the state and is subject to wide spatio- temporal variations depending upon the underlying rock formations, their structural fabric and geometry, surface expression etc.

As a field person, the officers of GSDA are always on to their tows to conserve and manage this precious natural resource. It is customary for them to get acquainted with common conversion of the measuring units, basic chemical quality units; engineering measurements etc. This helps in their day to day functioning.

It is indeed a pleasure for me to publish a reference book for the field officers, on the occasion of 38th Foundation Day of GSDA which will be immensely beneficial to officers as well as to Department in the routine working.

We, at the Head office of Groundwater Surveys & Development Agency, Pune are always at the healing task to smoothen your effort at the grass root level.

Wishing you a very happy 'Foundation Day'.

Vikas Kharage IAS
Director
Groundwater Surveys & Development Agency (MS) Pune 411005.

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MAHARASHTRA AT A GLANCE

- **Total area** - 30.77 million ha
- Location - Longitude - 72^{0}30' 00” to 80^{0} 30' 00”
  Latitude - 15^{0}40' 00” to 22^{0} 00' 00”
- Coastline - 720 KM.
- Total Population - 96.7 million (Urban - 41Rural - 55.7)
- Districts/Talukas/Cities - 35 / 353 / 336
- Total villages / Hamlets - 43711 / 45528

- **Physiography**

- Highly Dissected Plateau - 6.15 million ha
- Moderately Dissected Plateau- 15.39 million ha
- Undissected Plateau - 9.23 million ha

- **Rainfall Zone**

- High Rainfall - 2000 - 3500 mm
- DPAP Area - 400 – 700 mm
- Assured Rainfall - 800 – 1250 mm

- **Cultivable Area** - 21.04 million ha

- **Forest Area** - 6.19 million ha.

- **River Basin/Sub Basin** - 5 / 15

- Watersheds - 1505
- Mini Watersheds - 10101
- Assessment subunit - 2316

- **Surface Water Potential**

- Projects Major/Medium - 2488
- Projects Minor - 1469
- Irrigation Potential created - 39.57 lakh ha
- Potential Utilized - 24.42 lakh ha
- Area - Surface Irrigation - 11.47 lakh ha

• Cropping Pattern

- Konkan: Paddy, horticulture and vegetables.
- Western Maharashtra: Jawar, wheat, sugarcane, groundnut, onion, horticulture, sunflower .
- Central Maharashtra: Jawar, wheat, sugarcane, cotton, gram, vegetables, sunflower, saffola.
- Vidharbha: Paddy, Jawar, wheat, cotton, orange, gram, chilly.
- Khandesh: Jawar, wheat, banana, maize, grams, chilly.

• Groundwater Potential

- Recharge - 3.09 lakh ham
- Draft - 1.33 lakh ham
- Area irrigated by GW - 25.46 lakh ha
- Irrigation Wells - 14.46 lakh
- No. of OE/Critical/Semi-Criti.- 76 / 20 /163 watersheds

• Drinking Water Status (RWS)

- Dugwells - 90,000
- Borewells - 3,00,000
- Power Pumps - 14,000
- Single Village Scheme - 9,500
- Multi Village Scheme - 584
- On going Rural Schemes - 14,199
- Urban Water Supply - 460 working / 238 on going
- Investment made (Rs.) - Rural –16,000 / Urban – 7,000 Crores

DISTRIBUTION OF DIFFERENT GEOLOGICAL FORMATIONS OF THE MAHARASHTRA STATE

	Geological Formations	Sq. km.	Percent
V.	Pleistocene & Quaternary Alluvial Sediments	14,500	4.71
IV	Deccan Trap lava flows	2,50,000	81.24
III.	Gondwana sedimentary rock formations	4,800	1.55
II.	Vindhyan & Cuddapah Pre-Cambrian meta-sediments	6,200	2.02
I.	Archaeans & Dharwars Metamorphic Complexes	32,200	10.48
	T O T A L	3,07,700	

GEOGRAPHIC DISTRIBUTION OF ROCK FORMATIONS IN THE DISTRICT

AGE	ROCK FORMATIONS	GEOGRAPHIC DISTRIBUTION IN THE STATE
(1)	(2)	(3)
Recent and Pleistocene	Alluvium, Late rite, Soil, Sand etc.	Parts of Amaravati, Akola, Buldana, Jalgaon, Dhule, Bhandara, districts. Laterites in Kolhapur, Satara, Sangali, Ratnagiri, Sindhudurg, Raigad and Thane districts.
Lower Eocene to Upper Cretaceous	Deccan Traps: Volcanic lava flows with inter-trappeans and infra-trappeans [Lameta and bagh beds]	All the district of the state excepting Bhandara, Gondia and Gadchiroli
Jurassic [Upper Gondwana]	Chikiala and Kota stage: Limestone.	Sironcha tahsil of Gadchiroli district
Triassic	Pachmarhi and Makri stages: Clays, Sandstones.	Sironcha tahsil of Gadchiroli district and Achalpur tahsil of Amaravati district.
Permian [Lower Gondwana]	Mangali beds : Sandstones and Coal.	Warora tahsil ; Chandrapur district.
	Kamathi Series: Sandstones, Shales and Coal.	Nagpur, Chandrapur and Yavatmal districts.
	Barakar Series: Sandstones, Shales and Coal.	Nagpur, Chandrapur and Yavatmal districts.
Upper Carboniferous	Talchir Series.	Nagpur, Yavatmal, Chandrapur, Gadchiroli districts.
Pre-Cambrian	Vindhyan System: Limestone, Shales and Sandstones	Yavatmal, Chandrapur, Gadchiroli,
	Cuddapah System: Limestone and Shales	Sironcha tahsil ; Gadchiroli district
	Kaladagi Series:Sandstones, Conglomerates, Quartzites and Shales	Kolhapur and Sindhudurg
Archaeans Middle Dharwar	Sakoli Series: Iron ore series	Chandrapur, Nagpur, Bhandara, Gondia, Ratnagiri, Sindhudurg,
Lower Dharwar	Sauser Series	Nagpur, Bhandara, (Gondia.)
Archaeans	Older Schists (Unclassified crystalline)	Nagpur, Chandrapur, Bhandara, Gadchiroli, Gondia.

STATEMENT SHOWING DISTRICT WISE AREA

Sr,. No	District	No. Of Talukas	No. Of WS	AREA IN HECTARES Total	Hilly	Command	Poor Quality
1	2	3	4	5	6	7	8
1	THANE	15	34	955800.00	447268.00	19730.00	0.00
2	RAIGAD	15	17	715200.00	340041.00	15294.00	0.00
3	RATNAGIRI	9	20	820800.00	309493.00	6247.00	0.00
4	SINDHUDURG	8	11	520700.00	225482.07	2260.56	0.00
5	NASHIK	15	80	1553000.00	201253.00	163135.00	0.00
6	DHULE	4	65	719500.00	257007.00	66069.00	0.00
7	NANDURBAR	6	66	595500.00	37253.10	163584.00	0.00
8	JALGAON	15		1176500.00			
9	AHMEDNAGAR	14	80	1704800.00	114180.00	368134.30	0.00
10	PUNE	13	71	1564300.00	256009.00	243660.00	28422.00
11	SOLAPUR	11	64	1489500.00	5610.00	197286.00	0.00
12	KOLHAPUR	12	40	768500.00	206543.00	0.00	0.00
13	SANGLI	10	38	857200.00	9798.76	33455.19	5904.28
14	SATARA	11	50	1048000.00	165946.00	73632.75	0.00
15	AURANGABAD	9	52	1010700.00	77796.00	152345.00	0.00
16	JALNA	8	52	771800.00	0.00	54299.44	0.00
17	BEED	11	48	1069300.00	33550.00	104227.00	0.00
18	PARBHANI	9	51	621400.00	0.00	432136.00	0.00
19	HINGOLI	5	49	482700.00	12632.00	121449.00	0.00
20	NANDED	16		1052800.00			
21	OSMANABAD	8	41	756900.00	83367.00	40245.00	0.00
22	LATUR	10	39	715700.00	40354.00	44924.00	0.00
23	AMRAVATI	14	63	1221000.00	381761.38	35253.00	139373.00
24	YEOTMAL	16	64	1358200.00	198803.47	161103.01	0.00
25	BULDHANA	13	57	966100.00	196182.00	48109.00	55701.00
26	AKOLA	7	65	567600.00	54871.00	9377.00	75908.00
27	WASHIM	6	54	489800.00	181900.00	223371.00	0.00
28	NAGPUR	13		989200.00			
29	BHANDARA	7	54	408700.00	78186.50	246443.75	0.00
30	GONDIA	8	39	523400.00	46723.40	82025.00	0.00
31	WARDHA	8		630900.00			
32	CHANDRAPUR	15	58	1144300.00	81534.00	84979.00	0.00
33	GADCHIROLI	12	83	1441200.00	560354.90	22679.71	0.00
	TOTAL	353	1505	**30711000.00**	4603899.58	3215453.71	305308.28
	MUMBAI			60300.00			
		GRAND TOTAL			**30771300.00**		

BASINS OF MAHARASHTRA

Basin	No. of Watersheds	Area (sq. km)	District Covered
Narmada	08	1595	Dhule
Tapi East	184	32770	Dhule, Jalgaon, Nashik, Amravati, Aurangabad
Godavari	190	43283	Nashik, Ahmednagar, Aurangabad, Jalna, Beed, Parbhani, Nanded, Gadchiroli
Krishna	97	20237	Kolhapur, Satara, Sangli,
Westerly Flowing	97	31933	Thane, Raigad, Ratnagiri, Sindhudurg, Kolhapur, Nashik
Bhima	161	35922	Pune, Ahmednagar, Solapur, Satara, Sangli, Osmanabad
Wainganga	161	27558	Bhandara, Chandrapur, Nagpur, Gadchiroli, Gondia
Wardha	117	21397	Amravati, Wardha, Nagpur, Yeotmal, Chandrapur
Godavari Purna	101	16362	Aurangabad, Jalna, Parbhani, Buldana
Penganga	108	22972	Yeotmal, Nanded, Akola, Buldana, Parbhani.
Purna Tapi	98	16732	Buldana, Akola, Amravati, Jalgaon
Manjara	78	15835	Osmanabad, Latur, Beed, Nanded.
Sina	58	12234	Ahmednagar, Solapur, Beed , Osmanabad
Indravati	31	5488	Gadchiroli
Pranhita	16	3395	Gadchiroli

GROUNDWATER GLOSSARY

AQUIFER

A geologic formation having structures that permit appreciable water to move through it under ordinary field conditions.

It is a water saturated geologic unit that will yield water to wells or springs at a sufficient rate so that they can serve as practical sources of water supply.

AQUICLUDE

An impermeable geologic formation that may contain water but is incapable of transmitting significant water quantities (e.g.-clay).

AQUIFUSE

An impermeable geologic formation, neither containing nor transmitting water.

ARTIFICIAL RECHARGE

may be defined as augmenting the natural infiltration of precipitation or surface water into under ground formations by some method of construction, spreading of water or by artificially changing natural conditions. It is the practice of increasing by artificial means the amount of water that enters the groundwater reservoir.

CONE OF DEPRESSION

A drawdown curve shows the variation of draw down with distance from the well. The cone of depression is the conic shape that a draw down curve describes in three dimensions. The outer limit of the cone of depression defines the area of influence of the well.Any well, when pumped, is surrounded by a cone of depression. Each differs in size and shape depending upon the pumping rate, length of pumping period, aquifer characteristics slope of the water table and recharge within the zone of influence of the well.

The transmissibility of the aquifer affects the shape of the cone. In a formation with low transmissibility, the cone is shallow and has a large base with flat side slopes.

CONFINED AQUIFER

The confined aquifers, also known as artesian aquifers, occur where groundwater is confined under pressure greater than atmospheric by overlying relatively impermeable strata. In a well penetrating such an aquifer, the water level will rise above the bottom of the confining bed.

The piezometric surface of a confined aquifer is an imaginary surface coinciding with the hydrostatic pressure level of the water in the aquifer.

CONSUMPTIVE USE

All water, surface and subsurface released into the atmosphere by processes of evaporation and transpiration is consumptive use or evapotranspiration.

DARYC'S LAW

Refers to a measure of the permeability of rocks. One Darcy (D) equal to permeability such that 1 ml of fluid having a viscosity of one centipoise is flowing in one second under pressure differential of one atmosphere through a porous material possessing a cross sectional area of 1 sq cm& length of 1 cm. The working unit is taken as mili Darcy (m D) one thousandth of Darcy

DRAWDOWN

Draw down in a well means the extent of lowering of the water level when pumping is in progress or when water is discharging from a flowing well. Draw down is the difference, measured in mt., between the static water level and pumping level.

EFFECTIVE POROSITY

It may be defined as the ratio expressed as a percentage of the volume of water, which, after being saturated, can be drained by gravity to its own volume.

It is synonymous with specific yield.

EVAPOTRANSPIRATION

Sum of the quantities of water vapours evaporated by the soil and transpired by plants under existing meteorological and soil moisture conditions.

EFFLUENT STREAM

Where the groundwater seeps into the stream channel from the zone of saturation because the water table is higher. The stream is effluent with respect to groundwater.

INFLUENT STREAM

A stream of stretch of stream that contributes water to the zone of saturation is termed influent with respect to the groundwater.

FIELD CAPACITY

The capacity of the soil to hold pellicular water measured by soil scientists as the ratio of weight of water retained by the soil, the weight of dry soil.

GROUNDWATER HYDROLOGY

The science of the occurrence, distribution and movement of water below the surface of the Earth.

GEOHYDROLOGY

Has an identical connotation as groundwater hydrology.

HYDROGEOLOGY

It differs from geohydrology only by its greater emphasis on geology.

GROUNDWATER: Water in the zone of saturation is the only part of all subsurface water, which is properly referred to as Groundwater. It means water occupying all the voids within a geologic stratum from the saturated zone. This saturated zone is to be distinguished from an unsaturated, or Aeration-Zone where voids are filled with water and air. Unsaturated zones are usually found above saturated zones and extending upward to the ground surface.

GROUNDWATER DIVIDE

Line on water table from which the water table slopes downward away from the line on both sides.

HARDNESS OF WATER

Calcium and magnesium cause almost all the hardness of water. Total hardness (TH) is a measure of the calcium and magnesium content and is customarily expressed as the equivalent of calcium carbonate. TH is measured in parts per million of CaCO3, ppm of Ca and Mg.

HYDAULIC CONDUCTIVITY

The coefficient of permeability is also referred to as Hydraulic conductivity because of its analogy to electrical and thermal conductivity.

INFILTRATION GALLERIES

Is a horizontal permeable conduit for intercepting and collecting groundwater by gravity flow.

ISOHYETAL MAP

A map showing isohyets which are line drawn on a map passing through places having equal amounts of rainfall recorded during the some period at these places (these lines are drawn after giving consideration to the topography of the region is isohyets i.e. a line joining points of equal rainfall.

ISOBATH

Of water table is the line of map which connects all points that are at the same vertical distance above water table beneath a certain datum which may be grandee of mean sea level.

ISOBAR

Is the line joining points of equal barometric pressure.

ISOPACH

Map shows variations in stratigraphic thickness of formation by means of contour lines drawn through points where the formations have equal thickness.

ISOPERCENTAL MAP

A map showing lines connecting points of equal percentage of rainfall after showing the annual or monthly rainfall at each rain gauge station as a percentage of the annual long-average figures for that station.

PERCHED WATER TABLE

Is a special case of unconfined aquifer. This occurs wherever a groundwater body is separated from the main ground water by a relatively impermeable stratum of small aerial extent and by the zone of aeration above the main body of groundwater.

PERCOLATION

Flow through a porous substance.

PERMEABILITY Is defined as the capacity of a porous medium for Transmitting water. The coefficient of permeability is defined as the flow of water in gallons per day through a medium having a cross-sectional area of one square feet under a hydraulic gradient of one foot per foot at the prevailing temperature (expressed in m/sec. ft/sec)

PIEZOMETRIC SURFACE

Of a confined aquifer is an imaginary surface coinciding with the hydrostatic pressure level of the water in the aquifer.

PIEZOMETRIC LEVEL

Is the elevation of which the water level rises in a well that taps an artesian aquifer.

POROSITY

Of a water-bearing formation is that part of its volume, which consists of openings or pores- the proportion of its volume, not occupied by solid material. It is expressed as the percentage of void space to the total volume of the mass.

Porosity is thus a measure of water holding capacity of the formation. Not all of this water may be removed from ground by drainage or pumping a well, as molecular and surface tension forces will hold a portion of the water in place.

PUMPING LEVEL
This is the level at which water stands in a well pumping is in progress.

PUMPING TEST
Is the method for estimating aquifer permeability.

RADIUS OF INFLUENCE
Is the distance from the center of the well to the limit of the cone of depression. It is larger for cones of depression surrounding artesian wells than for those around water table wells.

RECHARGE AREA
This is the area supplying water to a confined aquifer.

RESIDUAL DRAWDAWN
After pumping is stopped, water levels rise and approach the static water level observed before pumping started. During such a recovery period, the distance that the water level is found to be below the initial static water level is called the residual draw down.

SAFE YIELD
Of ground water basin is the amount of water, which can be withdrawn from it annually without producing an undesired effect. Any draft in excess of safe yield is overdraft.

SPECIFIC CAPACITY
Specific capacity of a well is its yield per unit of draw down, usually expressed as gallons per minute per foot of draw down Dividing the yield by the draw down, each measured at the same time, gives the value of specific capacity

SPECIFIC RETENTION
is the ratio expressed as percentage of the volume of water it will retain after saturation against the force of gravity to its own volume.
is the ratio expressed as percentage of the volume of water it will retain after saturation against the force of gravity to its own volume.

SPECIFIC YIELD

is the ratio expressed as percentage of the volume of water which, after being saturated, can be drained by gravity to its own volume.

Specific yield plus specific retention equals porosity.

STATIC WATER LEVEL

This is the level at which water stands in a well when no water is being taken from the aquifer either by pumping or by free flow, it is generally expressed as the distance from the ground surface (or from a measuring point near the ground surface) to the water Level in the well.

STORAGE COEFFICIENT

is defined as the volume of water that an aquifer releases from or takes into storage per unit surface area of aquifer per unit change in the component of head normal to that surface.

The storage coefficient for an unconfined aquifer corresponds to its specific yield.

TRANSMISSIBILITY

Coefficient of Transmissibility is the rate of flow in gallons per day through a vertical strip of aquifer one feet wide and extending the full saturated thickness of the aquifer under a hydraulic gradient of one foot per foot at the prevailing temperature.

The Coefficient of Transmissibility equals the field coefficient of permeability multiplied by the aquifer thickness in feet.

WATER TABLE

The upper surface of zone of saturation is called water table.

WELL YIELD

Yield is the volume of water per unit of time discharged from a well either by pumping or by free flow. It is commonly measured as the pumping rate in litres per minute.

ZONE OF AERATION

This is the zone from ground surface to water table, wherein the openings are only partly filled with water.

ZONE OF SATURATION

This is the zone below the water table where all the openings are completely filled with water.

AERATION ZONE OR ZONE OF SUSPENDED WATER

The zone above the water table in which interstices are partly filled with ground air except in the saturated portion of capillary fringe.

BASE FLOW

The sustained or dry weather flow of streams resulting from the out flow of permanent or perched ground water and from the draining of large lakes and swamps. Also water from glaciers, snow and all other possible sources not resulting from direct runoff.

CONNATE WATER

Water which has entered a rock formation by being entrapped in the interstices of the rock material (either sedimentary extrusive igneous) at the time the material was deposited.

CATCHMENT AREA OR BASIN (OF AN AQUIFER)

The surface area composed of the intake area of an aquifer and all other areas which contribute surface water to the intake.

HYDRAULIC GRADIENT

The decrease in hydraulic head per unit distance in the soil in the direction of flow.

HYDRO ISOPLETH MAP

A map showing fluctuation of water table with respect to time and space.

HYDROGRAPH

A graphic plot of changes in flow of water or in elevation of water level against time.

HYDROLOGIC CYCLE

All movements of water and water vapor in the atmosphere, on the ground surface, below the surface and return to the atmosphere by evaporation and transpiration.

INDUCED RECHARGE OF AN AQUIFER

Discharge of water from a stream into an aquifer induced by lowering the water table.

INFILTRATION RATE CURVE

Curve showing the actual rate of infiltration during a particular storm.

INFLUENT SEEPAGE

Movement of gravity water in the zone of aeration from the ground surface towards the water table.

Movement of gravity water in the zone of aeration from the ground surface towards the water table.

Phreatic Cycle, Cycle of Fluctuation. The total time occupied by a period of rise and a succeeding period of decline of a water table. The most common kinds of cycles are daily, seasonal and annual.

Important Points in Well Schedule Form

MEASUREMENT POINT

Measurement point means measuring point. This is a point from which all measurements are taken. This may be the top of parapet of a well or top of the lineal across the well or sometimes top of the lining M.P. should be described and the height above/or below G.L. should also be recorded. The direction of M.P. should be mentioned.

HEIGHT OF PARAPET

This is to be measured from G.L.

• **Depth:** All depths must be measured from the measuring point.

• **D.W.L:** Depth to water level is measured from the measuring point. S.W.L represents static water level, which is that level reached by the well where it is not pumping for at least 24 hours. PWL means pumping water level. When the well is recovering after cessation of pumping, information regarding the static water level could be ascertained.

DRAW DOWN

This can be computed by ascertaining the S.W.L. or the P.W.L. whichever could not be measured at the time of visit, for computing Draw down. The S.W.L. and maximum PWL that may prevail on the day of visit, alone need be taken. (These two levels gradually decline with the onset of summer. Data on summer conditions are being recorded separately).

TRAJECTORY

One of the methods of measuring the rate of pumping is by the method of trajectory. The rate of pumping can also be ascertained by measuring the quantity of water that collects in a container of known volume in a specified time interval. Generally, the rate of pumping is to be expressed in liters per minute (L.P.M.)

DURATION OF PUMPING

Duration of pumping can be expressed in terms of hours and could be ascertained from the owners. It often happens that the well is pumped in a number of stages and these could be indicated. The quantity of water could be worked out by multiplying the rate of pumping by duration.

THE DISCHARGES OF PRIME MOVER FOR DIFFERENT HORSE POWER

Prime Mover	L.P.M.	L.P.H.
3 HP EM	300	18000
5 HP EM	375	22500
5 HP O E	300	18000
7.5HP EM	412	24750
10 HP EM	450	27000
Mhot	90	5400

RECUPERATION

It is to be noted that overnight recuperation is that amount of water that percolates into the well in a period of about 12 hours. The water level at the end of about 12 hours (overnight) is not always the same as S.W.L that may prevail of the end of 24 hours of recovery.

ONRQ (Metric) = 785*D2 * H

AQUIFER PERFOMANCE TEST FOR SHALLOW OPEN DUG WELLS

The specific capacity formula of Slichter can be used for analysing data on pumping tests for dug wells. The Slichter formula is as under:

$C = 2303 \ {}^{A}/_{t} \ \log 10 \ S_1 / S_2$ (in metric system in lpm/meter draw down)

Where C = Specific capacity

A = Effective cross sectional area of the well

t = time in minutes since pump stopped

S_1 = the total drawdown just before pump stopped

S_2 = the residual drawdown at any time since Pump stopped (t)

The application of the above formula indicates that in case of open wells shown "quiescent" (slow) recoveries, there exists some direct relationship between t and log S_1/S_2 in other words, if the values of "t" are plotted in against S_1/S_2 on semi-log graph sheet, with the later on the log scale, the points would generally fall on a straight line. This suggests that there is a continuous adjustment between the rate of infiltration and the hydraulic head acting at a given time.

The slope of the straight time plotted in semi-log graph sheet would be helpful in determining the values of T and S which can be substituted in the Jacob's formula, wherein.

$$T = \frac{2.3\ Q}{4\pi S}$$

Where T is **coefficient of transmissibility** in m^2 / day.

Q = rate of discharge in cubic meters per day

π = 3.14

and S (read as delta 'S') is the slope of the time draw-down graph expressed as the change in draw-down between any two values of time on the log scale whose ratio is 10 i.e. for one complete log cycle.

Once 'T' is calculated, the following formula based upon Jacob's formula can also be solved.

$$S = \frac{2.25 \times T \times t^{o} \times 6.96\ 10^{-4}}{r^2} \text{ (dimensionless)}$$

where S = storage coefficient

t^o = intercept of the straight line at zero draw down in days

r = Effective diameter

In case of large diameter dugwell, the “r” factor can be considered to be the effective diameter of the well itself.

PROCEDURE FOR DETERMINING MONITORING YIELD OF DUG-WELLS

In order to determine the yield of the well at a given instant, 'Trajectory Method' is generally adopted. In this method trajectory of the water falling through the delivery pipe of known diameter is measured. The vertical height of .30m is to be maintained between the point of trajectory and horizontal projection of outer and upper rim of delivery pipe. This horizontal distances is adjustable. The length of trajectory is always specified in inches.

The quantity of water discharged per minute is given by the formula:- Q = L x K where Q is the quantity of water yielded, L is the length of the trajectory while K is the constant of multiplication for the drop of 0.3 m. The values of K for several inner diameter of delivery pipe have been given in the enclosed table. The constant is variable for litres per min, when the delivery pipe is horizontal, and inclined.

A precaution needs to be taken in such measurements. Firstly the inner diameter of the pipe should be uniform and there should not be any coupling or piece of hosepipe attached to the end of delivery pipe. The pipe should be well above ground level so that the trajectory measurement is facilitated. Trajectory measurement will be on higher side when the pump is just started. It will be too small when the well is nearly dewatered. Hence it is advisable to measure the trajectory when the pump has run for 15 to 30 minutes and when there is no further decrease in trajectory.

Table for measurement of discharge by the Trajectory Method K, constant of multiplication for a drop of one foot

Inner dia of pipe (Inches)	Ltr/min	Ltr/hr
2	12.5	750
2 ¼	15.5	930
2 ½	19.3	1158
2 ¾	23.5	1410
3	27.6	1656
3 ¼	32.6	1956
3 ½	37.9	2274
3 ¾	43.5	2610
4	49.6	2976
4 ¼	55.6	3336
4 ½	62.5	3750
4 ¾	69.7	4182
5	77.2	4632
5 ¼	85.2	5112
5 ½	93.5	5610
5 ¾	102.2	6132
6	111.2	6672

TABLE SHOWING DISCHARGE FROM TRIANGULAR (v) Notch weirs with end contractions

Head (H) in inches	Flow in Litres per hour	
	90^0 Notch	60^0 Notch
1	500	290
1 ¼	870	500
1 ½	1375	800
1 ¾	2020	1165
2	2820	1625
2 ¼	3795	2185
2 ½	5930	2840
2 ¾	6250	3610
3	7770	4475
3 ¼	9500	5475
3 ½	11430	6590
3 ¾	13565	7840
4	15950	9200
4 ¼	18560	10725
4 ½	21400	12360
4 ¾	24540	14150
5	27950	16085
5 ¼	31580	18175
5 ½	35444	20426
5 ¾	39535	22720
6	43850	25450
6 ¼	48620	28170
6 ½	53620	30900
6 ¾	59070	34080
7	64530	37260
7 ¼	70435	40670
7 ½	76800	44300
7 ¾	83385	48170

WATER REQUIREMENT FOR VARIOUS CROPS (FOR 1-ACRE IRRIGATION)

Season	Name of the Crop	Crop Period in Days	Ac. Inch. depth required	K.L. water required	Water required in Ham	No. Of Watering required	Total Ac. inch. water	K.L. Water required	Total water req. in Ham
1	2	3	4	5	6	7	8	9	10
Kharif July – Sept.	Hybrid Jawar	120	2.5	269.25	0.026925 5	6	15	1615.5	0.16155
	Cotton	170 -190	2.5	269.25	0.02625	2	5	538.5	0.05385
	Paddy	120 -135	3.3	365.41	0.035541	3	9.9	1066.23	0.106623
	Sugarcane	365	3	323.1	0.03231	4	12	1292.4	0.12924
	Orange	365	2	216.4	0.02154	4	8	861.6	0.08616
	Banana	450	2	215.4	0.02154	4	8	861.6	0.08616
	Groundnut	120	2	215.4	0.02154	2	4	430.8	0.04308
	Vegetable	90 -110	2.5	269.25	0.02692 5	4	10	1077	0.1077
Rabi Oct. – Feb.	Wheat	120	3	323.1	0.03231	7	21	2261.7	0.22617
	Cotton	170 -190	2.5	269.25	0.026925	3	7.5	807.75	0.080775
	Sugarcane	365	3	323.1	0.03231	17	51	5492.7	0.54927
	Banana	450	2.5	269.25	0.026925	12	30	3231	0.3231
	Orange	365	2	215.4	0.02154	8	16	1723.2	0.17232
	Hybrid Jawar	135	3	323.1	0.03231	6	18	1938.6	0.19386
	Gram	105	2.5	269.25	0.026925	5	12.5	1346.25	0.134625
	Vegetable	90 -110	2.5	269.25	0.026925	12	30	3231	0.3231
Hot Weather Crop May-June	Cotton	170 -190	3	323.1	0.03231	3	9	969.3	0.09693
	Sugarcane	365	3.5	376.95	0.037695	12	42	4523.4	0.45234
	Banana	450	3.5	376.95	0.037695	20	70	7539	0.7539
	Orange	365	2.5	269.25	0.026925	12	30	3231	0.3231
	Vegetable	90 -110	3	323.1	0.03231	15	45	4846.5	0.48465

COMMON MAP SCALES

Scale of Map	Reduced Factor (R. F.)	Approximate metric	Area on the map for map for one square Inch (in acres)
1" = 16 miles	1 : 10, 13, 760	1 : 1000,000 (cm = 10 km)	163,800
1" = 4 miles (1 cm = 2.5 km)	1 : 2, 53, 440	1 : 250,000	10,240
1" = 2 miles	1 : 1, 26, 720	1 : 125,000 (1 cm = 1.25 km)	2560
1" = 1 mile 1" = 8 furlongs 1" = 5280'	1 : 63, 360	1 : 50,000 (1 cm = 500 m)	640
1" = 4 furlongs or 2640'	1 : 31, 680	1 : 25,000 (1 cm = 250 m)	160
1" = 2 furlong or 1320'	1 : 15, 840	1 : 15,000 (1 cm = 150 m)	40
1" = 1 furlong or 660'	1 : 7, 920	1 : 10,000 (1 cm = 10 0 m)	10
1" = 330' or 1" = 1/16 mile 1" = ½ furlong	1 : 3, 960	1 : 5,000 (1 cm = 50 m)	2.5

SLOPE, ASPECT AND ALTITUDE

Guidelines of all India Soil and Land use Survey (AIS & LUS) on slope categories (vide Soil Survey Manual, IARI, 1971).

Sr.No.	Slope Category	Slope (%)
1.	Nearly level	0 - 1
2.	Very gently sloping	1 - 3
3.	Gently sloping	3 - 5
4.	Moderately sloping	5 - 10
5.	Strongly sloping	10 - 15
6.	Moderately steep to steep sloping	15 - 35
7.	Very steep sloping	> 35

Methodology

Survey of India toposheet maps on 1: 50,000 scales are to be used for deriving the information on slopes, aspect and altitude. A land with five meters of vertical drop over a horizontal distance of 100 meters has 5% slopes. Accordingly, 10m or 20m vertical drop for every 100 meters of horizontal distance is 10% or 20% slope respectively.

Topographical maps on 1: 50,000 scale give contours with 20 meter interval or its multiple i.e. 40 m, 60m, 80m etc. The vertical drop can be estimated / measured from the contour intervals and the horizontal distance in between the contours can be measured from maps by multiplying the map distance with the scale factor. Close spaced contours on the map have higher percentage slope as compared to sparse contours in the same space. Thus density of contours on the map can be used for preparing the slope map that gives various groups / categories of slopes. The categories of slopes and corresponding contour spacing on 1: 50,000 scales are given below-

Slope Category	Lower and Upper Limit of Slope Percentage	Lower and Upper Limit of Contour Spacing
1	0 - 1%	More than 4 cm.
2	More than 1% up to 3%	More than 1.33 cm and up to 4 cm
3	More than 3% up to 5%	More than 0.8 cm and upto 1.33 cm.
4.	More than 5% up to 10%	More than 0.4 cm and and up to 0.8 cm
5.	More than 10% up to 15%	More than 0.26 cm and up to 0.4 cm
6.	More than 15% up to 35%	More than 0.11 cm and up to 0.26 cm
7.	More than 35%	0.11 cm and less

To illustrate the slope category 2 which is " more than 1% and up to 3% slope" the lower limit of contour spacing 1.33 cm means, over a horizontal distance of 1.33 cm x 50,000 = 66500 cm = meters there is vertical drop of 20 meters.

Thus the slope percentage is

$$\frac{20 \times 100}{665} = 3\% \text{ approx}$$

The upper limit of 4 cm contour spacing means, over a horizontal distance of 4 cm x 50,000 = 200000 cm= 2000 meters, there is a vertical drop of 20 meters. Thus the slope percentage is

$$\frac{20 \times 100}{2000} = 1\%$$

Thus all areas on the map having contour spacing between 1.33 cm and 4 cm belong to slope category 2 i.e. 1% to 3%. However, while drawing the boundary for each slope class smoothness of the boundary has to be achieved by the interpreter.

Aspect can also be derived from toposheet directly. For altitudinal zoning, the contours should be merged / grouped. The lower and upper limit of the altitudinal zones should be depicted by the respective contour lines.

Digital slope and aspect maps can also be generated using contours extracted from toposheets through Digital Elevation Model (DEM).

MORPHOLOGICAL CLASSIFICATION

Occurrence, storage and movement of Groundwater is greatly controlled by morphological set up in Hard Rock Terrain.

Influence of Morphology on Hard Rock Aquifer

The aquifer is controlled by weathered thickness. Hence, aquifer thickness is less on ridges, while aquifer thickness is more in the valleys.

The flow direction of groundwater concentrates in the valley; and hence valleys act as a storage zone; while the flow direction is radial on the ridges. Hence act as a run off zone, also for groundwater.

Watershed classification in relation to Basin -

For precise indexing of watershed and a ultimately of villages. It is necessary to classify the watersheds of basin in three zones. i.e. A - Run off zone, B - Recharge zone, C - Storage zone.

Thus the watersheds of same major zone are expected to have similar hydrogeological conditions, for e g., In any watershed falling in A zone of Godavari basin, run off is a dominant factor.

The basin in divided in 3 zones on the basis of gradient or slope of the area.

A - Run off zone - Area of steep slope, i.e. from the basin divide ridge to the foot hill of ridge.

B - Recharge zone - Area of moderate slope, from foot hill region, to area of gentle slope.

C - Storage zone - Area of gentle slope, adjoining to the major river and alluvial plains.

Sub zones in the watershed, area extend in each category -

After classification of watershed in a any given basin, individual watershed should be divided in a, (Run off sub-zone), b (recharge sub-zone), c (Storage zone) for classification of villages. Thus villages falling in one sub zone should have same index for eg. villages located in a sub zone of A watershed of Godavari basin will have index "Aa".

The hydro geological conditions of villages falling in one sub zone are expected to be similar. Thus the village indexing on the morphological basis provides general hydrological conditions of particular village for e.g. villages falling Aa sub zone, are unfavorable for occurrence of groundwater, while Cc villages are most favorable for occurrence of groundwater.

Following Guidelines should be observed for classification of villages.

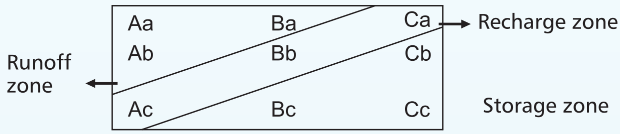
1) In the A watershed, area covered by (a) sub zone should be more than 60%. While area covered by (b) sub zone should be between 20 to 30% and area covered by (c) sub zone should range between 0 to 10%.

Similarly for B and C watershed area covered by (b) and (c) should be more than 60% respectively; in a B watershed area covered by (a) and (c) should range between 10% to 30%. While in C watershed, area covered by (a) sub zone should be very negligible and should range between 0 to 10%.

Category of watershed			A	B	C
a	-	Run off …	60%	30%	10%
b	-	Recharge	20%	60%	20%
c	-	Storage …	10%	30%	60%

Combination of zones -

A basin is divided in 3 major zones i.e. A, B, C and each major zone is divided in 3 sub zones, i.e. a, b, and c therefore in all there are 9 sub zones, and therefore villages are classified in 9 sub zones as given below -



From the above figure, it is seen that the villages falling in sub zones Aa, Ba, Ab have dominant common factor i.e. run off, by virtue of physiographical configuration, and hence this combination is called as a Run off zone, similarly the combination Bb,Ac Ca have a common factor of recharge and hence grouped in recharge zone; similarly the combination Cc, Bc, Cb have a storage dominant factor hence grouped as a storage zone.

DRAINAGE DENSITY RELATION

A i.e. run off zone has a high drainage density and is dominated by 1st order streams. Similarly B i.e. recharge zone has a moderate drainage density and is dominated by 2nd and 3rd order streams; while the drainage density is poor in C i.e. storage zone drainage is dominated by higher order stream.

DRAINAGE DENSITY IS GIVEN IN FOLLOWING TABLE.

Morpho unit	Drainage Density	Watershed classification	Sub zone of watershed
HDP (Runoff zone)	High	A	Aa,ab,Ba
MDP (Recharge zone)	Moderate	B	Bb,Ca,Ac
UDP (Storage zone) Valley fill	Poor	C	Cc,Cb,Bc

CHOOSING LOCATION OF OBSERVATION WELLS

While selecting and fixing the observation wells, the following guidelines are to be observed -

i) The well should have pierced the full aquifer thickness.
ii) It should be free from influence of surrounding surface water bodies, so as to know the only rainfall recharge.
iii) The observation well should represent the various formations occurring in the watershed,
iv) Areas such as perched water table and areas showing local anomalies be avoided,

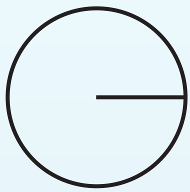
v) Only non-pumping wells should be selected.
Precaution should be taken to maintain time schedule while recording water levels.
Anomalous readings should be duly justified on record.

CALCULATION RELATED TO THE 500 METRES DISTANCE CONDITION

(AS STIPULATED IN CLAUSE 3 OF THE GROUNDWATER ACT 1993)

(1) FOR WELLS IN SEDIMENTARY ROCKS

Source Well



Area $= \pi r^2$

= 3.14 x 0.5 x 0.5

= 0.785 Sq.Km.

= 78.5 Hectares

Considering 1 Mt. saturated thickness of aquifer, the Total Volume of saturation thickness during Summer = 78.5 x 1 Mt. = 78.5 Ham.

Considering 0.07 as specific yield, the total quantity of groundwater that would be available. = 78.5 x 0.07 = 5.49 Ham.

Considering 50% of the recharge that will be available from upstream side of the Source Well. (*) = 5.49 x 0.5 = 2.74 Ham.

= 27,400 M3

Considering the requirement of Drinking Water from October to June i.e. for 270 days @ 70 lpcd. The requirement per soul. = 18.9 M3

Therefore, Population that is likely to be served By protecting the source of drinking water within 500 metres distance. = 1400 Souls.

(*) Note - Reversal of gradient is created by the cone of depression. Hence for protection of source well, the wells on the down-stream of the source well also need to be regulated, in order to avoid interference by another draw well in same area of influence in down stream.

CALCULATION RELATED TO THE 500 METRES DISTANCE CONDITION

(AS STIPULATED IN CLAUSE 3 OF THE GROUNDWATER ACT 1993)

(1) FOR WELLS IN HARD ROCKS

Source Well	Area = πr^2
	= 3.14 x 0.5 x 0.5
	= 0.785 Sq.Km.
	= 78.5 Hectares
Considering 1 Mt. saturated thickness of aquifer, the Total Volume of saturation thickness during Summer Ham.	= 78.5 x 1 Mt. = 78.5
Considering 0.07 as specific yield, the total quantity of groundwater that would be available. Ham.	= 78.5 x 0.02 = 1.57
Considering 50% of the recharge that will be available from upstream side of the Source Well. (*) Ham.	= 1.57 x 0.5 = 0.785
	= 7850 M3
Considering the requirement of Drinking Water from October to June i.e. for 270 days @ 70 lpcd. the requirement per soul.	= 18.9 M3
Therefore, Population that is likely to be served By protecting the source of drinking water within 500 metres distance.	= 500 Souls.

(*) Note - Reversal of gradient is created by the cone of depression. Hence for protection of source well, the wells on the down-stream of the source well also need to be regulated, in order to avoid interference by another draw well in same area of
influence in down stream.

DISTRICTWISE LIST OF OVER EXPLOITED WATERSHEDS AS PER GEC 2004

Sr.No.	District	Basin
1	NASHIK	GV 7, GV 09, GV 20, GV 21, GV 27, GV 29A, TE 80
2	DHULE	TE 124, TE 50B, TE 65, TE 76, TE 99
3	JALGAON	TE 07, TE 15A, TE 17, TE 2, TE2', TE 22, TE 25, TE 36, TE 59
4	AHMEDNAGAR	GV 102, GV 107, GV 109, GV 110, GV 111, GV 112, GV 125, GV 126, GV 22A, GV 31B
5	PUNE	BM 01, BM 04, BM 05, BM 09, BM 12, BM 18, BM 26, BM 59, BM 6, BM 69, BM 75, BM 76, BM 77, GV 114
6	SOLAPUR	BM 132, BM 87, BM 90, BM 93, SA 29
7	SANGLI	KR 36, KR 37, KR 39, KR 50, KR 52
8	SATARA	KR 2
9	LATUR	GV 97C, MR 15,MR 19,MR 33, MR 39, MR 43
10	AMRAVATI	PT 2, PT 20, PTP 2, WR 1, WR2, WR 3, WRC 1
11	BULDHANA	PT 10, PT 11
12	AKOLA	PTSB 1
13	NAGPUR	WRJ 2, WRJ 4
14	BHANDARA	WG 11
15	WARDHA	WRJ 4

LIST OF CRITICAL WATERSHEDS AS PER GEC-2004

Sr.No.	District	Basin
1	NASHIK	GV 24, TE 109
2	DHULE	TE 105A,
3	JALGAON	TE 18, TE4'
4	AHMEDNAGAR	GV 123, SA2
5	PUNE	BM 58, BM 70
6	SOLAPUR	SA 16
7	KOLHAPUR	KR 54
8	SANGLI	KR 40
9	SATARA	BM 85, KR 10,KR 32
10	AURANGABAD	GP 9, GV 41
11	AMRAVATI	WR 9
12	BULDHANA	GPA 1
13	NAGPUR	WGKK 2

GEOPHYSICS

DEFINITIONS:

ANOMALY: In geophysical surveys any deviation from uniform regional ternd of a physical property caused by variations in the character of target is known as anomaly.

APPARENT RESISTIVITY: The ratio of measured voltage to input current, the earth resistance, when multiplied by geometric factor of electrode configuration gives apparent resistivity. It would be true resistivity if the subsurface is homogeneous.

ANISOTROPY: Variation in physical property with direction of measurement is anisotropy. In electrical resistivity method micro-, and macro-, and pseudo-anisotropy are involved. Anisotropy of a geoelectrical layer is given as $\lambda=\sqrt{pt}\sqrt{pL}$ where pt and pL are transverse and longitudinal resistivities of a layer.

CONTACT RESISTANCE:
Electrical resistance developed between an electrode planted in the ground and the ground material immediately surrounding it. Contact resistance can be reduced by putting water at the electrodes and by increasing the area of contact.

CURVE MATCHING: A technique of interpretation in which field curve (apparent resistivity, chargeability etc) is visually matched with the theoretical curve for known layer parameters.

DAR ZARROUK PARAMETERS: The longitudinal unit conductance(S) and transverse unit resistance (T) of a geoelectrical layer are known as Dar Zarrouk (names of a place near Tunis) parameters. It was introduced by R.Maillet.

DEPTH OF INVESTIGATION: In dc resistivity method the depth at which a thin horizontal layer contributes maximum amount the total measured signal. It is maximum for two-electrode configuration (0.35 L) and minimum for Wenner configuration (0.11L), where L is the distance between two active electrodes.

GEOMETRIC FACTOR: A numerical value (in metre) depending on the relative spacing of electrodes.

GEOELECTRICAL LAYER: A sub-surface layer having distinct resistivity and thickness.

EDDY CURRENT: The current induced in conductive body by the primary EM field. Secondary EM field produced by the eddy current oppose the primary field.

EQUIVALENCE: If target response is a function of product or ratio of two parameters, variation in the parameters keeping the ratio or product constant can yield almost same response and the various combination of parameters are said to be equivalent. This brings in ambiguity in parameter estimation. It is pronounced if the target is buried and relatively thin. In multi-layer geoelectrical sequence the intermediate layers show equivalence over a range of parameters.

HOMOGENEITY / INHOMOGENEITY(HETEROGENEITY): It indicates spatial uniformity in physical property of a formation. It is function of scale of measurement in relation to the uniformity in physical property. Inhomogeneity or heterogeneity indicates non-uniformity in physical property with reference it the scale of measurement.
Longitudinal conductance: The ratio of thickness to the resistivity of a geoelectrical layer. Conventionally expressed as S=h/p (mhos).

NON-POLARIZING ELECTRODE:
A type of electrode, which is not affected by electrochemical potential generated between the electrode and ground material in which it is planted. Copper rod in copper sulfate solution is commonly used as non-polarizing electrode.

SUPPRESSION:
When response due to a layer is not resolved because of its small thickness and less contrast in physical property with the surrounding, the layer is said to be suppressed.

TRANSVERSE RESISTANCE:
The product of thickness and resistivity of a geoelectrical layer. Conventionally written as T=hxp (ohm.m*m).

WENNER CONFIGURATION: A collinear four-electrode configuration of potential and current electrodes in which all the electrodes are equidistant, i.e., the separation between potential electrodes (a) is 1/3rd the separation between current electrodes. The geometric factor is 2pie a.

PURPOSE OF GEOPHYSICAL SURVEYS:
Geophysical application is made mainly to identify the groundwater targets, their geometry and water quality prior to construction of groundwater structures.
(1) Assess groundwater pollution and movement of pollution plume in terms of Electrical conductivity,
(2) Define vadose zone characteristics to identify areas for artificial recharge to Groundwater,
(3) Identify waste disposal (land-fills) sites and impacts,
(4) Assess soil salinity,
(5) Demarcate seawater intrusion,
(6) Identify protective layer of aquifers,
(7) Monitor groundwater quality and direction of groundwater movement etc.
Besides, there could be effective applications in drought management, water supply in earthquake-hit areas and in areas and in areas of land subsidence due to over-development. Surface geophysical measurements can also be used to estimate hydraulic parameters of aquifers.

ELECTRICAL RESISTIVITY:
To identify groundwater yielding zones, their geometry, variation in quality (salinity) of groundwater and direction of groundwater movement.

PRINCIPLE:

Using Ohm's law, electrical resistivity of sub-surface geologic formation is determined through artificially energizing the subsurface and carrying measurements on the ground surface. Contrast in resistivity of a layer with the surrounding or effective presence (dependent of its relative resistivity and thickness) makes it detectable.

FIELD PROCEDURE: ELECTRODE CONFIGURATIONS:

For measuring Electrical Resistivity to prominent configurations is widely adapted those are Wenner, and Schlumberger configurations. The geometry factor for Wenner is= 2π a, in Schlumberger= π *(L*L-l*l)/2l.

SURVEY METHODS:

There are two types of survey methods. Electrical Profiling and Electrical Sounding. The Electrical Profiling gives the information of horizontal variations at a particular depth for a fixed electrode separation.

Vertical Electrical Sounding: It gives the variations of resistivities with depth at a fixed point on the ground.

ELECTROMAGNETIC SURVEYS: VERY LOW FREQUENCY (VLF) SURVEYS:

It is used to delineate conductive water bearing fracture zones in resistive hard rocks. For these surveys WADI VLF instrument is used. The WADI utilizes the magnetic components of the electromagnetic field generated by military transmitters that use the VLF frequency band. By WADI VLF instrument, measurements are taken along line at designed intervals. RAMAG Software is used to process the data.

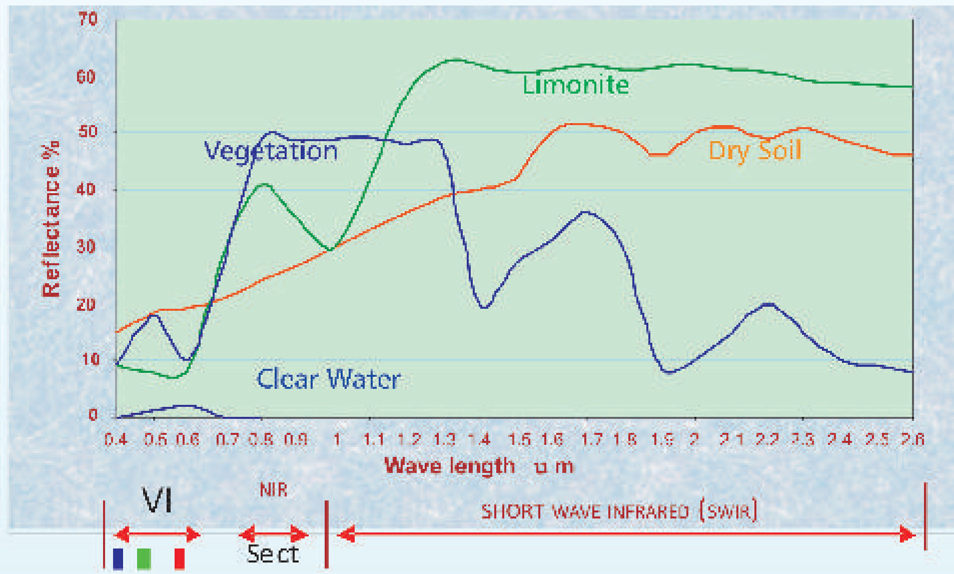
REMOTE SENSING:

Remote sensing in the simplest words, means obtaining information about an object without touching the object itself.

THE BASIC PRINCIPLE OF REMOTE SENSING -

1. In different wave length ranges of electromagnetic spectrum - Object reflects or emits a certain intensity of light
2. It is dependent upon the physical or compositional attributes of the object
3. Using information from one or more wavelength
4. It is possible to differentiate between types of object e.g. Soil, Vegetation, Agriculture fields, Water-bodies etc.

SPECTRUM REFLECTANCE CURVE



GLOSSARY OF TERMS

DIGITAL IMAGE-
Image represented in numerical form

DN-
Digital number, They are digital counts or gray level

EMR-
Electromagnetic Radiation, energy emitted as a result of Changes in atomic and molecular energy states and propagated through space at the light speed

ENHANCEMENT-
Process of altering the appearance of an image to extract better information

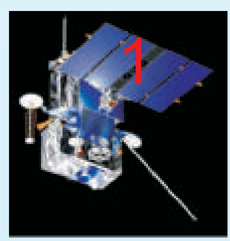
FREQUENCY-
Rate of signal oscillation measured in hertz(cycle of a wave)

GEOCODED DATA-
Imagery in which the data elements are unequally and systematically aligned along the axes of a coordinate reference system with known positions and scaling, typically a fixed cartographic projection

GEOSYNCHRONOUS-
An earth satellite orbit in which the satellite remains in a fixed position

GRAY SCALE-
A monochrome series of shades from black to white displayed in a strip
IMAGE-
Graphic recording of a scene by use of an optical or radiometric scanner
INFRARED-
That portion of the EMR spectrum approximately between 2.5 um and 100 um where radiation emitted by earth is larger than that reflected from the sun
MAP PROJECTIONS-
Any systematic arrangement of meridians and parallels portraying the curved surface of a spheroid or sphere upon a plane
NADIR-
The point on the earth's surface formed by a line from the earth's center through the space craft or air craft.
ORBIT-
Path, which an object takes around another object
PIXEL-
Jargon for picture element (Individual resolution cells or elements on an image or a photograph)
RADIATION-
The process by which electromagnetic energy is propagated through free space by virtue of joint adulatory variation in the electric and magnetic fields in space
RASTER-
The two-dimensional array of pixels in an image
SCATTERING-
The reflection and refraction of electromagnetic energy by particles in the atmosphere, frequently wavelength dependent
SIGNATURE-
Any characteristic or series of characteristics by which a material may be recognized. Used in the sense of spectral signature
SPECTRAL BAND-
An interval in the electromagnetic spectrum defined by two wavelength, frequency or wave numbers.

ELEMENTS OF REMOTE SENSING
Geological interpretation of image or photograph is primarily based on recognition elements for visual interpretation -.



GPS SYSTEM

GEOTECHNICAL OR TERRAIN ELEMENTS

LANDFORMS/TOPOGRAPHY :
Identification of soil material and rock type.
VEGETATION COVER:
Type & density is indicative of moisture and favourable condition of under lying soil and or rock.
DRAINAGE DENSITY & PATTERN:
They are characteristic of a given soil, rock type, structure or of complex of several materials.
EROSION PATTERN:
Erosion patterns it self speaks for the terrain material ex Sheet, Rill, Gully erosion.

LAND USE:
It gives the information about the soil condition.
OTHER STRUCTURES:
Analysis of features of mass movements, landslides.
Convergence of Evidence/Relationships/association
RELATION SHIP/ASSOCIATION OF FEATURES:
Studying an object with its associating features helps in analysing the terrain ex: linear feature with water body can be canal.
COMBINATION OF RECOGNITION ELEMENTS:
Usefulness of recognition elements is enhanced when they are used in combination, as mutually supporting elements ex:Water body & canal with flowing water gives you a darker tone.

WATER QUALITY

Water quality is determined by its physical, chemical & Bacteriological characteristic. Water quality decides its suitability for Drinking, Irrigation & Industrial purpose.

The main aim of sampling is to collect samples of the water of interest such that their quality represents the quality of that water.

For chemical analysis, white colour clean polyethylene bottles having 1 lit. capacity is used. Water sample is collected by washing bottles with same water two-three times. Collected water sample should be transported within 48 hrs to laboratory.

For Bacteriological analysis, glass bottle having 200-250ml capacity are used. These bottles must be washed & sterilized before hand. This can be carried out in an oven at170oc for minimum two hrs. Cap of this bottle should be rapped with brown paper. This prevents, microorganisms contamination while handling the bottle. Before sample collection mouth of tap must be sterilized by flame & water should be flushed out for few minutes. Glass bottle should not filled completely. After Sample collection it should be transported within 24hrs to laboratory. & should be kept in cool box.

BUREAU OF INDIAN STANDARD (BIS)
SPECIFICATION IS-10500-91, REVISED 2003.
FOR DRINKING WATER

Sr. No.	Characteristics	Acceptable	Clause for Rejection
1	Turbidity (NTU)	1	10
2	Colour (Unit on Platinum Cobalt Scale)	5	25
3	Taste & Odour	Unobjectionable	Unobjectionable
4	pH	7.0 to 8.5	<6.5 or > 9.2
5	Total Dissolved Solids (mg/l)	500	2000
6	Total Hardness (asCaCO3) (mg/l)	300	600
7	Chloride (as Cl) (mg/l)	250	1000
8	Sulphate (SO4) (mg/l)	200	400
9	Fluoride (as F) (mg/l)	1	1.5
10	Nitrate (as NO3) (mg/l)	45	45
11	Calcium (as Ca)(mg/l)	75	200
12	Magnesium (as Mg) (mg/l)	upto 30	100
13	Iron (asFe) (mg/l)	0.1	1
14	Maganese (as Mn) (mg/l)	0.05	0.5
15	Copper(asCu) (mg/l)	0.05	1.5
16	Aluminium (asAl) (mg/l)	0.03	0.2
17	Alkalinity (mg/l)	200	600
18	Residual Chlorine(mg/l)	0.2	<1.0
19	Zinc (as Zn) (mg/l)	5	15
20	Phenolic Compounds (as Phenol) mg/l)	0.001	0.002
21	Anionic Detergents (mg/l) (as MBAS)	0.2	1
22	Mineral Oil (mg/l)	0.01	0.03

Toxic Material			
23	Arsenic (as AS) mg/l)	0.01	No Relaxation
24	Cadmium (as Cd) mg/l)	0.01	Not more than 0.01
25	Chromium (as hexavalent Cr) mg/l)	0.05	Not more than 0.05
26	Cyanides (as CN) mg/l)	0.05	No Relaxation
27	Lead (as Pb) mg/l)	0.05	No Relaxation
28	Selenium (as Se) mg/l)	>0.01	Not more than 0.01
29	Mercury(Total asHg) mg/l)	>0.001	Not more than 0.001
30	Polynuclear Aromatic hydrocarbans(PAH)(mg/l)	0.001	0.002
31	Pectisides (Total,mg/l)	Absent	0.001
Bacteriological Quality			
32	Coliform (MPN)	Upto 10 in 100ml	Upto 10 in 100ml
33	E. Coli/ F. Coli (MPN)	Absent in 100ml	Absent in 100ml

Great range of water quality parameters can used to characterize water. Some parameters are of special important & deserve frequent attention.

pH is defined as, negative logarithm of H+ & OH- ion concentration. Range of pH is 0 to 14.

Acidic pH of water is its quantitative capacity to react with a strong base to a designated pH. Acidic range of pH is 0 to 7. **Basic pH** is its acid neutralizing capacity. Basic pH is 7 to 14.**Neutral pH** having 7.0 pH

Turbidity of water is caused by suspended & colloidal matter such as clay, silt finely divided organic & inorganic matter & other micro organism. Turbidity is an expression of the optical property that causes light to be scattered & absorbed rather than transmitted. Electronic nephelometers are the preferred instrument so its unit is Nephelometric Turbidity Unit **(NTU)**.

Water as it travels in the atmosphere through ground or over the land, dissolves a large variety of substances or salts. These substances in solution exist in their ionic form. The major cations (positively charged ions) comprise calcium (Ca^{2+}) Sodium (Na^{+}) & Potassium (K^{+}) & the associated anions typically include sulphate (SO_4^{2-}) bicarbonate (HCO_3) chlorides (Cl-). Other ions which may be present in smaller concentrations but can nevertheless be of environmental significance are B, F-, Fe^{2+}, Mn^{2+} and NO^{3-} .

The aggregates salts are measured as total dissolved solids (TDS). As a rough approximation water having less than 1500 mg / L TDS can be considered as fresh water. All waters in the environment contain dissolved solids.

THESE SALTS CAN BE CLASSIFIED AS :-

Major Constituents (1.0 to 1000 mg/L)	Secondary Constituents (0.01 to 10.0 mg/L)
Sodium	Iron
Calcium	Stronsium
Magnesium	Potassium
Bicarbonate	Carbonte
Sulphate	Nitrate
Chloride	Boron
Silica	Fluoride

WATER CHARACTERIZATION:-

Water can be characterized by performing a chemical analysis of their major ions. Major ions are as follows :

CATIONS	ANIONS
Calcium(Ca^{+2})	BiCarbonate(HCO_3^-)/ Carbonate(CO_3)
Magnesium(Mg^{+2})	Sulphate(SO_4^{2-})
Sodium(Na^+)	Chloride(Cl^-)
Potassium(K^+)	Nitrate (NO_3^-)

Calcium and Magnesium are common in natural water and are essential elements for all organisms. Combined with bicarbonates, carbonates, sulphates and other species contribute to hardness of natural water.

Using different diagrams and graphs data is represented after detail chemical analysis.

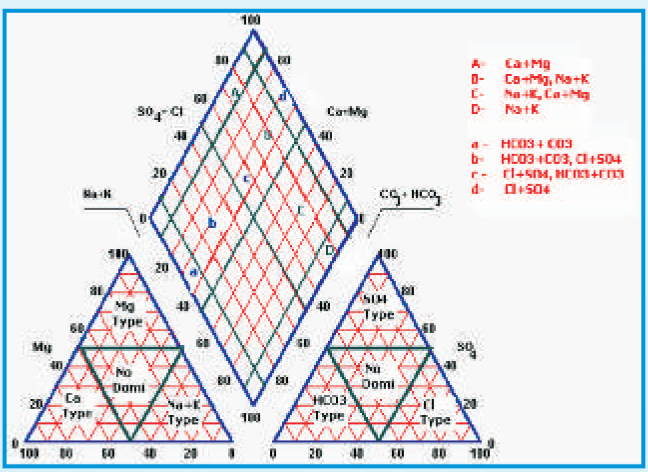
Piper diagram can be used to detect hydro chemical faecies of water sample. Hydro chemical faecies can be used to denote the diagnostic chemical characteristics of water in hydro geological system. Faecies generally reflects the geochemical processes that are operative in the larger host rock-water framework.

The data for major ions (mg/liter) is converted into 'equivalents per million (epm)' prior to plotting.

Cations are as percentage of total cations in meq / lit, plot as signal point on left triangle; while anions plot on right triangle. These two points are then projected in the central diamond shaped area. This signal point is thus uniquely related to the total ionic distribution.

In order to use this method, Na+ and K+ & CO32- and HCO3-are combined.

CATION FAECIES	ANION FAECIES
A) Ca+Mg,	a) HCO3+CO3
B) Ca+Mg ,Na+K	b) HCO3+CO3, Cl+SO4
C) Na+K, Ca+Mg	c) Cl+SO4, HCO3+CO3
D) Na+K	d) Cl+SO4



PERIODIC TABLE OF THE ELEMENTS

Such plots conveniently reveal similarities and differences among different samples because those with similar qualities will tend to plot together as groups.

Non-Metels · Alkali Metels · Alkaline Earth Metels · Isotopes · Lanthanides · Actinides · Noble Gases · Transition Metels · Other Metels

Common Oxidation States → +1 | Atomic Number → 19 | Atomic Symbol → K | Atomic Weight → 39.0983 | Electron Configuration of Outer Shells → 8-8-1

1/IA	2/IIA	3/IIIB	4/IVB	5/VB	6/VIB	7/VIIB	8/VIII	9/VIII	10/VIII	11/IB	12/IIB	13/IIIA	14/IVA	15/VA	16/VIA	17/VIIA	18/VIHA/0
+1 H 1 1.00794 1 Hydrogen																	0 Be 3 4.002602 2 Helium
+1 Li 3 6.941 2-1 Lithium	+1 Be 4 9.012182 2-2 Beryllium											+3 B 5 10.811 2-3 Boron	+2 C 6 12.011 2-4 Carbon	±1 ±2 ±3 +4 +5 N 7 14.00674 2-5 Nitrogen	-2 O 8 15.9994 2-6 Oxygen	-1 F 9 18.9984032 2-7 Fluorine	0 Ne 10 20.1797 2-8 Neon
+1 Na 11 22.989768 2-8-1 Sodium	+2 Mg 12 24.3050 2-8-2 Magnesium											+3 A1 13 26.981539 2-8-3 Aluminium	+2 Si 14 28.0855 2-8-4 Silicon	±3 +5 P 15 30.973762 2-8-5 Phosphorus	+4 +5 -2 S 16 32.066 2-8-6 Sulphur	±1 +5 +7 Cl 17 35.4527 2-8-7 Chlorine	0 Ar 18 39.948 2-8-8 Argon
+1 K 19 39.0983 -8-8-1 Potassium	+2 Ca 20 40.078 -8-8-2 Calcium	+3 Sc 21 44.955910 8-9-2 Scandium	+2 +3 +4 Ti 22 47.867 -8-10-2 Titanium	+2 +3 +4 +5 V 23 50.9415 -8-11-2 Vanadium	+2 +3 +6 Cr 24 51.991 -8-13-1 Chromium	+2 +3 +4 +7 Cr 24 54.93805 -8-13-2 Manganese	+2 +3 Fe 26 55.845 -8-14-2 Iron	+2 +3 Co 27 58.93320 -8-15-2 Cobalt	+2 +3 Ni 28 58.6934 -8-16-2 Nickel	+1 +2 Cu 29 63.546 Copper	+2 Zn 30 65.39 -8-18-2 Zinic	+3 Ga 31 69.723 -8-18-3 Gallium	+2 +4 Ge 32 72.61 -8-18-4 Germanium	±3 +5 As 33 74.92159 -8-18-5 Arsenic	+4 +6 -2 Se 34 78.96 -8-18-6 Selenium	±1 +5 Br 35 79.904 -8-18-7 Bromine	0 Kr 36 83.80 -8-8-8 Krypton
+1 Rb 37 85.4678 -18-8-1 Rubidium	+2 Sr 38 87.62 -18-8-2 Strontium	+2 Y 39 88.90585 -18-9-2 Yttrium	+4 Zr 40 91.224 -18-10-2 Zirconium	-3 -5 Nb 41 92.90638 -18-12-1 Niobium	+6 Mo 42 95.94 -18-13-1 Molybdenum	+4 +6 +7 Te 43 (97.9072) -18-13-2 Technetium	+3 Re 44 101.07 -18-15-1 Ruthenium	+3 Rh 45 102.9550 -18-16-1 Rhodium	+2 +4 Pd 46 106.42 -18-18-2 Paiindim	+1 Ag 47 107.8682 -18-18-1 Silver	+2 Cd 48 112.411 -18-18-2 Cadmium	+3 In 49 114.818 -18-8-3 Indium	+2 +4 Sn 32 118.710 -18-18-4 Tin	±3 +5 Sb 51 121.760 -18-18-5 Antimony	+4 +6 -2 Te 52 127.60 -18-18-8 Tellurium	±1 +5 +7 I 53 126.90447 -18-18-7 Iodine	0 Xe 54 131.29 -18-18-8 Xenon
+1 Cs 55 132.90543 -18-8-1 Cesium	+2 Ba 56 137.327 -18-8-2 Barium	57-71 See Lantha Barium	+4 Hf 72 178.49 -32-10-2 Hafnium	+5 Ta 73 180.9479 -32-11-2 Tantalum	+5 W 74 183.84 -32-12-2 Tungsten	+4 +6 +7 Re 75 186.207 -32-13-2 Rhenium	+3 +4 Os 76 190.2 -32-14-2 Osmium	+3 +4 Ir 77 190.2 -32-14-2 Osmium	+2 +4 Pt 78 195.08 -32-16-2 Platinum	+1 +3 Au 79 196.96654 -32-18-1 Gold	+2 Hg 80 200.59 -32-18-2 Mercury	+1 +3 Ti 81 204.3833 -32-18-3 Thallium	+2 +4 Sn 32 207.2 -32-18-4 Lead	Bi 83 (208.98037) -32-18-5 Bismuth	+2 +4 Po 84 (208.9824) -32-18-6 Polonium	±1 +5 +7 At 85 (209.9871) -32-18-7 Astatine	0 Rn 86 (222.0176) -32-18-8 Radon
+1 Fr 87 (223.0197) -18-8-1 Francium	+2 Ra 88 (226.0254) -18-8-2 Radium	89-103 See Actinides	+4 * Rf 104 (261.11) -32-10-2 Rutherfordium	* Db 105 (262.114) -32-11-2 Dubnium	* Sg 106 (263.118) -32-12-2 Seaborgium	+4 +6 +7 *Bh 107 (262.12) -32-13-2 Bohrium	Hs 108 -32-14-2 Hassium	* Mt 109 266.00 -32-15-2 Meitneum	* Uun 110 269.00 -32-16-2 Ununnilium	* Uun 111 272.00 Ununnilium	* Uub 112 277.00 Ununnilium	Unt 113	* Uuq 114 285.00 Ununguadium	0 Uup 115	*Uuh 116 289.00 Ununhexium	Uuh 117	0 Uno 118 293.00 Ununoctium

Elements 104-118 : Relatively recent elements. Based on 1987 IUPAC Table of standard atomic weights of the elements updated for the information updated available till 1997.

*Relative atomic mass of the isotope of that elements of longest known half-life.
• IUPAC recommendation 1997.

+3 La 57 138.9055 -18-9-2 Lanthanum	+3 +4 Ce 58 140.115 -20-8-2 Cerium	+3 Pr 59 140.90765 -21-8-2 Praseodymium	+3 Nd 60 144.24 -22-8-2 Neodymium	+3 Pm 61 (144.9127) -23-8-2 Promethium	+2 Sm 62 150.36 -24-8-2 Samarium	+2 +3 Eu 63 151.965 -25-8-2 Europium	+3 Gd 64 157.25 -25-9-2 Gadolinium	+3 Tb 65 158.92534 -27-8-2 Terbium	+3 Dy 66 162.50 -28-8-2 Dysprosium	+3 Ho 67 164.93032 -29-8-2 Holmium	+3 Er 68 167.26 -30-8-2 Erbium	+3 Tm 69 168.93421 -31-8-2 Thulium	+2 +3 Yb 70 173.04 -32-8-2 Ytterbium	+3 Lu 71 174.967 -32-9-2 Luytetium
+3 Ac 89 (227.0278) -18-9-2 Actinium	+4 Th 90 232.0381 -18-8-2 Thorium	+4 +5 Pa 91 (231.0388) -20-9-2 Protactinium	+3 +4 +5 +6 U 92 238.0289 -21-9-2 Uranium	+3 +4 +5 +6 Np 93 (237.0482) -22-9-2 Neptunium	+3 +4 +5 +6 Pu 94 (244.0642) -24-9-2 Plutonium	+3 +4 +5 +6 Am 95 (243.0614) -25-8-2 Americium	+3 Cm 96 (247.0703) -25-9-2 Curium	+3 +4 Bk 97 (247.0703) -27-8-2 Berkelium	+3 Cf 98 (251.0796) -28-8-2 Californium	+3 Es 99 (252.083) -29-8-2 Einsteinium	+3 Fm 100 (257.0951) -30-8-2 Fermium	+3 +4 Md 101 (258.10) -31-8-2 Mendelevium	+2 +3 No 102 (259.1009) -32-8-2 Nobelium	+3 Lr 103 (262.11) -32-9-2 Lawrencium

DECLARATION OF DRINKING WATER SCARCITY

Declaration of probable drinking water scarcity & its period is done by GSDA based upon the deficit rainfall and static water level depletion in observation wells fixed by GSDA. Actual rainfall up to September is considered & compared with last 10 years average rainfall for the month of September & accordingly Taluka wise deficit percentage is calculated. Static water levels of watershed wise observation wells, are recorded in the month of October and these are compared with the average SWL of last 5 years Oct. SWL readings.

Depending upon the comparative rainfall deficit & Static water level depletion, probable scarcity period is tentatively affirmed.

Sr.No.	Area	Deficit Rainfall during the year in %	Depletion in SWL of observation well during the year	Probable Scarcity period
1	Drought Prone Area & Assured Rainfall.	More than 20% deficit	3 m. & above 2 m to 3 m 1 m to 2 m 0 to 1 m	October onward January onward April onward Manageable scarcity
2	High Rainfall	a) More than 50% b) More than 50%	2 m to 3 m 1 m to 2 m	January onward April onwards

FAILED WELL SUBSIDY

Definition for determining failure of groundwater development structures of different types -

The scheme shall cover the following types of ground water structures constructed by individual or group of farmers for irrigation purposes with financial assistance from participating credit institutions -

(1) Shallow tube wells;
(2) Filter points;
(3) Dug wells and dug-cum-bore wells
(4) Bore wells

The norms for determining failure of different types of ground water structures including well failure on account of bad quality waters shall be as indicated hereunder:-

(a) Definition for determining failure of shallow tube wells in alluvial formations - If a shallow tube well constructed for a minimum diameter of 7.5 cms and a minimum depth of 30 mts. in alluvial formations having continuous yield of less than 4 litres per second in "Rabi", it may be considered to be a completely failed well.

(b) Definition for determining failure of filter point in alluvial formations - If a filter point constructed for a minimum diameter of 6.5 cms and a minimum depth of 10 mtrs in alluvial formation, having continuous yield of less than one litre per second in "Rabi" , it may be considered to be a completely failed filter point.

(c) Definition for determining failure of Dug wells/dug-cum-bore wells in both hard rock areas and alluvial formations - if a dug well constructed for a minimum diameter of 2 mtrs and a minimum depth of 10 mtrs or a dug-cum-bore well with additional boring of 5 mtrs depth having yield of less than 2 litres per second for continuous working duration of at least 2 hours per 24 hours in "Rabi" (to ensure proper recuperation over 24 hours period) it may be considered to be a completely failed well.

(d) Definition for determining failure for shallow tube wells /bore well in hard rock areas - if a shallow tubewell/borewell constructed for minimum diameters of 10 cms and minimum depth of 50 mtrs in hard rock formations has continuous yield of less than 2 litres per second in "Rabi", it may be considered to be a completely failed well subject however to the condition that individual cases of bore wells having a discharge below 2 lps but not less than 1.25 lps will be thoroughly scrutinized by the certifying agency with reference to the cropping pattern to examine the financial viability of the investment, before these are declared as failed wells eligible for full compensation.

(e) Definition for determining failure of wells due to bad quality water - A well may be considered to be a completely failed well due to bad quality water when the quality of water is such that all or any one of the three parameters viz. Electrical conductivity, residual sodium carbonate or boron is of a higher value than indicated below ;

Sr. No.	Soil Texture	Electrical conductivity Micro mho/cm	Residual sodium carbonate (ppm)	Boron(ppm)
1	Clay	2000	5	2
2	Clay Loam	3000	5	2
3	Loam	4000	5	2
4	Sandy Loam	6000	5	2
5	Sandy	8000	5	2

(f) Definition for determining structural failure of wells - A dug well may be considered to have failed due to structural failure if during excavation any unidentified sub-surface strata caves in to-cause collapse of side-wall to such an extent that re-excavation would be necessary for successful completion of the well or where a sheet rock or basement rock is met with, which would make further digging futile due to non availability of aquifer down below.

SOURCE STRENGTHENING STRUCTURES

Roof Top Rain Water Harvesting

This system is useful for the habitations, which do not have perennial drinking water source, & Pipe water supply is economically unviable measure. In this measure Rain Water can be in situ stored in tank of proper size or can be used for Groundwater Recharge through nearby dug wells or Bore wells.

Water quantity that can be available through roof top rainwater harvesting system can be derived by following formula.

Quantity of that can be Water available by RTRWH system (Q)in lits =

RFx AR x CostantK

RF = Yearly average Rainfall in mm
AR= Area of Roof in Sq.mtr
K = Roof top Run-off Constant

Roof Top Runoff constant (K) for various roofs is: -

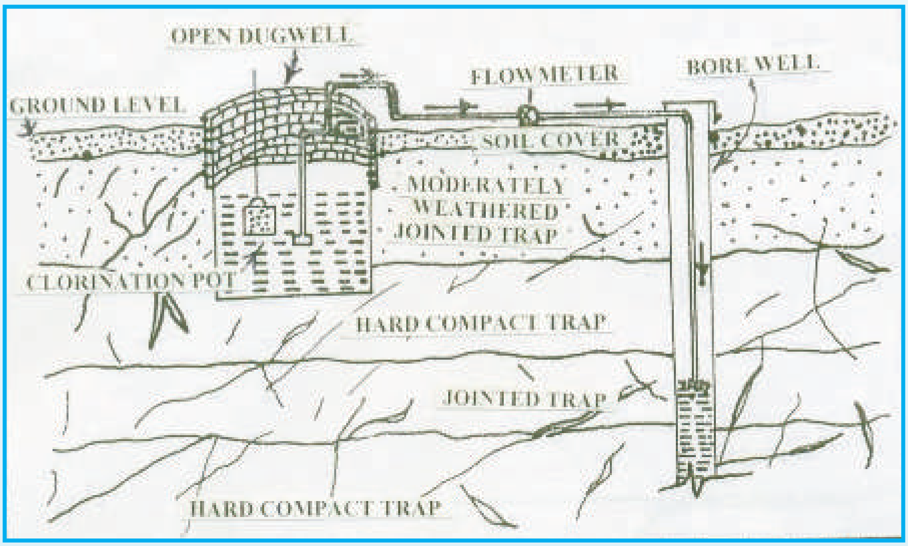
G.I.sheets (Tin):	0.9
Asbestos:	0.8
Tiled roof:	0.75
Cement Concrete:	0.70
Grass:	0.00

UNCONVENTIONAL TECHNIQUES

G.S.D.A. has developed unconventional techniques for strengthening of drinking water sources. These techniques include, fracture-seal-cementation, jacketing to the existing dug wells, bore-blast-technique, hydro fracturing, Stream blast techniques, bore well/well flooding etc.

a) Fracture Seal Cementation (FSC) :-

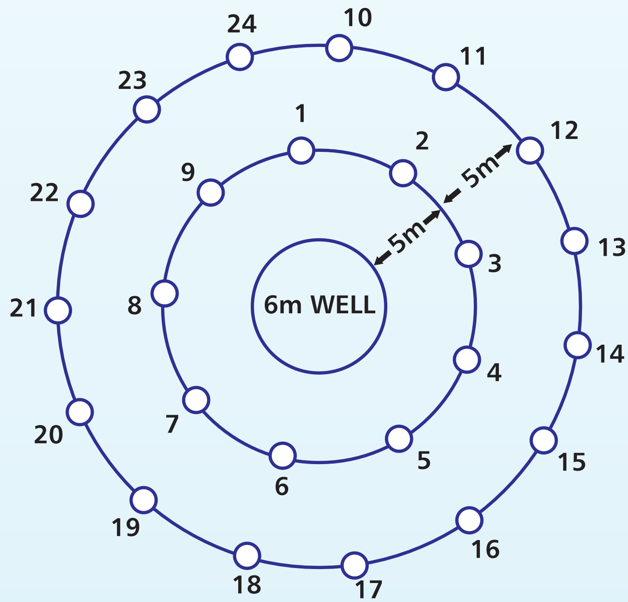
Fracture seal Cementation (FSC) is a technique to stop groundwater movement and increase the sustainability of groundwater in shallow sources. It is suitable in disintegrated rock combined with fractures and granular porosity. This technique is adopted after identifying the feasibility of site on the basis of geo hydrological



Under this process, normally one or two rows of boreholes are drilled to a depth of little more than the depth of dugwell in the surrounding area. Through these bores cement slurry is injected under desirable pressure so as to seal the existing fractures, resulting in formation of curtain across the discharge point. This technique creates an effect of 'Cut-off-Wall' or 'Underground Bandhara' in hard formation, especially where conventional cut of wall construction is too costly and time consuming. Geophysical Survey may be conducted before identification of site to know the intensity and extension of joints and fractures. Geophysical data will provide information to decide spacing between borewells and also number of rows to be taken for effective sealing.

b) Jacket Well Technique (JW) :-

The Construction of Jacket well around the dug well in hard rock areas increases effectiveê diameter of the well artificially, thereby increases the storativity and improves transmissivity of the aquifer. Boreholes and to a depth little less than of open dug well are drilled in a circular pattern around the targeted well.

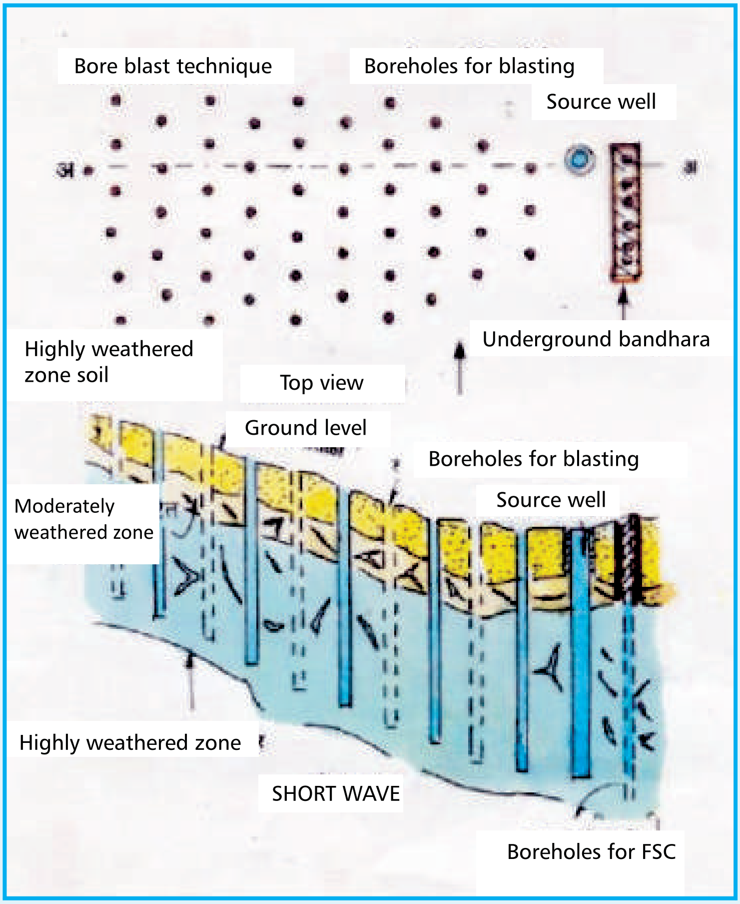


Subsequently blasting is carried out so as to create artificial fractures in the compact rocks. These bores are drilled either in circular semi circular or any other desired pattern depending upon the prevalent topographical and hydrogeological conditions. Explosives of required strength and quantity are used to create maximum fractures and to inter-connect them. Sand is generally staved in the boreholes for effective blasting operation and to keep cracks open even after blasting activity.

In some cases jacket well technique is supported by F.S.C. Technique.

c) Bore Blast Technique (BBT) :-

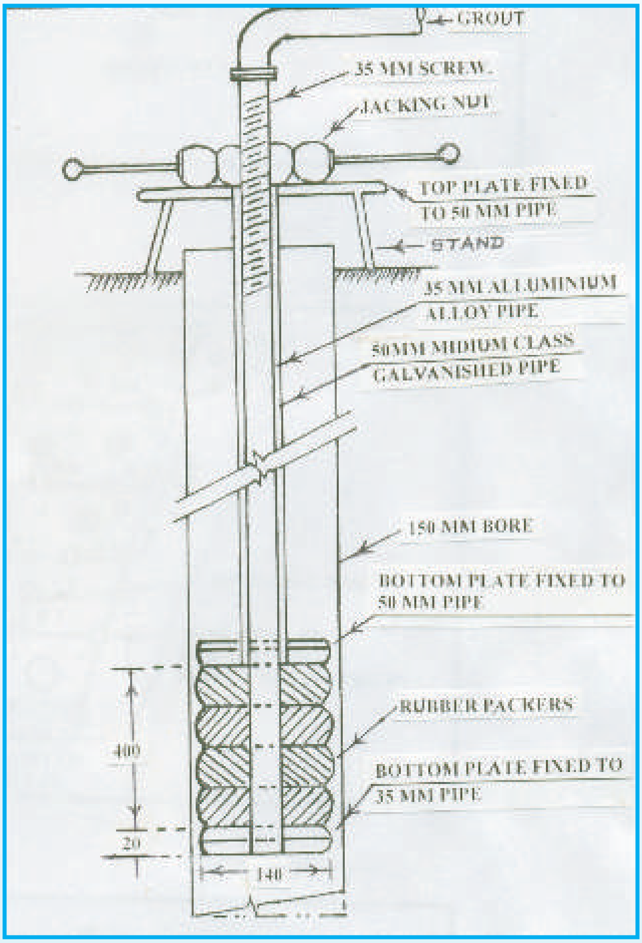
Bore blast technique is adopted to create more storage space for groundwater in massive and crystalline hard rocks by fracturing the bed rocks.



Hydrogelogical and Geophysical survey is carried out to locate such area where the rock can be blasted to develop cracks below the zone of weathering. Bores are drilled in staggered pattern & suitable types of explosives lowered in 2 to 3 sections in these boreholes for effective blasting. To arrest subsurface discharge cut off wall of black cotton soil is constructed at discharge point. This technique is applied in areas where landforms are mostly hilly. Being a high cost measure this technique should be adopted to provide drinking water, when no other measure is feasible/possible.

d) Hydrofracturing :-

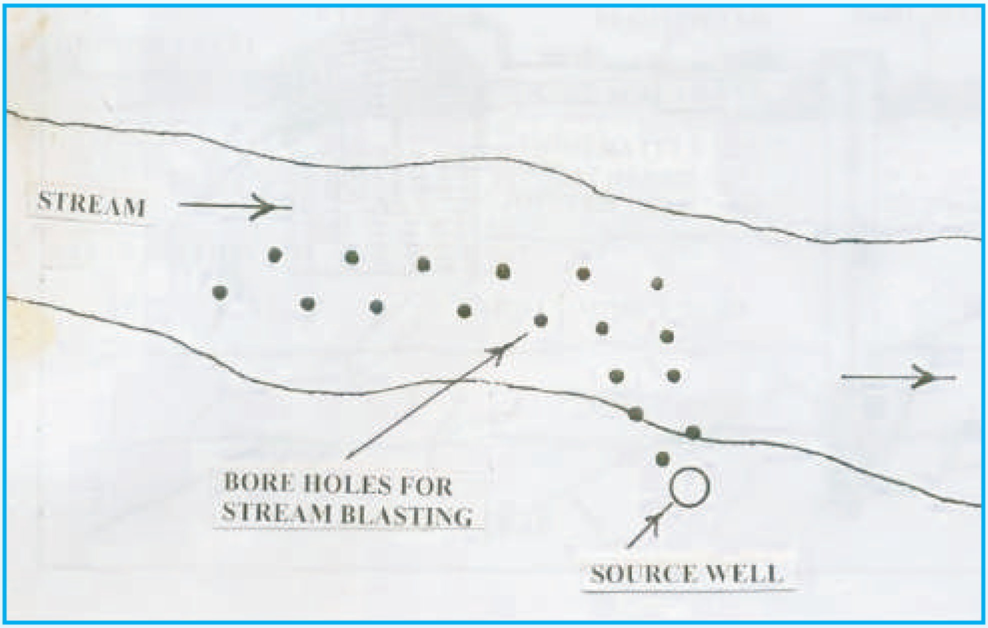
This technique is applied to rejuvenate poor yielding borewells or bore wells subsequently have became unsuccessful due to clogging of cracks and joints. Dry or poor yielding bore wells indicates that the fractures are not existing or if existing, they are not connected to the nearby ground water bodies or fractures may be clogged.



By this technique very high pressure is created in the confined section of the borewell. The high pressure cleans, opens, widens & extends the existing closed or clogged fractures and further connects them to nearby groundwater bodies. When confined section of borewell not having existing network of fractures then in few cases new fractures are created. Single and double packers can be used for hydro fracturing operation, depending upon site conditions.

e) Stream Blast Technique (SBT):-

Generally, drinking water wells are situated on nalla banks. At some places, the groundwater flowing below the nala bed has no hydraulic connectivity with the well, and the well becomes dry or partially dry during summer months. Such well can be rejuvenated by this technique, known as stream blasting.



In this technique, the area of nalla bed within the vicinity of well is investigated geophysically and geohydrologically. Then bores are drilled in the nala bed to a depth of open dugwell. These bores are in staggering pattern to get maximum blasting effect in minimum number of bores. Pattern and number of bores is decided considering the hardness of the strata to be fractured or sattered. These boreholes are further charged with explosives and blasted to artificially create fractures and joints. These artificially created fractures get connected to the well and divert groundwater from nalla to the well.

f) Artificial Recharge by Borewell Injection Technique :-

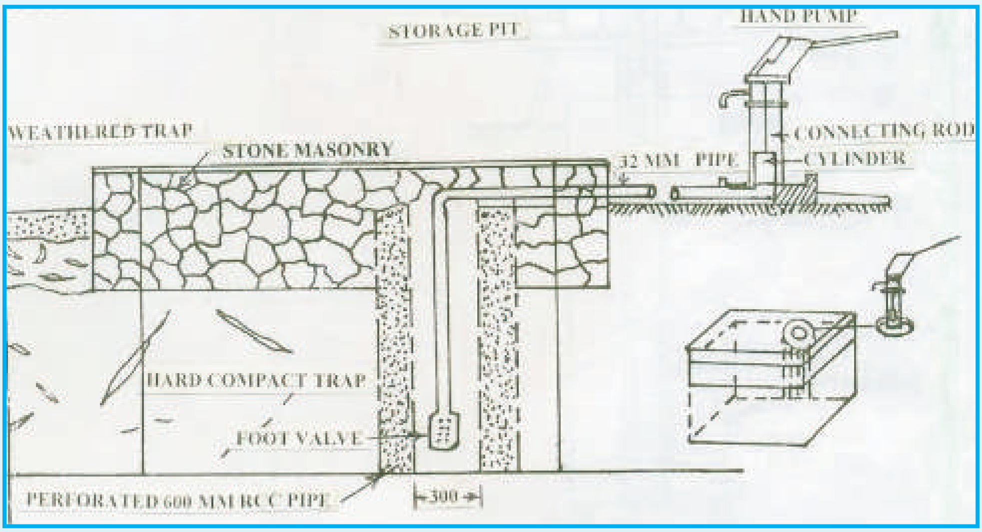
In some areas due to over-exploitation of groundwater, the water levels are rapidly depleting. Ultimately there is a reduction in the yield of existing high yielding wells, borewells and tubewells. In order to recharge the desaturated deeper aquifer, well flooding and borewell/tubewell injection technique can be implemented and surplus rain-water can be artificially recharge directly to the aquifer.

Prier to implementing the borewell injection technique the water intake test should be conducted. Groundwater extraction structure (dug well, bore well etc.) having intake capacity more than 3 LPS are proposed for execution of Project .
Generally existing structures can be used for this technique to reduce cost of project.

Excess water available in rainy and winter seasons can be utilized for flooding . This water should be free from contamination and should not react chemically with the available groundwater so that a precipitation of compounds (Calcium Carbonate) is avoided. Water being injected should also be free from suspended particles to avoid clogging of the aquifer system.

g) Storage Pit :-

Normally the hilly terrain in the state receives sufficient rainfall. But due to steep gradient, thin soil cover, limited weathered mantle and absence of joints-fractures in formation causes meager storativity for groundwater. Ultimately the habitations located in such area faces acute scarcity of drinking water in summer. In such area conventional measures, like piped water supply, dugwell or borewell etc. have limited utility due to technical and financial factors; hence drinking water provided by tanker or bullock cart. The measure like 'Storage Pit' is useful to collect water in required proportion with population. Small habitations (up to 200 souls) are considered for this unconventional measure.



In this Project, size of pit is fixed by volumetric analysis in accordance with population. Quantity loss in storage due to evaporation and other permissible seepages is also taken into account. Pit of required volume is excavated and curbed upto hard strata, (same as dugwell), to check the migration of stored water. Adopting concrete lining or cement grout at down streamside should seal aquifers encountered in pit. The streamside of aquifer, always kept unlined to facilitate incoming groundwater, through aquifer. It is expected that the storage can only be used in summer.

Excess water available in rainy and winter seasons can be utilized for flooding . This water should be free from contamination and should not react chemically with the available groundwater so that a precipitation of compounds (Calcium Carbonate) is avoided. Water being injected should also be free from suspended particles to avoid clogging of the aquifer system.

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DRILLING

Dual pump based Water Supply Scheme on existing Bore well.

Ground Water Surveys & Development Agency has developed a Dual pump based Water Supply Scheme on existing Borewell with least expenditure to solve these problems in rural area.

Here the Single-phase submersible pump with very low Horse Power is installed on existing borewell with Hand pump. Delivery from the submersible pump is stored in 5000 litre 'H.D.P.E.'water Tank. Thereafter water is supplied in every household by pipeline & taps.

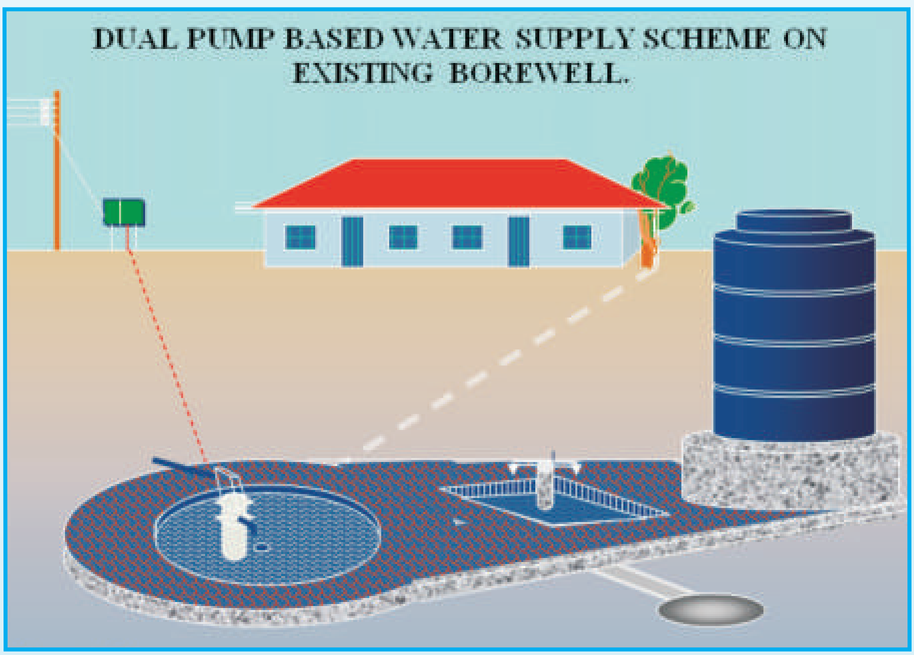
To make this scheme sustainable rainwater from nearby houses is collected & recharged in the bore well. This Scheme is suitable for the villages dependent on borewells. If this scheme is implemented in such villages there will be a 24 Hours Water Supply forever.

The main components in this scheme are as given below.

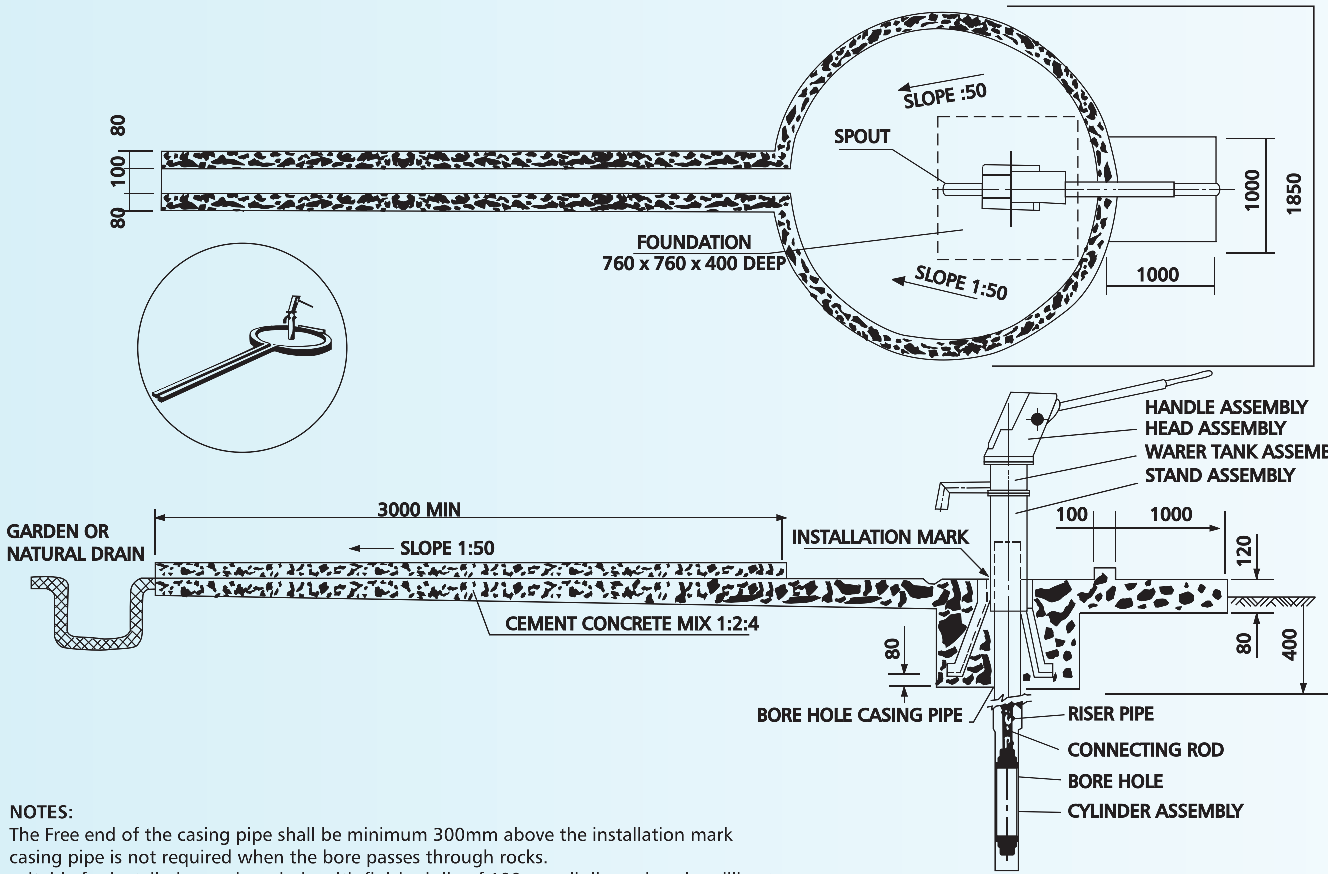
1) Existing Borewell with Handpump.
2) 1H.P. Single Phase Submersible Pump.
3) 5000 litres capacity H.D.P.E.TANK.
4) 25 MM Nominal Dia H.D.P.E. PIPE.
5) Roof top Rain Water Harvesting Structure.
6) Water Distribution System.

Advantages of Scheme:

1) 24 Hours Water supply from Borewell.
2) Water Supply can also be restored with the help of Hand pump during interruption in electricity supply such as load shading.
3) Low construction, low maintenance cost water supply scheme.
4) Sustainable due to Roof top Rain Water Harvesting.
5) Clean & pure water supply.



PLATFORM FOR INDIA MARK II DEEPWELL HAND PUMP



NOTES:
The Free end of the casing pipe shall be minimum 300mm above the installation mark
casing pipe is not required when the bore passes through rocks.
suitable for installation on bore hole with finished dia of 100mm all dimensions in millimeters.

TECHNICAL SPECIFICATION

Sr.No.	Particulars	BIS No	Measurements
1	India Mark - II Deepwell Handpump	IS 15500(PT2);2004	-----------
2	Handpump Platform construction	N.A.	As per the diagram enclosed
3	Riser pipe of IM-II Handpump 32 mm dia GI Pipe medium class 3 metre length	IS 1239; 1990	Nominal dia 32 mm thickness 3.2 mm
4	150 mm dia MS casing pipe ERW medium class	IS 1239;1990	150 mm nominal dia 166.50 mm outer dia maximum. Thickness 4.80 mm
5	150 mm MS casing pipe ERW medium class	IS 4270; 2001	168 mm outer dia. Thickness 5.4 mm
6	150 mm dia slotted MS casing pipe ERW medium class	IS 8110; 2000	166.6 mm outer dia. Thickness 5.4 mm
7	125 mm dia MS casing pipe ERW medium class	IS 4270;2001	141.3 mm outer dia metre. Thickness 5.4 mm
8	150 mm dia UPVC casing pipe	IS 12818; 1992	165.4 mm out dia. Thickness 5.7 to 6.5 mm
9	180 mm dia 6kg PVC casing pipe .	IS 4985; 1988	
10	HDPE pipe 25 mm dia	IS 4984;1995	Material grade PE-80 pressure rating PN-10
11	HDPE Tank 5000 Litre Capacity	IS 12701;1996	Overall dia 1800 to 2110 mm. Height 1800 to 2100 mm. Minimum weight of tank without lid 180 kg. Minimum wall & bottom thicknes 10.7 mm.
12	Submersible pump set. Suitable for 100 mm dia bore & submersible pump suitable for 150 mm dia bore	IS 8034; 1989	As per IS Specifications

UNITS AND CONVERSION FACTORS

LINEAR

1 inch =2.54 centimeter

1 foot =12 inch 30.48 Cm

1 mile = 5.280 feet
1.609 kilometers

10 millimeters = 1 centimeter = 0.394 inch

1 metre = 100 centimeters = 3.281 feet

1 Kilometer =1,000 metres = 0.621 mile

AREA

1 acre = 4.840 sq. yards

1 sq.mile = 640 acres =259 hectares

1 sq. kilometer =100 hectares
= 247.1 acres
= 0.386 square mile

1 hectare = 100 metre x 100 metres
= 10,000 sq.metre
=2.471 acres

VOLUME

1 cubic foot =0.028 cubic metre
=28.316 litres.

1 cubic metre = 1,000 litre
= 35.315 cubic feet.

1 million cubic feet = 11.574 cusec day
= 22.957 acre-feet
= 28,316.8 cubic metres

1 million cubic metre = 10 0 cubic metre
= 100 hectares metres
= 35.31 million cubic feet
=810.71 acre foot

1 thousand million cubic feet
= 22956.84 acre feet
= 385.8 cusec for one month
= 31.71 cusec for one year
= 6,228.8 million gallons
= 28.317millioncubicmet.res.
= 2,832 thousand hectare metre.
= 14 cm depth over 20,000 ha

1 cubic km = 10 0 cubic metre
= 1 milliard cubic metre
= 1 million cubic metres

1 million acre feet =43.56 thousand cubic feet.

1 hec. Metre = 10,000 cubic metre
= 0.353 million cubic feet
= 8.10 acre feet

1 cusec - day
= 0.0864 million cubic feet
= 1.9834 acre feet
= 2,446.57 cubic metres

1 cubic metre per second for one day
= 0.0864 million cubic metres.
= 8.64 hectare metre.
= 70.044 acre feet
=3.051 million cubic feet.

1 cusec month (30 days)
= 59.50 acre feet
= 2.592 million cubic feet
= 73,397.19 cubic metres

1 cusec-month (30 days)
=2 101.36 acre feet
= 91.54 million cubic feet

1 cusec-year (365 days)
= 723.97 acre feet
= 31.54 million cubic feet.
= 0.89 million cubic metres.
1 Gallon =0.55 litres

1 cumec year/cubic metre per second
for
one year.(365 days).
==31.54 million cubic metres.
==25,569.79 acre feet.
==1.11 thousand million cubic feet.

1 litre == 0.22 gallons

RATES OF FLOW

1 Cubic foot per second
= 0.028 cubic metre per second
= 28.317 litre per second
= 0.54 million gallons per day

1 cubic metre per second
= 35.315 cusec.
= 70.05 acre feet per day

1 Acre-feet per day
= 0.504 cusec.
= 0.014 cubic metre per second
= 14.16 litres per second

1 cubic kilometer per day
= 0.409 million
= 0.811 million acre-feet per day.

1 Hectare metre / day
= 0.116 cusec.
= 4.08 cusec.

1 litre per second.
= 0.0353 cusec.
1 litre per second per day
= 86.4 cubic metres.

Source.-ISI Publication No. IS : 786-1967' Conversion factors and Conversion Tables'- 1968 New Delhi.

EXTRA CONVERSION FACTORS

LENGTH

1 inch	= 25.4 mm
1 foot	= 0.3048
1 yard	= 0.9144 metres
1 furlong	= 201.168 metres.
1 mile	= 1,609344 kilometers.
1 millimeter	= 0.03937
1 metre	= 3,28084 feet
	= 1.09361 yard
1 kilometer	= 0.62137 miles

AREA

1 sq. inch	= 6.4516 sq. centimeter
1 sq. foot	= 0.092903 sq.metre
1 sq. yard	= 0.83613 sq. metre
1 acre	= 0.404686 hectare.
1 sq. mile	= 2.590 sq. kilometers
1 sq. centimeter	= 0.155 sq.inch
1 sq. meter	= 10.7639sq.feet
	= 1.19599 sq. yards.
1hectare	= 2,4711 acres
1sq. kilometer	= 0.3861 sq. mile.

VOLUME

1 cubic inch	= 16,3871 cucm.
1 cubic foot	= 0.028317 cu metre
1cubic yard	= 0.76455 cu metre
1 cubic centimeter	= 0.061024 cu inch
1 cubic metre	= 1.35.315 cu feet
	= 1.30795 cu yard

CAPACITY

1 ton = 1.01605 metric tone
1 tola = 11.6638 grams
1 seer = 0.9331 kilogram
1 mound =0.37324 quintal
1 metric tone = 0.9842 ton
1 gram = 0.085735 tola
1 kilogram = 1.07169 seer

1 quintal = 2.67923 maunds

Temperature

Centigrade $\frac{(°C)\ °C = 5\,(F-32)}{9}$

Fahrenheit $\frac{0F = 9C + 160}{5}$

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