

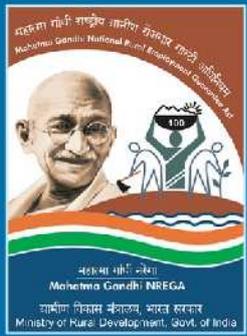


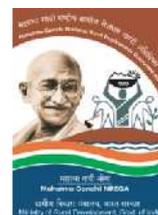
जल शक्ति अभियान
Jal Shakti Abhiyan
Ministry of Rural Development, Government of India



Empowering Village Communities for A Sustainable Water Future

A Resource Book for Jaldoots





Empowering Village Communities for A Sustainable Water Future

A Resource Book for *Jaldoots*



Prepared by

**Central Ground Water Board, Dept. of Water Resources,
River Development and Ganga Rejuvenation,
Ministry of Jal Shakti, Govt. of India**

and

**MARVI – Managing Aquifer Recharge and Sustaining Ground water Use
through Village-level Intervention**

November 2019

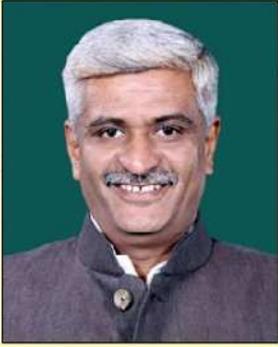
Partners



MARVI



गजेन्द्र सिंह शेखावत
Gajendra Singh Shekhawat



सत्यमेव जयते



एक कदम स्वच्छता की ओर

जल शक्ति मंत्री
भारत सरकार

Minister for Jal Shakti
Government of India

31 OCT 2019

MESSAGE

The development of ground water has played a vital role in India's socio-economic development. Ground water contributes to nearly 62% of total irrigated area of the country and nearly 85% of the rural drinking water supply. The limited ground water resources in the country are under threat due to the increasing demands of growing population, urbanization and industrialization. Intensive and unregulated ground water pumping in many areas has caused rapid and widespread decline in ground water level as well as reduction in the sustainability of ground water abstraction structures. The problem of reduction in ground water availability is further compounded by deteriorating ground water quality in some parts of the country. Time has now come to think beyond normal ways of implementing various government propelled interventions and partly switch over to community led interventions through participatory ground water management.

It gives us immense pleasure to know that MARVI (Managing Aquifer Recharge and Sustaining Groundwater Use through Village-level Interventions, an initiative of Australian and Indian partners for sustainable ground water management through community participation) in collaboration with Central Ground Water Board, Department of Water Resources, River Development & Ganga Rejuvenation, Ministry of Jal Shakti, Government of India has prepared a **Training Resources Book** for village level para hydrogeologists-*JAL DOOTS*. This is a step which will help facilitate participation of village communities in ground water resource management, ensuring a sustainable water future.

This training resource book will help the "*JAL DOOTS*" in empowering the village communities to plan and implement various interventions for augmenting ground water resources and managing its demand, including water conservation & rainwater harvesting, water resources assessment, monitoring of water levels and quality and water budgeting at Village/Gram Panchayat levels, Central Ground Water Board will impart the trainings of *JAL DOOTS* in association with other stake-holder organisations. I understand that this initiative will pave the way for training and capacity building of a large number of grass root level stakeholders throughout India, who will play a vital role for sustainable water management through micro level water resource planning.

(GAJENDRA SINGH SHEKHAWAT)



जल शक्ति
अभियान
संचय जल, बेहतर कल

Office : 210, Shram Shakti Bhawan, Rafi Marg, New Delhi-110 001

Tel: No. (011) 23711780, 23714663, 23714200, Fax : (011) 23710804

E-mail : minister-mowr@nic.in

रतन लाल कटारिया
RATTAN LAL KATARIA



जल शक्ति
और सामाजिक न्याय एवं अधिकारिता राज्य मंत्री
भारत सरकार
नई दिल्ली-110001
MINISTER OF STATE FOR
JAL SHAKTI AND SOCIAL JUSTICE & EMPOWERMENT
GOVERNMENT OF INDIA
NEW DELHI - 110001

Message

Groundwater is one of the most preferred sources of fresh water for various uses in India on account of its near universal availability, dependability and low capital cost. Increasing dependence on ground water as a reliable source of water has resulted in its indiscriminate extraction in various parts of the country without due regard to the recharging capacities of aquifers and other environmental factors. Experts believe that India is fast moving towards a ground water crisis due to its over-extraction and contamination because of rapid urbanization, industrialization etc. To address such challenges, Government of India is implementing appropriate measures/schemes in consultation with all the stake-holders. However, the process of ground water management can be hastened pan-India by promoting the participatory ground water management.

The highly uneven distribution of ground water availability and its utilization indicates that no single management strategy can be adopted for the country as a whole. On the other hand water utilization pattern of each sector along with socio-economic situation demands specific and decentralized solutions of ground water management, implemented with community participation. Lack of awareness/knowledge and capacity at the village and community level in our country is a major constraint in achieving active participation of the communities in judicious ground water resource management

In order to build the capacity of para-hydrogeologists - JAL DOOTS, MARVI (Managing Aquifer Recharge and Sustaining Groundwater Use through village-level Interventions, an initiative of Australian and Indian partners for sustainable ground water management through community participation), in collaboration with Central Ground Water Board (CGWB) has prepared a "Training Resources Book" dealing with both scientific and practical aspects of ground water resource management at the community level. These JALDOOTS after their knowledge upgradation shall be visiting the villages to further train the youths/farmers for enhancing their knowledge for sustainable water management.

The initiative by MARVI and Central Ground Water Board is highly appreciated and I sincerely hope this will contribute immensely to the sustainable water management in the country.


(RATTAN LAL KATARIA)



जल बचाव - जल संवय

215, श्रम शक्ति भवन, रफी मार्ग, नई दिल्ली -110 001, 215, Shram Shakti Bhawan, Rafi Marg, New Delhi-110 001

दूरभाष : (011) 23708419, 23718759, फ़ैक्स : 011-23354496, Tel. : (011) 23708419, 23718759, Fax : 011-23354496

Delhi Residence : 4A, Telegraph Lane, Firoz Shah Road, New Delhi, Phone : 011-23329660

Residence : 352, Katariya Kunj, Mata Mansa Devi Complex, Sector-4, Panchkula, Haryana, Tel. : 0172-2555352,



॥ नमामि गंगे ॥
निर्मल अतिस लोकपाला ।



Australian Government
**Australian Centre for
International Agricultural Research**



GPO Box 1571
Canberra ACT 2601
ACIAR House, 38 Thynne Street
Fern Hill Park, Bruce ACT 2617
T (61 2) 6217 0500
F (61 2) 6217 0501
E aciar@aciar.gov.au
ABN 34 864 955 427

Message

Policy makers aiming to ensure equity of access, efficiency of use and sustainability of water resource management cannot achieve this objective in the abstract – they need to involve water users and other stakeholders. Managing groundwater as a common pool resource requires engagement at grassroots level. Building ‘water literacy’ of village communities is essential to allow them to participate effectively in the groundwater dialogue and to assist communities and other stakeholders to improve their decision making around groundwater use and long-term management impacts.

The Australian Centre for International Agricultural Research (ACIAR) supports a range of agricultural research for development projects through partnerships with countries in the Asia-Pacific Region, to support sustainable economic growth, better livelihood opportunities and food security. *Managing Aquifer Recharge and Sustainable Groundwater Use through Village-level Intervention* (MARVI) is one such project, conducted in India. The project is led by Western Sydney University in collaboration with CSIRO Land & Water in Australia; and Arid Communities and Technologies, Development Support Centre, Maharana Pratap University of Agriculture and Technology, Vidya Bhawan Krishi Vigyan Kendra and the International Water Management Institute (IWMI) in India.

In this project, researchers, rural development facilitators and local villagers worked together to initiate participatory groundwater monitoring in the Dharta and Meghraj watersheds in Rajasthan and Gujarat states. This involved developing participatory approaches to capacity building where villagers, called *Bhujal Jaankars (BJs)*, a Hindi word meaning ‘groundwater informed’, were trained in their local settings through relevant theory and practical exercises. This allowed BJs to perform geo-hydrological evaluation of their area, monitor groundwater and share their findings and experiences with their village communities. As result, a well-designed program of capacity building and the model for on-going support and nurturing evolved. This allowed BJs to play an important role in monitoring watertable depth and other data and sharing of the groundwater information with the local village community to influence the sustainable use of groundwater.

I am pleased to see that the MARVI approach, learning and experiences are helping the Jaldoot program, a very important grassroots level initiative of the Jal Shakti Ministry, the Government of India. Implementation of the Jaldoot program at a large scale will provide valuable learning to MARVI partners, and further develop and refine the MARVI approach of participatory groundwater management, relevant to large areas of South Asia and the water and food security of hundreds of millions of people.

Professor Andrew Campbell
Chief Executive Officer

ACIAR
Research that works for developing
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aciar.gov.au



Message

Water is a critical resource for the economic growth and wellbeing of communities, and it is an important element in the United Nations Sustainable Development Goals. Australia and India share many common water challenges as a consequence of rapid urbanisation, climate change and increasing competition for water from different sectors. Underpinning the research of Western Sydney University is a commitment to delivering positive economic, social and environmental outcomes for communities locally, nationally and globally. In the last 10 years, the University has developed important partnerships with India in education, research and outreach. Western Sydney University is proud to have played a significant role in MARVI (Managing Aquifer Recharge and Sustaining Groundwater Use through Village-level Intervention) - a major transdisciplinary research project with a number of Australian and Indian partners and under the leadership of Professor Basant Maheshwari.

The MARVI project is focused on developing village-level, participatory models and tools to assist in improving groundwater supplies and reducing demand through the direct involvement of farmers and other affected stakeholders. A unique feature of MARVI is the use of scientific measurements by villagers, applied together with their local knowledge, to make sense of village groundwater availability. This unique and insightful information is communicated to farmers and others in their own language, which in turns allows for local decision making and actions.

Capacity building among local participants is an important part of the MARVI approach to participatory groundwater monitoring and management. Western Sydney University is privileged to have led the MARVI project and contributed to the development of the Jaldoot Resource Book to be used by the Jal Shakti Ministry across India to achieve its national water mission. I am confident that this collaboration with the Jal Shakti Ministry and MARVI partners will provide significant opportunities in the long-term for knowledge sharing in the water sector.

A handwritten signature in black ink, appearing to read 'Barney', with a long horizontal flourish extending to the right.

Professor Barney Glover AO
Vice-Chancellor and President
Western Sydney University

यू. पी. सिंह, आई. ए. एस
U.P. SINGH, IAS
सचिव
SECRETARY



भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास
और गंगा संरक्षण विभाग
श्रम शक्ति भवन
रफी मार्ग, नई दिल्ली-110 001
GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES,
RIVER DEVELOPMENT & GANGA REJUVENATION
SHRAM SHAKTI BAHWAN
RAFI MARG, NEW DELHI-110 001
<http://www.mowr.gov.in>

FOREWORD

India, with 2.4% of world's geographical area is home to nearly 16% of the world population but blessed with only 4% of its fresh water resources. Ground water has steadily emerged as the backbone of India's agriculture and drinking water security due to its ubiquitous availability and ease of extraction. Nearly 62% of irrigation, 85% of rural water supply and 45% of urban water supply needs in the country has been estimated to be sourced from ground water resources. As per the latest assessment, nearly 63% of the available ground water resources presently being utilized in the country on an average. Though this may not look alarming, there is wide variability in availability of ground water and its utilization, with parts of Northwest and South India suffering from over-exploitation whereas parts of Eastern India still having sub-optimal utilization of available resources. Increasing demand, coupled with ground water contamination at places and the anticipated impact of climate change are likely to further worsen the situation in future. Hence, sustainable development and efficient management of this scarce resource has become a major challenge in India though Government of India through various policy guidelines/schemes are putting efforts in consultation with all the stake-holders to address this vital issue.

Lack of a proper scientific understanding of the ground water situation at the grass root level, lack of attention to demand-management measures and near-absence of community participation in ground water management have led to the concept of participatory ground water management, under which efforts shall be made to train all the stake-holders including the farmers/youths in villages through para-hydrogeologists - JALDOOTS for sustainable management of water resources.

The main aim of the Resource Book prepared by MARVI (Managing Aquifer Recharge and Sustaining Groundwater Use through Village-level Interventions, an initiative of Australian and Indian partners for sustainable ground water management through community participation) in collaboration with Central Ground Water Board is to develop and train JAL DOOTS in water resources related issues who in turn will train the villagers/stake-holders.

I believe that this endeavor by the MARVI and CGWB will be a significant step in our journey to ensure empowerment and capacity building of communities to enable them to manage their ground water resources through a judicious mix of various interventions to ensure long-term sustainability of this precious resource.

(U.P. SINGH)

जल संरक्षण - जीवन संरक्षण
Conserve Water - Save Life

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Module 1: Understanding the Water Cycle

To understand ground water, we need to understand the water cycle. Both ground water and surface water are connected and so what happens to one can affect the other.

Water never leaves the Earth. It is constantly being cycled through the atmosphere, oceans and lands in liquid, gas or solid forms. This process, known as the **water cycle**, is driven by energy from the sun. The water cycle is crucial to the existence of life on our planet.

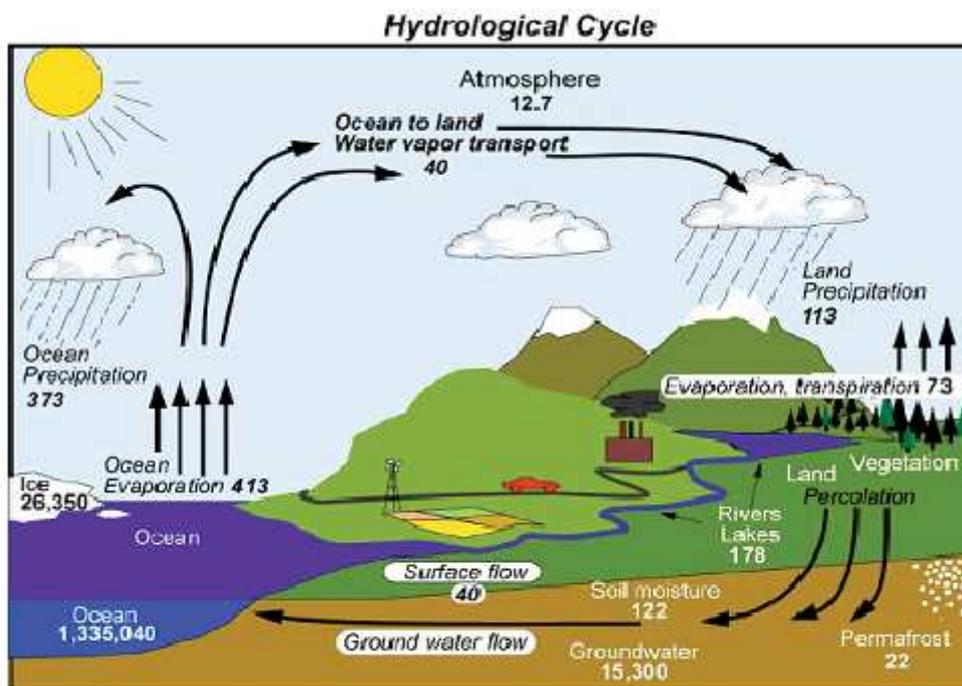


Water cycle is an endless process of movement of water around our planet

The Water Cycle

The water cycle is also called the hydrologic cycle. In the water cycle, water from oceans, lakes, swamps, rivers, plants and even from people and animals, is converted into water vapours and released into the atmosphere. Water vapours condense into millions of tiny droplets that form clouds. Clouds lose their water as rain or snow, that either infiltrates into the ground or runs off into rivers and lakes or escapes into the atmosphere. The water that infiltrates into the ground is either taken up by plants or moves deeper below the ground eventually replenishing the ground water. Plants suck up moisture from the soil and lose water from their leaves in the form of water vapours, a process called transpiration, that transfers water back into the atmosphere. Some of the water that runs off into rivers, flows into ponds, lakes, or oceans also evaporates back into the atmosphere. The cycle continues!

Water that enters and percolates through the soil is very important as it recharges the ground water. We know that ground water resources in India are under serious threat from over-use and thus it is very important to replenish the ground water through recharge. Some of the ground water is discharged into streams and that is why we continue to see flows in streams and rivers long after the rains (base-flow). Ground water moves through rocks and sand from one region to another. Therefore, when one draws water from a well, the water from adjoining areas moves into maintain the water level. This also means that ground water pumping draws ground water from long distances from beneath someone else's land.



Units: Thousand cubic km for storage, and thousand cubic km/yr for exchanges
 Note: 1 cubic kilometer = 1,000,000,000,000 Liters of water

Source: Trenberth et al. 2007 (© 2007 American Meteorological Society).

Water storage in ice and snow: Some of the precipitation is stored in the form of ice and snow, such as in Antarctica where about 90% of the total ice on Earth is currently stored. Most of the remaining 10% is in the Greenland ice cap.



A smaller amount is present at high elevations, e.g. in mountain ranges such as the Himalayas, the Andes and the Rocky Mountains. Accumulation of snow leads to compaction and formation of ice, which gradually becomes so heavy that it starts to move slowly. This mass of moving ice is called a glacier. The Greenland ice cap contributes to the global water cycle (estimated to be 517 cubic km every year) as some of the Greenland glaciers reach to the sea and icebergs break off the glacier, move with currents in the ocean, and melt. Climate change is expected to cause faster melting of glaciers and consequently a rise in sea levels.

Water storage underground: Most of the available freshwater is stored underground as ground water. Water can remain stored underground for a long time, which means the ground

water can serve as a long-term resource as well as a buffer against major fluctuations in the water cycle (e.g. drought). However, for its sustainability we need to make sure we do not over-exploit it. The following table gives an idea of the time scales associated with the residence time in different water storages.



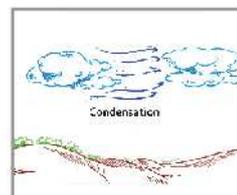
We can store water underground for hundreds of years.

Category	Residence time* scale
Atmosphere	days
Soil moisture	weeks
Rivers and lakes	months
Ground water	years to several thousand years
Ocean	tens of thousands of years

*Residence time = typical storage volume/ flow rate through the storage

Know the key terms of the water cycle

Condensation: Water vapours condense on tiny dust, salt or smoke particles and form droplets. In this way, water vapours form clouds - this is called condensation.



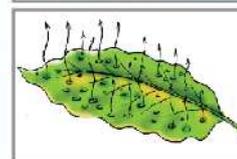
Precipitation: Following condensation, the droplets grow in size. When the water droplets in the clouds get too heavy, they fall back on to the Earth - called precipitation. This includes rain, snow and hail, but most precipitation is in the form of rain.



Evaporation: Heat energy from the sun causes water in puddles, streams, rivers, seas or lakes to change from a liquid to a water vapour form called evaporation. The vapours rise into the air and gathers in clouds.

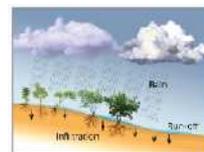


Transpiration: Transpiration is the process by which plants lose water through their stomata present in leaves. Stomata are tiny pores found in the epidermis of leaves and stems. Surrounded by a pair of guard cells they open and close depending on plant's need for gas exchange. Transpiration gives evaporation a bit of a hand in getting the water



vapour back up into the air. It also helps plants to grow, absorb carbon dioxide and to release oxygen.

Infiltration and percolation: The process where water on the surface enters into the soil (infiltration) and moves deeper into subsurface (percolation) and in time to the ground water.



Runoff: When rain falls on the land, some of the water infiltrates into the ground, while most of the remaining water runs off on the land surface and into nearby streams or rivers. This water is called runoff. Sometimes large volumes of runoff water during heavy rains results in a flood.



The water cycle can be altered by way of a change in the land use due to urbanisation, mining and clearing of forests. The rise in temperature due to greenhouse gases (climate change) can significantly influence the water cycle. For example, in recent years many areas have experienced greater incidences of droughts and floods due to changes in rainfall patterns.

How to measure rainfall?

(Courtesy: Australian Bureau of Meteorology)

Rainfall data are very useful for making a lot of decisions. It helps farmers deciding which crops to grow and engineers in designing dams and bridges. Good rainfall data from local areas are often hard to find or are unreliable. Therefore, it is a good idea to measure and record your own rainfall daily. This way you can also keep track of rainfall with time.



Instruments

The standard instrument for the measurement of rainfall is the 203 mm (8 inch) rain gauge. The rain gauge is made of a circular funnel with a diameter of 203 mm which collects the rain into a graduated and calibrated cylinder. This can measure up to 25 mm of precipitation at a time.

In modern automatic weather stations a Tipping Bucket Rain Gauge is employed. There are two advantages of this type of rain gauge. Firstly, it never needs to be emptied, and secondly the amount of rainfall (and even the rate at which the rain is falling) can be recorded automatically. An electronic pulse is generated each time the volume of water collected in one of the small buckets causes the bucket to tip. This is equivalent to 0.2 mm of precipitation. The time and number of tips are then recorded electronically.

Where and how to install a rain gauge?

Gauges sited near buildings, fences and trees do not give accurate measurements. The distance of the gauge from buildings, trees or other objects should be at least twice the height of the obstruction (h), and preferably four times the height. For example, the gauge should be installed more than 10 m away from a 5 m high building.



The top surface of the gauge should be horizontal and chest high; the grass and vegetation around it should be less than a knee high.

Fasten it securely to a post or something solid so that it does not blow over in strong winds and storms.

How to read a rain gauge?

Read every day at the same time, as near to 9 am as possible. During heavy rains it may be necessary to read and empty the gauge frequently to prevent it from overflowing. Add this amount to next 9 am reading.

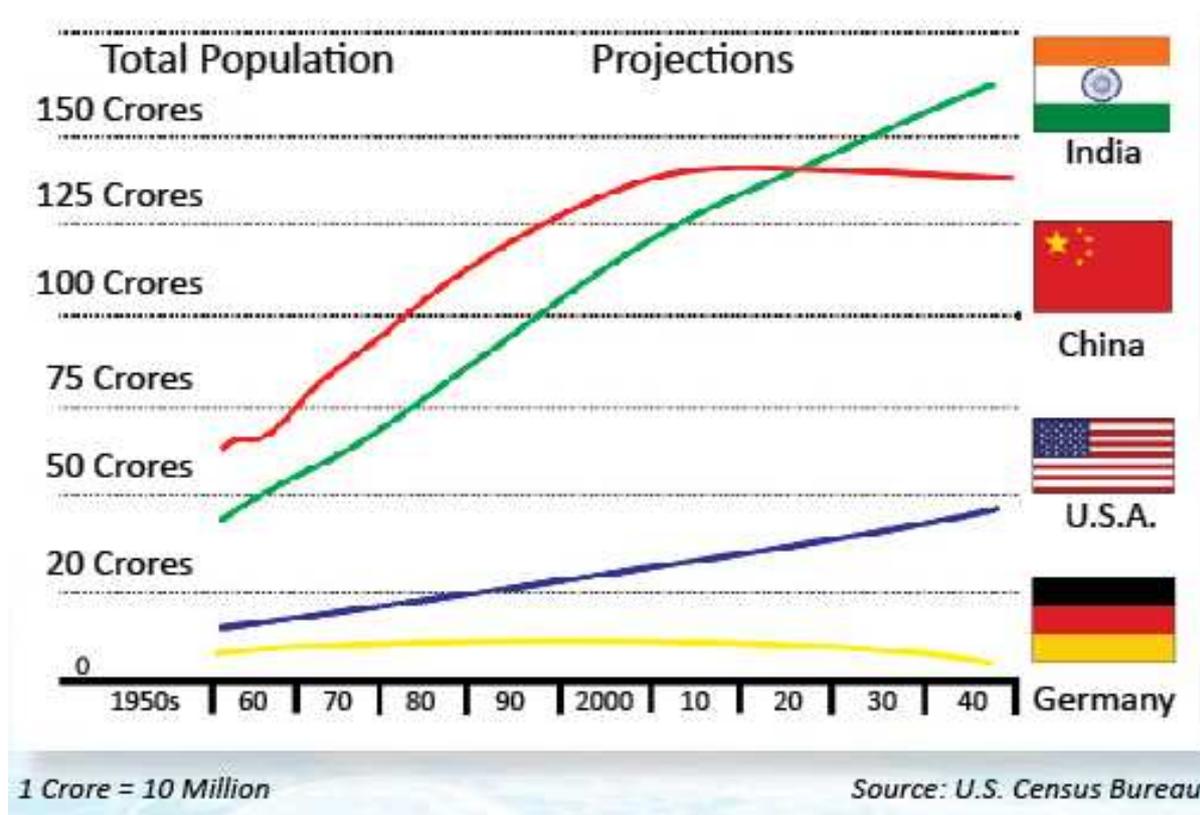
To read the contents of the rain gauge, first ensure that the gauge is vertical. Bring your eye level with the surface of the liquid in the gauge and read from the scale the position of the liquid surface.

Make sure you read the bottom of the liquid surface and not the meniscus, which is the slightly higher lip formed where the water surface meets the cylinder wall.

How to record rainfall?

Keeping a proper record of rainfall is as important as the appropriate installation of a rain gauge and regular reading of rainfall. Rainfall is an important indicator of water availability in a village or a town. Long-term records help in developing a water budget for a village. Meaning how much water is available, how much can be harvested in check dams and then to recharge ground water. It helps in calculating the size of recharge structures needed and the resulting ground water recharge. Rainfall amounts should be carefully recorded in a notebook and an example of a Table is shown in the Activities section of this module.

Human influence on the water cycle



Since water is central to life, virtually all human activities have some impact on the water cycle. Whether it is to do with using land to build homes or to grow food or undertake industrial activities to manufacture goods for our daily use, we affect the water cycle through all of these activities. Some key human activities that have major impact on the water cycle are discussed next.



By 2050, there will be more than 9.8 billion people living on Earth

Population growth and deforestation



Shutterstock/Rich Carey

Human population on the Earth has grown dramatically in the last 100 years, nowhere more so than in India. The world population increased from about 1.5 billion 100 years ago to more than 7 billion people in 2016. This unprecedented growth of population resulted in clearing of many forest areas to release land for agriculture, industry and habitation. It is estimated that every year more than 10 million hectares of forests are either cleared or destroyed by fire. As trees transpire water from land into the atmosphere, the large-scale deforestation means there is less total water that is being sent back into the atmosphere and more water running off or infiltrating, thus affecting the water cycle.

Urbanisation and industrialisation

The world's population is not only growing rapidly but also becoming rapidly urbanised, as people migrate from rural to urban centres. Small towns are becoming like cities and need facilities like safe water supply and sewerage systems. As urban centres rapidly encroach on land that previously supported natural vegetation that contributed to transpiration, thus the urbanisation influences the water cycle. Cities increase demand on water resources and generate wastewater that needs to be managed. For example, the water falling on roofs, roads and hard surfaces (pavements) runs off rapidly without infiltrating into the soil and recharging ground water.



Shutterstock/Radiokafka

Many industrial processes require high volumes of water and release polluting chemicals. The industrial process of making the cement that we use for construction of buildings and infrastructures (a basic need for urbanisation) is a simple example of a carbon dioxide (CO₂) emitting activity. Let us consider the impact of these gases on our water cycle.

Release of greenhouse gases and climate change

Human activities such as power generation using fossil fuels (e.g. coal, petroleum, natural gas), deforestation, industrial activities and agriculture release certain gases into the atmosphere such as carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). These gases trap heat in the atmosphere and are therefore called "greenhouse gases". Many other industrial activities release greenhouse gases such as hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride, and nitrogen trifluoride. These gases are typically emitted in much smaller quantities than CO₂, but they are more powerful in terms of global warming.



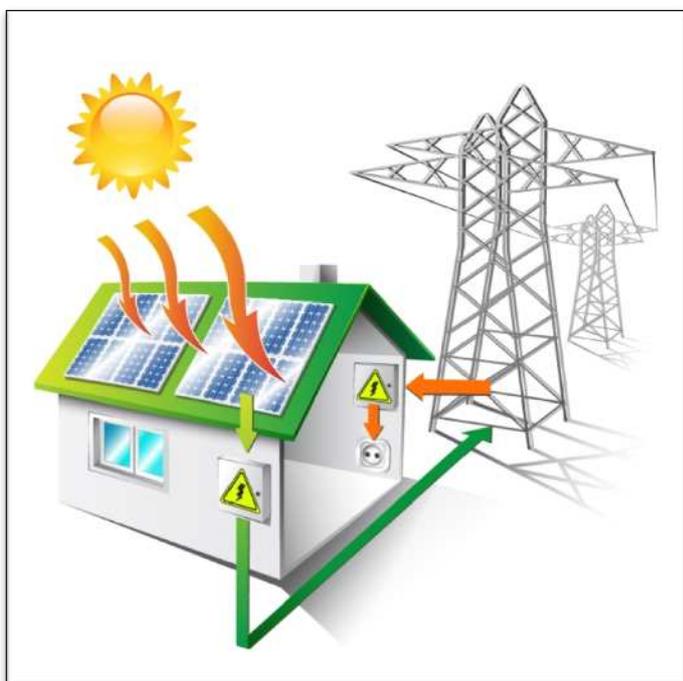
Climate Change has a major effect on the water cycle

The build-up of greenhouse gases in the atmosphere has resulted in "climate change", that is the Earth is progressively becoming warmer. It is predicted that at least a 2°C change in Earth's average temperature is almost unavoidable now. "Global Warming" has a major effect on the water cycle in terms of distribution and amounts of rainfall.

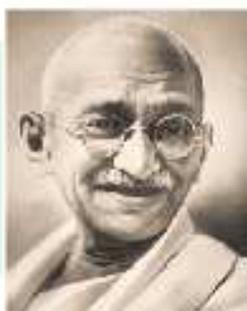
With increased temperatures, the glaciers are melting away and thus affecting the distribution of water on land. In addition, as temperature increases more water is evaporated in the form of water vapours. Water vapours also add to further warming, through a similar effect as greenhouse gases. The effect of climate change on the water cycle may lead to uneven distribution of rains resulting in extreme weather events such as draughts, floods and cyclones.



Cleaner source of energy such as solar and wind are needed to minimise greenhouse gases



CO₂ makes the bulk of the total greenhouse gas emissions and therefore there is a global effort to reduce its emission. India has set a goal to reduce its carbon emission (CO₂) by 35% by 2030 (compared to 2005). Use of fossil fuel for energy production is a major contributor to the carbon emission and therefore alternative (cleaner) sources of energy production, such as solar and wind power are needed. India has initiated major solar power programs to generate cleaner electricity in coming years. Plants absorb CO₂ from atmosphere and store (sequester) it on land and therefore planting trees helps mitigate climate change.



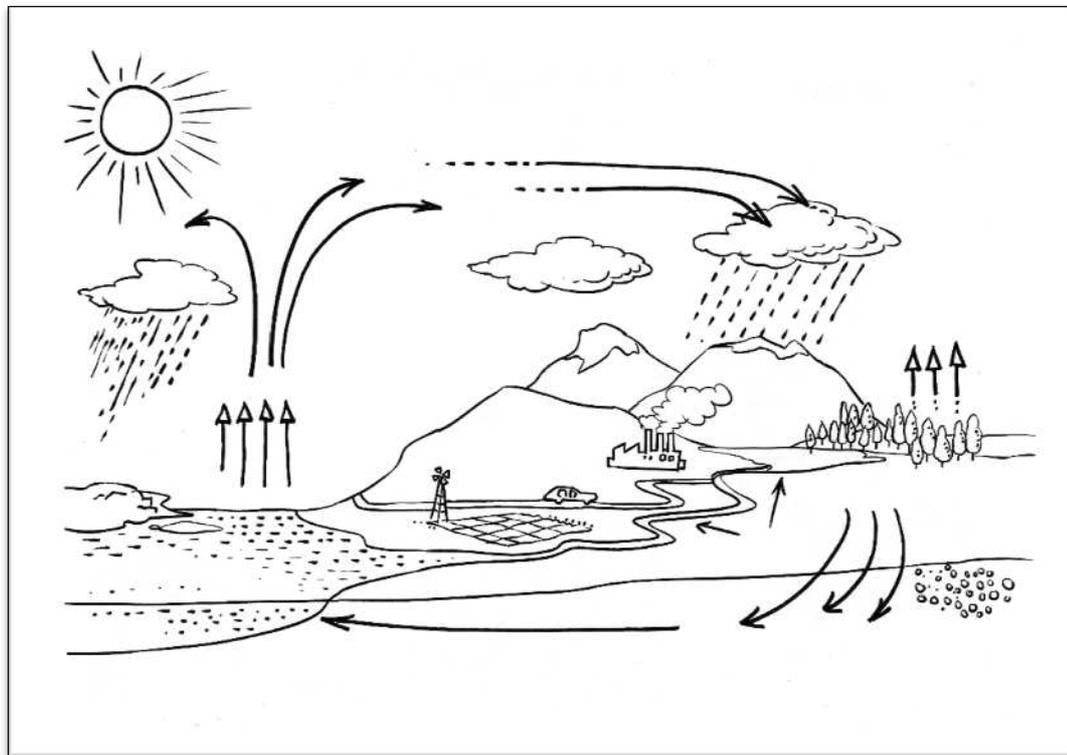
“Earth has enough resources to meet people’s needs, but will never have enough to satisfy people’s greed.”

Mahatma Gandhi

Suggested activities

Activity 1

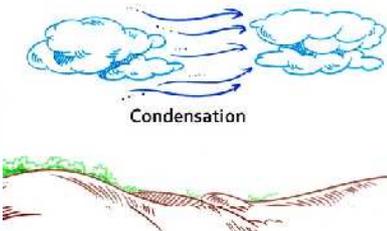
1. Name the different processes associated with the water cycle

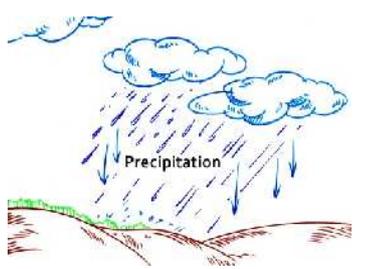
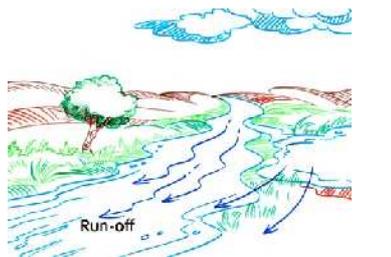
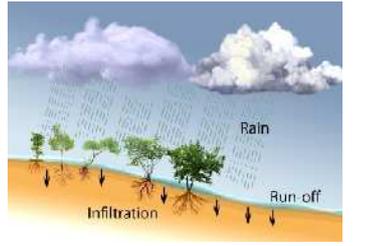
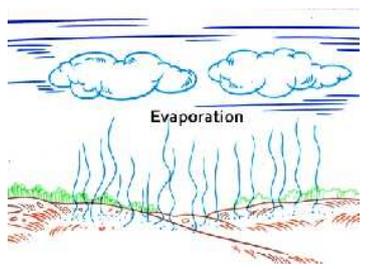


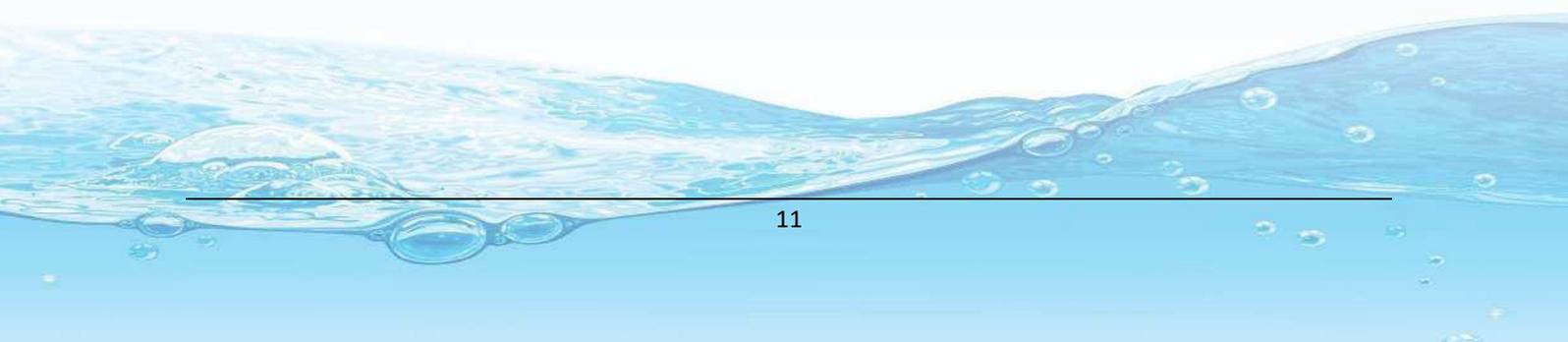
Activity 2

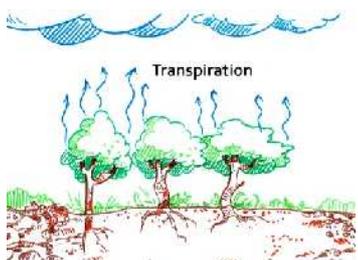
Record each process and its importance for the following components of the water cycle.

Discuss these in a group.

Sr no	Process	Process (what is it and how this takes place)	Importance (How it impacts our lives)
1	Condensation 		
2	Precipitation		

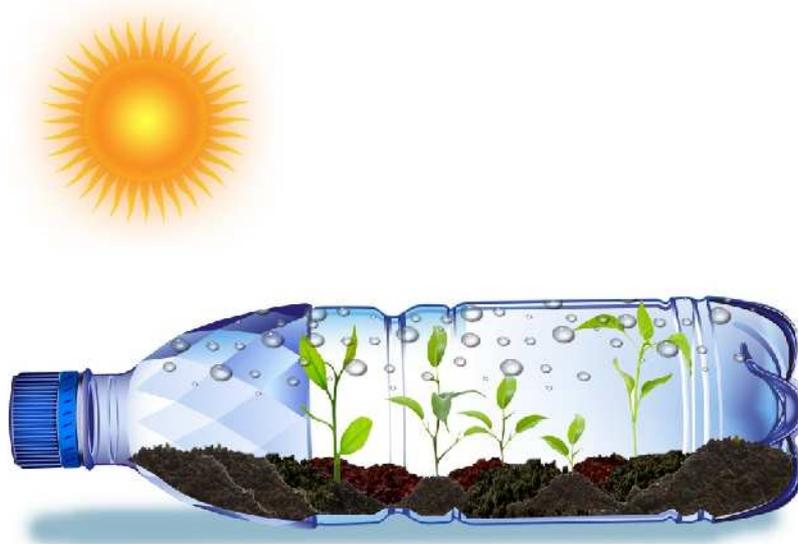
	 <p>Precipitation</p>		
3	<p>Runoff</p>  <p>Run-off</p>		
4	<p>Infiltration/Percolation</p>  <p>Rain</p> <p>Run-off</p> <p>Infiltration</p>		
5	<p>Evaporation</p>  <p>Evaporation</p>		



6	Transpiration  A diagram illustrating the process of transpiration. It shows three green trees with roots in the soil. Blue arrows point upwards from the leaves of the trees, representing water vapor being released into the atmosphere. The word "Transpiration" is written in the center of the diagram.		
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Activity 3

Build your own water cycle based on suggestions below:



What you need

- A plastic bottle or a large glass container
- Potting soil
- Seeds or seedlings
- Water, tape, knife, plastic wrap

What to do:

- Cut the bottom of the plastic bottle.
- Place the bottle sideways and add a layer of soil (as shown in picture).
- Sow seeds or plant seedlings in the soil.
- Seal the bottom back on the bottle.
- Remove the cap (and put it somewhere safe as you will need it again).

Water the soil gently and carefully.

Place in a sunny spot.

When the seedlings are growing well, put the cap on and place the bottle in a sunny spot.

Watch the transpired water condensing on the bottle and the water cycle working.

Describe your observations from this experiment.

Activity 4

Install a rain gauge in your school yard following instructions above in this module. Take turns to read the rain gauge daily and record the observations in your notebook. Draw charts from the data and compare this month or year’s data with long term average rainfall that is available from the Indian Meteorological Department in your region. You may find this data from their site on internet also.

Rainfall Register (mm of rainfall per day) Location:.....,

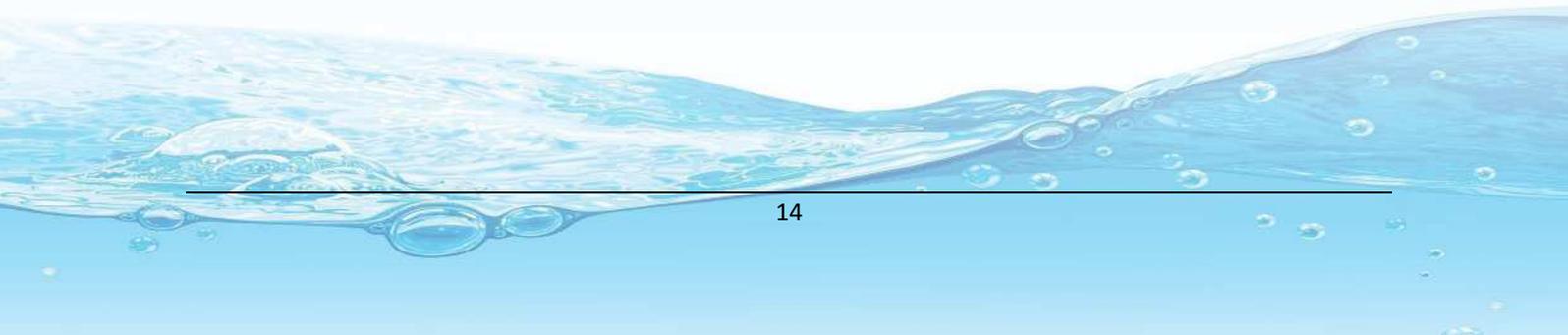
Year:....., Recorded by:.....

Dt	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
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Monthly total (mm):

Total number of rainy days:



Module 2: Understanding Ground Water

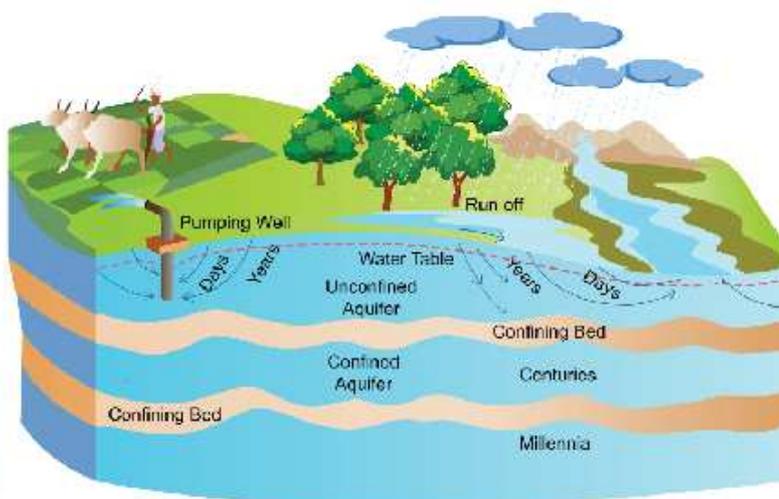
Adapted from Nature Geoscience/USGS

What is ground water?

Any water that is below the ground surface is ground water. Unlike water in rivers and reservoirs, we cannot see this water but it is a very important source of water for drinking, irrigation, industries and the environment.

The water that fills the pore spaces in rocks (fractures and other such openings of rocks and other geological materials), sediment, and soil deep beneath the surface is called ground water. In other words, ground water is contained in any pore spaces underneath the surface of the ground.

The water drawn from the ground water is derived from rainfall and infiltration within the normal water cycle.



Aquifer

Aquifers are geological formations composed of permeable sand and gravel (in alluvial systems) or fractured rocks (in hard rock systems) that are capable of storing water and allowing it to flow, in sufficient quantities, to wells and springs. Aquifers perform two functions- firstly that of “storing” water and secondly that of transmitting it from one location to another.

The transmissivity of an aquifer (that is how easily water flows through the aquifer) depends on the pore size and connectivity of pores or fractures.

Water table

The water table is the level at which the ground water is found. If you dig a well in the ground, and it reaches an aquifer, the well will fill up with water to a certain depth or level which is known as the water table. Knowing the depth of the water table is very important – periodic measurements can indicate whether the depth of water table is falling or rising.

In a year of a good monsoon, the water table depth is expected to rise and it will fall when there is drought. In India, the water table year after year is going down (ground water getting deeper), meaning the current amount of pumping cannot be sustained. For sustainable supplies, less water needs to be pumped out and ground water recharge needs to be increased.

An explanation of water table and wells

When water is withdrawn from a well, the level of water in the well gets lower, and water flows from the aquifer into the well. This causes the water level to drop in the aquifer with the biggest fall being at the edge of the well, and progressively smaller falls further from the well. This new shape of the water table is called a drawdown cone that is centred on the pumping well.

When a drawdown cone from one well impinges on another well, it will reduce the amount of water that can be pumped from the second well, and if the water table is lowered below the base of the second well that well will run dry, regardless of whether water is pumped out or not. The owner of a new or a deeper tube well, assuming it is not a dry well, will get a new supply of water, and in so doing will create a drawdown cone that can influence how much water, if any, can be pumped from the adjoining dug wells.

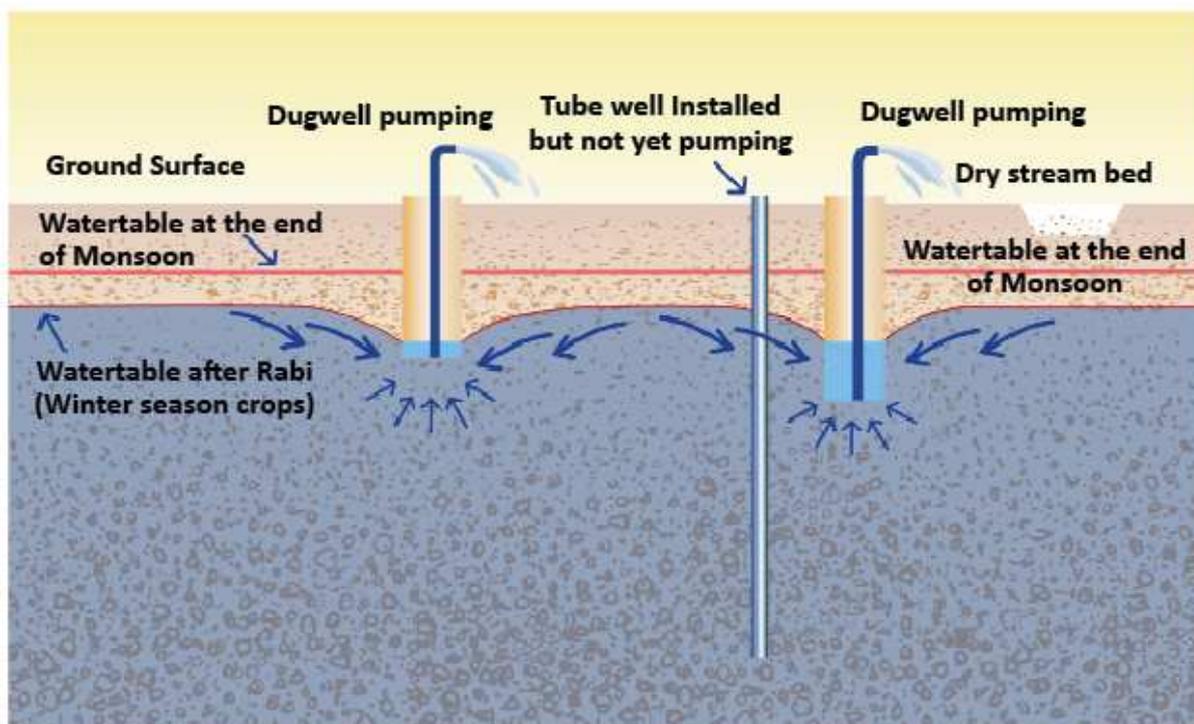


Figure. Pumping from dug wells only.

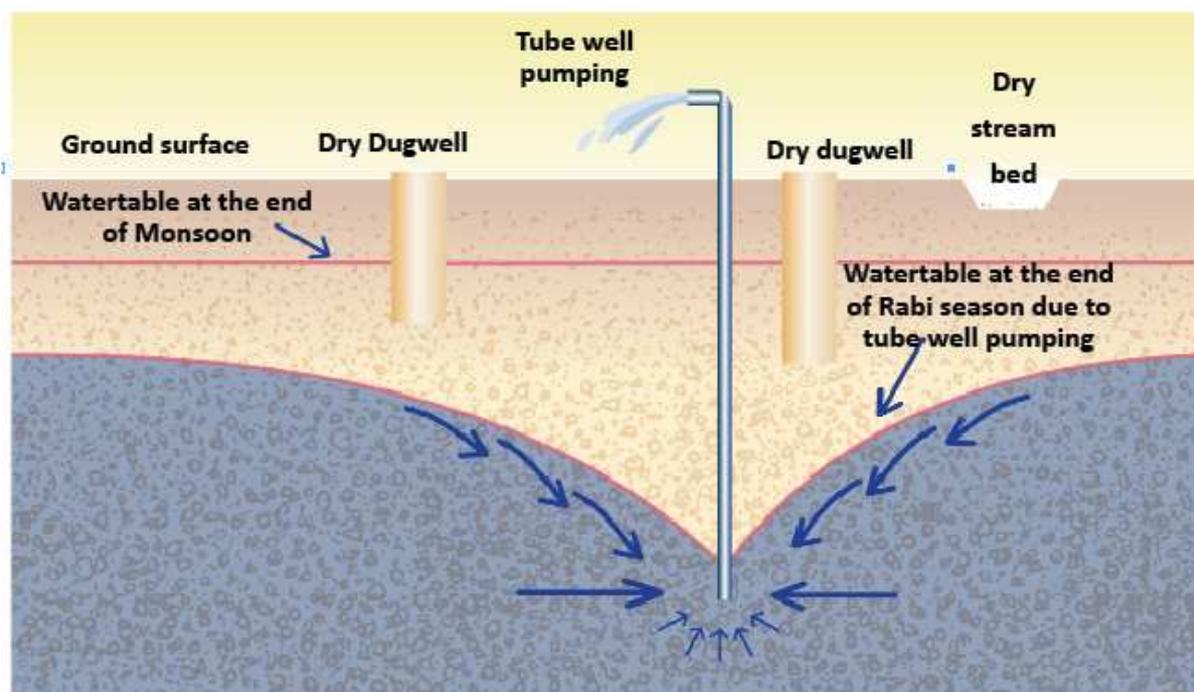


Figure. Pumping from tube well and dug wells resulting in drying of dug wells.

The influence of pumping will spread with time. Water that would have been recovered from dug wells now goes to the tube well instead. The same or smaller total volume of water can be recovered by the village, but instead of it coming from all dug wells it will come from a smaller number of tube wells.

When there are multiple tube wells in a village, the drawdown cone of one tube well can impinge on another. Because most tube wells are only cased near the surface, water can run down the tube well from upper water bearing layers to lower layers due to the absence of an extensive confining layer between them.

The only circumstances where building a new tube well will produce more water for the village is when there is no connection between upper and lower aquifer layers.

How important is ground water in India?

India is the largest user of ground water in the world. It uses an estimated 248 cubic kilometres of ground water per year - over a quarter of the global total.

Ground water is a major source of irrigation and industrial uses in India. In India, about 75% of irrigation water comes from ground water sources. About 85% of rural water demand and about 50% of urban water demand in India is met by ground water.

The demand for ground water is even greater in times of drought. Ground water accounts for one-third of the total water used by humans worldwide. Ground water is also important for the environment. Ground water helps water flow in streams and rivers during dry periods and maintains wetlands and lakes.

Many people in cities nowadays also rely on ground water for their daily needs due to inadequate supplies of water from traditional water supply sources. Farmers in India, often rely on ground water to provide water for their crops when rains do not fall during the cropping season.

Ground water is commonly used as a source of drinking water supplies in India. It is often a more convenient source of water, and it is often considered less vulnerable to pollution than surface water. However, once polluted, ground water is more difficult to clean up than rivers and lakes. Increasingly treated surface water is being supplied to people in India.

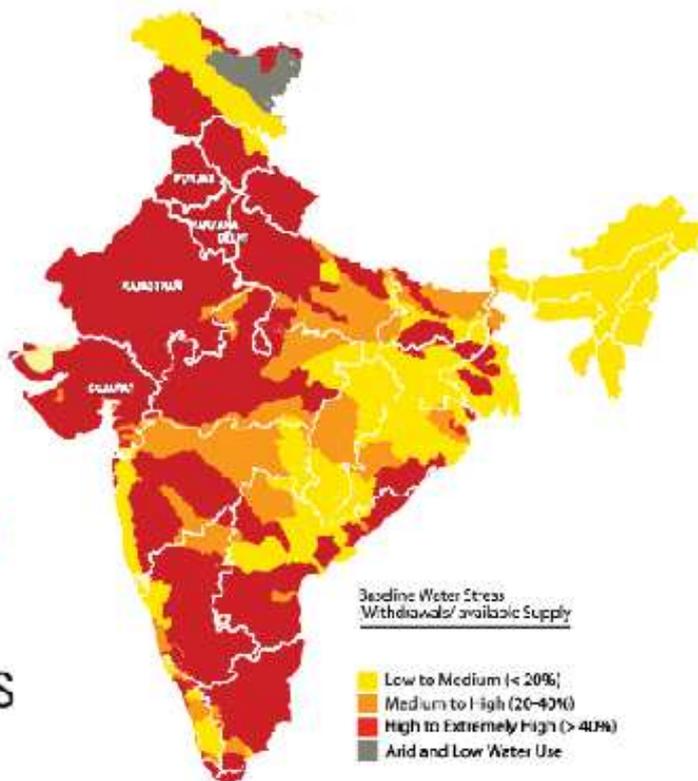
Overexploitation of ground water in India

Ground water, although a huge resource, is not infinite. Its overexploitation in many parts of India is leading to a decline in water table and even the drying up of shallow wells. Therefore, many people do not have enough ground water for drinking purposes and for irrigating their crops.

Water levels in more than half of the all wells in India are becoming deeper year after year. Some farmers are resorting to tube wells to access water from deeper aquifers. Generally, it is not possible or economical for a small farmer to extract deeper ground water. Due to widespread pumping through tube wells, these aquifers are also being exhausted now. Further, the quality of ground water from deeper aquifers is sometimes poor due to the

presence of salts, heavy metals and other substances that are harmful to people, crops and soils.

More Than
Half
of India
Faces
High to
Extremely
High
Water Stress



www.indiawaterportal.in

 WORLD RESOURCES INSTITUTE

As mentioned earlier, ground water in India is a critical resource. An increasing number of cities, towns and villages across the country are running out of ground water supplies and the ground water has become unsustainable. Punjab, Haryana, Gujarat, Rajasthan, Tamil Nadu are some of the states that are experiencing the greatest decline in ground water levels. If we do not take suitable action now (see module 10), it will seriously limit drinking and irrigation water supplies leading to serious social, economic and environmental consequences.

Situation in Gujarat and Rajasthan

The map on the left shows that the ground water sources in many states of India, including Rajasthan and Gujarat, are under stress. It is clear from the map that ground water in the country is over-used. The Government of India have now categorised many assessment Units (Block, Mandal, Taluka, Watershed or District) throughout India as over-exploited, critical and semi-critical to ensure that appropriate measures are taken to improve the situation.

Why ground water levels are dropping?

- Over exploitation – too many users and too many wells.
- Limited regulation – permission required for digging a well only for industries, infrastructure units and mining projects as of now - no restrictions on ground water use for agriculture.
- Insufficient ground water recharge from rainfall due vagaries of monsoon and large-scale urbanisation.
- Other reasons such as cultivation of high water consuming crops, inefficient irrigation practices etc.

What may happen if the ground water level keeps falling?

- Shallow wells become dry during dry season.
- Not enough water for growing crops and therefore people's livelihood is affected.
- Not enough water for drinking and other uses.
- People have to fetch water from long distances, leaving little time for other work and this can affect income.
- Water quality may become poorer and people's health may be affected.
- As the water table goes deeper, power costs of pumping water will increase considerably.



Why ground water is becoming saline?

- Not enough recharge is occurring.
- When the water level in wells goes down in the coastal areas, seawater may intrude and make the ground water saline.
- Shallow wells have water, which is a recharge from rain in recent years. But deeper ground water is older water that is sometimes saline.

What can we do to fix the problem?

There are two basic steps involving the local communities with help from government and non-government organisations: (i) Enhance ground water recharge (ii) Manage ground water extraction.

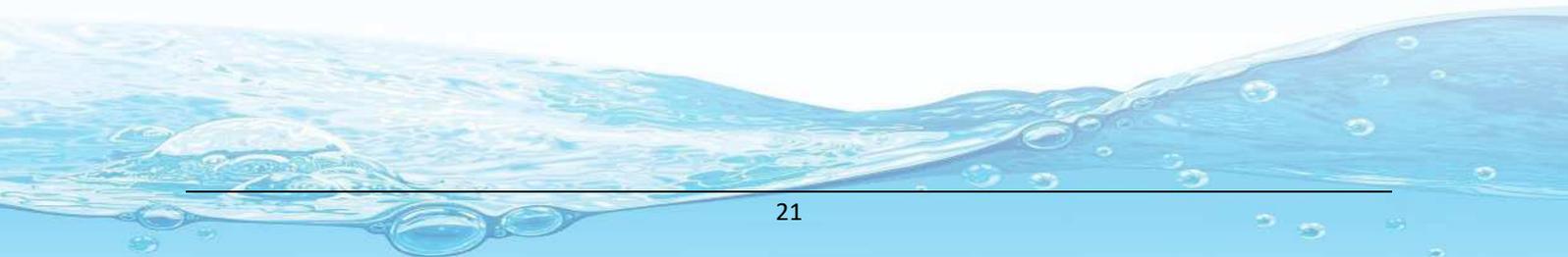
Communities can help replenish the ground water resources by allowing greater infiltration of rainwater into the ground and by creating ponds and other water storage structures on land surfaces. Such actions can increase natural recharge significantly. At the same time, we can reduce the demand on the ground water by choosing crops that require less water, improve irrigation efficiency as well as recycling and reusing water.



This check dam helps detain stream water for longer periods and increase recharge of ground water.



Low Water Consuming Crops such as Castor can reduce ground water use significantly.



Suggested activities

Individual activity:

List how ground water is used in your house, your village and community?

Group Activity 1

Discuss and note down- Are there other sources to supplement the above needs?

Discuss and note down- What happens if ground water is not available?

Discuss and note down - Why digging deeper is not a solution to the problem?

Group Activity 2

Find out the levels of ground water around your village and discuss what the water table depth was 20 years ago and what has changed over those years to influence the water table.



A Jaldoot taking ground water measurement with measuring tape

Group Activity 3

Learn about ground water from locals

Jaldoots (JDs) discuss among themselves and others and learn what has changed in terms of water levels in wells around their village or town. They prepare the following table and discuss with the group by bringing together their data and list what major changes have taken place.

What was the scenario 25 years back...

What were you using ground water for then?

Approximately how many wells were in the village?

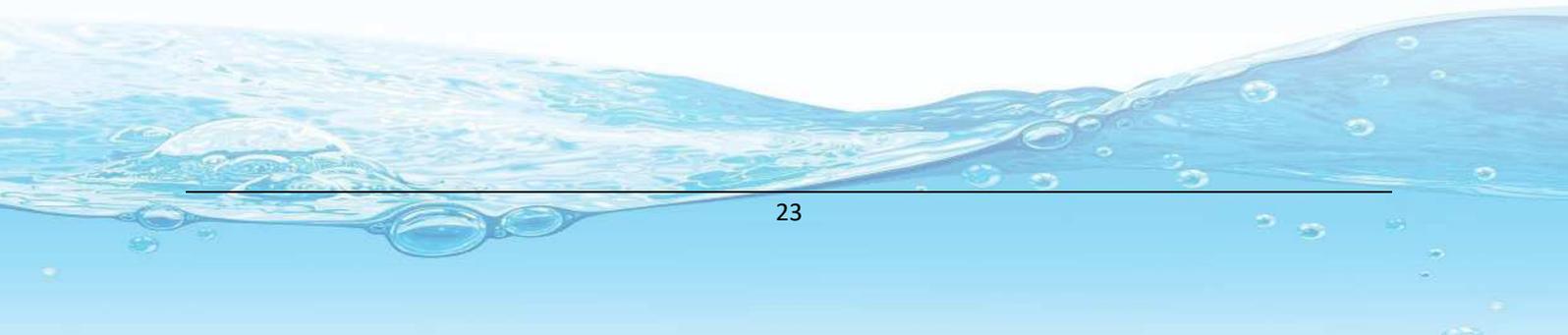
How deep the ground water wells were?

Which crops were grown – if ground water was used for irrigation?

What was ground water quality like? (Fresh /saline/fluoride rich etc.)

What do you think is the major issue with ground water now?

What did farmers do to increase recharge of ground water?



Module 3: Understanding Aquifers and Ground Water Movement

Aquifer – The Reservoir for Ground Water

Geological formations that yield sufficient water are known as aquifers. They are formations porous and permeable enough to sustain economic exploitation of ground water. They have vast aerial extent where ground water flows under gravity at a very slow pace. Commonly sand, gravel and pebbles serve as good aquifers in the alluvial/coastal areas while fractured and weathered zone developed on a massive rock proves as potential aquifer systems in the hard rock terrains.

Types of Rocks and their Properties

Ground water is stored in the fractures of rocky formation and within the pore spaces of unconsolidated formations. However, the wider fracture / pore size facilitates more storage of ground water. Further, the water bearing capacity depends on the degree of consolidation of rocks. There are three basic types of rocks on earth - Igneous rock, Sedimentary rock and Metamorphic rock. The different types of rocks and their relevance with respect to ground water are discussed below.

Igneous rocks

- Formed out of magma and lava and are known as **primary rocks**.
- If molten material is cooled slowly at great depths, mineral grains may be very large.
- Sudden cooling (at the surface) results in small and smooth grains.
- Granite, gabbro, Rhyolite, pegmatite, basalt, etc. are some of the examples of igneous rocks.

Sedimentary rocks

- Sedimentary or detrital rocks formed as a result of denudation of igneous and metamorphic rocks (by weathering and erosion).
- These deposits through compaction turn into rocks. This process is called lithification.
- Cover 75 per cent of the earth's crust but volumetrically occupy only 5 percent.
- They are layered or stratified formations of varying thickness. Example, sandstone, shale etc.

Metamorphic rocks

- The word metamorphic means ‘change of form’. Formed under the action of pressure, volume and temperature (PVT) changes.
- Metamorphism occurs when rocks are forced down to lower levels by tectonic processes or when molten magma rising through the crust comes in contact with the crustal rocks.
- Metamorphism is a process by which already consolidated rocks undergo recrystallization and reorganization of materials within original rocks.
- In the process of metamorphism in some rocks grains or minerals get arranged in layers or lines. Such an arrangement is called foliation or lineation. Sometimes minerals or materials of different groups are arranged into alternating thin to thick layers. Such a structure in is called banding.
- Gneiss, slate, schist, marble, quartzite etc. are some examples of metamorphic rocks.

	
<p>Basalt is a fine-grained, dark-coloured extrusive igneous rock composed mainly of plagioclase and pyroxene.</p>	<p>Granite is a coarse-grained, light-coloured, intrusive igneous rock that contains mainly quartz, feldspar, and mica minerals</p>
	
<p>Gabbro is a coarse-grained, dark-coloured, intrusive igneous rock that contains feldspar, pyroxene, and sometimes olivine.</p>	<p>Pegmatite is a light coloured, extremely coarse-grained intrusive igneous rock. It contains large grains of quartz, feldspar, mica and some important mineral like tourmaline, beryl.</p>

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<p>Diorite is a coarse-grained, intrusive igneous rock that contains a mixture of feldspar, pyroxene, hornblende and sometimes quartz.</p>	<p>Rhyolite is a light-coloured, fine-grained, extrusive igneous rock that typically contains quartz and feldspar minerals.</p>

 <p>© geology.com</p>	 <p>© geology.com</p>
<p>Sandstone is a clastic sedimentary rock made up mainly of sand-size (1/16 to 2 mm diameter) weathering debris.</p>	<p>Conglomerate is a clastic sedimentary rock that contains large (> 2 mm in diameter) rounded particles. The space between the pebbles is generally filled with smaller particles and/or chemical cement that bind the rock together.</p>

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<p>Shale is a clastic sedimentary rock that is made up of clay-size (<1/256 mm in diameter) weathering debris. It typically breaks into thin flat pieces.</p>	<p>Coal is an organic sedimentary rock that forms mainly from plant debris. The plant debris usually accumulates in a swamp environment. Coal is combustible and is often mined for use as a fuel.</p>

	
<p>Siltstone is a clastic sedimentary rock that forms from silt-size (between 1/256 and 1/16 mm diameter) weathering debris.</p>	<p>Dolomite (also known as "dolostone" and "dolomite rock") is a chemical sedimentary rock that is very similar to limestone. It is thought to form when limestone or lime mud is modified by magnesium-rich ground water.</p>
	
<p>Gneiss is a foliated metamorphic rock that has a banded appearance and is made up of granular mineral grains. It typically contains abundant quartz or feldspar minerals.</p>	<p>Marble is a non-foliated metamorphic rock that is produced from the metamorphism of limestone or dolostone. It is composed primarily of calcium carbonate.</p>
	
<p>Quartzite is a non-foliated metamorphic rock that is produced by the metamorphism of sandstone. It is composed primarily of quartz.</p>	<p>Schist is a metamorphic rock with well-developed foliation. It often contains significant amounts of mica which allow the rock to split into thin pieces. It is a rock of intermediate metamorphic grade between phyllite and gneiss.</p>

	
<p>Slate is a foliated metamorphic rock that is formed through the metamorphism of shale. It is a low-grade metamorphic rock that splits into thin pieces.</p>	<p>Phyllite is a foliated metamorphic rock that is made up mainly of very fine-grained mica. The surface of phyllite is typically lustrous and sometimes wrinkled. It is intermediate in grade between slate and schist.</p>

Fractures

Fractures occur in massive rocks due to breaking under differential stress conditions. Two parameters influence fracture patterns: the orientation of the fractures and their frequencies. Orientation of fractures is based on the state of stress within the rock i.e. both stress difference and orientation of the principal stresses. In contrast, the frequency or spacing of fractures is based on the properties of the rocks in which the fractures have formed. Fractures play an important role in the occurrence and movement of ground water in an otherwise massive rock formation.



Extensional fractures



Shear fractures

Types of Soils

Soil develops slowly over time and is composed of many different materials. Inorganic materials, or those materials that are not living, include weathered rocks and minerals. Soil comprises of solids and voids space. Voids include air and water. When rainwater get infiltrate, it occupies and move through void space. If the voids spaces are completely filled with water means soil is fully saturated. Basically, there are 4 basic types of soils on the earth;

Sandy soil consists of small particles of weathered rock. It is fairly coarse and loose so water is able to drain through it easily. While this is good for drainage, it is not good for growing plants because sandy soil will not hold water or nutrients.

Silty Soil consists of fine sand and will hold water better than sand. When a handful of dry silt is held in hand, it would feel almost like flour and if water is added, it would do a fair job of holding the water and feels slick and smooth.

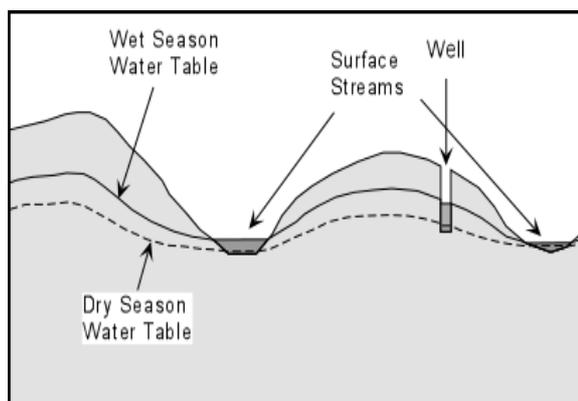
Clayey Soil is very fine-grained, its particles are even smaller than silt. Hence, there is little space between the fine grains for air or water to circulate. Therefore, clay does not drain well.

Loamy Soil is a mixture of clay, sand and silt soils. Its nature will vary depending on how much of each component is present, but generally provides good drainage.

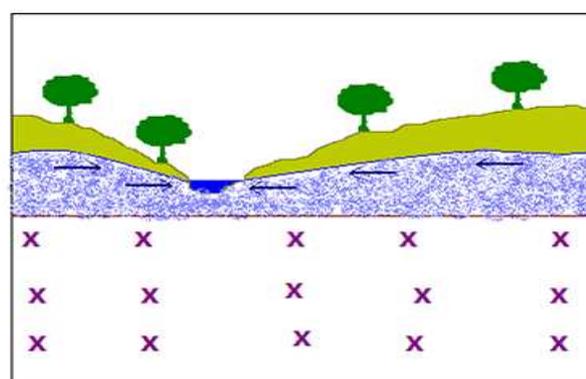


Ground water Movement

Ground water constitutes one portion of this water circulatory system. Water bearing geological formations on the earth's crust act as reservoirs for storage of water and conduits for its transmission. The process of receiving water by the ground water reservoir is called ground water recharge. Water enters these formations from the ground surface by percolation, after which it travels slowly for varying distances until it returns to the surface by action of natural flow under gravity.



Ground water flows at a slow pace under the influence of gravity and horizontal flow is the dominant component. The flow of ground water depends on the permeability of the aquifer and the hydraulic gradient of the water table/piezometric surface. While water flows a few kilometres in a day on the surface, the same passes only a few meters in highly permeable sand and gravelly formation under a hydraulic gradient same that of the land slope.

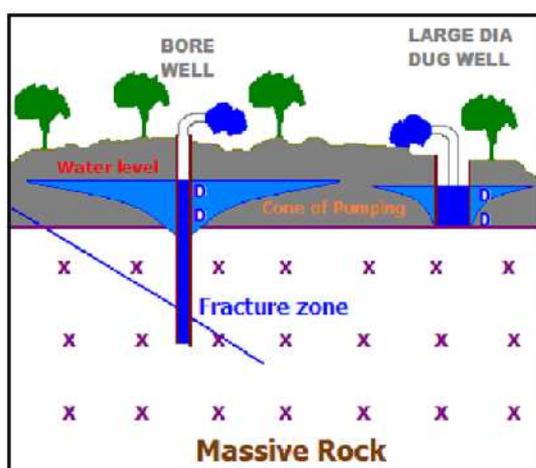


Base Flow: Ground Water contributing to the river/streams during lean season

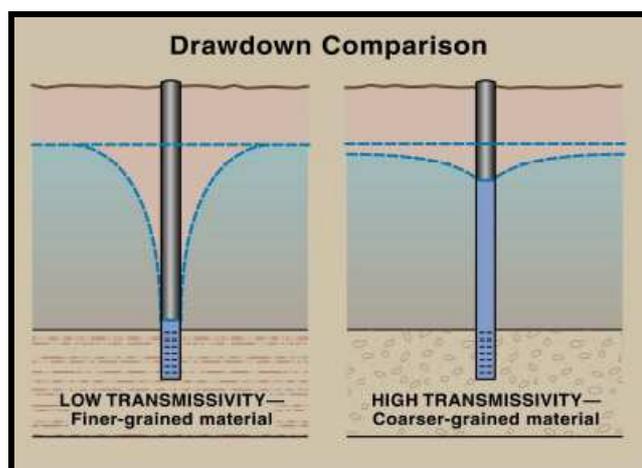
Effects of Pumping on Ground Water

When a well is pumped, water level in the well starts declining with time at a faster rate during early pumping and stabilizing later. The difference of pumping water level from the static one is called drawdown (DD).

During pumping ground water rushes towards the well from the aquifer under the impact of drawdown and the water table / piezometric surface forms an inverted cone. The spread of the cone is more in confined aquifer than in unconfined one. Thus the impact of pumping is felt in areas overlying this cone of pumping. Generally, this cone spreads with the duration of pumping and hence long duration pumping definitely have impact on nearby wells tapping the same aquifer. However, pumping from dug well will have little impact on the neighbourhood.



Impact of Pumping on different aquifer systems



Control of Aquifer property on drawdown

Ground Water Quality

The quality of water is defined as its acceptability with respect to its specific uses. A suitable quality of water is one whose characteristics make it acceptable to the needs of the water.

It can be completely defined and estimated by studying its physical, chemical and bacteriological characteristics.

Physical Characteristics

Turbidity: Turbidity of water is a measure of the cloudiness. It is caused by the presence of clays or suspended matters which scatters and absorbs light and appears muddy or turbid. The turbidity depends upon the fineness and concentration of particles present in water. Turbidity is measured in laboratory with the help of an instrument called Turbidity meter which works on the principle of measuring the interference caused by water sample to the passage of light rays. The standard turbidity of 1 unit (1mg/l) is that turbidity which is caused by 1 mg of silica (SiO₂) in 1 litre of distilled water.

Colour: Generally, ground water is colourless. But if its appearance is coloured then it may be due to certain impurities which may be due to presence of coloured organic substances or due to the presence of metals such as iron, manganese and copper, which are abundant in nature.

Taste and Odours: Clear water is tasteless. But due to presence of high concentration of salts of chloride water tastes saline. Presence of sulphate of Ca^{2+} Mg^{2+} gives a bitter taste to water. Similarly, clear water is odourless but due to presence of some organic and inorganic chemicals, algae and other microorganism it may give foul odour.

Chemical Characteristics:

Naturally ground water contains mineral ions. These ions slowly dissolve from soil particles, sediments, and rocks as the water travels along mineral surfaces in the pores or fractures of the unsaturated zone and the aquifer. They are referred to as dissolved solids. Some dissolved solids may have originated in the precipitation water or river water that recharges the aquifer.

The chemical constituents of water can be divided into three groups: major constituents (1 - 1000 mg/l), minor constituents (0.01 - 10 mg/l) and trace elements (0.0001 - 0.1 mg/l). The total mass of dissolved constituents is referred to as the total dissolved solids (TDS). In water, all of the dissolved solids are either positively charged ions (cations) or negatively charged ions (anions). The total negative charge of the anions always equals the total positive charge of the cations. A higher TDS means that there are more cations and anions in the water.

Major Cations: Na^+ , K^+ , Mg^{++} , Ca^{++}

Major Anions: Cl^- , SO_4^{--} , HCO_3^- , CO_3^{--} (very little amounts)

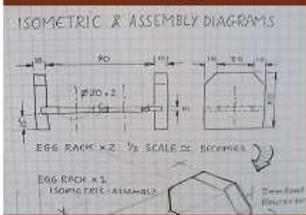
Minor Constituents: Fe^{++} , B, NO_3^- , F^- , PO_4^{--} , etc bear special importance for deciding ground water suitability for drinking water.

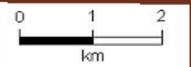
Trace Elements: Arsenic, Lead, Zinc, Mercury, Cadmium < Copper, Barium and Chromium etc also controls ground water portability.

Module 4: Preparing Basemaps

What is a Map?

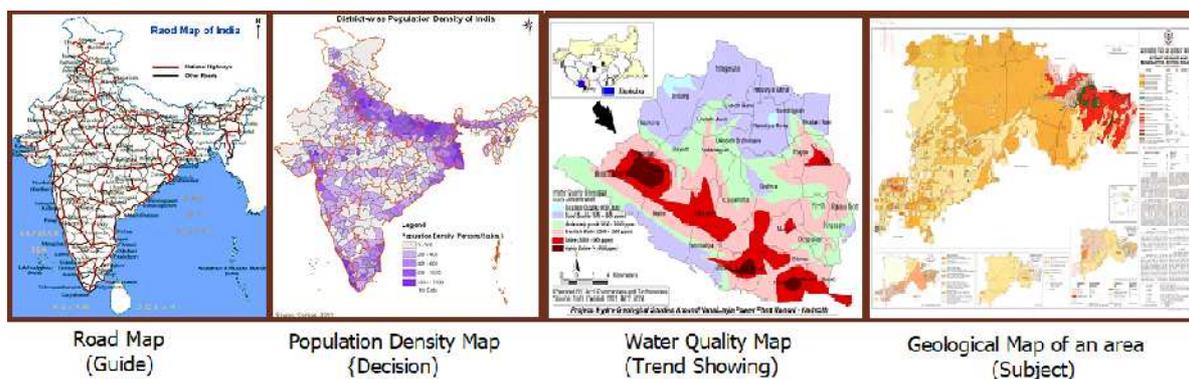
Definition: A map is a presentation of any unit of land on a piece of paper or cloth that can be studied through symbols, measured through scale and located through direction.

Painting	Drawing	Map
		
Can Read through Color, Shape Measure through Judgment of Relative size	Can Read through Features can Identify by symbol Measurement of size through scale conversion	Can Read through Features can Identify by symbol Measurement of size through scale Location based on Direction

DIFFERENCE BETWEEN PAINTING – DRAWING – MAP			
INFORMATION PRESENTATION	SYMBOL	SCALE	DIRECTION
			
Painting	Y	X	X
Drawing	Y	Y	X
Map	Y	Y	Y

Types of Maps

- Guide Map - Road map
- Subject related map - Watershed, drainage, geology etc.
- Trend showing maps - Population growth, reduced water level, water quality maps
- Decision making maps - Cadastral maps, mineral maps etc.



Purposes of Basemap

A basemap is a fundamental map that contains information for those who need to refer to it repeatedly throughout the project or process. In the case of Jaldoots training and as the focus to teach village level land and water resource management planning. A basemap should have following information:

- Village boundary
- Farm land and survey information
- Streams and rivers
- Slope
- Important local land marks within the village
- Settlements
- Roads network and connectivity
- Existing traditional /large water bodies

How to Prepare a Basemap?

There is no single map that contains all of the above information and therefore to prepare a basemap there needs to be two maps such as (1) Cadastral Map and (2) Toposheet which contain the above information. Along with these two maps, there needs to be some consultations with village people to identify and locate important local landmarks that people use to visualise the respective areas in their mind and to communicate to farmers and other stakeholder for an effective water management and planning at village and / or Gram Panchayat level.

Cadastral Maps are available at

- District Land Record Office
- Taluk or Panchayat Office

Contains Information about

- Farm Lands
- Local Roads

- Grazing Lands
- Traverse Land
- Settlements
- Tanks

Toposheets are available at

- Survey of India

Contains Information about

- River and Streams
- Roads
- Contours
- Height Points
- Water Bodies
- Important Landmarks

Process of Synthesising Information from Secondary Sources

- Cadastral maps contain two dimensional information i.e. mostly length and area while a Toposheet contains three-dimensional information i.e. length, area and height.
- There is a need to visualise three-dimensional information by studying contour lines and teaching the meaning of contour lines and how to interpret them and determination of slope directions.

Scale of both maps is different and due to this the size of a cadastral map is larger than Toposheet.

- There is a need to understand the enlargement of toposheet and the reduction of cadastral maps to make them a similar scale and size.
- Decide a convenient scale so that the map can be of a handy size.
- Study the scale of a cadastral map and Toposheet scale.
- Many different styles are there to describe cadastral maps.
 - Such as 1 cm = 80 m; 1 inch = one chain of 33/66 feet etc. To convert this, you need to understand scale conversion.
 - Toposheet scale is mostly represented as 1:50000 i.e. the one centimetre in any direction has an actual size of 500 m.

Length: 1 feet = 3048 meter

Length: 1 meter = 3.28 feet

Area: 1 Ha = 100 m X 100 m = 10000 sq. m

Area: 100 ha = 1000 m X 1000 m = 1 sq. km

Area: 1 Acre: 10 sq. Chain (66×660 ft) = 43560 ft² = 4047 m²

Area: 1 Hectare = 2.471 Acre

Enlargement and Reduction of Maps

The enlargement and reduction of maps can be done by the following method:

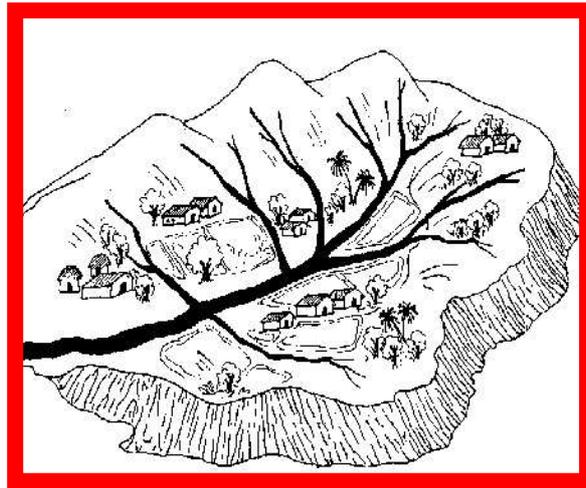
- Enlargement = increase the size of map and reduce the scale
- Reduction = decrease the size of map and increase the scale
- The Photocopy machine has the predetermined capacity to enlarge or reduce maps.
- Further the machine can do enlargements or reductions based on a determined percentage.
- Once both the maps are of same scale, the next step is to trace all the information from the cadastral map onto a semi-transparent tracing sheet.
- Superimpose and align this tracing sheet on Toposheet through aligning common points and features such as old tank locations, roads any other identical features.
- Then on the tracing sheet draw the following information from toposheet:
 - Drainage and rivers
 - Other roads not shown on cadastral maps
 - Contour lines
 - Important landmark features such as temples, hill peaks etc.
- Now a Photocopy of synthesised tracing sheet is taken.
- The map thus prepared is to be verified with the village community with additions and corrections of information taking assistance of the local experienced people.
- Finalisation of map giving proper symbol to each feature.
- Legend is to be prepared as follows on the map:
- Legend should have scale (Ex: 1 : 10000)
- Legend should have symbols (as given below)
- Legend should have direction (North Arrow)

- After giving proper border, basemap is ready for use.

	Settlement
	Road
	Streams/Rivers
	Tank
	Temple
	Farm
	Contour
	Dug / bore well

Watershed

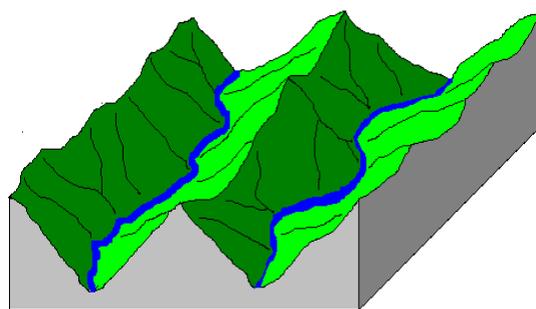
- Watershed is a geo-hydrological unit draining at a common point by a system of streams.
- Water divide/drainage divide/ridge line is the line that separates adjacent drainage basins.
- In hilly area the divide lies along topographical ridges or may be a single range of hills or mountains.



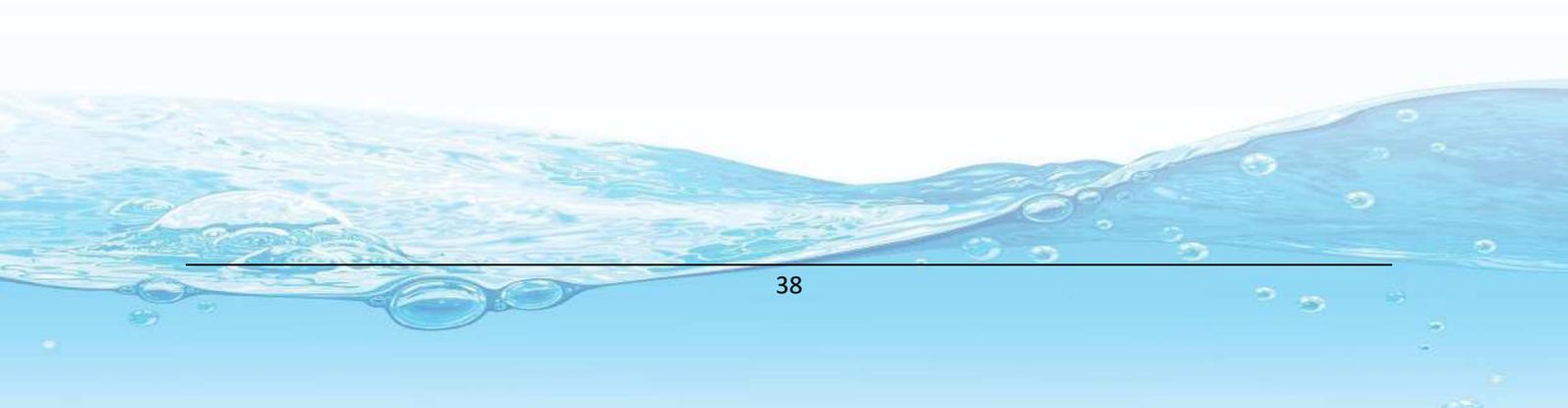
Schematic view of an watershed



Watershed with drainage network

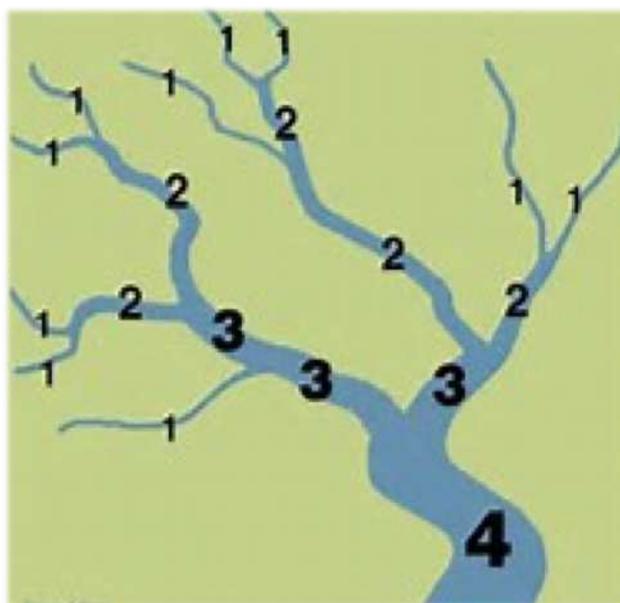


Water divide / Drainage divide



Order of Streams

Stream order is a measure of the relative size of streams. The smallest tributaries are referred to as first-order streams, while the largest river in the world, the Amazon, is a twelfth-order waterway. First- through third-order streams are called headwater streams. Over 80% of the total length of Earth's waterways is headwater streams. Streams classified as fourth- through sixth-order are considered medium streams. A stream that is seventh-order or larger constitutes a river.



Stream ordering

Module 5: Analysing Land Uses

What is Land Use?

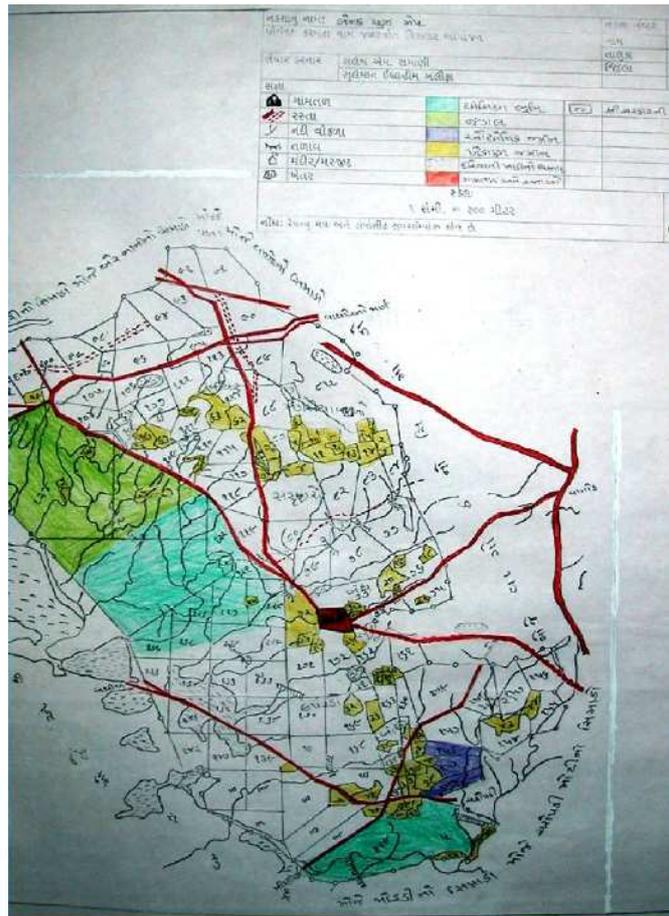
Land use is the use of land by human beings to satisfy their needs such as settlements, agriculture production, pasture land and forest etc. All types of land use are important to understand from a water requirement point of view. Therefore, important teachings during land use mapping are:

- Classification of various land use patterns in the village – this will be used later during planning map.
- Calculation of areas under different land use – this will be used during water balance calculation.

Land Use classification

Land Use classification can be taught in the following ways:

- Each trainee is to be asked to list the various uses of land use in his / her village.
- Summarise the list and sort out total land uses.
- Then categorise and sub-categorises them as per purposes.
- National Remote Sensing Centre (NRSC) in May 2006 devised a Land Use & Land Cover classification system as its standard operational procedure. The major classes are
 - (i) Built Up
 - (ii) Agricultural land
 - (iii) Forest
 - (iv) Wasteland
 - (v) Wetlands
 - (vi) Water bodies
 - (vii) Others



- (i) Built Up Area
 - 1. Settlement
 - 2. Road and communication network
 - 3. Mining and Industrial areas
- (ii) Agricultural land
 - 1. Rainfed agriculture
 - 2. Irrigated agriculture
- (iii) Forest
 - 1. Natural forest
 - 2. Shrubs
 - 3. Artificial Forest (Plantation)
- (iv) Wasteland
 - 1. Cultivable waste land
 - 2. Non Cultivable waste land
- (v) Wetlands
- (vi) Water bodies
 - 1. River / Stream
 - 2. Pond / Tank
 - 3. Reservoir / Dam / Weir
 - 4. Sea
- (vii) Others (Grazing land)

Preparation of Land Use Map

- Each team should be sent to their study village/area.
- Hold group discussions with different groups of village people and identify and locate various land use as per the list prepared during class.
- Design specific colour code for land use after field visits.
- Colour each land with prescribed colour for identified land use.
- Prepare legend on the Map

Land Use Area Calculation

- Trace boundaries of different types of land use on graph paper with the help of carbon paper.
- Use different graph paper for different land use patterns.
- Calculate unit area per square cm of graph paper based on scale of basemap.
- Tip: If basemap has a scale 1cm = 100 m, then it is for one full square of graph paper 10000 sq. M or one hectare.
- Prepare table of land use area on map
- Edit Legend of basemap with land use information

Note: These calculated land uses will be used for land use wise water demand estimation in watershed and water balance map.

Name of Map		No.	
Project Name		Village	
		Taluka	
Prepared By		District	
Legend			
	Settlement		Temple
	Road		Farm
	Streams/Rivers		Contour
	Tank		
			Land Use
			Rain fed Agriculture
			Irrigated Agriculture
			Water bodies
Scale 1 CM= _____ M			N 
Note: The map has prepared by superimposing Cadastral map on Toposheet and incorporating Land Use data collected from field studies			

Module 6: Understanding Landforms

What is Landform? Why it is Important for Water Management?

Landforms are configurations of land in the form of morphological features such as hills, plains and pediments which are governed by some physical processes, and govern land use patterns. Understanding this aspect is important because occasionally due to regional geological conditions it shows the availability of local aquifers.

Identification and Classification of Landform

First step for is to ask trainees to list out and characterises what kind of land features they have seen in the surrounding areas of their habitation. Second step is to ask what kind of land characteristics they have observed in their land use areas such as slope, composition of material, shape of the land form and any sudden changes in features. Above exercise should followed by the lecturer explaining the following:



Clay or Thermocol Model showing Landforms of an area

What is Geomorphology?

Geomorphology is the study of the nature and history of landforms and the processes which create them. Landforms are produced by erosion or deposition, as rock and sediment is worn away by earth-surface processes like air, water & ice and transported & deposited at different localities. The different climatic environments produce different suites of landforms. As an example dunes are landforms characteristics of deserts, while drumlins are associated with glaciers Geomorphologist map the distribution of these landforms so as to understand better their occurrence.

What is the Geomorphic process?

- Endogenic – Processes which originate within the earth.
 - Volcanic eruption
 - Earthquake
 - Plate movement
 - Folding & Faulting
- Exogenic – originate on earth's surface and within the atmosphere
 - Weathering & Erosion (Disintegration & Decomposition)
 - Deposition
 - Evaporations
- Physical agents responsible for different physical process
 - Water – river, ocean /marine, moisture, ice
 - Wind
 - Temperature
 - Slope and Gravity
- Classification of Landforms
 - Based on shape
 - Linear – Scarps, valley, ridges
 - Areal – plains, pediments, hills
 - Based on resultant processes
 - Erosional landforms – pediment zones
 - Depositional – alluvium plains, colluviums plains/fans
 - Tectonic land – Hills, uplifted rocky uplands

How to Identify and understand Landform?

This will involve field visit to the various areas to see and understand physiography and landform with following steps.

- The theory of landform followed by field exposure to show various landform. Exposure sites should be river channels, hilly terrains, coastal banks, tectonically disturbed areas where an expert will show various landforms originated due to respective processes.
- To teach this the trainer has to organise visits in all surroundings and all physiographic divisions and has to show various dominant landforms in the respective physiographic divisions and explain all the physical processes that played a role to craft landforms.
- After the field visits all trainees should divide into groups and be given a task to look at different aspects of landforms like slope, composition of material from size and

shape point of view, location, responsible agent and the process for material/sediment generation.

Analysis and Group Work based on Field Visit

First of all, trainees should be divided into three groups for analysis of their understanding on geomorphology. The group work should be (01) Listing and discussion on the physiographic processes; (02) Listing and actions of different natural agents responsible for landform formation; and (03) listing of various landforms observed during field exposure and their respective characteristics. After group discussion a presentation to be performed by each group – that will help to recall all aspects learnt.

Landform Map Preparation

This group discussion will be followed by theory of how to identify landforms in their assigned study village/area. JDs will be taught how contour lines represent different landforms and slopes. To do this exercise toposheet will be used and then a basemap will be given to respective JD teams to identify various feature/landforms that exist in their study village/area. The model making exercise will then be taught to trainees to visualise their study village's morphological features.

- To prepare the model they need sponge sheet; thickness of one sheet can consider as interval between two successive contour
- Cut these sponge sheets according to the contour shapes on basemap.
- Lay out each sheet as shown in basemap – use some adhesive (e.g., Fevicol™) to stick the sheet
- Once all sheets are arranged, use a canvas cloth to cover it.
- Spread wooden powder over cloth with adhesive coating to give a natural land texture.
- Draw different features as shown on the basemap such as river channels, settlement areas, roads and other aspects.
- If required, colour some of the features as per their appearance in the field.
- Place entire sponge model on plywood to prevent any damage.

After the model preparation the JDs will go to their assigned study village to understand and characterise geo-morphological aspects of their study area/village along with the classifications.

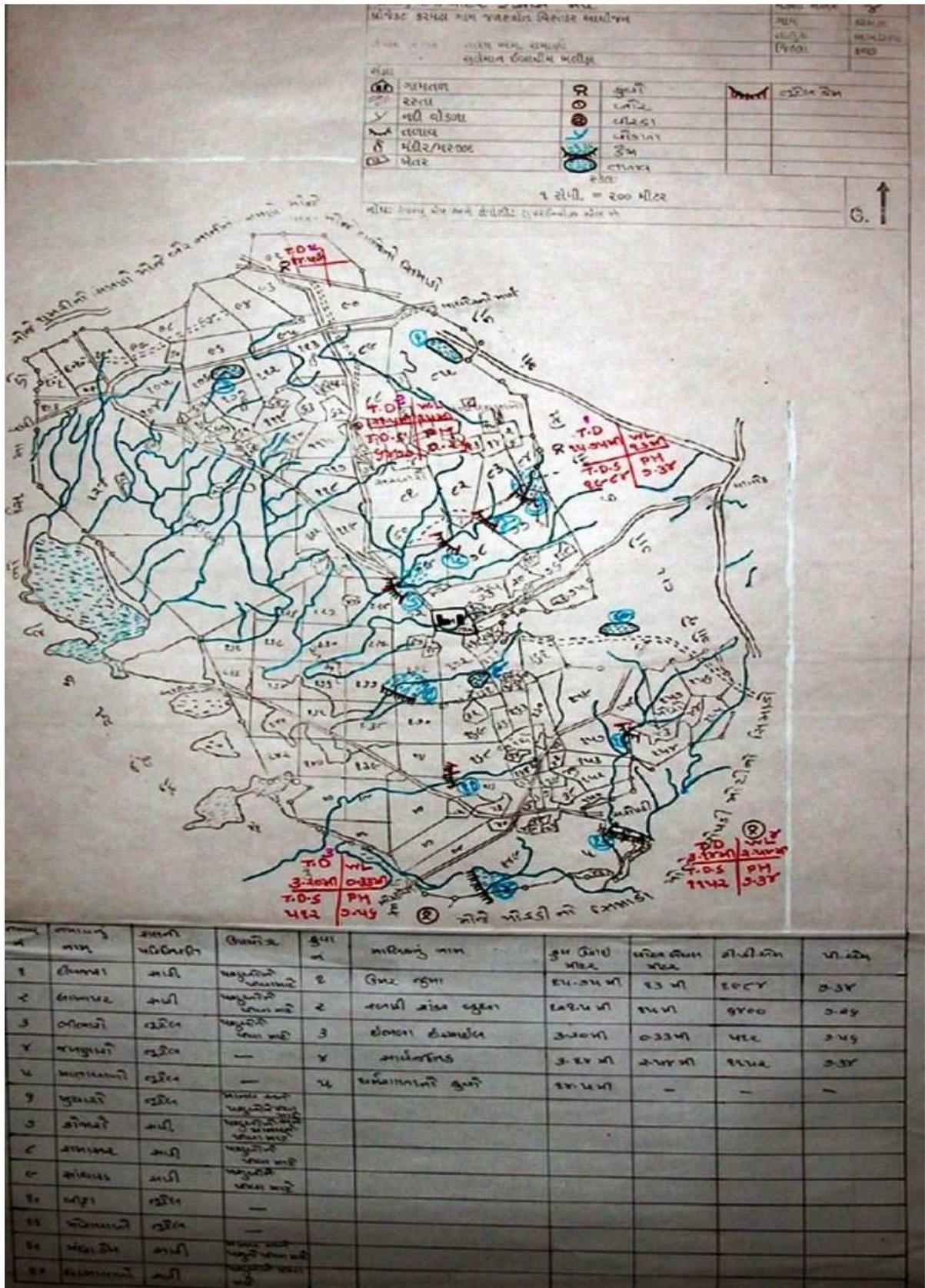
Module 7: Assessing Village Water Resources

The assessment of local water resources is an important exercise for JDs to better manage water for village communities. In particular, it gives them an idea about the existing potential of water sources of the village. The important elements are type, purpose, inflow areas, outflow areas, supply potential, type of water harvesting structures, associated problem with them, and people's perspective on water resources.



Material Requirement

Base Map (2 copies), Pencil, Paint color, favigol - gum, Color pencils, Scissors, sponge sheets, color brush, canvas/cotton cloth, wooden powder Carbon paper, Calculator, Scale, Ply wood sheet



What is Water Resource?

Water resources in any area are available in the form of surface water structures such as a pond, tank, dam, canal, river channel, well, hand pump, tube well, step well, temporary sources, pipeline and rainwater harvesting tank. For this planning exercise local structures are more important and therefore, large focuses should remain to understand local structures which are in the range of community reach.

Therefore, the following are the key steps for assessing village water resources:

Step 1:

List all local water resources and their use in the community. This exercise can be done in the classroom or in the field by JDs.

Step 2:

Locate all water resources on the basemap by following below activities. N.B. This exercise should be done in villages with focused group discussion followed by site inspection.

- Hold consultations with villagers for surface/ground water structure's locations on the basemap.
- List out direction wise water resources.
- Ask some of the village people to locate particular names/numbers on map along with the local name.
- In case of surface water, ask villagers to draw the flow lines shown in the basemap and refer to respective toposheet.
- Visit each water body to correct field information.
- In case of ground water recharge structure (e.g. Check dam), identify possible ground water inflow and recharge directions
- Discuss variations in water levels and ground water structure depth in different parts and directions of the village. This will give an idea about the occurrence of ground water from a water table and aquifer type point of view.

During listing classify water bodies by considering following categories		
Category	Sub Category	Structures
Source	Surface	Tank, Dam, Pond, Canal, Check dam, Percolation dam, River channel
	Groundwater	Well, Tube well, Hand pump, step well
Construction Material	Earthen	
	Cement Concrete /Un-coarse Rubble masonry	
Use Wise	Drinking water for Human Domestic use only Drinking Water cattle Drinking water for both (Human and Cattle) Percolation / Recharge structure Irrigation Structure Abandoned/disused/unused Storage structure	

Step 3

Analyse village water resource information, including detailed inventory of each structure.

Step 4

Explain how to hold an inventory of surface as well as ground water structures by learning each component of inventory formats 1 and 2.

N.B.: All the formats should be in local language.

- Learn how to fill information into forms. Give demonstration on how to collect information and fill in the format on two to three structures of each category (i.e. surface and ground water).
- JDs will have trained in the use GPS device to observe longitude and latitude.
- The JDs will be given an exercise to observe longitudes and latitudes of selected structures of different types. Give each JD group a kit for water resource inventory having following materials with them: (i) Basemap, (ii) forms for well inventory and surface water structures, (iii) measuring tape, (iv) water sample bottles, (v) TDS meter, (vi) sketch pen, and (vii) stickers for labelling
- JDs learn about how to measure water quality during this exercise. The water quality assessment can be done in three ways: by asking farmers about the suitability of water quality for crops they growing, taste of water or by measuring total dissolved solid concentration with the help of TDS meter.

Source No. (Code No.)					Date		
Village		Panchayat		Block		District	
Description				Note			
Local Name				Inflow	Length of Outlet	Height of Outlet	
Type and Use	Pond for drinking purpose (human use) – within the village						
	Pond for domestic purpose (human use) – within the village						
	Pond for drinking purpose (animal use) – within the village						
	Pond for drinking purpose (animal use) – periphery of the village						
	Irrigation Dam (submergence area in acre)						
	Recharge pond						
	Check dam						
	Wells for drinking water			(Nos.)		Irrigated area (in acres)	
	Irrigation wells			(Nos.)			
	Bore wells for drinking water			(Nos.)			
	Irrigation bore wells			(Nos.)			
	Dug-cum-bore wells for drinking			(Nos.)			
Dug-cum-bore wells for irrigation			(Nos.)				

Give the following information about the above-mentioned sources			
Submergence area			Sq. m.
Depth of water			m
When was the last time the above water body was completely filled? (mention the year)			
Once it was completely filled, how much time did it take to empty it? (mention in months)	No. of Months		From which month water started to fill up the above water body? (month & year)
Approx. how many inches of annual rainfall will fill up the water source completely (i.e. up to over flow)		(inch)	
Current management system		By community	
		By village or any other organisation	
		By government	
		No management system	
Present condition or status of the source	Functional or in good condition		
	Any damage or repair maintenance required for the source (describe briefly)		
	Siltation in the water body (depth in m)		
	Any other aspects about the source		
History of the source			

Name of the surveyor (1)		Signature
Name of the surveyor (2)		Signature

Form 2: Well Inventory

Date: _____

Code number _____

Village		Block		District	
Name of well owner					
Type of well	Open well		Bore		Well and bore
Usage	Regular		Regular time interval		Not in use

Direction and distance of well in reference to Village: _____ Survey number _____

Place of measurement: _____

Total depth: _____ meter length/ width/ diameter of well: _____ meter

Information of construction of well depth of casing/ curbing: _____ meter

Level of water in meters (ask farmer for earlier years)											
present		Earlier year monsoon	pre		Earlier year monsoon	post					
Is bore in well? Mark tick								yes		no	
Number											

Type											Write horizontal or vertical
diameter											Write in inch
Pumping machinery	Diesel engine			Elec. Motor			Submersible pump				
Tick mark	H. P.			H. P.			H. P.				
Pumping time daily		Hour	Time to empty well				How many meters water goes down?				
			Time to filling								

Information of strata in well (if there is bore in well, write its information)					
Number of strata	Type (English or local name)	Depth from ground level meter	Thickness of strata meter	Remarks (salinity, availability or non-availability etc.)	
1					
2					
3					
4					
Usage (mark tic)					
Drinking water	Number of human population	Other domestic use		irrigation	Acre
	Number of animal population				
Quality of ground water:					
1. Colour: Colourless_____ Coloured_____ Turbid_____					
2. Odour: Odourless_____ less bad smell_____ heavy bad smell_____					
3. Taste: Sweet water_____ Brackish_____ Saline_____					

Information on geographical conditions (tick wherever applicable else mention yes/no/in figures)					
Is it in alluvial plain?		Is it in hilly terrain?		Is it in uneven region?	

Situation of well in drought condition:

Quality of water	No change			Deterioration in water quality	
Quantity of water	No change		Depleted	Dried up	
History of well or any important information					

Name of surveyor

1. _____ 2. _____

Step 5

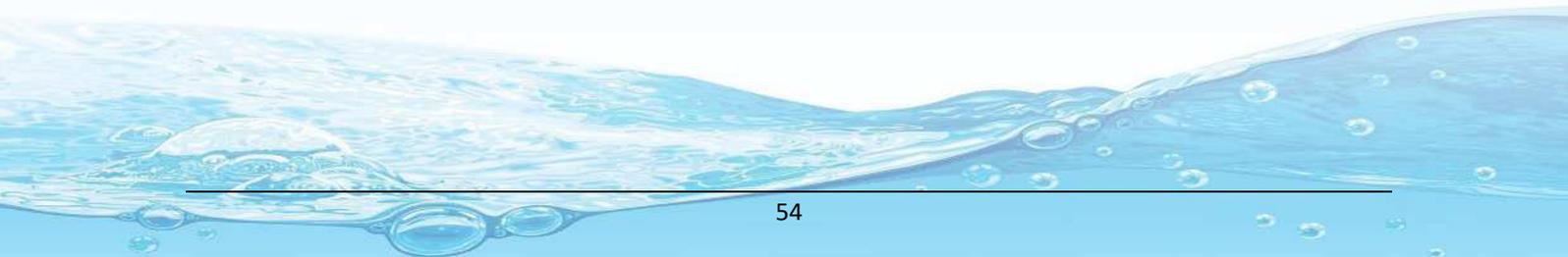
Collect both forms from JDs and suggest any changes or corrections.

Step 6

Analyse information into tables for surface and ground water as shown in following tables.

Step 7

- After preparing the above tables on a basemap show information regarding water resource in following ways;
- Assign numbers/codes to all water resources.
- Assign different colours and symbols for different types of water resources as shown in following index
- Mention water level, water quality, aquifer name and depth of well near to some wells - To input this information identify wells in surrounding areas of village.
- Finalise the water resource map with a description of water resources based on data analysis. The description should explain Type of water resource.



- Reliability of existing water resources in term of seasons, drought period, quantity and quality from a supply point of view general problems with surface and ground water resources.

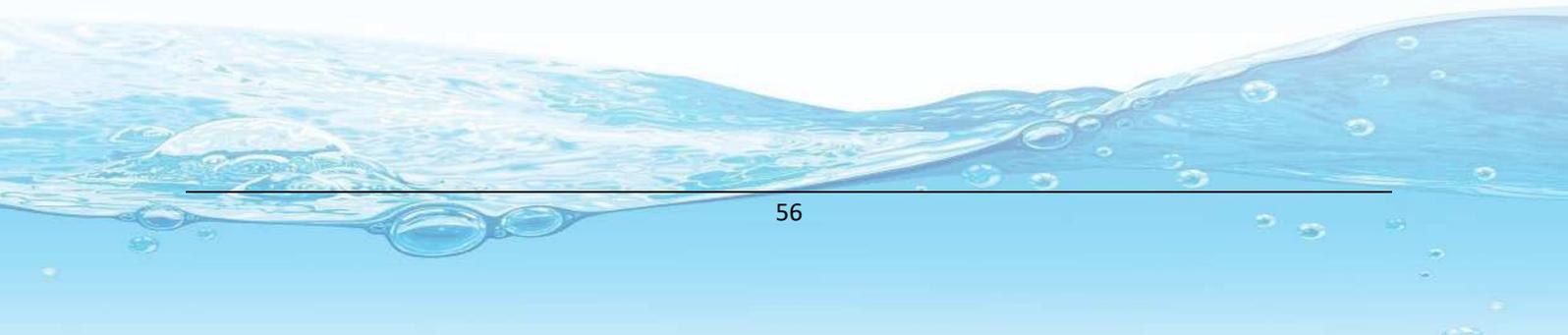
Structure	Symbol
Tank/Pond	
Check dam	
Canal	
Well	
Tube Well	
Step Well	JD can decide
Hand pump	JD can decide
Different colour code can use for used / unused / breached structures	

For Surface Water

Sr. No.	Name of Structure	Use	Existing Storage Capacity (CUM)	Catchment Area (Ha/SqKm)	Minimum Rainfall required to fill the structure (Inch)	Water Storage Duration (Months)	Ownership	Existing Status	Remarks

For Well Inventory Information

Sr. No.	Well Owner	Use	Depth (Mt)	Water Level Depth (Mt)	Lifting Device with its capacity (HP)	Aquifers (Local Name of rock given by Villagers)	Water Quality (TDS in ppm)	Changes in WL in Drought	Changes in quality in Drought	Remarks



Module 8: Mapping Surface Geology and Aquifer

The understanding of surface geology is important from defining water harvesting strategy point of view whereby one can identify recharge area, water storage area, soil moisture conservation area and any other strategies required to improve water quality and quantity in the area.

First of all, we need to have some understanding of area level strategies for land and water management in simplified ways in the form of a matrix, for example shown below water harvesting strategies based on geo-hydrological characteristics of sedimentary saline terrain.

After developing a broad understanding of the area level land and water management strategies, the JDs learn to prepare geological map of the area in the following way:

- JDs start with an explanation on geological evaluation history and origin of the area/region where the trainees come from.
- JDs are asked to divide themselves into groups and they go to different areas of village and search various stones as per their knowledge and ability to identify differently.
- JDs describe samples collected in terms of the following parameters
 - Colour
 - Hardness
 - Texture Composition
 - Size of particles
 - Any other special characteristic that JDs are able to identify
- JDs receive lecture input on different type of rock formations emphasising the following aspects:
 - Rock forming processes
 - Rock type and relevant characteristics of different types of rock
 - Igneous, Sedimentary, and Metamorphic
 - Classification of various rocks
 - Rocks occurring in the trainee's areas
- JDs also develop an understanding of hydraulic properties of rocks considering the following
 - Properties
 - Porosity, permeability, grain size, grain shape, water storage ability, water release ability
 - Relationship between rock and water

Type	Storage	Recharge	Release	Flow
Aquifer	Yes	Yes	Yes	Yes
Aquiclude	Yes	Yes	No	No
Aquifuge	No	No	No	No
Aquitard	No	No	Yes	Yes

Simple Matrix for Resource Development Strategies

Catchment Description		Water Harvesting Techniques			
Location	Geomorphic Unit	Permeable Stratum		Impermeable stratum	
		Non Saline	Saline	Non Saline	Saline
Upper Catchment	Hills, Rocky uplands	CD	GS	ST Large	ST Large
Middle-Upper Catchment	Undulating Plains	GS(U/S) SD (M) SCD (D/S)	STp - STr	ST Large	GS & Stp
Middle-Lower Catchment	More or less even Plains	GS (U/S) & PT (M) SCD (D/S)	GS (U/S) & PT (D/S)	GS (U/S) & ST (D/S)	GS & Stp
Lower Catchment	Flat lands	FB & WW	FB & WW	ST Small	ST Small
		SCD	SCD	FB & WW	FB & WW
Key					
Groundwater Recharge	CD	Check Dam	ST	Storage Tank	
Soil Moisture Conservation	GS	Gabbian Structure	FB	Farm Bund	
Surface Storage	PT	Percolation Tank	STp / STr	Silt Trap/Staggered Trench	
Salinity Prevention	SCD	Subsurface Check dam	WW	Waste Weir	



After this understanding, JDs are asked to analyse well data especially observed rock layers in wells and identify aquifers in their study village.

Once this identification is completed, JDs go for field visit to see geological conditions of the region, associated issues, challenges and opportunities for village level water resource management. The visit may help in observing effectiveness of water body locations, geological rock formations of different ages, traditional methods of water resource management and other aspects.

During field work the trainer can explain different geological and tectonic aspects of the region by showing a particular structure on site and its influence on water management. Such site may be a dyke, folded strata, fracture or fault scarp. During this explanation the trainer must ask how to identify and characterise a particular feature with the proper scientific method and what are the observations needed for this.

It is important that each JD collect samples of different rocks types and ages. After completion of the field visit, all JDs are divided into different groups to understand geology of the area as follows:

Group A - arrange all the samples from oldest to youngest age and also write the scientific and local name of each rock.

Group B - write characteristics of each sample from a rock and water relation point of view and classify it as aquifer, aquiclude, aquifuge and aquitard.

Group C - write and describe changes taking place in rocks due to associated physical processes.

Group D - write about history and geological characteristics of the rocks.

Through above exercise, JDs will develop the understanding of regional geo-hydrological characteristics of the village they are studying.

After geo-hydrological understanding, JDs develop geological map the following activities:

- Meet with village elders to gain local knowledge of the hydrogeology.
- List rock formations found in village in different direction.
- Locate each formation on the basemap.
- Visit the study area and finalise the basemap with geological formation.

Finally, prepare the geological map by giving proper colour and symbols to different rock formations and geological structures like dyke and fault scarp. JDs can also show subsurface geological strata as a lithology of wells based on well inventory data in different directions of village so that one can also get the subsurface geological idea. The final outcome of this map is to show recharge areas of an aquifer.

Module 9: Analysing Watershed and Village Water Balance

The watershed and water balance module is mainly a classroom module where JDs learn the following aspects:

- What is a watershed?
- How to delineate watershed boundaries (Ridgeline)?
- How to characterise - based on landform and land use pattern?
- How to estimate broad water balance through estimating rain water inflow, surface runoff (overland flow)
- How to estimate water demand in a watershed?
- How to estimate water balance (against the demand)?
- How to strategise land and water management activities?

Understanding Watershed

Step 1

Firstly, JDs are shown watershed basin pictures followed by an exercise with the help of toposheets.

- JDs are asked to identify different contours in either ascending or descending orders on map and learn about what contours indicate.
- JDs observe that the direction of ascending orders of contour shows increasing slopes and descending orders of contour shows decreasing slopes. They also observe that the direction of slope is always perpendicular to contour.
- JDs identify points in map where slopes are in opposite directions and they draw a line connecting all these points. This gives them the ridge line and the area bounded by this is called watershed
- Similarly, they identify points where slope directions converge on each-other to locate valleys on the map.

Step 2

After completion of the ridgeline demarcation, JDs draw ridge lines on their copy of the basemap.

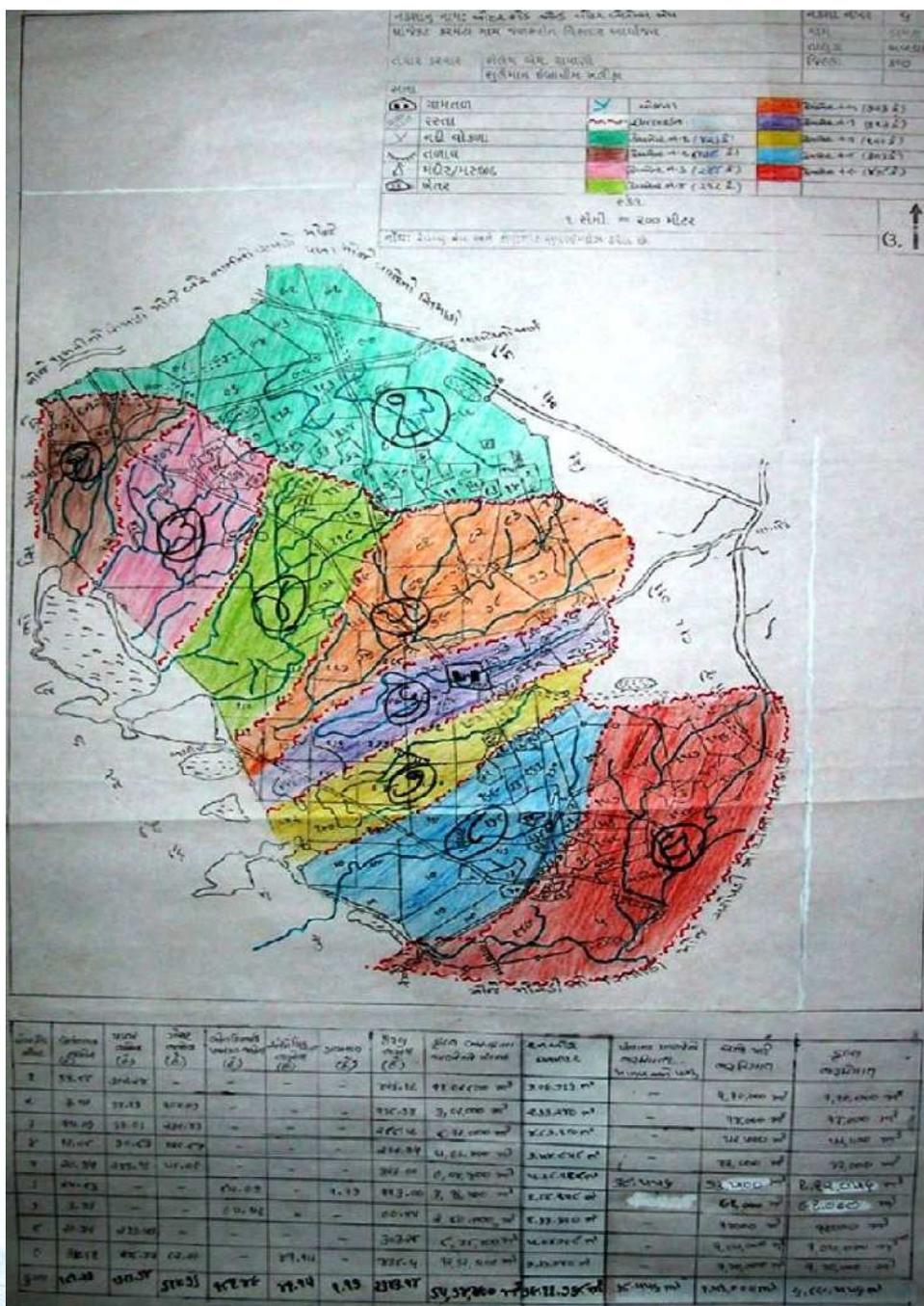
Step 3

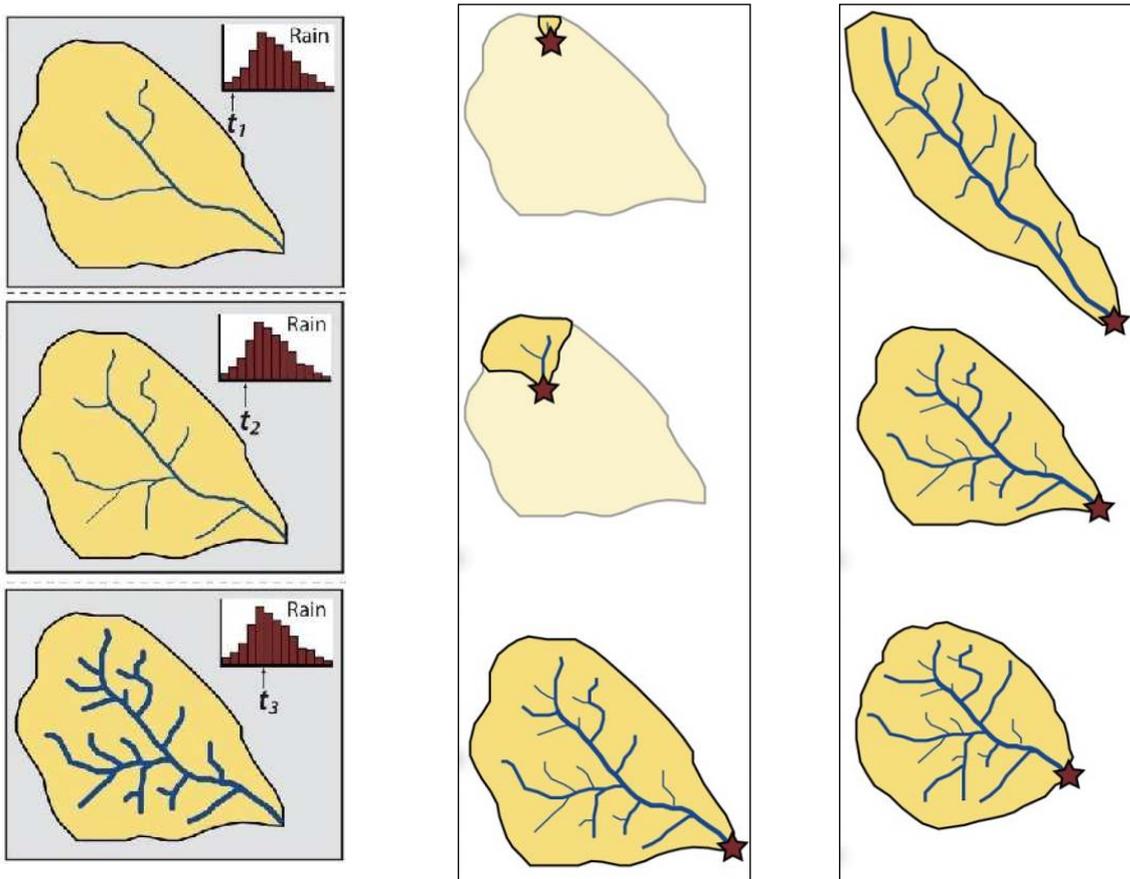
JDs are helped to study different components of watershed: (i) streams and rivers; (ii) catchment area (iii) different parts of watershed i.e. upper, middle, and lower part; (iv) size of watershed and (v) shape of watershed.

Step 4

JDs are asked to characterise their study village/area watersheds and calculate catchment areas. (Follow the same method for calculation of area as used for land use area calculation)

Step 5: Give a different colour code to each watershed on the basemap so that it can be easily identified in the study village.





Drainage Density & Watershed

Area – Size of Watershed

Shape of Watershed

- Compare all these characters of watersheds with other thematic maps and ask trainees to see a relationship between geomorphology and geology with watershed.
- Classify watersheds as per size and shape as follow

Size	Micro, Macro, Mega watershed
Shape	Fan shape, Elongated

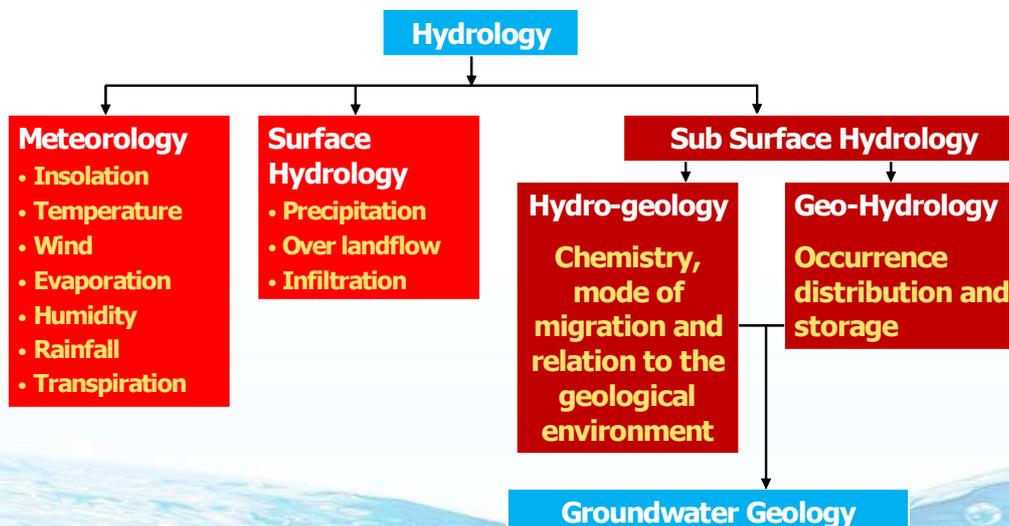
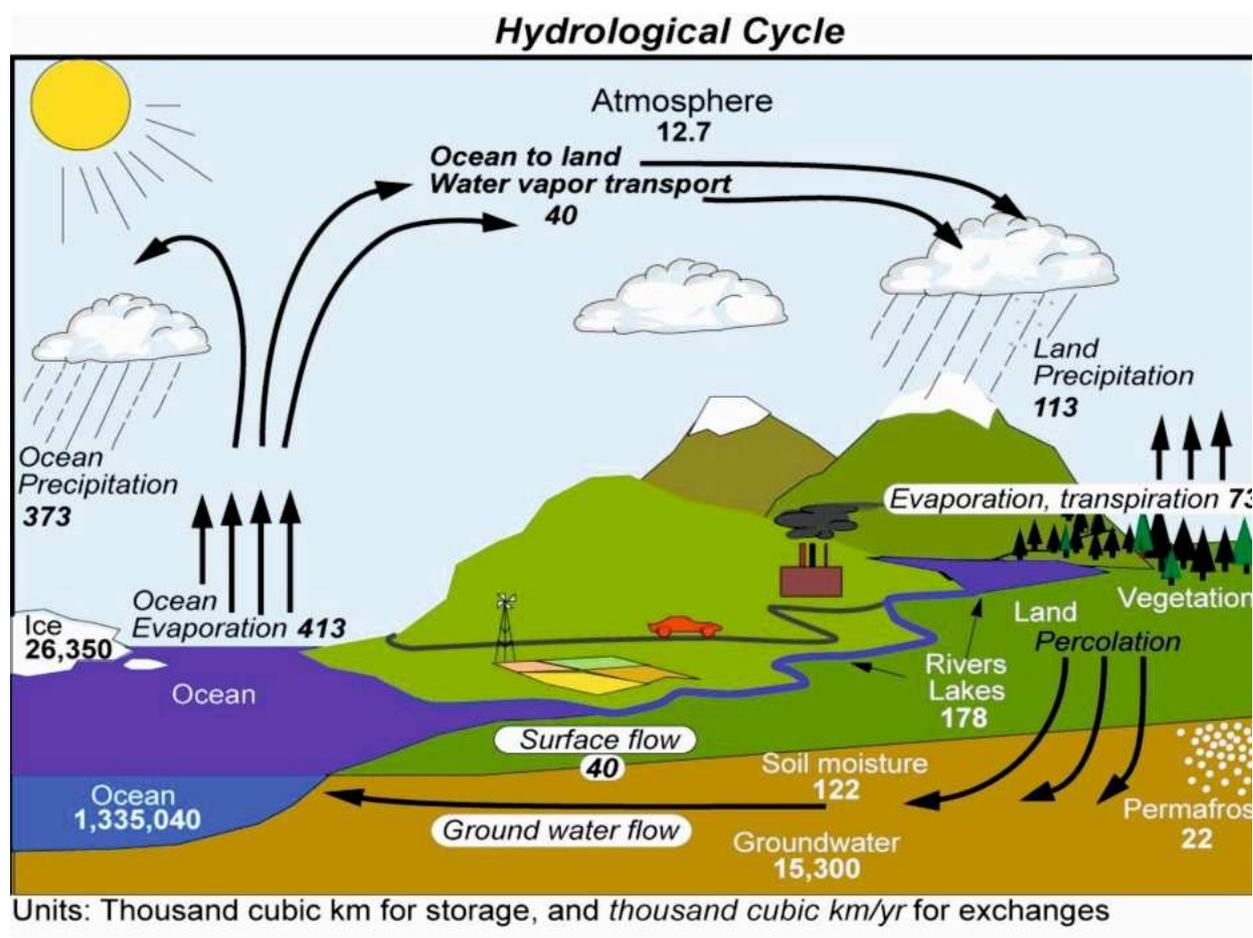
Examples on how to study relationship of watershed with different terrain characteristics.

- Reasons for low drainage density may be due to gentle slope, hard rock.
- Long shape of the watershed may indicate tectonic control, elongated hilly terrain, fracture control etc.
- High drainage density may be due to more fractures, chemical leaching etc.

Estimating Water balance

Step 1

JD discuss in group about hydrological cycle with the help of posters, power point presentations, and animation movies. They also learn about rainfall, rainfall pattern, rain cycle and characteristics of local rainfall and other climatic parameters such as temperature, wind, evaporation and evapotranspiration. The JDs then discuss how watershed plays an important unit for developing water resource planning.



Step 2

JDs are facilitated to discuss about the importance of water balance and estimation of its different components of the area:

- Average annual rainfall
- Rainwater inflow
- Runoff
- Water demand

A. Average annual rainfall estimation

- JDs learn about rainfall measurement using rain gauges
- Obtain historical rainfall data of the nearest location through the nearest relevant office or download through internet.

Estimation of average annual rainfall

Data Sources	Purpose																				
Irrigation Department	To measure inflow in irrigation dam																				
Meteorology Department	Collects all weather data for forecasting weather, disaster preparedness and planning																				
Research Institutions	For research																				
Agricultural departments	For crop plan advice																				
Ports and Airports	For vessels and aircraft timetable and plan																				
Besides these, there are many more institutions which also collect data for specific purposes																					
<p>Example</p> <table border="1"> <thead> <tr> <th>Year</th> <th>Annual Rainfall</th> </tr> </thead> <tbody> <tr> <td>2010</td> <td>540</td> </tr> <tr> <td>2011</td> <td>320</td> </tr> <tr> <td>2012</td> <td>470</td> </tr> <tr> <td>2013</td> <td>900</td> </tr> <tr> <td>2014</td> <td>125</td> </tr> <tr> <td>2015</td> <td>260</td> </tr> <tr> <td>Total Rainfall</td> <td>2615</td> </tr> <tr> <td colspan="2">Total number of years = 6</td> </tr> <tr> <td colspan="2">Sum of Total Rainfall=2615mm</td> </tr> </tbody> </table>	Year	Annual Rainfall	2010	540	2011	320	2012	470	2013	900	2014	125	2015	260	Total Rainfall	2615	Total number of years = 6		Sum of Total Rainfall=2615mm		<p>Average Annual Rainfall =</p> $\frac{2615 \text{ mm (Sum of total years' rainfall)}}{6 \text{ (Total number of years)}}$ <p>The Answer is 435.83 mm Say 436 or 440 mm</p>
Year	Annual Rainfall																				
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B. Rainwater inflow in Watershed area

- First of all, convert rainfall in m by dividing total mm rainfall by 1000 i.e. 440 mm/1000 = 0.44m
- Select the catchment and if the catchment area is in Ha than multiply these with 10000 that will give square meter area e.g. if the catchment area is 500 Ha than it is 5000000 sqm
- Third multiply catchment area with rainfall by using following equation
- Lastly calculate receivable rainfall for all the catchment of the study area/village

$$\text{Rainfall received in catchment/Watershed} = \text{Total Catchment Area (sq. M)} \times \text{Rainfall (M)}$$

Example

Total received Rainfall by Catchment = 5000000 sq. M (Catchment area) X 0.4 M (Rainfall) = 2000000 cum

C. Run off estimation

After computing total received rainfall it is important to estimate how much water flowing out from each catchment area. To estimate runoff JDs has to refer to land form and land use map to characterise each catchment area. To estimate runoff, the following method is proposed to be taught as it is checked in many small areas.

BARLOW'S METHOD

Based on extensive studies on different catchments in Uttar Pradesh (North India) region Barlow, (1912) had proposed the following equation to estimate runoff for up to 130 sq. km. size watersheds

$$R = k \times p = k_1 \times k_2 \times p$$

R= Run off; P= Rainfall; k1 =Catchment coefficient; k2 =Rainfall Coefficient

Estimation of Catchment coefficient (k1)

Catchment Class	Characteristics	K1
A	Flat cultivated and black cotton soil	0.10
B	Flat, partly cultivated soil	0.15
C	Average catchment	0.20
D	Hills and plains with little cultivation	0.35
E	Hilly and steep regions with hardly any cultivation	0.45

Estimation of Rainfall coefficient (k2)

Rainfall	K2				
Class	A	B	C	D	E
Light	0.7	0.8	0.8	0.8	0.8
Medium	1.0	1.0	1.0	1.0	1.0
Heavy	1.5	1.5	1.5	1.7	1.8

Light Rain = <25 mm/day

Medium Rain = 25-75 mm/day

Heavy or continuous down pour = > 75 mm/day

Example

A Catchment has 50 persons, 10 Buffalo, 7 Cow 45 goats 35 Ha rain-fed agriculture area and 20 Ha of grassland then the total demand of the catchment is...

Demand	Considerations		Annual Demand cum
For Human	$(70 \times 50 \times 365)/1000$		894.25
For cattle	$(30 \times 30.83 \times 365)/1000$	ACU = adult cattle unit can be consider as 10 Buffalo (10 ACU) + 7 Cow (5.83 ACU) Cow = 45 goats (15 ACU) Total ACU are 30.83	337.80
For agriculture	0.4 m x 350000	100 mm irrigation and four irrigation per Ha area	140000
For Grass land	0.4 m x 200000		80000
Total Demand			221231

Computation of Balance

Water Balance can be calculating by using following formula.

Water Balance = Water Remains in Catchment after Run off – Total Demand

There are two kinds of balance - negative or positive

- Negative balance means demand is more than remaining rain water in the catchment
- Positive means demand is less than remaining rain water in the catchment

In the case of the above example the following balance can be computed

Balance = Water Remain in the Catchment (2000000 – 1156000 = 844000) - Demand 221231 Cum = 622768 CUM

That means the catchment area need not develop water resources but it has highly surplus water that needs to be managed to solve the problem.

IMPORTANT: WATER BALANCE IS AN IMPORTANT TOOL TO DECIDE STRATEGY AS FOLLOWS

Based on balance two kind of strategies can be decided

- For negative balance = check the possibility to harvest runoff water and develop water resources in the catchment
- For positive balance
 - If the balance is very high than there needs to be only management of existing water resources
 - If the balance is marginal then there is a need to maintain the balance by using various demand side management practices like introducing water efficient technologies, change in practices etc.

Step 3. Compiling all this information in watershed and water balance maps.

Catchment Code	Total Area (Ha)	Received Rainfall (CUM)	Runoff (CUM)	Demand (CUM)					Balance (CUM)	Strategy
				Human	Cattle	Agri	Grass land	Total		

Module 10: Planning and Managing Village Water Resources

Understanding planning ideology

This whole process can be taught by organising exposure field visits in successfully planned and implanted project areas. Also by understanding how village people have built an understanding of their land and water resources and planned different activities and achieved sustainability. During field exposure the candidates have to observe different hardware activities along with group discussions with the village community focusing on following aspects:

- How they understood their resources.
- How they have identified and quantified their problem exactly.
- What were the challenges they faced during planning and how they resolved them?
 - If there any conflict arisen during the process how they resolved it.
 - What are new possible problems that they can predict and what preparedness they are planning?
- How they are managing the different resources use wise.
- How they come together.
- Any institutional arrangements for management.

Review all previous works and share with village people

After the exposure visit, each JD group has to review all the maps and share all this knowledge with their respective study village people discuss possible strategies for land and water management planning. Here JDs review all planning tools that they have used during geological mapping and water balance

C. Planning Processes

Once consensus comes from the community, then strategy and land and water resource activities are listed with villagers.

- Drinking water for humans and cattle.
- Soil moisture conservation for rain fed agriculture.
- Ground water recharge activities.

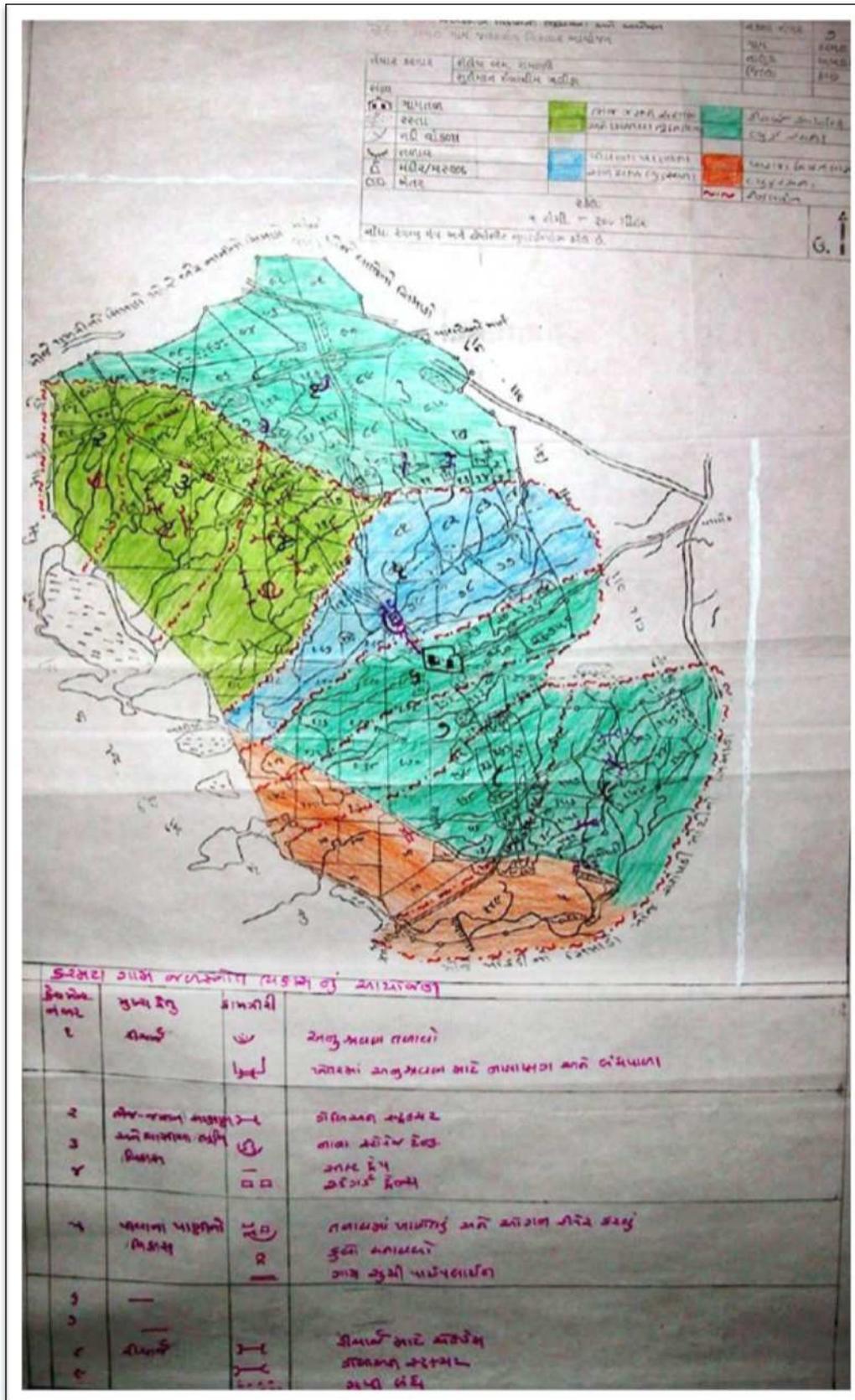
- Soil moisture conservation for grassland development.
- Surface water harvesting
- After listing of activities, JDs check their maps and study feasibility of all activities suggested by villagers.
- Considering the feasibility, JDs discuss different activities with different stakeholders such as farmer groups, women groups, animal husbandry community etc.
- In addition to this, JDs also verify the plan with experts.

After ascertaining feasibility, the team share all their views with the villagers and get approval on their plan.

- After ascertaining feasibility, consultation and verification, the draft plan should be prepared by JDs.
- This plan is shared with entire village by organising a village level meeting

D. Finalisation of planning map

After completion of all the field level activities the planning should be mentioned on the basemap showing strategies and different activities with proper colours and symbols.



Module 11: Implementing Efficient Water Use Technologies

Irrigation

Irrigation is the artificial application of water to the crop field at needed intervals. Irrigation helps to grow agricultural crops, maintain landscapes, and increase the productivity where rainfall is not sufficient to meet the crop demands.

Importance of Irrigation

Irrigation is necessary for agriculture and farming due to the following reasons:

- i. Plants absorb minerals and nutrients from the soil via their roots. These minerals are dissolved in the water present in the soil. Then the water transports these nutrients to all parts of the plant, enabling growth and photosynthesis.
- ii. Irrigation provides the moisture that is crucial during the germination phase of the plant's life cycle.
- iii. Irrigation also makes the soil more fertile (by adding moisture to it) and easier to plough
- iv. Proper irrigation also increases yield from the farm.

Surface Irrigation

- In all the surface methods of irrigation, water is either ponded on the soil or allowed to flow continuously over the soil surface for the duration of irrigation.
- It does not result in high levels of performance.
- This is mainly because of uncertain infiltration rates which are affected by year-to-year changes in the cropping pattern, cultivation practices, climatic factors, and many other factors

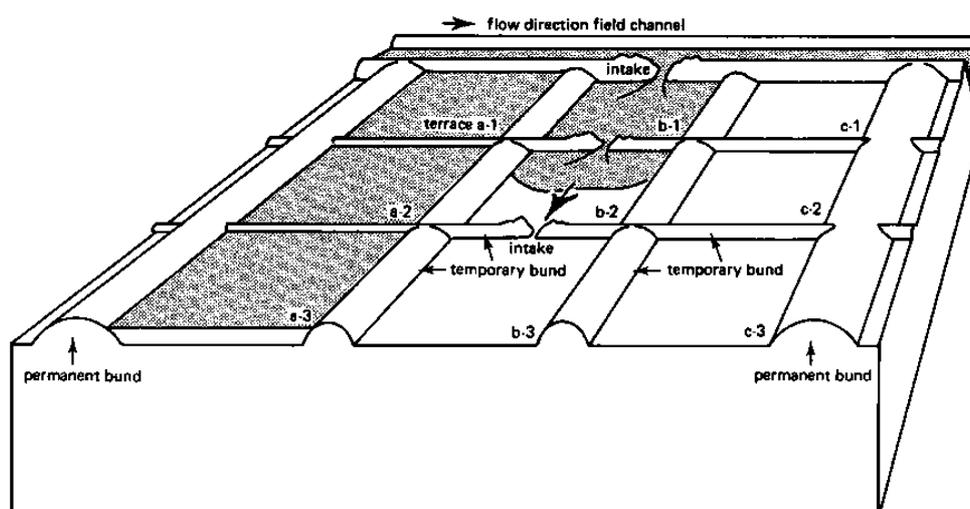
Uncontrolled Flooding

- When water is applied to the cropland without any preparation of land and without any levees to guide flow of water on the field, the method is called 'uncontrolled', wild or 'free' flooding.
- Uncontrolled flooding generally results in excess irrigation at the inlet region of the field and insufficient irrigation at the outlet end.
- Efficiency is reduced because of either deep percolation or flowing away of water from the field.
- The advantage of this method is the low initial cost of land preparation.

Controlled Flooding

Border strip method

- Border strip irrigation (or simply 'border irrigation') is a controlled surface flooding method of applying irrigation water. In this method, the farm is divided into a number of strips. These strips are separated by low levees (or borders).
- The border strip method is suited to soils of moderately low to moderately high intake rates and low erodibility.
- This method, however, requires preparation of land involving high initial cost. Schematic diagram of border irrigation is shown in below figure



Schematic diagram of Border Strip Method of Irrigation

Check Method

- The check method of irrigation is based on rapid application of irrigation water to a level or nearly level area completely enclosed by dikes as shown in below figure.
- In this method, the entire field is divided into a number of almost levelled plots (compartments or 'Kiaries') surrounded by levees.
- This method is suitable for a wide range of soils ranging from very permeable to heavy soils.
- Loss of water through deep percolation (near the supply ditch) and surface runoff can be minimized and adequate irrigation of the entire farm can be achieved. Thus, application efficiency is higher for this method.
- There is some loss of cultivable area which is occupied by the levees.



Furrow method

- An alternative to flooding the entire land surface is to construct small channels along the primary direction of the movement of water and letting the water flow through these channels which are termed 'furrows', 'creases' or 'corrugation' as shown in below figure.
- Furrows necessitate the wetting of only about half to one-fifth of the field surface. This reduces the evaporation loss considerably.
- Furrows provide better on-farm water management capabilities for most of the surface irrigation conditions, under variable and severe topographical conditions.
- Possibility of increased erosion
- Furrow irrigation requires more labour than any other surface irrigation method. This methods application is limited to row crop like potato, groundnut



Sprinkler Irrigation

This system mimics the phenomenon of rain. Water is carried by pipes to central locations on the farm. Sprinklers placed here distribute the water across the fields. This is the most efficient method to irrigate the uneven land. Sprinkler system also provides the best coverage regardless of the size of the farm. Schematic diagram and field application of sprinkler irrigation method is shown in below figure.

Sprinkling is the method of applying water to the soil surface in the form of a spray which is somewhat similar to rain. Rotating sprinkler-head systems are commonly used for sprinkler irrigation. Each rotating sprinkler head applies water to a given area, size of which is governed by the nozzle size and the water pressure.

Alternatively, perforated pipe can also be used to deliver water through very small holes which are drilled at close intervals along a segment of the circumference of a pipe. Sprinklers have been used on all types of soils on lands of different topography and slopes, and for many crops. The following conditions are favourable for sprinkler irrigation:

- Very previous soils which do not permit good distribution of water by surface methods,
- Lands which have steep slopes, easily erodible, and difficult to levelling and also not cost effective.
- Irrigation channels which are too small to distribute water efficiently by surface irrigation, and
- Lands with shallow soils and undulating lands which prevent proper levelling required for surface methods of irrigation

Advantages:

- Low water loss and hence saves water (Irrigation efficiency is about 75 to 85%)
- Enhances plant growth and crop yield
- Saves labour and energy
- Control weed growth
- No soil erosion
- Improves fertilizer application efficiency
- Suitable for any topography
- Uniform application of water



Typical Sprinkler irrigation system

Disadvantages:

- High skill in design, installation, and subsequent operation.
- High initial cost, cannot adopt by ordinary farmers
- Clogging of small conduits and openings due to sand, clay particles, debris, chemical precipitates and organic growth.
- Not suitable for closely planted crops such as wheat and other cereal grains.
- Poor application efficiency in windy weather and high temperature
- High evaporation losses
- Water should be free of debris

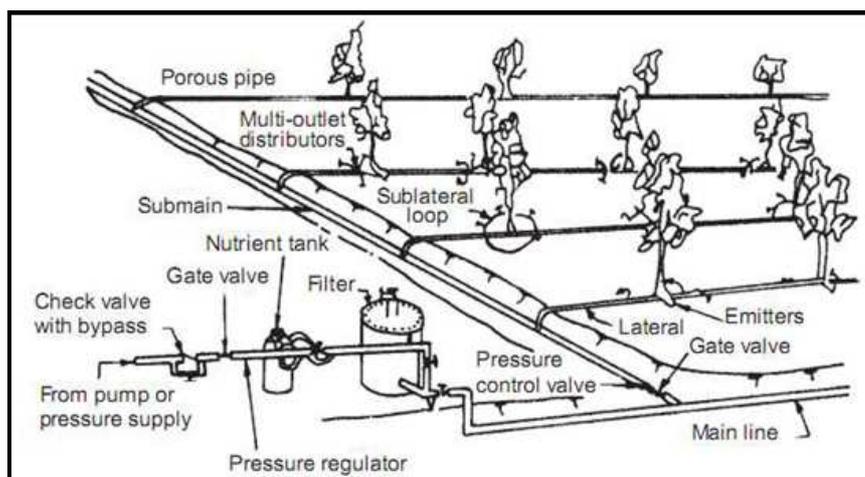
Physical damage to crops by application of high intensity spray

Drip Irrigation

The most commonly used method of irrigation these days is the drip method. They lay the pipes in rows near the crops or plants. These plastic pipes have holes in them. Water seeps from these holes drop by drop, hence the name drip irrigation. This is an extremely efficient method of irrigation as it reduces water wastage.

- Trickle irrigation system comprises main line, sub-mains, laterals, valves (to control the flow), drippers emitters, pressure gauges, water meters, filters, pumps, fertilizer tanks, vacuum breakers, and pressure regulators.

The drippers are designed to supply water at the desired rate (1 to 10 liters per hour) directly to the soil. Low pressure heads at the emitters are considered adequate as the soil capillary forces causes the emitted water to spread laterally and vertically.



Line Sketch of typical Drip Irrigation System



Drip Irrigation system installed at field

Quality of Irrigation Water

- Irrigation water must not have direct or indirect undesirable effects on the health of human beings, animals, and plants.
- The irrigation water must not damage the soil and not endanger the quality of surface and ground waters with which it comes into contact.
- The presence of toxic substances in irrigation water may threaten the vegetation besides degrading the suitability of soil for future cultivation.
- Surface water, ground water, and suitably treated waste waters are generally used for irrigation purposes. The various types of impurities, which make the water unfit for irrigation, are classified as:
- Sediment concentration in water

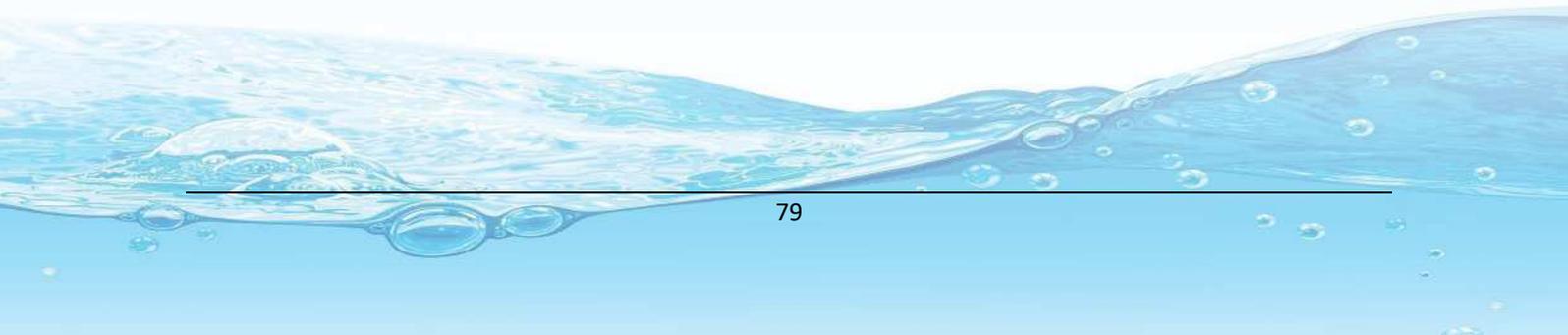
- Total concentration of soluble salts in water
- Proportion of sodium ions to other ions
- Concentration of potentially toxic elements present in water
- Bacterial contamination

Soil Moisture Conservation Techniques

The main objective of soil moisture conservation is to minimize the amount of water lost from the soils through evaporation (water loss directly from the soil) and transpiration (water loss occurring through the plants) – or combined, the evapotranspiration. Preserving soil moisture is important means to maintain the necessary water for agricultural production, and also helps minimize irrigation needs of the crops. This is especially important in areas where rainwater and/or ground water resources for irrigation are scarce or decreasing due to climate change or other causes.

Natural mulch consists of dead leaves, twigs, fallen branches and other plant debris which accumulate on the earth's surface. It also called the organic mulch. It will be adding more nutrients to the soil and improves the soil health and increased the crop productivity. Organic mulching technique is given in below figure.







Inorganic materials used for mulches do not add nutrients or humus to soil and do not decompose except after long exposure to weathering. Otherwise these materials are effective mulches, and several are permanent and quite attractive.



Implementation

There is a variety of methods that can be used to conserve soil moisture. Most of these are relatively low cost and complexity approaches, primarily relying on the presence of required materials and technical capacity locally. Many of the methods rely on providing some kind of cover for the soil to minimize evapotranspiration and direct soil exposure to heat and sun. Generally, most methods used for soil quality improvement and conservation, will also yield benefits to soil moisture conservation. Examples of methods for reducing excess soil moisture loss include following:

- Spreading manure or compost over the soil – this minimizes evapotranspiration and also provides valuable nutrients to the soil through processes of decomposition
- Mulching – mulch is a layer of organic (or inorganic) material that is placed on the root zone of the plants. Examples of mulch materials include straw, wood chips, peat. Inorganic mulch in form of plastic sheeting is also used. Mulching is most suited for low to medium rainfall areas, and less suited for areas with very wet conditions.

Conservation tillage – reducing or, in extreme cases, completely eliminating the tillage to maintain healthy soil organic levels which increases the soils capacity to absorb and retain water. Conservation tillage is a specific type of such approach where crop residue is left on the soil to reduce evapotranspiration, and protect soil surface from wind, sun and heavy rain impacts.

- Crop rotation – growing different types of crops every season helps improve soil structure and thus water holding capacity. Examples include rotating deep-rooted and shallow rooted crops that make use of previously unused soil moisture, as plants draw water from different depth levels within the soil. Crop rotation may also improve soil fertility and help control pests and diseases.
- Green manuring – growing of plant materials with the sole purpose of adding to the soil for improved organic matter and nutrients. The improved soil quality then also improves water retention capacity.
- Deep tillage – suited for some areas and soils, deep tillage can help increase porosity and permeability of the soil to increase its water absorption capacity.
- Mixed cropping and inter-planting - cultivating a combination of crops with different planting times and different length of growth periods.
- Contour ploughing – by ploughing the soil along the contour instead of up- and downward slopes, the velocity of runoff is reduced, creating even barriers, and more water is retained in the soils and distributed more equally across the cropland.
- Strip cropping - growing erosion permitting crops and erosion resisting crops in alternate strips. Other soil moisture conservation techniques may include rainwater harvesting to minimize runoff and collect water for use on site. For more technologies on this see technology sheet Rainwater harvesting for infiltration.

Module 12: Creating Awareness and Mobilising Community

For conservation of ground water, awareness generation among the community is very important. The main objective is to reach out the local communities to promote awareness for conservation, preservation and the efficient use of water resources. Participatory ground water management means the involvement of all people/ organizations who utilizes ground water. The aim of participatory ground water management is to bring together the scattered experience of ground water management and to train persons for participatory ground water management.

India is having 6,38,365 villages, 2,65,000 gram panchayats and 640 districts and currently facing a daunting set of water-related challenges as the demand for the fresh water increasing day-by-day. The National Water Policy, 2002 has emphasized that the management of water resources should incorporate a participatory approach by involving not only the government agencies but also all stakeholders in various aspects of planning, design and management. Recognizing the need for legal framework for Participatory Irrigation Management (PIM), the Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR, RD & GR) has brought out a model act to be adopted by the States for this purpose. Presently more than 61,000 Water Users' Associations (WUAs) have been formed in 23 States covering an area of about 12.55 million hectares. Despite this progress, PIM is not working effectively in all States. The constraints in the implementation of PIM like deficiencies in the irrigation supply system, lack of training and leadership, cooperation of Irrigation Departments, etc. are need to be addressed adequately.

Over large areas of the country there is uncontrolled indiscriminate exploitation of ground water. This has resulted in very high level of stage of ground water withdrawal in respect to annual recharge in many areas causing fast depletion of water. Any management measures taken by the government alone does not yield the desired results due to large number of ground water stakeholders spread over in far off areas. No monitoring mechanism can be effectively developed to keep a watch or check on ground water withdrawal. Also in absence of any rule / law regarding the ground water uses the stakeholders cannot be forced any reform measures or self-discipline as regards to the ground water uses/withdrawal, by the government. A question arises then how to motivate the stake holders including the large numbers of farmers owning the wells and industries to willingly adopt the reforms for management of ground water in stress areas. There may be requirement to go for demand side management requiring discipline in ground water withdrawal as per the availability of the resource.

The following aspects emerge from the above:

- The stakeholders should be made aware about the local ground water occurrence, issues, vulnerability, recharge and resources.
- They must be convinced for undertaking respective management measures willingly and collectively.
- Ground water management will be effective only when there is active participation and involvement of well owners and other stakeholders.
- Some institutional arrangement/mechanism should be developed to implement management measures.

Participatory Ground Water Management

The goal of a Participatory Ground Water Management (PGWM) should be equitable, safe and sustainable management of India's ground water resources through improved systems of aquifer mapping, utilization, awareness and governance.

- Why do we need PGWM?
- What are the Objectives & Outcomes of PGWM?
- Who are the partners and who are the facilitators?
- What is the role of partners and facilitators?
- What about capacity building?

Know your Aquifer, Manage your Aquifer

Implementation of an integrated aquifer mapping and ground water management programme is possible only through strong partnerships between various stakeholders. Stakeholders' participation contributes towards conservation, management and protection of resources.

Awareness among the school children of rural and urban area can also be created through organising painting & essay writing competitions in a sporting way at school levels. Children are the best medium to propagate the messages even to their elders and others also awareness through documentary films on 'community based cooperative management of ground water' themes can be created among the school children and villages. For awareness, material like maps, brochures, pamphlets can be distributed among the students and exhibitions of working models & pictures can be organised.

- Can the local people identify and understand the complexities associated with occurrence, storage and withdrawal of ground water?
- What is the reliability of data collection and analysis done by local people?
- Can the community and stakeholders be trained in scientific data collection and simple analysis?

First Self Help Groups (SHG), NGO and panchayat people has to be trained. They should be aware about the basics of aquifer such as hydrologic cycle, rainfall, origin of ground water, water table, ground water quality. They should be aware about the different fundamental parameters like static water table, pumping water level, drawdown, yield of bore well, capacity of pump, fluctuation of water table between Pre and Post – monsoon.

Village wise water level and rainfall data throughout India has to be collected by participatory ground water management (PGWM). From these data, farmers can do water balance studies of their field and can do crop water budgeting and ultimately decide which crop has to be taken up in their field.

Many projects are implemented by the government for different purposes such as drinking water etc. But around 50 % of the project fails after 3 to 4 years of implementation of the project. The people are not involved in the project and not aware about the basics to make the project success. People should be aware how the project can be beneficial to them and their involvement is necessary. Long term sustainability of the project is possible only through participation of local people.

Role of individuals in awareness generation and community mobilisation

Shri Anna Hazare in 1975 and Shri Rajendra Singh in 1985 are the pioneer of promoting participatory approach in water management. Ralegan Siddhi village in Ahmadnagar district of Maharashtra was a degraded village before 1975. He implemented different water harvesting structures to catch every drop of rain by developing drainage system, trenches, check dams, drainage plugs, percolation tank etc. by developing and designing micro-watershed specific schemes. After implementation of the project the crop production of the village increased and ultimately the livelihood of the people.

