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Water Resources Scenario in India: Its Requirement, Water Degradation and Pollution, Water Resources Management

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ABSTRACT

Earth's water resources, including rivers, lakes, oceans, and underground aquifers, are under stress in many regions. Humans need water for drinking, sanitation, agriculture, and industry; and contaminated water can spread illnesses and disease vectors, so clean water is both an environmental and a public health issue. In this article, learn how water is distributed around the globe; how it cycles among the oceans, atmosphere, and land; and how human activities are affecting our finite supply of usable water. The earth is sometimes called the watery planet as this is the only member in our solar system which has an abundant supply of water. Water is used as a raw material for various metabolic processes. It is an important ecological factor. It is also a very good solvent medium and has sustained life on earth ever since the biological origins of the living organisms. Water as a resource has been known to humans since the remotest past and has been used by them as an essential life-supporting ingredient. The water resources in India can be classified into three aspects for the purpose of study. Each of these categories is a part of the earth's water circulatory system. Water is the most important source of energy in the Indian economy. About 25 per cent of electricity generated in the economy is from the hydel sources. The other important use of water is irrigation. In a country where agriculture gives twists and turns to the whole economy, provision of water can make all the difference; it can either stimulate the economic activity or depress it altogether. The important sources of water can be classified into two parts: (i) surface water, and (ii) ground water. Surface water is available from such sources as rivers. lakes, etc. Ground water is available from wells, springs, etc. Other sources of water which have not as yet been tapped in the country, but nevertheless represent a potential source are: saline springs, snow and ice-fields. Surface water sources are replenished by rainfall. Of the two sources, surface water is more important and possesses potential of growth in future. Surface water is available in the form of vast network of rivers available in the country. Overall India possesses large reservoirs of water, but these are inadequate as compared to their requirements. Compared to countries such as the USA, which stores about 5,000 cubic meters per capita and China, which stores around 1,000 cubic meters per capita, India's dams can only store 200 cubic meters per person. A UN report (Water for People, Water for Life, 2003) ranks India 133rd in a list of 180 countries for its poor water availability. It also ranks India 120th for water quality in a list of 122 countries. A recent World Bank report reveals that per capita availability of water in India is 1,185 m^3, against 9,628 m^3 in the USA, 3,371 m^3 in Japan, and 2,183 m^3 in China. A late-2009 report by the US National Aeronautical and Space Administration brings out that the withdrawal of water in India is far higher than the recharge. This amounts to mining underground reserves built over thousands of years. 360 districts have reported water level decline of over 4 meters during the past 20 years. In nearly one-third of the blocks in the country, ground water reserves have been or are close to exploitation and this figure is likely to cross 60 per cent in another 25 years. As brought out by The UN World Water Development Report, 2009, the consequences are harrowing: drought and famine, loss of livelihood, the spread of water-borne diseases, forced migrations and even open conflict. Water is precious natural resource for sustaining life and environment. Effective and sustainable management of water resources is vital for ensuring sustainable development. In view of the vital importance of water for human and animal life, for maintaining ecological balance and for economic and developmental activities of all kinds, and considering its increasing scarcity, the planning and management of water resource and its optimal, economical and equitable use has become a matter of the utmost urgency. Management of water resources in India is of paramount importance to sustain one billion plus population. Water management is a composite area with linkage to various sectors of Indian economy including the agricultural, industrial, domestic and household, power, environment, fisheries and transportation sector. The water resources management practices should be based on increasing the water supply and managing the water demand under the stressed water availability conditions. For maintaining the quality of freshwater, water quality management strategies are required to be evolved and implemented. Decision support systems are required to be developed for planning and management of the *water resources project. There is interplay of various factors that govern access and utilization of water resources and in light of the increasing demand for water it becomes important to look for holistic and people-centred approaches for water management. Clearly, drinking water is too fundamental and serious an issue to be left to one institution alone. It needs the combined initiative and action of all, if at all we are serious in socioeconomic development. Safe drinking water can be assured, provided we set our mind to address it. The present article deals with the review of various options for sustainable water resource management in India.*

Index Terms- *Water resources, surface water, Groundwater, water degradation, water pollution, water resources management.*

1. Introduction:

Rapid increase in population and its uneven spatial distribution cause changes in water needs for meeting the domestic, agricultural, recreational and industrial demands. Various water resources projects have been constructed cri being planned to meet the growing needs of water in different sectors. The uneven distribution of precipitation causer; highly uneven distribution of available water both in time and space, which leads to floods and droughts affecting vast areas of our country. Man's activities such as changes in land use, deforestation or afforestation, agricultural practices, urbanisation, and construction of water resources projects, etc. influence the hydrological cycle to a certain extent which in turn, modifies the pattern of natural availability of fresh water supplies with respect to time and space. This necessitates the accurate assessment of surface water and ground water resources and their quality for their optimum utilisation. Water is the most essential natural resource for life next to air and is likely to become a critical scarce resource in many regions of the world. Proper assessment of the availability and planning for the efficient use of the various natural resources is the primary requirement for any developmental activity. Of the different resources, water is the only one which is essentially required for all types of the developmental activities in every part of the world. Water differs markedly from most other natural resources by its remarkable property of continuous markedly renewal in the water cycle. Another important property of water is that, regardless of the number of times it is used by man, the quantity of water on the earth is not reduced, and in the water cycle, its purity is restored and it is available for use once again. The relative quantities of the earth's water contained in each of the phases of the hydrologic cycle are presented in Table 1-0. The oceans contain 96.5% of the earth's water, and of the 3.5% on land, approximately 1% is contained in deep, saline ground waters or in saline lakes, leaving only 2.5% of the earth's water as fresh water. Of this fresh water, 68.6% is frozen into the polar ice caps and a further 30.10% is contained in shallow ground water aquifers, leaving only 1.3% of the earth's fresh water mobile in the surface and atmospheric phases of the hydrologic cycle. The proportions of this water in the atmosphere, soil moisture and in lakes are similar, while that in rivers is less and that in snow and glacier ice is greater. A small amount of biological water remains fixed in the living tissues of plants and animals. All the data on the earth's waters cited here are taken from a comprehensive study of world water balance conducted in the Soviet Union during the International Hydrological Decade. These values arc estimates, and future studies made with more comprehensive data will lead to refinement of these values.

It is remarkable that the atmosphere, the main vehicle driving the hydrologic cycle, contains only 12,900 km^3 of water, which is less than 1 part in 1000000 of all the waters of the earth. Atmospheric water would form a layer only 25 mm (1inch) deep if precipitated uniformly on to the earth's surface (Maidment, 1992).

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Despite the fact that the available water is only a small fraction of the total water around us, it is large enough as compared what we need for our day to day requirements. But still we are facing water scarcity at many places on several occasions. And an explanation of this circumstance can be found in an in-depth study of the hydrology of various river basins.

The water resources which are available for use are mainly in the form of runoff of the rivers and from ground water.

Table 1-0 Major Stocks of Water in the Global Hydrological Cycle (adapted from Dingman, 2002)

SL No	Form of Water	Area Covered (km²)	Volume (km³)	% Total Water Reserves
1	2	3	4	5
1	World oceans	361,300,000	1,338,000,000	96.5
2	Groundwater	134,800,000	23,400,000	1.7
3	Glaciers and permanent snowpack	324,600,000	48,128,200	3.48
4	Ground ice in permafrost zone	21,000,000	300,000	0.022
5	Freshwater lakes	1,236,400	91,000	0.007
6	Saltwater lakes	822,300	85,400	0.006
7	Marsh water	2,682,600	11,470	0.0008
8	River water	148,800,000	2,120	0.0002
9	Water in biosphere	510,000,000	1,120	0.0001
10	Atmospheric water	510,000,000	12,900	0.001
11	*TOTAL WATER RESERVES*	*510,000,000*	*1,385,948,610*	*100*
12	***FRESH WATER***	***148,800,000***	***35,029,210***	***2.53***

2. The Hydrologic Cycle: The Hydrologic Cycle is one of the most important processes in the natural world, and is perhaps one that we all take for granted. All of the world's water is subject to this process, which sees the water change forms, locations, and accessibility. In its most basic assessment, water changes between three different states in this cycle. It variously takes the form of liquid, gas, and solid: water, steam or vapor, and ice. Throughout the cycle, the water will undergo changes between these three forms many times: water freezing into ice, ice melting into water, water evaporating into water vapor, and that vapor then condensing to become water once more.

The hydrologic cycle, also known as global water cycle or the H_2O cycle, describes the storage and movement of water between the biosphere, atmosphere, lithosphere, and the hydrosphere. According to Wikipedia, *"The water cycle, also known as the hydrological cycle or the H_2O cycle, describes the continuous movement of water on, above and below the surface of the Earth."*

The natural circulation of water near the surface of earth is portrayed in Figure 1.0.

Water is most commonly found in its liquid form, in rivers, oceans, streams, and in the earth. The sun's rays constantly warm the water found in these places and, whether through this heat or through man-made means, the water particles gain energy and spread, turning the water from a liquid into a vapor through evaporation. The water vapor, thus becoming less dense, rises with the warm air into the sky where it sticks to other water particles to form clouds.

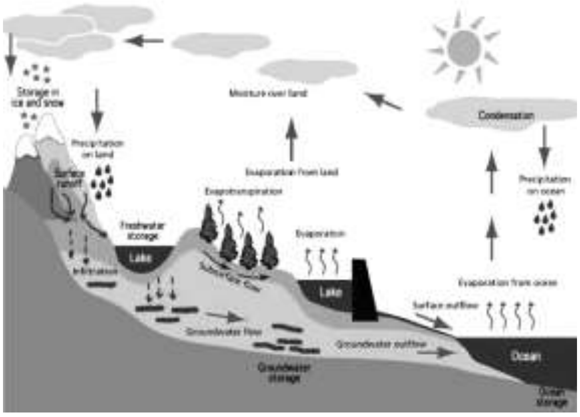

Figure 1.0: Hydrological cycle

Typically, we consider the boiling point of water to be a hundred degrees centigrade, which is certainly true when pressure and humidity are normal. However, places such as mountains, where humidity is low and pressure is even lower, require less energy to boil away the water.

Along with the water vapor, some small particles can often rise up to form clouds. It is not only liquid water that can evaporate to become water vapor, but ice and snow, too. This process is simple enough, however there are a few things to note about evaporation.

1) This simple explanation, however, does not do justice to the complexity of the hydrologic cycle, which comprises many more steps. Here is a breakdown of the different steps of the hydrologic cycle.

i) Evaporation: – is frequently used as a catch-all term to refer to the process of water turning to water vapor, however there is another distinct term for the evaporation of water from a plant's leaves.

ii) Evapotranspiration: – makes up a large portion of the water in the planet's atmosphere due to the sheer surface area of the globe covered by flora. The majority of water in the atmosphere comes from lakes and oceans – around ninety per cent – but in terms of land-based water, evapotranspiration is an important player.

iii) Sublimation: – as the process is called, results from when pressure and humidity are low as noted above. It is not only liquid water that can evaporate to become water vapor, but ice and snow, too. Due to lower air pressure, less energy is required to sublimate the ice into vapor. Other factors which can aid in sublimation are high winds and strong sunlight, which is why mountain ice is a prime candidate for sublimation, while ground ice sublimation is not so common. A good, visible example of sublimation is dry ice, which emits a thick layer of water vapor due to its lower energy requirement.

2) The further above sea level one gets, the cooler the air. When water vapor reaches this plane, it cools significantly and clumps together. So, stuck together, this newly formed cloud is subject to the movement of the wind and the changes in the air pressure, which is what moves the water around the planet. There are a couple of things that can happen to the vapor in this state.

i) Precipitation/Rainfall**:** – Refers to vapor that cools to any temperature above freezing point (zero degrees centigrade) will condense, becoming droplets of liquid water. These droplets form when the water vapor condenses around particles and other matter that rises up with the water during evaporation, giving a nucleus to the water droplet so that it can clump together. Once a number of these tiny, particle-based droplets form, they collide and clump together as larger droplets. At a certain point, the droplet will become big enough that its mass will be subject to the force of gravity at a rate faster than the force of the updraft in the air around it. At this point, the water falls to earth.

ii) Snow**: –** Refers to frozen water falling from the sky. When it is particularly cold or the air pressure is exceptionally low, these water droplets will crystalize before falling.

iii) Sleet**:** – Is a bitterly cold, half-frozen slush. This third state occurs when the conditions are not quite cold enough to keep the crystals frozen and the water either does not freeze fully or if precipitation occurs in particularly cold conditions, or conditions in which the air pressure is very low, then these water droplets can quite often crystallize and freeze. This causes the water to fall as solid ice, known melts somewhat in the process.

3) When water falls to earth, it quite often ends up on tarmac or over man-made surfaces where it quickly evaporates again.

i) Infiltration**: –** is water that doesn't evaporate after precipitation and falls into soil and other absorbent surfaces. The water moves throughout the soil, saturating it.

ii) Groundwater Storage**: –** Is water that has not precipitated or run off into streams or rivers, but instead moves deep underground forming pools known as "groundwater storage". In groundwater storage, water joins

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up in the soil and forms pools of saturated soil instead of escaping the soil. These pools are called “aquifers”.

***iii) Springs*: –** occur when an aquifer becomes oversaturated, and the excess water leaks out of the soil onto the surface. Most commonly, springs will emerge from cracks in rocks and holes in the ground. Sometimes, if conditions are particularly volcanic, the spring will heat up and form “hot springs”.

***iv) Runoff*: –** After heavy rainfall has saturated the soil it will cease to absorb water and additional rainfall, as well as melted snow and ice, will simply flow off of the surface. The flow follows gravity down hills, mountains, and other inclines to form streams and join rivers. This is known as “runoff”, and it is the principle way in which water moves along the Earth’s surface. The rivers and streams are pulled by gravity until they pool together to form lakes and oceans.

***v) Streamflow*: –** is the direction the runoff takes to form a stream and it is this flow which dictates the river’s currents depending on how close they are to the ocean. Because ice and snow make up a large portion of the water involved in runoff, heatwaves are a principle cause of flooding as the water stored on the surface is suddenly released into runoff flow. In particular, a warm spring following a cold winter can result in quite spectacular flood, as a large volume of water gets stored in ice and snow only to quickly melt and form new streams.

***vi) Ice Caps*: –** occur when a large volume of snow falls and is not evaporated or sublimated, the ice compacts under its own weight to form these caps. Ice caps, glaciers, and ice sheets contain a huge amount of water, and those found in the polar regions of the planet are the largest stores of ice found in the world. As the atmosphere warms up slowly, more and more of this ice melts and evaporates, releasing more water into the hydrologic cycle. It is this process which causes rises in the ocean levels.

The hydrologic cycle happens continuously, with all different steps happening simultaneously around the world. The biggest concern that many have with the hydrologic cycle is the availability of drinkable water, which is something that is constantly in flux, and the melting of the huge ice storage sheets at the polar caps. Having an understanding of the different steps of the hydrologic cycle is an important step in understanding what effect human activity has on the world’s water.

3. Water Resources in India: The water resources are classified into two main sources viz. (i) surface water; and (ii) ground water. Their unit of measurement is ‘BCM’ (billion cubic metres). A large amount of water precipitates and goes out as waste. Further, even the available water also cannot be fully used as utilisation has a bearing on its storage and supply to required places of usage. It is in this context that ‘utilizable water resource potential’ is to be distinguished from available water source. As we know very well, and we study in the unit later, there are parts of India where there is recurrent situation of floods; equally, there are other parts where there is acute situation of periodic drought. Unless the available excess water in one place is stored and then channelized to another place where it is scarce, the utilization of available water resource leaves a gap. Let us, therefore, begin by taking a look at the available/usable water supply in India

4. Utilizable Water Resource Potential: Table 1.1 presents a synoptic picture of available and usable water resource in India. The total availability of surface water is estimated at 1953 BCM of which only 35 percent is utilised. However, out of the total availability of ground water (estimated at 432 BCM), a much higher utilization of nearly 92 percent is there. The scenario is thus indicative of a much higher utilization level of

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ground water potential as compared to the surface water potential. The two source of water resource taken together, the percentage of current utilization is about 46 percent. Due to the inadequate achievement on creating the infrastructure required to store and channelize (or transport) the surface water potential, there is an excess withdrawal of ground water potential. Evidently, therefore, harnessing the available surface water potential needs to be focused upon more for which required storage capacity needs to be built. The total availability of usable water estimated at 1086 BCM is less than the projected total water requirement of 1180 BCM by the year 2050. The situation thus calls for water conservation and management measures to be pursued seriously. While this is one profile of the availability/utilization of water, another way of looking at its utilization is by its sectoral demand/needs.

The estimates made for the Eleventh Five Year Plan (2007-12) on the sectoral demand for water in India (Table 1.2) places the highest demand of about 83 percent for irrigation (by the year 2025). While the demand for drinking water is expected to be roughly the same (at about 7 percent of total demand over the period 2010 to 2050), the 'energy sector' and the 'industrial sector' would be requiring a far higher share of water by the year 2050 (as compared to its current and projected demand for the years 2010 and 2025 respectively). Evidently, with improvements in standard of living and growing population, the demand for water from these two sectors of usage (viz. energy and industry) would be higher. Areas of concern, parallel to the increased usage by these sectors, are those of rising pollution levels and the resulting decline in the quality of water resources. These are also, therefore, among the critical areas warranting higher policy and research attention.

5. Water Resources Requirement: Availability of water resources in our county as mentioned above, shows a great deal of spatial and temporal variability. Country's developmental process, increase in population and expansion of economic activities inevitably lead to increasing demands for water use in diverse fields. Hence, overall national planning and resource management in respect of water with emphasis on allocation of priorities among its diverse uses is necessary.

5.1 Existing Scenario of Water Use: Consumptive uses of water obviously are:
i) rural and municipal water supply,
ii) Industrial water supply, and

Table1.1: Availability of Water Resources in India

(Figure in BCM)

Sl. No	Source of Water by Availability / Usage Potential	Amount of Water
1	2	3
1	Available surface water	1553
2	Usable surface water	690 (35.3)
3	Available ground water	432
4	Usable ground water	396 (91.7)
5	Total available water (surface + ground)	2385
6	Total usable water (surface + ground)	1086 (45.5)
7	Estimated present quantum of use	600
8	Projected total water requirement in year 2050	973/1180 (low/high estimate)
9	Precipitation over the Indian land mass	40000

Source: National Commission on Irrigated Water Resource Development
Note: Figure inside brackets is percentage to respective total

Table 1.2: Projected Water Demand by Sectors of Usage —2010 to 2050

Sl. No	Sector	Demand for water (in BCM) in year		
		2010	2025	2050
1	2	2	4	5
1	Irrigation	688 (84.6)	910 (83.2)	1072 (74.1)
2	Drinking water	56 (6.9)	73 (6.7)	102 (7.0)
3	Industry	12 (1.5)	23 (2.1)	63 (4.4)
4	Energy	5 (0.6)	15 (1.4)	130 (9.0)
5	Others	52 (6.4)	72 (6.6)	80 (5.5)

Source: Eleventh Five Year Plan

iii) Irrigated Agriculture.

The principal consumptive use of water is for irrigation. The Planning Commission recognised the crucial importance of developing irrigation to increase agricultural production and accordingly assigned a very high priority to it in the plans. Giant schemes like the Bhakra

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Nangal, Hirakud, Damodar Valley, Nagarjuna sager, Rajasthan Canal project, etc. were taken up to increase the irrigation potential and thereby contribute to maximising the agricultural production.

The ultimate irrigation potential from major, medium and minor irrigation schemes is estimated at 113 M. ha of which 58 M. ha is from major and medium schemes and 55 M. ha from minor irrigation schemes.

The irrigated area in the country was only 22.6 M. ha in 1950-51. As compared to this the potential that has been created upto 1989-90 (i.e. the end of VIIth Five Year Plan) is about 78 M. ha comprising 42 M. ha by surface water and 36 M. ha by ground water. The actual area irrigated is 38.4 M. ha from surface water and 32.5 M. ha from ground water. The quantum of water used for irrigating these areas is of the order of 300 km^3 of surface water and 128 km^3 of ground water.

Quantum of water being utilised for other consumptive uses is far less than that used for irrigated agriculture. The water for community water supply, is the most important requirement in its own way, and it constitutes about 5% of the total water use. While rural areas may be able to live with the ground water, urban areas have to depend heavily on the surface waters.

It is roughly estimated that about 7 km of surface water and 18 km of ground water are being used for community water supply in urban as well as rural areas. However, organised water supply and sanitation programmes are yet to cover the entire country. Under the International Drinking Water Supply and Sanitation Decade Progrmnme launched in 1981 it has been aimed adequate drinking water facilities to 90% to the urban population and 85% of rural population, and sanitation facilities to 50% of urban population and 5% of rural population.

Water use by industries has not so far been precisely estimated. Paper, petrochemicals, mining, fertilizer, chemical and steel industries are some of the highly Water intensive industries. Rough estimates indicate that the present water use in the industrial sector is of the order of 15 km^3, from both surface and ground water sources.

Table1.3: Actual utilisation of water resources

Sector	Actual utalisation in M.ha.m
1	2
i) Irrigation using surface water	31.12
ii) Irrigation using ground water	12.80
iii) Community water supply (Urban and rural area)	2.50
iv) Industrial use	1.50
v) Energy generation	0.45
Total	48.37
or say	50

The water uses by thermal and nuclear power plants with installed capacities of 40000 MW, and 1465 MW respectively has at present been estimated to be about 4 km^3. This supply is mostly from surface water sources.

As far as hydropower generation is concerned, against the total assessed potential of 85550 MW, only is begin tapped by the existing and ongoing schemes put together. Hydropower generation is a non-consumptive use, but requires water supply falling through a height. The water is released back into the stream after hydropower generation, is, thus, available again for consumption and other water uses.

The actual utilisaüon of our water resources upto Seventh Plan (1989-90) under various heads is given hereunder:

5.2 Projected Water Needs: Population in the country is steadily growing and is expected to approach 100 crores by the turn of the century and 150 crores by 2025. The per capita food availability is at present low and needs to be increased. The food grain

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production should increase to 240 million tons by the year 2000 from the present level of 170 million tons. This rate of growth in food grain production can be achieved through extension of irrigated areas. and by increasing the grain yield per unit area assuming that there may not be any significant increase in net sown area. It has been established that productivity of irrigated areas is at least double, if not more of unirrigated areas in respect of wheat and rice crops. Therefore, irrigation will be the prime input for increasing the food grain Output.

The Eighth Five Year Plan envisages creating additional irrigation potential of 10 M. ha from surface water and another 10 M. ha from ground water. This would mean that at the end of Eighth Plan, 97 M. ha of irrigation potential would have been created. Of this 52 M. ha would be fed by surface sources and 45 M. ha would be using ground water. Rough estimates indicate that by the year 2000, water use for irrigation will increase to 630 km^3 (420 km^3 of surface water and 210 km^3 of ground water). By 2025, it may reach a level of 770 km^3 (510 km of surface and 260 km^3 of ground water). In the domestic water supply sector, even after achievement of the targets set by the International Drinking Water Supply and Sanitation Decade Programmes ending 1990-91, of urban population and 15% of rural population would be still left without drinking water facilities.

It has been roughly estimated that by the year 2000, community water supply requirement may go upto 30 km^3 from the present use of 25 km^3, while the industrial demand may go upto 30 km^3 from the present use of 15 km^3. Consumptive requirements for thermal power may be about 6 km^3. By 2025, the demand for community water supply may be around 53 km^3 and that for industrial supply 120 km^3. The power plants may demand 15 km^3 of water. The total storage required for hydropower will be about 375 km^3. The total requirement of water (including other needs also) by the year 2025 is thus estimated to be around 1050 km^3. The annual requirement of fresh water upto the year 2025 for various use in given in Table 1.4.

Table 1.4: Annual Requirement of Fresh Water in cubic kilometres (km^3)

Sl. No	Water use	1985		2000		2025	
		Surface water	Ground water	Surface water	Ground water	Surface water	Ground water
1	2	3	4	5	6	7	8
1	Irrigation	320	150	420	210	510	260
2	Other uses:						
	i) Domestic &Live-Stock		16.70		23.70		40.00
	ii) Industrial		10.00		30.00		120.00
	iii) Thermal power		2.70		3.30		4.00
	iv) Miscellaneous		40.60		58.00		116.00
	Sub Total	40	30	80	40	150	90
	Total		540.00		750.00		1050.00

6. Precipitation: The term "precipitation" denotes all forms of water like rainfall, snowfall, hail, frost and dew reaching the earth's surface from the atmosphere. Only the rainfall and snow contribute significant amounts of water. Rainfall, the predominant form of precipitation causes stream flow particularly the flood flow in most of the rivers in India. The spatial and temporal variation in rainfall in the country is mainly responsible for many hydrological problems, such as floods and droughts.

6.1 Forms of Precipitation: Under proper weather conditions, the water vapour condenses over nuclei to form tiny water droplets of sizes less than 0.1 mm in diameter. The nuclei normally available in plenty are usually salt particles or products of combustion. Wind speed facilitates the movement of clouds while its turbulence retains the water droplets in suspension. Water droplets in a cloud are somewhat similar to the particles in a colloidal suspension. Precipitation results when water droplets come together to form larger drops. The net precipitation and its form depend upon a number of meteorological factors, such as the weather elements like wind, temperature, humidity and pressure in the volume region enclosing the clouds and the ground surface at the given place.

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The following conditions are required for precipitation formation:

i) The atmosphere must have moisture,

ii) There must be sufficient nuclei present to aid condensation,

iii) Weather conditions must be good for condensation of water vapour to take place, and

iv) The products of condensation must reach the earth.

For the formation of clouds and subsequent precipitation, it is necessary that the moist air masses cool leading to condensation. Under certain favourable conditions when a warm air mass and cold air mass meet, the warmer air mass is lifted over the colder one with the formation of a front. The ascending warmer air cools with the consequent formation of clouds and precipitation. Some of the terms and processes connected with the weather systems associated with precipitation are given below:

Rain: It is the principal form of precipitation in India. The term "rainfall" is used to describe precipitation in the form of water drops of sizes larger than 0.5 mm. The maximum size of a raindrop is about 6 mm. The larger drops tend to break up into small drops during their fall from the clouds.

Snow: Snow is another important form of precipitation. Snow consists of ice crystals which usually combine to form flakes. New snow has an initial density varying from 0.06 to 0.15 g/cm3 with an average value of 0.1 g/cm3, In India, snow occurs only in the Himalayan regions.

Drizzle: The water droplets are less than 0.5 mm in diameter and rainfall intensity (rate at which rainfall occurs) less than 1mm per hour. The drops being very small appear to be floating in the air.

Glaze: When rain or drizzle come in contact with cold ground with around 0oC temperature, the water drops freeze to form an ice coating called, glaze or freezing rain.

Sleet: Sleet may occur when a warm layer of air lies above a below-freezing layer of air at the earth's surface and are generally transparent ice pellets with diameters of 5 mm or less formed as a result of the freezing of raindrops or the freezing of mostly melted snowflakes.

Hail: It is a showery precipitation in the form of irregular pellets or lumps of ice of size more than 8 mm. Hails occur in violent thunderstorms in which vertical currents are very strong.

7. Surface Water Resources: India with a geographical area of 329 million hectares (M. ha) receives an annual precipitation of about 4000 cubic kilometres (km^3), including snowfall. Out of this amount seasonal rainfalls of the order of 3000 cubic kilometres (km^3). Rainfall in India is dependent in different degrees on the south-west and north-east monsoons, on shallow cyclonic depressions and disturbances and on violent local storms which form in regions where cool humid

Table 1.5: Average Annual Flow in the Indian River Systems (CWC, 1987) (In cubic kilometres)

Sl. No	Basin	Average Annual Flow	Utilisable Flow
1	2	3	4
1	Indus (upto border)	73.303	46.00
2	a) Ganga (up to border)	501.643	250.00
	b) Brahmaputra (up to border)	499.914	24.00
	c) Barak etc.	90.800	
3	Godavari	118.982	76.30
4	Krishna	67.790	58.00
5	Cauvery	20.695	19.00
6	Pennar	6.858	6.856
7	East flowing Rivers between Krishna and Pennar and between Mahanadi and Godavari	16.948	13.110
8	East flowing Rivers between Pennar and Kanyakumari	17.725	16.732
9	Mahanadi	66.879	49.990
10	Brahmani and Baitarani	36.227	18.297
11	Subernarekha	10.756	6.813
12	Sabarmati	2.883	1.925
13	Mahi	11.829	3.095
14	West flowing Rivers of Kutch Kathiawar including Luni	15.098	14.980
15	Narmada	42.966	34.500
16	Tapi	16.967	14.500
17	West flowing Rivers from Tapi toTadri	110.887	15.068
18	West flowing river from Tadli to Kanyakumari	71.981	14.932
	Total	1801.123	684.100

Source: Central Water Commission Ministry of Water Resources

winds from the sea meet hot dry winds from the land and occasionally reach cyclonic dimension. Most of the rainfall in India takes place under the influence of south-west monsoon between June to September except in Tamil Nadu where it is under the influence of north-east monsoon during October and

November. The rainfall In India shows great variations, unequal seasonal distribution, still more unequal geographical distribution and frequent departures from the normal. As per the estimates made by Dr. A.N. Khosla, the founder chairman of Central Water and Power Commission, the total average annual flow of all the river systems of India is found to be 1673 cubic kilometres. In this estimation runoff has been considered as a function of rainfall and temperature. Central Water and Power Commission during 1952 to 1956 estimated the surface water resources of the country as 1881 cubic kilometres. These estimates are based on the statistical analysis of the available flows of rivers and suitable rainfall runoff relationships in case of meagre amount of observed data. Rao (1975) has stated the country's available annual surface runoff as 1645 cubic kilometres. India is a subcontinent of vast dimensions, being home to about one billion people. And, then it is a developing country, racing facts to catch up with the developed world in her efforts to keep improving the lot of its citizens. One of the crucial input-resources for this gigantic task is water, which available a plenty in some regions of India while it is scarcely available (or even not available at all as available at uneconomical cost) in other areas. But looking from an overall perspective point of view, India is not deficient in this resource and can cater to its needs through appropriate utilization of its surface as well as ground water potential. Thus, the estimates of surface water resources of the country vary from 1645 to 1881 cubic kilometers. Most of surface flow of the rivers occurs during the monsoon season of 4 to 5 months and particularly as flood flows. The basin wise average annual flow in Indian river systems is summarized in Table 1.5.

8. Ground Water Resources: India is a vast country having diversified geological setting. Variations exhibited by the rock formations, ranging in age from the Archaean crystalline to the recent alluvia, are as great as the hydrogeological conditions. Variations in the land forms are also not insignificant. The land profile varies frorn sea level at the coasts to the lofty peaks of the snow-clad Himalayan Intonations, attaining staggering altitude upto about meters. Variations in the nature and composition of rock types, the geological structures, geomorphological set up and hydrometeorological conditions have correspondingly given rise to widely varying ground water situation over the sub-continent.

In the high relief areas of the northern and north-eastern regions of the Himalayan ranges, the various conspicuous hill ranges of Rajasthan, and the Central and Southern Indian regions, the presence of very steep-slope conditions and their geological structures offer extremely high runoff, and thus very little scope tor rain water to find favorable conditions of detention and then circulation as ground water. The large alluvial tract extending over 2000 km in length from Punjab in the West, to Assam in the East, often referred to as Sindhu-Ganga-Brah1naputra Plan, is perhaps, the most potential and important region from the view point of ground water resource.

Almost the entire Central and Southern India is occupied by a variety of hard rocks with hard sediments (including carbonate rocks) in the intertectonic and major river basins. Rugged topography, hard and compact nature of the rocks formations, the geologic structures and meteorological conditions have yielded and environment which allows ground water storage in the weathered residium and its circulation in the underlying fracture systems. The hard rock terrains, river valleys and abandoned channels, wherever having adequate thickness of porous material, act as potential areas for ground water storage and development. It is observed that sustained yield from fracture system down to 200 m is possible in certain hard rock areas of Peninsular India.

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There is a wide variation in the chemical quality of ground water in the country, reflecting the diverse of geohydrological, hydrometeorological, topographic and drainage conditions and artificially imposed conditions, such as surface water irrigation. The coastal and deltaic tracts, particularly in the East Coast, are covered with vast. and extensive alluvial sediment. Though these tracts are productive in terms of water yield yet the overall ground water regime in coastal areas suffer from salinity hazards. Ground water development in coastal areas should be regulated such that contamination of the fresh ground water body with sea water is avoided. Salinity in ground water also exist in inland areas, apart from coastal areas, in parts of Punjab, Haryana, Uttar Pradesh. Rajasthan and Gujarat. This is generally confined to arid and semi-arid regions. In some of the canal command areas where there is progressive rise of water table. it brings about water logging conditions resulting in increase of salinity in the top soils and rendering cultivable land barren. Conjunctive use of surface water and ground water should be practised as an effective method to check the water logging conditions in such areas.

Analysing basin-wise ground water resources potential Table 1.6 it is observed that Ganga basin has the maximum utilisable resources for irrigation having of the country's total ground water resources for irrigation. Godavari basin is the next in terms of utilisable resources, accounting for 10% of the country's resources. As per the utilisation of ground water which has been attained upto 1989-90 (the latest year for which such data is provided by Central Ground Water Board) Ganga basin is utilising 48.64 km which is about 42% of the country's utilisation. Indus is the next higher utiliser, together they account for 56% of country's net draft.

For the country as a whole 70% of the utilisable resources are yet. to be tapped. The stage of development of ground water

resources is more than 50% for Indus. Madras composite and south Tamil Nadu composite and Cauvery basins.

Figure-1.1: Women carrying Ground Water far from Residential Places

Table 1.7: Ground Water Potential in the States and Union Territories of India

(Units: km³/year)

Sl. No	Name of the State/Union Territory	Utilisable Resources for Irrigation	Net Draft (1989-90)	Potential Available for future Development	Stage of Ground Water Development %	Net Draft per million persons
1	2	3	4	5	6	7
1	Andhra Pradesh	36.86	8.78	20.08	23.80	13
2	Arunachal Pradesh	1.22	0.00	1.22	0.00	0
3	Assam	18.42	0.80	17.62	4.33	4
4	Bihar	28.43	5.47	22.96	19.23	6
5	Goa	0.45	0.03	0.42	7.71	3
6	Gujarat	19.13	7.17	12.0	37.40	17
7	Haryana	7.25	5.81	1.43	80.21	35
8	Himachal Pradesh	0.29	0.07	0.22	23.55	1
9	Jammu and Kashmir	3.74	0.05	3.69	1.24	1
10	Karnataka	13.76	3.70	10.06	26.85	8
11	Kerala	6.59	1.01	5.58	15.78	3
12	Madhya Pradesh	50.76	7.33	43.43	14.44	11
13	Maharashtra	32.10	7.74	24.36	24.11	10
14	Manipur	2.68	0.00	2.68	0.00	0
15	Meghalaya	1.04	0.00	1.04	0.00	0
16	Mizoram	------		Not Assessed	------	------
17	Nagaland	0.62	0.00	0.62	0.00	0
18	Orissa	19.79	1.41	18.38	7.13	4
19	Punjab	16.05	15.76	0.29	99.21	78
20	Rajasthan	10.80	5.82	4.98	53.89	13
21	Sikkim	------		Not Assessed	------	------
22	Tamil Nadu	22.43	13.56	8.87	60.44	24
23	Tripura	2.14	0.10	2.04	4.54	4
24	Uttar Pradesh	71.25	26.16	44.54	37.49	91
25	West Bengal	18.74	4.10	14.64	21.90	6
26	Andaman & Nicobar(UT)	------		Not Assessed	------	------
27	Chandigarh (UT)	0.04	0.06	0.02	168.57	9
28	Dadra & Nagar Haveli (UT)	0.04	0.01	0.03	13.89	7
29	Delhi (UT)	0.25	0.22	0.03	88.31	2
30	Daman and Diu (UT)	0.011	0.009	0.002	88.82	9
31	Lakshadweep (UT)	------		Not Assessed	------	------
32	Pondicherry (UT)	0.20	0.01	0.10	50.66	12
	Total	385.12	115.18	261.33	973	371

Source: Ground water statistics, 1992, Central Ground Water Board

Looking at the utilizable ground water resources state wise Table 1.7, it is observed that maximum potential exists in Uttar Pradesh followed by Punjab and Tamil Nadu. Together these states account for 41 % of Country's utilisable ground water resources for irrigation. Among the states maximum level of ground water development in absolute terms have taken place in Uttar Pradesh, followed by Madhya Pradesh and Andhra

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Table 1.6: Ground Water Potential in the River Basins of India

(Units: km³/year)

Sl. No	Name of the Basin	Utilisable Resources for Irrigation	Net Draft (1989-90)	Potential Available for future Development	Stage of Ground Water Development %
1	2	3	4	5	6
1	Indus	21.53	17.34	4.19	80.53
2	Ganga	148.88	48.64	100.24	32.67
3	Kutch and Saurashtra Composite	10.60	5.01	5.59	47.24
4	Chambal Composite	6.66	2.50	4.16	37.55
5	Narmada	10.10	2.03	8.07	20.07
6	Tapi	6.75	1.96	4.79	29.05
7	Subernarekha	1.54	0.13	1.41	8.72
8	Brahmani with Baitarni	4.30	0.31	3.99	7.06
9	Mahanadi	18.09	1.07	17.02	5.90
10	North East Composite	19.37	2.89	16.48	14.92
11	Godavari	39.42	6.87	32.55	14.98
12	Krishna	22.30	6.50	15.80	29.20
13	Pennar	4.29	1.63	2.66	37.90
14	Madras and South Tamil Nadu Composite	15.69	9.00	6.69	57.37
15	Cauvery	10.45	5.71	4.74	54.66
16	Western Ghats	15.10	3.24	11.86	21.45
17	Brahmaputra	22.05	0.78	21.27	3.55
18	Meghna	7.93	0.20	7.73	2.48
	Total	385.10	115.81	269.29	30.07

Source: Ground water statistics, 1992, Central Ground Water Board

Pradesh. Punjab has almost fully utilised its ground water resources available for irrigation. Haryana, Tamil Nadu and Rajasthan are other states which have utilised more than 50% of available ground water resources. Looking at the per capita development of ground water potential, Punjab is way ahead of other states in this respect. Net draft per million persons in Punjab is 78 km which is more than five times the net draft per million persons for the country as a whole. Haryana's per capital net draft is also 2.5 times the national average. Among the major states' Tamil Nadu, Uttar Pradesh and Gujarat also have higher achievements than national average for per capita development of ground water resources.

9. Ground water availability: As of April 2015, the water resource potential or annual water availability of the country in terms of natural runoff (flow) in rivers is about 1,869 Billion Cubic Meter (BCM)/year.2 However, the usable water resources of the country have been estimated as 1,123 BCM/year. This is due to constraints of topography and uneven distribution of the resource in various river basins, which makes it difficult to extract the entire available 1,869 BCM/year.

Out of the 1,123 BCM/year, the share of surface water and ground water is 690 BCM/year and 433 BCM/year respectively. Setting aside 35 BCM for natural discharge, the net annual ground water availability for the entire country is 398 BCM.

The overall contribution of rainfall to the country's annual ground water resource is 68% and the share of other resources, such as canal seepage, return flow from irrigation, recharge from tanks, ponds and water conservation structures taken together is 32%.4 Due to the increasing population in the country, the national per capita annual availability of water has reduced from 1,816 cubic metre in 2001 to 1,544 cubic metre in 2011. This is a reduction of 15%.

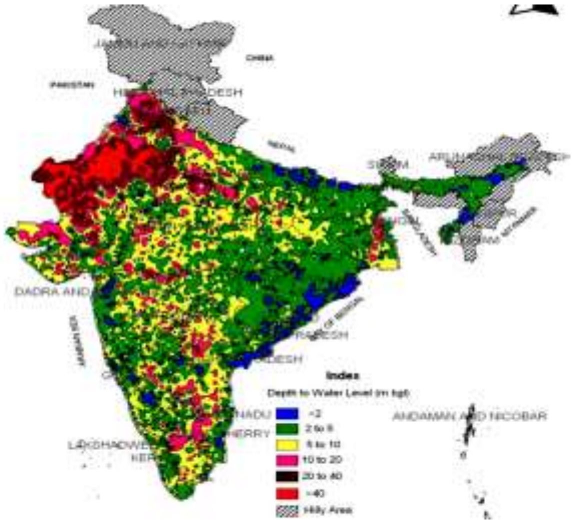
The Map 1 indicates that ground water is available at a lower level in the north-western region of the country. There are other significant pockets across the country where the depth of the water level is more than 10 metres. This implies that one has to dig deeper to reach the water table in these regions. When the ground water level crosses 10 metres, sophisticated equipment is required to extract it. Ground water resources in the country are assessed at different scales within districts, such as locks/mandal talukas/watersheds. round water development is a ratio of the annual ground water extraction to the net

Table 1.8: Status of Ground Water Development in India

Sl. No	Name of the State	Ground Water Development in 2011 (%)
1	2	3
1	Andhra Pradesh	37
2	Arunachal Pradesh	0
3	Assam	14
4	Bihar	44
5	Chhattisgarh	35
6	Delhi	137
7	Goa	28
8	Gujarat	67
9	Haryana	133
10	Himachal Pradesh	71
11	Jammu and Kashmir	21
12	Jharkhand	32
13	Karnataka	64
14	Kerala	47
15	Madhya Pradesh	57
16	Maharashtra	53
17	Manipur	1
18	Meghalaya	0
19	Mizoram	3
20	Nagaland	6
21	Orissa	28
22	Pondicherry	90
23	Punjab	172
24	Rajasthan	137
25	Sikkim	26
26	Tamil Nadu	77
27	Telangana	55
28	Tripura	7
29	Uttar Pradesh	74
30	Uttarakhand	57
31	West Bengal	40
	Total	62

Source: Central Ground Water Board; PRS.

annual ground water availability. It indicates the quantity of ground water available for use. Table 1.8 below compares the level of ground water development in the country over the past two decades.

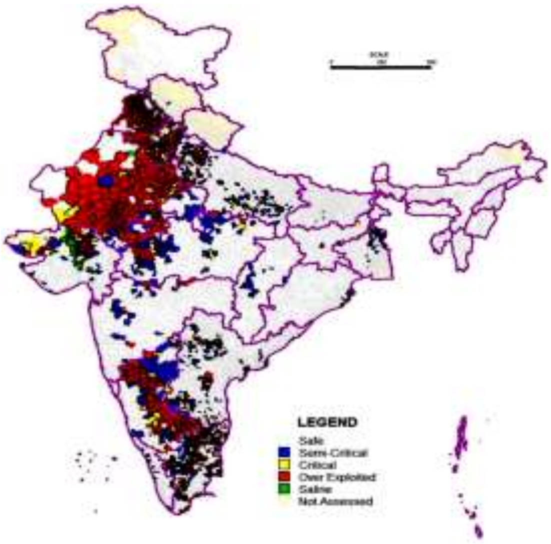


Sources: Central Ground Water Board; PRS.
Note: *Total includes union territories

Map 1: Depth to water level (pre-monsoon, 2014)

The level of ground water development is very high in the states of Delhi, Haryana, Punjab and Rajasthan, where ground water development is more than 100%. This implies that in these states, the annual ground water consumption is more than annual ground water recharge. In the states of Himachal Pradesh, Tamil Nadu and Uttar Pradesh and the Union Territory of Puducherry, the level of ground water development is 70% and above. In rest of the states, the level of ground water development is below 70%. Over the years, usage of ground water has increased in areas where the resource was readily available. This has resulted in an increase in overall ground water development from 58% in 2004 to 62% in 2011, as illustrated in Map 2. accessible and forms the largest share of India’s agriculture and drinking water supply. 89% of ground water extracted is used in the irrigation sector, making it the highest category user in the country. This is followed by ground water for domestic use which is 9% of the extracted groundwater. Industrial use of ground water is

2%. 50% of urban water requirements and 85% of rural domestic water requirements are also fulfilled by ground water.



Sources: Ground water scenario in India, November 2014, Central Ground Water Board; PRS

Map 2: Categorization of ground water assessment units

10. Irrigation through ground water: The largest component of ground water use is the water extracted for irrigation. The main means of irrigation in the country are canals, tanks and wells, including tube-wells. Of all these sources, ground water constitutes the largest share. Wells, including dug wells, shallow tube-wells and deep tube wells provide about 61.6% of water for irrigation, followed by canals with 24.5%. Over the years, there has been a decrease in surface water use and a continuous increase in ground water utilisation for irrigation. As can be seen, the share of tube wells has increased exponentially, indicating the increased usage of ground water for irrigation by farmers. The dependence of irrigation on ground water increased with the onset of the Green Revolution, which depended on intensive use of inputs such as water and fertilizers to boost farm production. Incentives such as credit for irrigation equipment and subsidies for electricity supply have further worsened the situation. Low power tariffs have led to excessive water usage, leading to a sharp fall in water tables. The statistics of water resources in India as shown Table 1.9 below.

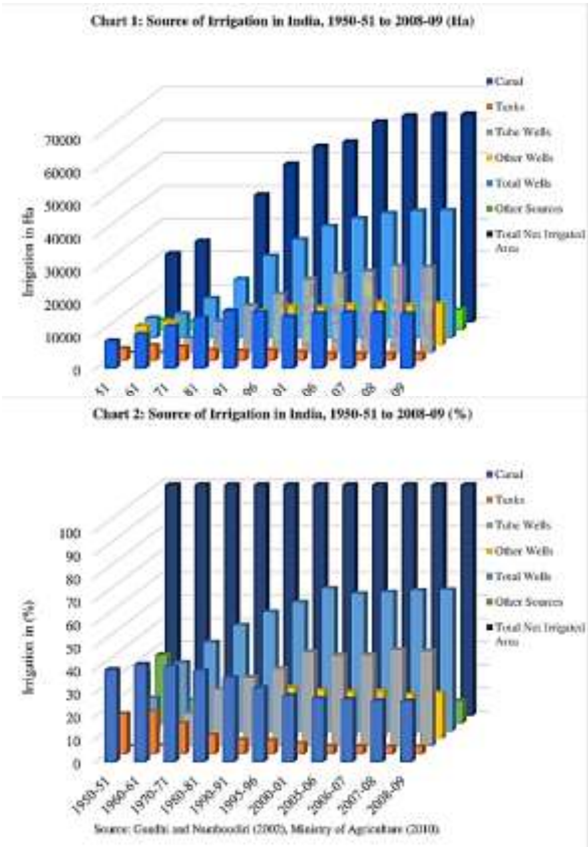


Table 1.9: Statistics regarding water resources in India

Sl. No	Parameter	Unit (Billion Cubic Meter/year)
1	2	3
1	Annual availability	1869
2	Usable water	1123
3	Surface water	690
4	Ground water	433

11. Ground water extraction and use: Experts believe that India is fast moving towards a crisis of ground water overuse and contamination. Ground water overuse or overexploitation is defined as a situation in which, over a period of time, average extraction rate from aquifers is greater than

Table 2.0: States and Districts affected by Geogenic Contamination in Ground Water

Sl. No	Geogenic Contaminants	No. of affected States	No. of affected Districts
1	2	3	4
1	Arsenic	10	68
2	Fluoride	20	276
3	Nitrate	21	387
4	Iron	24	297

Source: Central Ground Water Board; PRS.

the average recharge rate. In India, the availability of surface water is greater than ground water. However, owing to the decentralised availability of groundwater, it is easily accessible and forms the largest share of India's agriculture and drinking water supply. 89% of ground water extracted is used in the irrigation sector, making it the highest category user in the country. This is followed by ground water for domestic use which is 9% of the extracted groundwater. Industrial use of ground water is 2%. 50% of urban water requirements and 85% of rural domestic water requirements are also fulfilled by ground water.

12. Ground water contamination n: Ground water contamination is the presence ofcertain pollutants in ground water that are in excess of the limits prescribed for drinking water. The commonly observed contaminants include arsenic, fluoride, nitrate and iron, which are geogenic in nature Other contaminants include bacteria, phosphates and heavy metals which are a result of human activities including domestic sewage, agricultural practices and industrial effluents. The sources of contamination include pollution by landfills, septic tanks, leaky underground gas tanks, and from overuse of fertilizers and pesticides. It has been pointed out that nearly 60% of all districts in the country have issues related to either availability of ground water, or quality of ground water, or both. Table 2.0 shows the number of states and districts affected by geogenic contaminants as on July 2014.

The Committee on Estimates 2014-15 that reviewed the occurrence of high arsenic content in ground water observed that 68 districts in 10 states are affected by high arsenic contamination in groundwater. These states are Haryana, Punjab, Uttar Pradesh, Bihar, Jharkhand, Chhattisgarh, West Bengal, Assam, Manipur and Karnataka.

13.Water Degradation: Water degradation (or water depletion) is the misuse and also the pollution of water supplies. Often, individuals throughout the world have to deal with either limited water supplies, or polluted water, often causes by human actions. While there are a number of factors that causes water degradation, among the main actors responsible are humans.

Factors that causes and effects of water degradation:

i) A lack of water, as well as worsening conditions of water are just some of the effects of human behavior as it pertains to the world's water supply.

ii) In fact, as pollution and mismanagement of water continues, there will continue to be many implications of these activities on water degradation.

iii) Specifically, "Decreased water quantity results in a reduction of water available for such uses as drinking and irrigation. Because there is less water, there is usually a greater concentration of pollutants and salinity in the water.

iv) This causes the quality of the stream bed to deteriorate, resulting in a reduced biodiversity of plants and animals."

v) In addition, Human health is at risk with the degradation of our water supply.

vi) Pathogens concentrated in our water can cause serious health problems to both humans and animals.

vii)Higher standards of living and longevity are directly related to the reduced incidence of certain diseases.

viii) Many of these diseases are related to the quality of water (including cholera, diptheria and typhoid)" (disweb.rmit.edu).

ix) In fact, “the United Nations reports that over half of the world’s hospital beds are occupied by people suffering from illnesses linked to contaminated wage, and more people die each year from polluted water than are killed in all forms of violence including wars” (Rowntree, Lewis, Price, & Wyckoff, 2015: 57). Plus, the issue of water degradation has also impacted children. Take the case of Haiti, for example. Scholars point out that “even before the 2010 earthquake, almost 20% of all deaths of children under five were directly tied to waterborne diseases”.

x) The same authors also argue that the figures could be higher, given the issue of limited clean water at internally displaced persons camps within Haiti.

Figure 1.2: Water pollution

In addition, we need to be mindful of other effects of water degradation. For example, “With a reduction in water quality comes additional costs – the cost of treating the water to a standard that is acceptable and the cost of acquiring alternative water if treatment of the current water supply is not possible. In the event of our water supplies being degraded to an unacceptable level or reduced, we need to consider reuse and recycling options. Such options would include biological toilets and air cooling”.

Moreover, if clean water is not accessible nearby, this can place additional strains on individuals who not have to go look for clean water sources. As some point out, “women and children, for example, often bear the burden of providing water for family use, and this can mean walking long distances to pumps and wells and then waiting in long lines to draw water. The result is that their daily time budget for other activities, such as school or work, is severely curtailed.

In the United States, the country is facing serious water degradation issues. Here, communities not only have water pollution that they have to deal with, which could impact their health, but despite laws to counter pollution, the challenges of water degradation continue to exist. Some companies, in their work, are polluting waters with toxic chemicals (Rowntree, Lewis, Price, & Wyckoff, 2015: 72).

14. Water pollution: Water pollution is any chemical, physical or biological change in the quality of water that has a harmful effect on any living thing that drinks or uses or lives in it. When humans drink polluted water it often has serious effects on their health. Water pollution can also make water unsuited for the desired use.

Water pollution is the contamination of water bodies, usually as a result of human activities. Water bodies include for example lakes, rivers, oceans, aquifers and groundwater. Water pollution results when contaminants are introduced into the natural environment.

Water pollution is one of the biggest issues facing India right now. As may be evident, untreated sewage is the biggest source of such form of pollution in India. There are other sources of pollution such as runoff from the agricultural sector as well as unregulated units that belong to the small-scale industry. The situation is so serious that perhaps there is no water body in India that is not polluted to some extent or the other.

In fact, it is said that almost 80% of the waterbodies in India are highly polluted. This is especially applicable of ones that some form or the other of human habitation in their immediate vicinity. Ganga and Yamuna are the most polluted rivers in India.

14.1. Causes of water pollution in India: The single biggest reason for water pollution in India is urbanization at an uncontrolled rate. The rate of urbanization has only gone up at a fast pace in the last decade or so, but even then, it has left an indelible mark on India's aquatic resources. This has led to several environmental issues in the long term like paucity in water supply, generation and collection of wastewaters to name a few.

The treatment and disposal of wastewater has also been a major issue in this regard. The areas near rivers have seen plenty of towns and cities come up and this has also contributed to the growing intensity of problems. Uncontrolled urbanization in these areas has also led to generation of sewage water. In the urban areas water is used for both industrial and domestic purposes from waterbodies such as rivers, lakes, streams, wells, and ponds. Worst still, 80% of the water that we use for our domestic purposes is passed out in the form of wastewater. In most of the cases, this water is not treated properly and as such it leads to tremendous pollution of surface-level freshwater.

This polluted water also seeps through the surface and poisons groundwater. It is estimated that cities with populations of more than one lakh people generate around 16,662 million litres of wastewater in a day. Strangely enough, 70% of the people in these cities have access to sewerage facilities. Cities and towns located on the banks of Ganga generate around 33% of wastewater generated in the country

Figure 1.3: Polluted water poison

Following are some other important reasons of increasing levels of water pollution in India:

1. Industrial waste
2. Improper practices in agricultural sector
3. Reduction in water quantity in rivers in plains
4. Social and religious practices like dumping dead bodies in water, bathing, throwing waste in water
5. Oil leaks from ships
6. Acid rain
7. Global warming
8. Eutrophication
9. Inadequate industrial treatment of wastes
10. Denitrification

14.2. Effects of water pollution in India: Water pollution can have some tremendously adverse effect on the health of any and every life form living in the vicinity of the polluted water body or using water that has been polluted to some extent. At a certain level polluted water can be detrimental to crops and reduce the fertility of soil thus harming the overall agricultural sector and the country as well. When sea water is polluted it can also impact, oceanic life in a bad way. The most fundamental effect of water pollution is however on the quality of the water, consuming which can lead to several ailments.

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In fact, as far as India is concerned polluted water is one of the major factors behind the general low levels of health in India, especially in the rural areas. Polluted water can lead to diseases such as cholera, tuberculosis, dysentery, jaundice, diarrhoea, etc. In fact, around 80% stomach ailments in India happen because of consuming polluted water.

Figure 1.4: Industrial waste

14.3. Solution of water pollution in India: The best way to solve these issues is to prevent them. The first major solution in this context is conservation of soil. Soil erosion can contribute to water pollution. So, if soil can be conserved, we can prevent water pollution too. We can follow measures such as planting more trees, managing erosion in a better way, and use farming methods that are better for the soil. In the same vein it is also important to follow the right methods in disposing toxic waste. For starters, we can use products that have lesser amounts of volatile organic compounds in them. Even in cases where toxic material like paints, cleaning supplies, and stain removers are used, they need to be disposed off in the right way. It is also important to look into oil leaks in one’s cars and machines.

It is said that leaked oil even from cars and machines is one of the principal contributors to water pollution. Hence, it is important to look at cars and machines, which run on oil, on a regular basis, to check them for any possible oil leak. It is important after work especially in factories and production units where oil is used to clean up the wasted oil and either dispose it properly or keep it for later use. Following are some other ways in which this problem can be addressed adequately:

1. Cleaning up waterways and beaches
2. Avoiding the usage of non-biodegradable material like plastic
3. Being more involved in various measures pertaining to preventing water pollution.

15. Water resources management in India: India is facing a serious problem of natural resource scarcity, especially that of water in view of population growth and economic development. The annual average rainfall in the Indian terrain is a healthy 1869 Km^3 which is much more the world average. The rainfall in India shows a very high spatial and temporal variability. That indeed is the reason for water resource management becoming a complex affair in India, for, the rainfall that is received during this short period has to be distributed for a variety of activities.

Traditionally India has been agriculture-based economy and hence is the importance of development of irrigation schemes so as to reduce the dependence on ground water by effective utilisation of the river waters. The annual potential groundwater recharge from rainfall in India is about 342.43 Km^3, which is 8.56 % of the total annual rainfall of the country. While rain is a vital source of water for almost the whole of the Indian peninsula, the snowmelt from the glaciers of the Himalayan belt is a significant contributor to the water source to the valley parts and the foothill region of the Himalayas. While an exact value of water resources of the country is a difficult ask, estimates of the water resources has been done in a comprehensive manner by the Ministry of Water Resources. An analysis of the resources gives a very rosy picture, however the complexities involved in harnessing the resources in an optimum manner is what is causing nightmares to the ministry. There is a need to ensure a delicate balance between the inflows to the water resources of a region and the outflow components.

The National Water Policy stipulates that the total quantity of nation's ground water pumped out must be limited to annual recharge. Scientist using NASA's Gravity Recovery and Climate Experiment (GRACE) satellites have determined that ground water in North Western region of India is decreasing at a alarming rate. If the ground water table goes down the government will be forced to think of alternatives which is more efficient use of river waters. The facts state that though water resource availability is adequate till year 2020 but because of the current rate of growth of the population the availability will become critical after 2020. Also, the fact that India will be forced to look at other sources of river water than those granted by the IWT.

15.1 Drought: The drought prone area assessed in the country is of the order of 68% of the total land mass which is roughly equivalent to 51.12 M.ha. Many interior parts of peninsular India, such as the Deccan plateau, Southern and Central India come under the grips of dry spells even in the monsoon season itself due to scanty rainfall. Drought is not the result of a single cause, but a cumulative effect of many causes. Not only the availability of water for irrigation of agricultural lands is acutely hit, but also the day to day life is subjected to inconvenience due to shortage of water for personal use.

History has chronicled several droughts in India, and no part of India has escaped dry spells due to failure of monsoons and the resultant drought. A disturbing fact as an offshoot of drought conditions is that even crime rates such as robbery and looting steeply increase, as a sequel to the migration of people affected by drought looking for a decent life, but taking to unsocial activities in the absence of job opportunities. Also, it is during these times that sharing of river water by riparian states is a cause for concern. What is paradoxical is that states which have a long coastline or lesser water resources at their areas have not taken any steps to come out of this problem by way of concentrating on desalination, drip irrigation, rain harvesting changing crop pattern requiring less water etc.

15.2 Drought prone areas in India: The total area affected by inadequate rainfall is a little over one million square kilometres. The areas which are drought prone are Thar Desert terrain, Kalahandi- Koraput belt, areas such as North Arcot, (Tamil Nadu) Anantpur and Chittoor (Andhra Pradesh) Bellary and Bijapur (Karnataka) Osmanabad and Aurangabad (Maharashtra). Most of the areas in this rain shadow zone is densely populated with hard working, knowledgeable and enterprising people. There are several towns having more than 100,000 population, besides innumerable villages situated in this zone. Sparse vegetation, Pediment type of wastelands and deep levels of ground water table make life difficult in these places. Wastelands dominate over cultivable fields and in the cultivable lands too only one crop is grown in a year. Proper water management in this terrain is capable of transforming the arid to semi-arid conditions to a highly productive areas This area is ideal for drip/ sprinkler irrigation to reclaim the drought affected areas. Examples exist as is done at Israel.

A few more pockets of chronic drought prone areas are- Ramanathpuram and Thirunelveli districts of Tamil Nadu, the linear corridor between Coimbatore and Pallakad and the Saurashtra and Kachchh regions of Gujrat. Also reports of arable lands

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situated slightly further away from the flood plains and the Deltaic regions of Ganges, Godavari, Krishna and Cauvery rivers coming under the grip of water scarcity for agricultural activities. Locations like Kodaikanal, Udhagamandalam and Nilgiri hills in Tamil Nadu, and Dehradun and Mussorie in Uttaranchal are examples of excessive human interference leading to unsustainable urban development and decadent imbalance in availability of water resources in areas otherwise known for copious rainfall.

A generation ago farmers in Gujrat used bullocks to lift water from shallow wells in leather buckets. Now farmers draw water from 300 metres below ground using electrical pumps. According to state water officials, water tables are dropping by 6 metres every year. India had a pump revolution in the last four decades and farmers have drilled approximately 21 million tube wells into the saturated strata beneath their fields. Every year farmers bring another million wells into service mostly outside the control of state irrigation authorities. These pumps powered by subsidised electricity work day and night to irrigate fields of more water consuming crops like rice, sugarcane and alfalfa.

The problem is serious and severe and keeping in view that agriculture is the backbone of our economy, replenishment methods like placing numerous dams across river beds, water harvesting and water shed schemes to recharge our underground resources besides flood management need to be given the right impetus. In crop production there is a need to encourage modern methods of irrigation.

In spite of an abundance of water resources it has not been easy for the state to tap these resources. Discussion of internal water disputes is far beyond the scope of the dissertation and is therefore not being mentioned; however, one disagreement due to the distribution of water of the Indus river system is worth having a look. Disagreement over the sharing of river waters from the Indus river system has been one of the major causes of the violent secession movement in the Punjab province of India in the 1980s and 1990s. This Sikh dominated province has been traditionally provided with a water supply from the Beas, Sutlej and Ravi Rivers. The demands of the downstream provinces of Rajasthan and Haryana persuaded the Indian government to construct canals and divert 60 per cent of Punjab's water and energy to Hindu majority regions. This became a major point of confrontation due to which insurgency was encouraged.

15.3 Floods: India is highly vulnerable to

floods. Out of the total geographical area of 329 million hectares (M. ha), more than 40 M. ha is flood prone. Floods are a recurrent phenomenon, which cause huge loss of lives and damage to livelihood systems, property, infrastructure and public utilities. It is a cause for concern that flood related damages show an increasing trend. The average annual flood damage in the last 10 years period from 1996 to 2005 was Rs. 4745 crores as compared to Rs. 1805 crore, the corresponding average for the previous 53 years. This can be attributed to many reasons including a steep increase in population, rapid urbanization growing developmental and economic activities in flood plains coupled with global warming.

An average every year, 75 lakh hectares of land is affected, 1600 lives are lost and the damage caused to crops, houses and public utilities is Rs.1805 crores due to floods. The maximum number of lives (11,316) was lost in the year 1977. The frequency of major floods is more than once in five years.

Floods have also occurred in areas, which were earlier not considered flood prone. An effort has been made in these Guidelines to cover the entire gamut of Flood Management. Eighty per cent of the precipitation takes place in the monsoon months from June to September. The rivers a bring heavy sediment load from catchments. These, coupled with inadequate carrying capacity of rivers are responsible for causing floods, drainage congestion and erosion of river-banks. Cyclones, cyclonic circulations and cloud bursts cause flash floods and lead to huge losses. It is a fact that some of the rivers causing damage in India originate in neighboring countries; adding another complex dimension to the problem. Continuing and large-scale loss of lives and damage to public and private property due to floods indicate that we are still to develop an effective response to floods. NDMA's Executive Summary Guidelines have been prepared to enable the various implementing and stakeholder agencies to effectively address the critical areas for minimising flood damage.

Map 3: Area Liable to Floods

15.4 Water Demand and Resource Management: If the total water availability in India is analysed that the logical conclusion would be that that there is adequate water for all. However, water availability on the Indian subcontinent is strongly influenced by a number of climatic and geographic factors. Together these combine to provide India with enough freshwater to meet the various demands arising from the agricultural, industrial and domestic sectors. However, the actual distribution of water resources over space and time limits access to certain geographic regions and during a few months of the year. Government policies and economic incentives have also influenced the water distribution and consumption across India.

In view of the existing status of water resources and increasing demands of water for meeting the requirements of the rapidly growing population of the country as well as the problems that are likely to arise in future, a holistic, well planned long-term strategy is needed for sustainable water resources management in India. The water resources management practices may be based on increasing the water supply and managing the water demand under the stressed water availability conditions. Data monitoring, processing, storage, retrieval and dissemination constitute the very important aspects of the water resources management.

These data may be utilized not only for management but also for the planning and design of the water resources structures. In addition to these, now days decision support systems are being developed for providing the necessary inputs to the decision makers for water resources management. Also, knowledge sharing, people’s participation, mass communication and capacity building are essential for effective water resources management. Water conservation implies improving the availability of water through augmentation by means of storage of water in surface reservoirs, tanks, soil and groundwater zone. It emphasizes the need to modify the space and time availability of water to meet the demands. This concept also highlights the need for judicious use of water. There is a great potential for better conservation and management of water resources in its various uses. On the demand side, a variety of economic, administrative and community-based measures can help conserve water. Rainwater harvesting is the process to capture and store rainfall for its efficient utilization and conservation to control its runoff, evaporation and seepage another way through which we can improve freshwater availability is by recycle and reuse of water. It is said that in the city of Frankfurt, Germany, every drop of water is recycled eight times. Use of water of lesser quality, such as reclaimed wastewater, for cooling and firefighting is an attractive option for large and complex industries to reduce their water costs, increase production and decrease the consumption of energy. This conserves better quality waters for potable uses. Currently, recycling of water is not practised on a large scale in India and there is considerable scope and incentive to use this alternative. Another strategy, which needs consideration, is changes in water pricing structures.

16. Conclusions:

India is a vast country with a wide variety of climate and hydrological environments, snow clad mountains of the Himalayas in the north, a long coastline in the south, desert in the western part, alluvial plains to the north and hard rock regions to the south. The rainfall is seasonal in nature and most of it falls during the five monsoon months (June to October) with erratic patterns leading to floods as well as droughts in different parts of the country. To meet the increasing demands of the growing population, there has been considerable development of water resources in the country. The increasing rate of water resource devotement activity and utilization of water for various uses including domestic and industrial purposes, has focused attention on various hydrological aspects of surface water and ground water resources. The application of the science of hydrology is increasingly becoming necessary in all aspects and all stages of water resource development and management.

The ground water hydrology is a combination of concepts and perspectives that pertains to the scientific, engineering and management aspects of ground water in the hydrological cycle. It encompasses the occurrence, origin, movement, quality. recovery and use of ground water. At present, utilisation of ground water has become a tenet in every nation's water resources development policy. The rational limit of ground water exploitation is that quantity which may be withdrawn a ground water reservoir with a prescribed development policy during a definite planned period taking into account the technical and the economic efficiency and the water quality within the adopted standard. The rational limit of the rate of ground water exploitation should be such that protection from depletion and from pollution is adequately provided, negative ecological effects are reduced to a minimum, and economic efficiency of exploitation is attained.

India with a geographical area of 329 million hectares receives the annual precipitation-of about 4000 km^3, including snowfall. Out of this seasonal rainfall is of the order of 3000 km^3. The availability of water shows a great deal of variability from-place to place. The ultimate irrigation potential from major, medium and minor irrigation schemes is estimated at 113 M. ha of which 58 M. ha.is from major and medium schemes and 55 M. ha from minor irrigation schemes. The surface water resources of the country in the form of-average annual flow in the river systems are estimated to be about 1881.12 km^3. Due to the

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topographic, hydrological and other constraints, it is assessed that only 700 km^3 of surface water may beneficially utilized by the conventional methods of development. The utilizable ground water potential of India for irrigation has been assessed as 385.10 km^3 per year, and the net draft of ground water for the year 1989-90 has been estimated as 115.81 km^3 /year. The annual requirement of fresh water for various uses for the year 1985 was 540 km^3. It is assessed to be about 750 km^3/year by the year and about 1050 km^3/year by the 2025.

Reference

1. Linsley, R K and Franzini, J B (1979) "Water Resources Engineering", Third Edition, McGraw Hill, Inc.

2. Mays, L (2001) "Water Resources Engineering", First Edition, John Wiley and Sons

3. "Water Resources of India", Rakesh Kumar, RD Singh and KD Singh, Current Science, Vol 89, No 5, Sep 2005, pp794.

4." Alarming Scarcity of Water in India", NK Garg and Q Hassan, Current Science Vol 93 No 7 10 Oct 2007.

5. National Water Resource at a Glance Wrmin.nic.in accessed on 18 Nov 2009.

6. Rakesh Kumar, R D Singh & K D Sharma Water Resources of India.

7. Indian Ministry of Water Resources, National Water Policy. Retrieved 09 Nov 2009 from GRACE reveals ground water dept.

8. Drought in India, Challenges and Initiatives, p5, PACS Programme 2001-08.

10. Harendar Raj Goutam Water Crisis and Rain Water Harvesting Kurukshetra Quaterly p4.

11." Managing Water Conflicts" by Ashok Swain, pp 21.

12." Water privatization and Implications in India", Anitha Sampath, Association for India's Development.

13. ADB, 2007. Institutional Options for Improving Water Management in India: The Potential Role of River Basin Organization, a publication of Asian Development Bank, New Delhi, India (Publications stock No. 110507).

14. CDNWFL, 2013. Report of the Committee for Drafting of National Water Framework Law. Ministry of Water Resources, Government of India, New Delhi.

15. Goyal, V.C. and Singh, O., 2014. Pilot Basin Studies in India Using IWRM Concept: Building Partnership with Stakeholders. International Symposium on Integrated Water Resources Management, CWRDM, Kozhikde, Kerala, India, 1153-1159.

16. Grigg, N.S., 1996. Water Resources Management: Principles, Regulations, and Cases. McGraw-Hill, New York.

17. Gulhati, N.D., 1968. Inter-State River-Cooperative Approach Essential for Optimum Development, India. Journal of Public Administration, 14(4).

18. Harsh, J., 2012. IWRM and IRBM concepts envisioned in Indian water policies. Current Science, 102(7), 986-990.

19. Mahto, S. and Srivastava, R., 2012. Need for Integrated Water Resources Management in India. India Water Week 2012 - Water, Energy and Food Security: Call for Solutions, New Delhi.

21. NCIWRDP, 1999. Report of National Commission for Integrated Water Resources Development Plan. Ministry of Water Resources, Government of India.

22. NWM, 2010. Draft Guidelines for Integrated Water Resources Development and Management. National Water Mission, Government of India, Central Water Commission, Basic Planning and Management Organization, New Delhi.

23. NWP, 2012. National Water Policy. Ministry of Water Resources, Government of India, p. 2.

24. Shah, A. and Prakash, A., 2010. Integrated Water Resource Management in India: From Critique to Constructive Engagement. Central Research Institute for Dryland Agriculture, Hyderabad, India, 333-346.

25. UNEP-DHI, 2009. Integrated Water Resources Management in Action. World Water Assessment Programme, DHI Water Policy, UNEP-DHI Centre for Water and Environment.

26. Chadha, D.K. (2006). Development and management of ground water resources of India: an Overview. In Groundwater Modelling and Management, edited by N.C. Ghosh and K.D.
Sharma, Capital Publishing Company, New Delhi.

27. CPCB (1999) Water Quality Status and Statistics 1996 & 1997. Central Pollution Control Board, New Delhi, 403 pp.

28. Government of India (2008). National Water Mission, under National Action Plan on Climate Change: Comprehensive Mission Document, Volume – II. Ministry of Water Resources, New Delhi.

29. IWRS (2001). "Theme paper on management of Floods and droughts" Water Resources Day, Indian Water Resources Society.

30. Jain, S.K., Agarwal, P.K., and Singh, V.P. (2007). Hydrology and Water Resources of India, Springer, the Netherlands. .

31. MoWR (2003) Problems Facing the Water/Irrigation Sector: Water Quality Issues. Ministry of Water Resources,

32. National Water Policy (2002) Ministry of Water Resources, Government of India, New Delhi.

33. NCIWRD (1999) Integrated Water Resources Development – A Plan for Action. Report of The National Commission for Integrated Water Resources Development. Ministry of Water Resources, Government of India, New Delhi.

34. RBA (1980). Report of Rashtriya Barh Ayog (National Flood Commission), Ministry of Irrigation, Government of India, New Delhi.

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Journal Publications

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1. “Indian Scenario of Water Resources - An Overview, Integrated Water Management and Major Issues related to Indian Waters " in ISSN:2321-7758, Vol.6., Issue.5, 2018 Sept-Oct., PP 64-70, International Journal of Engineering Research by Venkata Raju. B

2. “An Overview of Integrated theory of Irrigation Efficiency and Uniformity and Crop Water Use Efficiency Indian Waters " in ISSN:2321-7758, Vol.6., Issue.6, 2018 Nov-Dec., PP 11-26, International Journal of Engineering Research by Venkata Raju. B