1 INTRODUCTION

Water is a vital natural resource which forms the basis of all life. It is very important tool for human development, a key resource in all economic activities ranging from agriculture to industry. With ever increasing pressure of human population, there is severe stress on water resources. The finite nature of renewable fresh water makes it a critical natural resource to examine in the context of population growth. Our capacity for capturing and storing fresh water has expanded throughout history, and we are learning how to use it more efficiently.

Only a tiny fraction of the planet's abundant water is available to us as fresh water. About 97% of the total water on earth is found in the oceans and is too salty for drinking, irrigation, or industry. The remaining 3% is fresh water. About 2.997% of it is locked up in ice caps or glaciers or is buried so deep that it costs too much to extract. Only about 0.0035 % of Earth's total volume of water is easily available to us as soil moisture, exploitable ground water, water vapor, and lakes and streams.

The total quantity of groundwater on Earth is estimated as more than 50 million cu.km. of this, 4 million cu.km. is considered as a reasonable quantity of fresh water that could be exploited, which excludes water that will not drain from small pore spaces, saline water and water lying deep in confined aquifers. The distribution of Earth's Water Resources are given in Table 1.1 (Reference : Anjaneyulu Y., "Introduction to Environmental Science".)

1.1 Water Resources of World

The present global population of 6.185 billion is expected to rise to 8.303 billion by the year 2025. Current water demand of about 6,650 km^3 to produce plant food is expected to rise to 9,000 km^3 by 2025.

At present, the demand for water is growing by 2.4% per year. Total water use in the world has increased as follows

1000 km^3/year in 1940

4130 km^3/year in 1990

5000 km^3/year in 2000

6650 km^3/year in 2002

Table – 1.1 Earth's Water Resources

Water Resource	Volume (Thousands of Km^3)	% Total Water
Total	14,03,377	100
Ocean	1370000	97.6
Ice and snow	29,000	2.07
Groundwater down to 1 km	4000	0.28
Lakes and reservoirs	125	0.009
Saline lakes	104	0.007
Soil moisture	65	0.005
Biological moisture in plants and animals	65	0.005
Atmosphere	13	0.001
Swamps and marshes	1.7	0.0001
Rivers and streams	1.7	0.0001

(Source : Anjaneyulu Y, "Introduction to Environmental Science", BS Publications, Hyderabad)

At least one fifth of the world's people lack access to safe drinking water. 80 countries account for 40% of the world's population. Forecasts are that by 2025 as much as 2/3 of the world's population will be affected by moderate to severe water scarcity unless appropriate mitigation measures are taken. The number of countries having water shortage at present is 28 (population 315 million), and by 2025, this number will increase to 50 (including India) involving a population of 3 billion. The demand for usable water, like any other resource, is increasing fast with the continuous increase in per capita demand, prolific use of water using gadgets and increased recreational activities. It is now the urgent need to raise the awareness of the importance of protecting the Earth's freshwater resources. (Reference : Anjaneyulu Y., "Introduction to Environmental Science".)

There is tremendous increase in the Global Water usage in different sectors like agricultural, industrial and domestic. However there is considerable variety how these resources are used in different parts of the world.

The total quantity of groundwater on Earth is estimated at more than 50 million cu. km. Out of this, 4 million cu.km is considered as a reasonable quantity of fresh water that could be exploited, which excludes water that will not drain from small pore spaces, saline water and water lying deep in confined aquifers.

Depletion of groundwater sources due to the withdrawal of water at a rate far exceeding the natural recharge rate is currently a matter of global concern.

1.2 Water Resources of India

India occupies a strategic position in Asia, looking across the seas to Arabia and Africa on the west to Burma, Malaysia to the east end. Geographically Himalayan ranges keep India apart from the rest of Asia. Water in India is not only a usable commodity but a very sentimental and religious value is attached to it, spiritual cultures of India have mushroomed on the banks of various holy rivers, abundance and greenery of India had attracted many invaders.

In India, out of total rainfall in an area of 3290 lakh hectares, a rainfall of 4000 BCM (Billion Cubic Meters) annually occurs. Out of the total, 41 % is lost in evaporation, 40% is lost as run off, 10% is retained as soil moisture and 9% seeps in for recharging ground water. Out of total available water resource 1869 BCM, the usable; water resources are only 1122 BCM, which consists surface water 690 BCM, ground water 432 BCM. The present per capita available water resources is 1122 m^3 and by 2050 it is likely to reduce to 748 m^3. When the countries per capita water availability is less than 1700 m^3 it is considered as water stress country. Table 1.2 gives account of India's water budges with estimated water demand in 2025.

Table – 1.2 India's Water Budget

Category	1985		2000		2025	
	Surface Water (BCM)	Ground Water (BCM)	Surface Water (BCM)	Ground Water (BCM)	Surface Water (BCM)	Ground Water (BCM)
Domestic/live stock	16.70		28.70		40.00	
Industries	10.00		30.00		120.00	
Thermal power	2.70		3.30		4.00	
Miscellaneous	40.60		58.00		116.00	
Subtotal	40	30	80	40	1990	90
Irrigation	320	150	420	210	510	260
Subtotal	360	180	500	250	700	350
Total	**540**		**750**		**1,050**	

(Source : Anjaneyulu Y, "Introduction to Environmental Science", BS Publications, Hyderabad)

From the increased activities in the water sector lately, one can infer that overall awareness about importance of water has increased. Increasing demand and decreasing availability of fresh water is bound to result in water scarcity in near future. Some parts of the world are already recognized as water-scare areas while water scarcity in other parts is predicted to be round the corner. It is now widely accepted that the solution to the water scarcity lies only in efficient use of available water by good water management.

1.3 Water Resources of Gujarat

Water resources of the Gujarat are divisible into two distinct categories Surface Water Resources and Ground Water Resources. Gujarat State can be divided in to four physiographic regions, North Gujarat, South Gujarat, Saurashtra and Kachchh.

1.3.1 Surface Water Resources

Out of 37392.57 Mm^3 total available surface water resources, storage of 26340.82 Mm^3 surface water resources is in the reservoirs of existing major, medium and minor Irrigation Projects and 1144.74 Mm^3 surface water resources in existing recharge structures is kept as committed resources. Remaining 11137.83 Mm^3 is available surplus surface water resources.

1.3.2 Ground Water Resources

Gujarat Water Resources Development Corporation (GWRDC), Gandhinagar and regional office of the Central Ground Water Board (CGWB), Ahmadabad have worked out Talukawise dynamic ground water resources of the State for the Year 2004. As per this report, the total annual replenishable ground water resource is about 1512434 ha m. After making a provision of 147740 ha.m. for domestic, industrial and other uses, the net annual ground water availability is 15020.38 ha m. Against this the annual ground water draft from all sources is 1196907 ha m including allocation for domestic and industrial requirement supply up to next 25 years. Thus, the stage of ground water development for the state as a whole, works out to be 79.69%. The areas categorized as "Over-exploited" where the stage of ground water development exceeds the annual replenishable limit and "Critical" where the stage of ground water development is more than 90% face ground water scarcity and need further augmentation through suitable artificial recharge techniques. (Draft Report on identification of feasible areas for managed aquifer recharge in Gujarat State, Task Force constituted by Government of Gujarat, (November 2008)). Following table No. 1.3 gives overall account of surface and ground water resources of Gujarat State.

Table – 1.3 Surface And Ground Water Resources of Gujarat

Region	Surface Water Mm³	Ground Water Mm³	Total Mm³
North Gujarat	31750	3950	35700 (71.40 %)
Central and South Gujarat	3600	4300	7900 (15.80 %)
Saurashtra	3300	2000	5300 (10.60 %)
Kachchh	650	450	1100 (2.20 %)
Total	38000	12000	50000

Source: Ph.D. Thesis of Dr. M. S. Patel, Impact of Check Dams on Ground Water Regime and Existing Irrigation Project of Rajkot District, Saurashtra Region of Gujarat State.

1.4 Rivers

The river runoff is one of the main sources of fresh water which meets various water demands. Though it is continuous and renewable by the hydrological cycle, river runoff represents the dynamic component of the total water resource, in contrast to the less mobile volumes of water contained in lakes and groundwater reservoirs. Table 1.4 contains details of the drainage areas of the rivers in different regions of the world. (Reference: Anjaneyulu Y.,"Introduction to Environmental Science")

Table – 1.4 Location and Drainage Area of the World's Largest Rivers

River	Location	Drainage Area 10^6 Km^2
Amazon	America (south)	6.15
Zaire	Africa	3.82
Orinoco	South America	0.99
Jansei (Yangtze)	Asia (China)	1.94
Brahmaputra	Asia	0.58
Mississippi	North America	3.27
Yenisei	Asia (Russia)	2.58
Lena	Asia (Russia)	2.49
Mekong	Asia (Vietnam)	0.79
Ganges	Asia	0.97
St. Lawrence	North America	1.03
Parana	South America	2.60
Irrawaddy	Asia (Burma)	0.43
MacKenzie	North America	1.81
Columbia	North America	0.67
Indus	Asia (India)	0.97
Hunagho (Red)	Asia (Vietnam)	0.12
Huanghe (Yellow)	Asia (China)	0.77

(Source Berner and Berner, 1996)

1.4.1 Rivers and River Basins of India

The rivers in India can be classified as

a) Himalayan water system (Indus, Ganga, Brahmaputra, Chinab, Jhelum, Ravi and Beas)

b) Deccan Plateau water system (Narmada,Tapti, Mahanadi, Godavari, Krishna, Periyar)

c) Coastal water systems and

d) Others, including inland water systems.

Table 1.5 gives the drainage area of some major Indian rivers.

Table – 1.5 Stream Flow and Drainage Areas of Major Indian River System

River Basin	Annual Stream flow (cu.km.)	Drainage Area (sq.km.) x 10^3
Indus	321	42
Ganga	550	975
Brahmaputra	590	580
Godavari	115	312
Mahanadi	131	141
Krishna	57	259
Cauvery	18	88
Narmada	40	99

(Source: K.L. Rao, India's Water Wealth, Orient Longman (1975), and National Seminar on "New Perspectives in Water Management")

The water resources of India drain from 19 major drainage basins. The largest drainage area, Ganga-Brahmaputra-Meghna, covers 34 percent of the area of the country. This basin has three rivers-Ganga, Brahmaputra, and Meghna-that join before draining into the Bay of Bengal. The Ganga, the largest river basin, covers a substantial area, with climate ranging from monsoonal in Uttar Pradesh, Madhya Pradesh, Bihar and West Bengal to arid in Haryana and Rajasthan in the west There are four other large basins.

The basin of the Indus River that flows in a southwesterly direction to Pakistan covers 10 percent of the total drainage area of India. The basins of the Godavari, Krishna and Mahanadi rivers draining to the sea in the east cover 22 percent of the total drainage area. Eight other medium-sized basins-of the Sabarmati, Mahi, Narmada and Tapi rivers flowing west and the Subarnarekha, Brahmani-Baitarani, Pennar and Cauvery Rivers flowing East covers 15 percent of the total drainage area. The remaining small river basins are divided into four major drainage areas. These are the basins of:

a. The westerly flowing rivers in the Kutch and Saurashtra regions of the state of Gujarat, and the Luni river
b. The westerly flowing rivers south of the Tapi basin
c. The easterly flowing small and medium-sized rivers between the Mahanadi and Pennar basins;
d. The easterly flowing small and medium-sized rivers between the Pennar basin and Kanyakumari at the southern tip of India

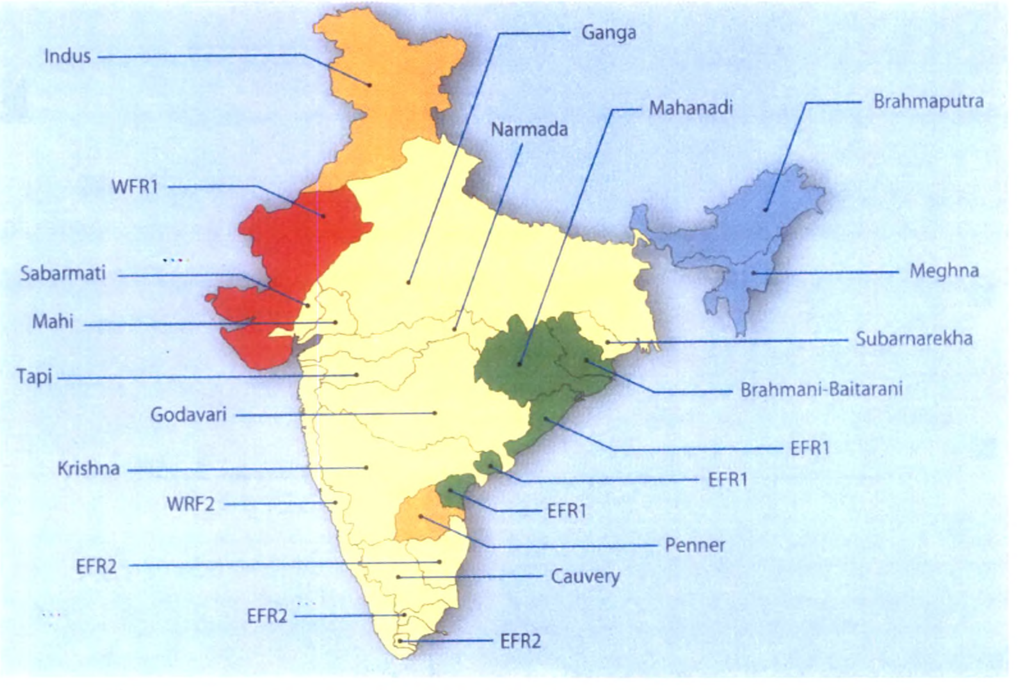

Figure 1.1: River Basins of India

The population distribution is uneven across the basins. The Ganga basin, with only about a quarter of the total drainage area, has about 40 percent of the total population of India. The next five largest basins-Mahanadi, Brahmaputra, Krishna, Godavari, and Indus cover 46 percent of the drainage area, but have only 30 percent of the population. About 75 percent of the people in all the river basins still live in rural areas and the livelihoods of most of them depend on agriculture. Thus, the development and management of available water resources are crucial factors in rural development and poverty alleviation in India. (Reference : Amarasinghe

Upali, Sinha A.K. and others, "Spatial Variation in Water Supply and Demand across River Basins of India")

1.4.2 Rivers and River Basins of Gujarat

From the water resources consideration the state can be divided into four major physiographic regions. There are 185 river basins which can be distributed region wise as follows:

Region	Nos. of River Basins
North Gujarat	05
Central & South Gujarat	12
Saurashtra	71
Kachchh	97
TOTAL	185

Except Narmada, Tapi and Mahi rivers, all other rivers In the eastern part of the state, originate on the western slopes of the eastern hills. They flow in the direction almost at right angle to the boundary i.e. towards southwest (Sabarmati and Mahi rivers) in the northeastern part, towards almost west (Narmada, Tapi, and Dhadhar) in the central region and towards northwest (Kolak, Par, Ambica, etc.) in the southern part. Most of the rivers in the alluvial plain meander with very wide courses whereas those in rocky tracts have deep and narrow courses. The rivers in Saurashtra and Kachchh originate from the Central uplands and represent a radial drainage pattern. Table 1.6 lists Region and Basin Wise Water Resources of Gujarat.

Table – 1.6 Region and Basin Wise Water Resources of Gujarat

Sr. No.	Region / River Basin	Availability of water (Mm^3)
North Gujarat		
1	Rel	49
2	Banas	854
3	Saraswati	404
4	Rupen	445
5	Sabarmati	3548
	Sub Total	5300
Central and South Gujarat		
6	Mahi	5650
7	Dhadhar	3600
8	Narmada	15150
9	Kim	435
10	Tapi	4900
11	Mindhola	340
12	Purna	580
13	Ambica	640
14	Auranga	380
15	Par	290
16	Kolak	180
17	Damanganga	680
18	Other rivers	2875
	Sub Total	35700
Saurashtra		
19	Shetrunji	950
20	Bhadar	932
21	South Saurashtra	1794
22	North Western Saurashtra	1194
23	North & North Eastern Saurashtra	1860
24	Eastern Saurashtra	1170
	SUB TOTAL	7900
Kachchh		
25	Kachchh	1100
	Grand Total of The State	50000

Source: Ph.D. Thesis of Dr. M.S.Patel, Impact of Check Dams on Ground Water Regime and Existing Irrigation Project of Rajkot District, Saurashtra Region of Gujarat State.

1.5 Water Scarce World : Problems and Perspective

Today, around 3800 km^3 of fresh water is withdrawn annually from the world's lakes, rivers and aquifers. This is twice the volume extracted 50 years ago. World population has passed 6 billion.

Projections say that it will reach a peak of between 7.3 billion and 10.7 billion around 2050 before total population begins to stabilize or fall. 50 liters per person per day covers basic human water requirements for drinking, sanitation, bathing and food preparation. In 1990, over a billion people had access to less than 50 liters of water a day. Agriculture accounts for about 67 per cent of withdrawals, industry uses 19 per cent and municipal and domestic uses account for 9 per cent.

One third of the countries in water-stressed regions of the world are expected to face severe water shortages this century. By 2025 there will be approximately 6.5 times as many people- a total of 3.5 billion living in water-stressed countries. By the end of the 20th century, there were over 4 5,000 large dams in over 150 countries. The average large dam today is about 35 years old. Since average construction periods generally range from 5 to 10 years, this indicates a worldwide annual average of some 160 to 320 new large dams per year.

During the 1990s, an estimated $32-46 billion was spent annually on large dams, four-fifths of it in developing countries. Of the $22-31 billion invested in dams each year in developing countries, about four-fifths was financed directly by the public sector. About one-fifth of the world's agricultural land is irrigated, and irrigated agriculture accounts for about 40% of the world's agricultural production.

Half of the world's large dams were built exclusively or primarily for irrigation, and an estimated 30 to 40 per cent of the 271 million hectares of irrigated lands worldwide rely on dams. Dams are estimated to contribute to 12-16 per cent of world food production. Hydropower currently provides 19 per cent of the world's total electricity supply, and is used in over 150 countries with 24 of these countries depending on it for 90 per cent of their supply.

Floods affected the lives, on average, of 65 million people between 1972 and 1996, more than any other type of disaster, including war, drought and famine. There are 261 water sheds that cross the political boundaries of two or more countries. A number of key international rivers lack a basin-wide agreement that defines a process for establishing equitable water use between riparian States.

Cost performance data confirms that large dam projects often incur substantial capital cost overruns. The average overrun was half again as much as the projected cost. The bulk of hydropower projects have delivered power within a close range of pre-project targets but with an overall tendency to fall short of targets.

At current rates, water fees are rarely sufficient to recover both capital and recurrent costs for water supply systems in many developing countries. Growing concern over the cost and effectiveness of large dams and related structural measures as long-term responses to floods has led to support for integrated flood management as opposed to flood control. Multi-purpose schemes are inherently more complex and many experience operational conflicts that contribute to under performance on financial and economic targets. Substantive evaluations of project performance are few in number, narrow in scope, and poorly integrated across impact categories and scales.

Caught between growing demand for fresh water on one hand and limited and increasingly polluted water supplies on the other, many developing countries face difficult choices. Populations continue to grow rapidly. Yet there is no more water on earth now than there was 2,000 years ago, when the population was less than 3 per cent of its current size. Rising demand for water for irrigated agriculture, domestic (municipal) consumption, and industry are forcing stiff competition over the allocation of scarce water resources among both areas and types of use.

Today 31 countries, accounting for under 8 per cent of the world population, face chronic freshwater shortages. By the year 2025, however, 48 countries are expected to face shortages, affecting more than 2.8 billion people 35 percent of the world's projected population. Among countries likely to run short of water in the next 25 years are Ethiopia, India, Kenya, Nigeria, and Peru. Parts of other large countries, such as China, already face chronic water problems.

1.5.1 Indian Perspective of Water Problem

India is one of the wettest countries in the world in terms of average annual rainfall, yet there are problems of distribution of surface water, both spatially and temporally with wide variations. Groundwater extraction in the country already represents very less development. Groundwater overuse, aquifer depletion salt-water ingress in the fresh quality zones and water logging and salinity in canal command areas are becoming serious problems.

India will be requiring about 1,2010,000 lakh cubic meters of water in the year 2050 AD to cater to the needs of about 150 crores population for food, drinking water, domestic, industrial, navigational, environmental and ecological requirements due to which there is a great need to conserve water. Indian lands facing the shortage of water may be due to the curse of the god or mismanagement, if we look at the deserts of some developed countries we learn lesson, and our conscious is stirred and a new sense of doing is inflicted, water conservation emerges as sense of doing and check dams are part of the doing.

The total groundwater reserves of India up to a depth of 300 meters are estimated to be at 3,700 million hectare meters (M.ha.m) and the usable groundwater at around 42 M.ha.m., per year. Out of this, 27.37 percent is exploited. The state of Uttar Pradesh has a usable potential of 9.27 M.ha.m per year followed by Madhya Pradesh (5.95 M.ha.m. /y), Andhra Pradesh (2.21 M.ha.m./y) and Gujarat (2.03 M.ha.m./y).

Depletion of groundwater sources due to the withdrawal of water at a rate far exceeding the natural recharge rate is currently a matter of global concern. The widespread use of ground water for irrigation in several parts of India also is leading to a marked fall in the ground water table. There are reports of declining ground water sources in the states of Punjab, Haryana, Uttar Pradesh, Maharashtra, and Andhra Pradesh in the wake of intensive irrigation through tube wells.

Water crisis in the Gujarat is deepening. This is because of limited water resources are increasingly not in a position to meet the requirements arising from population growth and development process. At the same time Water Resources Development efforts are governed on quality and quantity of rainfall, geo hydrological conditions, quality of infrastructure (electricity) and cooperation between government and Non Government Organisations. Water problems also have great deal of spatial variability. In Saurashtra due to hard rock formation the possibility of holding large quantity of water is quite remote. In North Gujarat there is over exploitation of groundwater leading to severe deterioration of quality of water. This has created grievous situation in Sabarkantha and Mehsana Districts. South Gujarat is blessed with good rainfall. Hence, extraction of groundwater is comparatively less. However, due to topological conditions major quantity of rainwater of South Gujarat goes away to sea. There is a problem of water logging in Surat and Valsad Districts of South Gujarat. At the same time the coastal areas of both the districts have the problem of water quality - especially salinity ingress. (From 'Creative Destruction:' Is that How Gujarat is adapting to Groundwater

Depletion? Synthesis of 30 ITP Field-Studies, by Tushaar Shah and Rohit Desai)

1.5.2 Necessity for Water Resources Development in Gujarat State

After formation of the Gujarat state in may 1960, it is striving hard to improve its economy as well as regional development in all fields. To achieve agricultural and industrial development, all efforts are put to develop the water resources of state. For equitable development of entire state, major medium and minor irrigation schemes across the rivers of the state are being taken up at all feasible storage sites.

Gujarat has very limited water resources. The characteristic feature of the rains in Gujarat is the variation of precipitation. Its occurrence in a short spell of the year and its variation are erratic not only during monsoon but also varies from region to region. The state's total surface water resources work out to 2-3 percent of the water resources of India.

1.6 Solutions for A Water Short World

As populations grow and water use per person rises, demand for fresh water is soaring. Yet the supply of fresh water is finite and threatened by pollution. To avoid a crisis, in much of the world polluted water, improper waste disposal, and poor water management cause serious public health problems. Such water-related diseases as Malaria, Cholera, Typhoid and Schistosomiasis harm or kill millions of people every year. Overuse and pollution of water supplies also are taking a heavy toll on the natural environment and pose increasing risks for many species of life.

It may already be too late for some water-short countries with rapid population growth to avoid a crisis. Many other countries can avoid the coming crisis if appropriate policies and strategies are formulated and acted on soon. Whether water is used for agriculture, industry, or municipalities, there is much room for conservation and better management. Effective strategies must consider not only managing the water supply better but also managing demand better. To avoid catastrophe over the long-term, it also is important to act now to slow the growth in demand for fresh water by slowing population growth.

The world needs a 'Blue Revolution' to conserve and manage freshwater supplies in the face of growing demand from population growth, irrigated agriculture, industries, and cities just as the Green Revolution transformed agriculture in the 1960s. A Blue Revolution will require coordinated responses to problems at local, national, and international levels.

Locally led initiatives show that water can be used much more efficiently. When communities manage freshwater resources efficiently, they also manage other natural resources better, improve sanitation, and reduce disease. At the national level, especially in water-short regions with dense populations, adopting a watershed or river-basin management perspective is a needed alternative to uncoordinated water-management policies by separate jurisdictions.

At the international level countries that share river basins can fashion workable policies to manage water resources more equitably. Development agencies need to focus more on assuring the supply and management of freshwater resources and on providing sanitation as part of development and public health programs.

A water-short world is an inherently unstable world. As the next century dawns, water crises in more and more countries will present obstacles to better living standards and better health and even bring risks or outright conflict over access to scarce freshwater supplies. Finding solutions should become a high priority now.

1.6.1 Water Harvesting in the World

Water Harvesting has been an age-old phenomenon in our country. Known by various local names such as Jal Talais of Uttar Pradesh, Haveli System in Madhya Pradesh, Khadin, Johads and Paals in Rajasthan etc., these structures have contributed to domestic water security and aided irrigation in most parts of the country. Mapping of the net irrigated area by various sources in India indicates that tank irrigation, which is a type of water harvesting structure, still forms a significant part of the irrigation water supply especially in the Southern states of India.

Though water harvesting structures were an important means of irrigation in many parts of our country till the late 19th century and in some places, as late as the early 20th century, a number of these structures were allowed to deteriorate in favour of modern irrigation systems in the form of dams by the colonial government as well as the Indian government. There is a lot of evidence of neglect of these systems since British times (CSE, 1997). High state subsidies and encouragement by the state in other ways for the major and medium projects and increase in groundwater use owing to green revolution technology led to neglect of water harvesting structures and made them seem uneconomical. Further, public control of these structures by village Panchayats and irrigation department meant that local communities lost interest in their management. Failure of governing bodies to collect irrigation charges and a general lack of control over the behavior of the users with regard to withdrawls and rapid siltation due to the failure to carry out de-silting etc led to many of these tanks becoming defunct. An opinion soon grew, to the effect that the days of irrigation through water harvesting structures were over. Government of India's irrigation policy was biased towards Major and Medium Projects. This led to more than 63% of the irrigation budget of the country being devoted to such projects with an outlay of around Rs. 1,378,088.1 billion at constant 96-97 prices. Development of these projects followed a political economy of their own leading to the neglect of many areas of the country as far as expansion of irrigated area was concerned.

The lack of public investment in many of the neglected areas was met through increase in private investment in pumps and tube wells to meet the water requirements of irrigation, which had increased manifolds through the coming of High Yielding Varieties. Green revolution had ensured that for the first time agriculture was able to produce surpluses large enough to put the farm economies on a path of progressively increasing farm incomes. However in the semi arid areas the groundwater driven agricultural bubbles began to collapse due to alarming depletion in groundwater levels. To counter these threats water harvesting is being looked upon as a serious option for recharging of the groundwater levels. The quest to sustain groundwater levels and consequently farm incomes has been a major reason behind the upsurge in interest towards water harvesting structures in the last decade.

1.6.2 Water Harvesting in India & Gujarat

Participatory Irrigation management (PIM) refers to the involvement of Irrigation users in all aspects and at all levels of irrigation management. "All aspects" includes the initial planning and design of new irrigation projects or improvements, as well as the construction, supervision, financing, decision-making, operation, maintenance, monitoring, and evaluation of the system. "All levels" refers to the full physical limits of the irrigation system, up to the policy level. In any management function, including the setting of policies can and should have a participatory dimension to it.

The Irrigation Inquiry Committee (in 1938) appointed by the Government of Bombay under the Chairmanship of the eminent engineer and administrator, Shri M. Viswesuarayya, had recommended that operation and maintenance below minors should be turned over to the farmers' co-operative societies and that water should be supplied to them on a volumetric basis. The

Command Area Development Program started in 1974 with a view to bridging the gap between the irrigation potential created and utilized envisaged farmers organizations from the start as necessary to run the micro system. The Sixth Five Year Plan (1980-1985) emphasized the need for the participation of farmers in the management of Irrigation. The National Water Policy adopted in 1987 also stressed that "Efforts should be made to involve farmers progressively in various aspects of the management of the irrigation system, particularly in water distribution and collection of water rates". In 1987, the Ministry of Water Resources issued guidelines for farmers' participation. The guidelines cover the following:

a. The necessity of involving farmers
b. Past experience in India and Abroad
c. Objectives of farmer's participation in the management of irrigation
d. The methodology for the formation of farmers associations and their area of operation
e. The duties and responsibilities of Irrigation Department
f. Incentives to farmers
g. Training.

The Report (1992) of the committee on the pricing of Irrigation Water (the Vaidyanathan Committee); set up by the Planning Commission had suggested for a substantial reduction in the sphere of responsibility of government and the encouragement of user groups to take over maintenance, management of water allocations, and collection of water rates for a group of outlets serving at least a village. Since 1995 the Govt. of India introduced the holistic approach under the term Participatory Irrigation Management and started providing the Central Assistance for promoting PIM by the State in the irrigation projects.

The total geographical area of India is 329 million hectors (M.ha). The total cultivable area of the country at present is 142 M.ha. At the time of independence (1947) the irrigation potential in India was 22 M.ha and by the end of 2000 it is around 90 M.ha. The Ultimate Irrigation Potential is estimated to be 113 Mha.

Gujarat has 12.42 M.ha. of culturable area in its geographical area of 19.60 M.ha. At present, hardly 27% of the cultivable lands are being provided with irrigation facilities from all sources (Government and Private). Concerted efforts should be made to ensure that the irrigation potential created is fully utilized and the gap between the potential created and its utilization is removed. For this purpose the command area development approach should be adopted in all irrigation projects.

While irrigation has expanded so tremendously in India that now it has the second largest area under irrigation anywhere in the World after China, there has been a woeful lack of management culture in this sector. The ethos in the irrigation agency is design and construction oriented, the exclusive emphasis is on physical works. Very little emphasis has been given to the operation and maintenance of the system and distribution of water. As a result of this lack of attention to management, the delivery of water to the farmers has become unreliable in timing of delivery as well as its volume and inequitable.

It's a time to develop more refined and nuanced understanding of the peculiarities of Asia's groundwater socio-ecology and a resource management approach suited to its genius. In much of Asia, modem groundwater development occurred in a chaotic, unregulated fashion shaped by millions of tiny private users. Now, in many parts of India where groundwater is under worst threat of depletion- there is a growing groundswell of popular action-equally chaotic and unregulated- in rainwater harvesting and local groundwater recharge. At the frontline of this movement are regions like Rajasthan and Gujarat in India where untold havoc and misery are a certain outcome if the groundwater bubble were to burst. Here, rather than waiting for governments and high science to come to their rescue, ordinary people, communities, NGOs and religious movements have made groundwater recharge everybody's business. Many scientists and technocrats feel lukewarm about this groundswell of activity; but chances are that here in lie the seeds of decentralized local management of a natural resource. For long, people in Asia treated water like manna from haven and saw no need to manage it; but now that they have begun to 'produce' water, we find first inkling of community efforts to manage it. These popular recharge movements and then offer the foundation on which Asia can build new regimes for sustainable groundwater management.

1.6.3 The Check Dams and Water Harvesting

In post independence period numbers of large and mid size water resources schemes were taken up on hands, some completed and implemented and some of them shelved and could not see the light of the day, others still lingering to be shaped. But this passing phase widened the thinking and great many lessons were learnt. This learning shifted the focus from large dams to miniscule models that are called check dams, very effective, visible and digestible concept is here to tap the water where it is, surplus to be passed further only after fulfilling the need first where it is.

Check dams are basically water-harvesting structures constructed across small nallahs and / or rivulets to capture and store rainwater in the form of small ponds. The stored water is partly used by lift irrigation of adjoining area, a part of it percolates down to recharge the shallow aquifers and a part is lost by evaporation. As the depth of water in a check dam is shallow, unless it is used quickly, most of it will be lost by evaporation. There will be no water in the check dam by the end of winter season. Loss due to evaporation varies from 2.5 to 3.0 m depth of water per year. Of course, some water may be available through open wells from the recharged shallow aquifer even after winter. (Reference: Dave K G, "Some Aspects of Construction Of Check Dams In The Catchment Area Of Reservoirs"). Check dams are known by different names in different regions as follows:

Region	Name Of Structures
Uttar Pradesh	Jal Talai
Madhya Pradesh	Haveli
Rajasthan	Johad, Khadin and Paal

Advantages and utility of check dams to intercept and store rainwater, which would otherwise have flowed away to the sea, is undisputable. But construction of check dams in the catchment areas of existing reservoirs located particularly in scarcity-prone areas having low reliability is altogether a different matter.

In the context of rural Gujarat, activity of constructions of check dams is a very positive and pious approach where collective consciousness of people is used with grassroots mobilization of local resources and community participation, which is forming sustainable approach of living.

1.6.4 Issues Related to Check Dams

It is believed by many people that if the river flow is impeded at the upper level by check dams, large dams will hardly get enough water. In general check dams raise both moral and scientific issues. The moral issue is that a democratic government does not have the right to allocate water, which is such a basic human need, to urban people at the expense of rural people. It must ensure that all people get water and if it is in short supply, all must share the shortage equally. Check dams and groundwater recharge can help poorer people. The most often raised question is, "Will these check dams may reduce water inflow into the larger downstream reservoirs?"

This is exactly what the Rajasthan irrigation department told Tarun Bharat Sangh (TBS) when it built its first johad in Alwar district and ordered it to be pulled down. TBS refused and the officialdom could not pick up the courage to take on the ire of the villagers. TBS went ahead making many more johads and in the 503 sq km watershed of the 45-km-long Arvari river some 238 water harvesting structures had been constructed by the mid-1990s by the 70 villages located within its watershed. The work started in 1986 and low and behold, the Arvari, till then a drain that flowed during the monsoon did not dry up but slowly became a perennial river. In 1990, it had a flow till October and, by 1995, it had become perennial. TBS now lays claim to revival of five rivers. The Sadguru Foundation working in the tribal areas of Dahod district in Gujarat itself has seen the same revival of rivers by making a cascade of check dams across what were earlier dead rivers. Rajasthan irrigation engineers were dumbfounded by the revival of the Arvari proving their technical whims and fancies wrong.

Hydrogeologist R. N. Athavale who visited the Arvari watershed has made the estimates based on his experience to explain the revival of rivers. Earlier, only 15 per cent of the rainfall would go into the soil 5 per cent becoming soil moisture and about 10 per cent going deep into the ground, most of it below the bottom of the wells and the level of the Arvari bed because of the depleted groundwater reserve. Therefore, only 5 per cent of the rainfall would slowly seep into the Arvari and villagers could use just about 1 per cent for drinking and irrigation. Now, with check dams, 35 per cent goes into the soil instead of 15 per cent. As a result, the monsoonal runoff to the Arvari has dropped from the earlier 35 per cent of the rainfall to only 10 per cent. But an estimated 22 per cent of the total rainfall now seeps into the Arvari from the recharged groundwater reserve in the post-monsoonal months to give it a perennial flow. The villagers themselves now use about 3 per cent of the total rainfall that falls in the watershed with which they can take two crops a year. In other words, as Athavale puts it, check dams and other water harvesting structures do not reduce the quantity of water flowing into the lower dams, they only streamline the flow over the year. (Reference : Kshotriya Mohan, Prof. (Avinash) ,"Arvari Nadi ke Punerjanma ki Katha")

1.6.5 Structures Constructed by Various Agencies in Gujarat

Check dams in Gujarat are taken up on hand by Government as well as the Non Government Organization(NGO). Government agencies involved are local Government (Panchayat), forest, District Rural Development Agency and regular state Water Resource Deptt. Under public participation scheme Government of Gujarat has constructed major chunk. During the year 1999-2000, 1000 check dams were constructed. Quantum Leap was made and up to Nov 2000 10,700 check dams were constructed (out of which 7000 were seen overflowing) and up to Sept. 2002, 20,000 mark was achieved (SPSJSY, Government of Gujarat scheme, 2001-2003) Nearly 30,000 check dams have been constructed in rural Gujarat over a period of last four years, 15000 check dams constructed in the period 1999-2001, and Govt plan to construct more than one and half lakhs (a hundred and fifty thousand) such check dams. In addition to check dam construction, government has a unique experiment of making "Bori-bunds", or gunny bag dams that harvest and store rainwater, successfully implemented it with the active involvement of people and communities. With very nominal cost, water is harvested, stored and used. The concept of local communities giving their labour for local water harvesting is a Gandhian principle that this government has carried into the 21^{st} century, and successfully implemented. (Speech of Chief Minister of Gujarat at Global Investors' Summit, 2003) (Reference : Singh Man Mohan, "Impacts on environment: check dams in state of Gujarat (India)" article on internet).

1.7 Necessity of The Study

While on one hand there is a world wide boom for water conservation and water resources management, every sector and every section of the society shows deep concern for it. Social scientists and NGOs have concentrated their activities in this field. However it is now a high time that this awareness of the society is given right scientific technical perspective. Water resources management is basically a field based on hydrology and the effectiveness of the efforts by any individual or organization largely depends on fact that such efforts are how much proper by the consideration of hydrological principles. While there are numerous examples of works of socialist NGOs in this direction there is hardly any example of its proper scientific, technical evaluation except evaluation of activities of Tarun Bharat Sangh by Dr.Agrawal.

1.8 Objectives of the Study

The objective of the present study is to study an effect of irrigation cum artificial recharge structures particularly check dams in the region of a small river basin. To accomplish this objective study of rainfall and its pattern, morphology of the study area and water table fluctuations are analyzed and studied. A conceptual mathematical model is developed.

In general the objectives of the study can be summarized as follows

a. To study rainfall pattern and rainfall characteristics in Machhan River Basin.
b. To study morphology of the Machhan River Basin
c. To study Ground Water Level fluctuations in the Machhan River basin.
d. To develop a mathematical model for studying influence of checks dams on runoff.