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Groundwater Scenario in Andhra Pradesh

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Acronyms

A.P. – Andhra Pradesh

ANGRAU – Acharya N.G.Ranga Agricultural University

APFMIS – Andhra Pradesh Farmers' Management of Irrigation Systems

APWALTA – Andhra Pradesh Water, Land and Trees Act

bcm – billion cubic meters

CAD – Command Area Development

CGWB – Central Groundwater Board

CPDCL – Central Power Distribution Company Ltd

cum – cubic meter

E.C – Electrical Conductivity

GEC – Groundwater Estimation Committee

GoAP – Government of Andhra Pradesh

GOI – Government of India

MCM – million cubic meters

m.ha – million hectares

mm – millimeter

MU – million units

MW – Megawatt

ppm – parts per million

sq. km – square kilometer

TDS – Total Dissolved Salts

tmc – thousand million cubic feet

UN – United Nations

WCM – Water Conservation Mission

WUA – Water Users' Association

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Current WASHCost Working papers

Executive Summary

Andhra Pradesh with a geographical area of 0.275 million sq. km is characterized by a variety of physiographic features ranging from hills to undulating plains and a coastal deltaic environment. The state has three major river basins – those of the Godavari, the Krishna and the Pennar. It falls in the semi-arid region of Peninsular India with hot summers and cool winters. Geomorphologically, the state can be divided into pediplains, coastal alluvial plains and hill ranges. The average annual rainfall is 940 mm with a high of 1200 mm in Srikakulam district and a low of about 550 mm in Anantapur district. The major part of the rainfall (66%) is received from the south-west monsoon during June-September, with the north-east monsoon (October–December) contributing only about 25 per cent of the annual rainfall. Based on rainfall and crops that could be grown, the state is divided into nine agroclimatic zones - High altitude and Tribal Zone, Krishna Zone, Godavari zone, North coastal zone, Northern Telangana zone, Central Telangana Zone, Scarce rainfall zone, Southern Telangana zone and Southern zone.

Andhra Pradesh is underlain by rock types ranging from Archaean rocks to Recent (Holocene) alluvium with a wide range of texture and structure. Nearly 85 per cent of the state, i.e., about 0.233 million sq. km, is underlain by hard rocks comprising igneous, volcanic, metamorphic and hard sedimentary rocks. The remaining 15% of the area, i.e., 0.042 million sq. km is underlain by soft rocks comprising Tertiary rocks, Gondwana sandstones, shales and alluvium of Recent age. Dolerite dykes, quartz reefs, feldspathic and pegmatite veins extending from a few metres to a few kilometres cut across the country rocks at many places. The dolerite dykes have intruded along major prominent fractures. The vertical joints in granites are also aligned to the major direction of fractures and lineaments. Phosphate rocks containing fluoride-bearing minerals are the main source of fluoride in groundwater.

The total water resources, both surface water and groundwater in the state, are estimated to be 108.15 bcm (3820 tmc), out of which about 62.29 bcm (2200 tmc) are being currently utilized for drinking, agriculture, industry and power generation. The annual per capita availability of water works out to slightly more than 1400 cum, and present annual per capita utilization is about 800 cum. As per UN indicators, the state falls in the "water scarce" category warranting appropriate water governance techniques.

The State is drained by 4 major rivers – Godavari, Krishna, Pennar and Vamsadhara – and their tributaries, dividing the state into 40 river basins and into 81 surface water sub-basins ranging in size from 90.65 sq. km to 15,699 sq. km. As per the present estimates the Godavari river basin has about 21.52 bcm (760 tmc) surplus water, while the other river basins have about 6.51 bcm (230 tmc). The water resources of Krishna and Pennar basins are completely utilized in years of normal rainfall, and further development in these basins will mainly depend on management of flood waters.

Groundwater plays an important role in many areas of the state because it is more reliably available than surface water. Groundwater, until recently, has been viewed as a sustainable resource for irrigation and accounts nearly 50 per cent of the net irrigated area in the state.

At present groundwater meets 85 per cent of the domestic needs in rural areas and around 30 per cent of urban and 50 per cent of industrial demands. However, added to increase in demand and lack of well-defined property rights, availability of institutional financing for development of agro wells and subsidized electricity for pumping groundwater for irrigation has led to over-exploitation in semi-arid parts of the state resulting in quality and quantity problems in water supply. The total groundwater resources, as estimated by the State Groundwater Department (2007), are 34,700 MCM (17,886 in non-command area + 16,814 in command area) and utilization is 14,112 MCM (10,526 in non-command area + 3,586 in command area), while balance available resource is 20,588 MCM (7,360 in non-command area + 13,228 in command area). The average stage of groundwater development for the entire state is 41 per cent. The stage of Groundwater development in Non command area is 59 per cent whereas it is 21 per cent in command areas.

Excessive extraction of groundwater for irrigation is impacting drinking-water sources to a great extent and is of great concern. Consequent on installation of more than 3.5 million India Mark II hand pumps, over 0.12 million piped water supply schemes for drinking water purposes, and over 20 million power-driven pumps for irrigation and industrial needs, groundwater levels have declined leading to drying up of wells. The competing demands have exacerbated the quantitative and qualitative shortage in availability of water for domestic needs. The state is divided with respect to groundwater status into four categories, based on the percentage of groundwater exploitation given in parentheses — safe (<70%), semi-critical (70% to 90%), critical (90 to 100%) and over-exploited (>100%). About 5096 villages covering 111 mandals fall in over-exploited category consequent on drying up of shallow aquifers. Analysis of about 1000 water samples collected from piezometers in the month of May from 2005 onwards indicated that the electrical conductivity (E.C.) is above the permissible limit in 16 per cent, fluoride in 12 per cent and nitrates in 33 per cent of the samples. Quality of groundwater, especially for drinking, is a major concern as it affects health of rural people and deprives them of their livelihood.

The area irrigated through groundwater has also increased from 0.8 million hectares in 80s to about 3.1 million hectares in 2007-08. The area irrigated per well is either reduced or constant, but water is being drawn from greater depths. The overall stage of groundwater development across the state has increased from 28 per cent in 1985 to 41 per cent in 2007. However, this may not be sustainable in the long term. Non-command areas where the groundwater availability is 52 per cent while utilization is nearly 59 per cent constitute 77 per cent of the area of the state. Over-utilization is thus creating a wide gap between demand and supply.

In order to sustain availability of groundwater and economy in its use, several measures have to be initiated. The most important of them are (i) improving the recharge of groundwater, (ii) improving water-use efficiency in intensively irrigated areas by promoting conjunctive use of surface water, rainwater and groundwater, and (iii) promoting less water-intensive crops that give higher net returns per unit of water.

The Government of A.P., to ensure the above, has introduced participatory irrigation management systems by passing APFMIS Act in 1997, which makes farmers responsible for management of the irrigation systems. In all, 10,292 Water Users Associations at the tertiary level, and 170 Distributory Committees covering 10.0 million farmers have started working in 1997 to cover 2.0 m.ha of irrigated land. The water charges collected are being ploughed back to WUAs, Distributory Committees and Project Committees to meet operation and maintenance costs. The functioning of the farmers' associations and committees is reviewed regularly to enhance their effectiveness.

At present any landowner can legally abstract any amount of water unless the geohydrology limits it. The lack of well-defined rights, and the invisibility and indivisibility of groundwater along with its complex flow characteristics make monitoring of the resource difficult. The only institutional approach left to manage groundwater for checking over-development of groundwater and for mitigating its environmental consequences is through establishing a regulatory framework. Towards this end, the Government introduced the Andhra Pradesh Water, Land and Trees Act (APWALTA) in 2002 to promote water conservation and reduce over-exploitation of this vital resource.

Groundwater Scenario in Andhra Pradesh

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Introduction

The important functions of water are related to consumption, production and ecology, and hence water is intimately linked to food supply and livelihood security. Consumption of water is for drinking by humans and livestock; availability of water in sufficient quantity and of required quality will therefore have direct bearing on the quality of life. Water, when used for irrigation, enhances agricultural productivity. In its ecological function, water when contaminated leads to poor quality of life, with the result that appropriate management strategies are required to protect wetlands and maintain ecosystems and habitats. Over-abstraction from aquifers in coastal areas leads to the additional risk of salt-water intrusion into fresh water. Threats to aquifers include anthropogenic pollution, excessive abstraction leading to pollution, well-head contamination and naturally occurring contamination causing change in acidity or alkalinity of the aquifer. Access to reliable and good quality water through proper management reduces the costs of water supply and economic development.

Groundwater is important in many areas of the state because it is more reliably available in specific quantity than surface water supplies. Groundwater, until recently, has been viewed as a sustainable resource for irrigation and accounts for nearly 50 per cent of the net irrigated area in the state. At present groundwater meets 85 per cent of domestic needs in rural areas and perhaps 30 per cent of urban demand and 50 per cent of industrial demands. However, increase in demand and lack of well-defined property rights, accessibility to institutional financing for development of agro wells and provision of subsidized electricity for pumping groundwater for irrigation have led to over-development in semi-arid parts of the state. As a result, availability of groundwater is

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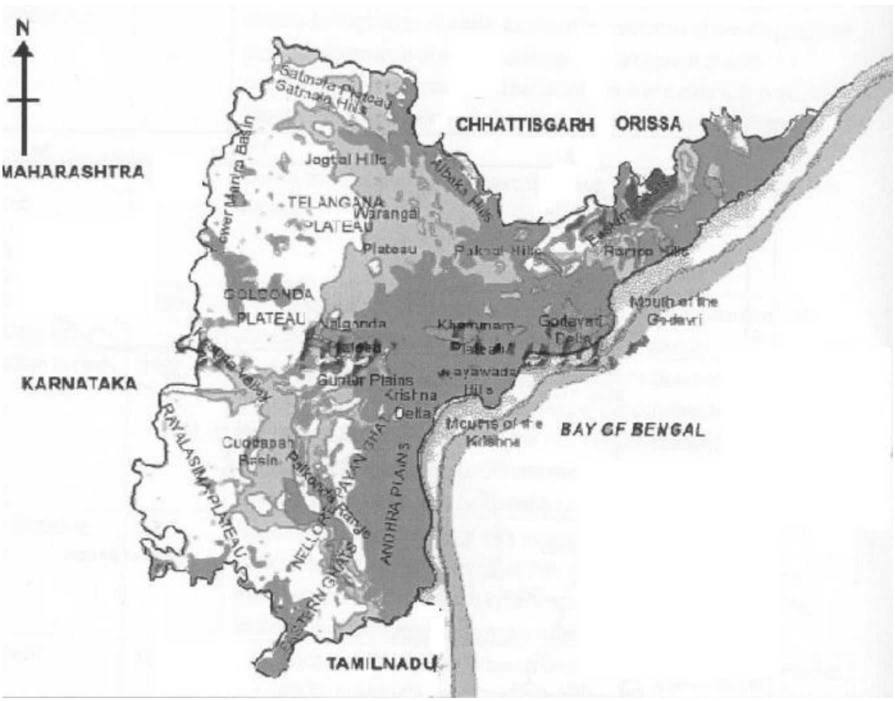
threatened by depletion and by deterioration in quality due to saline intrusion in the coastal region and fluoride contamination in semi-arid areas. Water quality in peri-urban areas is a major problem due to contamination from waste water and industrial effluents. As a consequence, economic growth in rural areas and health of rural and urban communities are at stake. In view of the important role of the groundwater in economic development, socio-ecological status of groundwater in the state is presented below along with an overview of initiatives undertaken by the Government for sustaining the precious groundwater resource.

Physiography and Climate

Andhra Pradesh state, consisting of an area of 0.275 million sq.km, is endowed with a variety of physiographic features ranging from hills and undulating plains to a coastal deltaic environment. The State has three major river basins – those of the Godavari, the Krishna and the Pennar. The entire state falls in the semi-arid region of Peninsular India and is characterized by hot summers and cool winters. Geomorphologically, the state can be divided into pediplains, coastal alluvial plains and hilly areas. The physiographical features of Andhra Pradesh are presented in Fig 1.

Fig. 1 Physiographical Map of Andhra Pradesh



Source: Department of Groundwater, GoAP, 1989.

Resource Base

One of the major challenges in the state for ensuring access to water and reducing rural poverty is the nature of the resource itself. Though in aggregate terms water is sufficient to meet the current demand in all except drought years, spatio–temporal variations in its quantity and quality are major constraints as determined by rainfall, soil and terrain characteristics. The state receives an annual rainfall of 940 mm on average with wide variations among the districts. Annual rainfall ranges from 1200 mm in Srikakulam district to about 550 mm in Anantapur district. The majority of the rainfall (66%) is received from the south-west monsoon during June-September, the north-east monsoon (October–December) contributing only 25 per cent of the annual rainfall. Based on the rainfall and crops that could be grown, the state is divided into nine agro-climatic zones: High altitude and Tribal Zone, Krishna Zone, Godavari zone, North coastal zone, Northern Telangana zone, Central Telangana Zone, Scarce rainfall zone, Southern Telangana zone and Southern zone (Fig. 2).

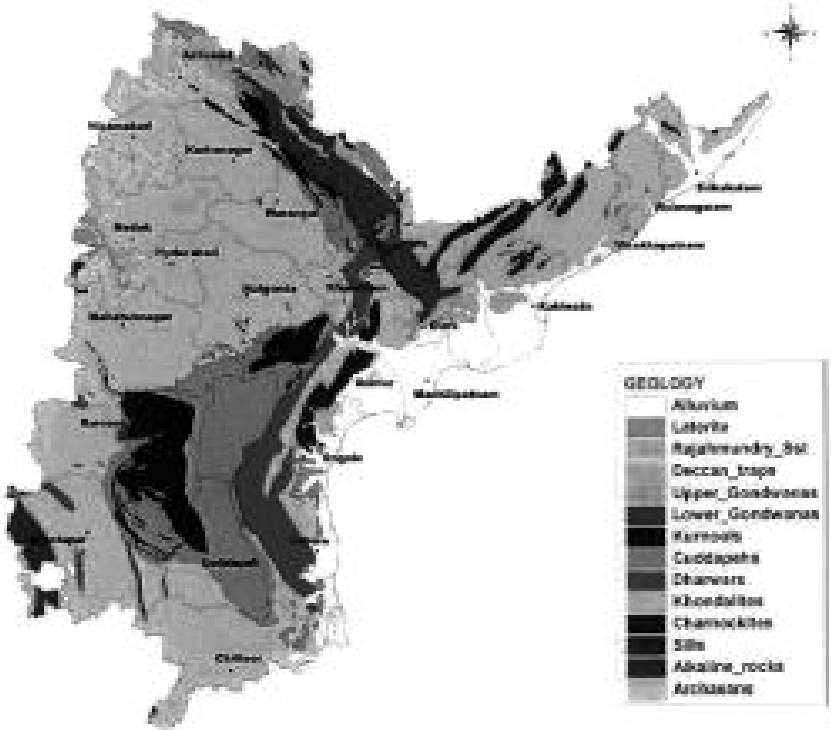
Fig. 2 Agro-climatic Zones of Andhra Pradesh

Source: Annual Report 2007-2008, ANGRAU, Hyderabad

Geology

The state of Andhra Pradesh is underlain by rock types ranging from Archaean to Recent (Holocene) alluvium with varied texture and structure. Nearly 85 per cent of the state, i.e., about 0.233 million sq. km, is underlain by hard rocks consisting of igneous, volcanic, metamorphic and hard sedimentary rocks. These are mainly granites, gneisses and khondalites (in the Eastern Ghats), Cuddapahs (middle upper Proterozoic), Kurnools and Deccan traps (Eocene). The remaining 15 per cent of the area, i.e., 0.042 million sq. km is underlain by soft rocks comprising Tertiary and Gondwana sandstones, shales and alluvium of Recent age. Dolerite dykes, quartz reefs, and feldspathic and pegmatite veins extending from a few metres to a few kilometres cut across the country rock at many places. The dolerite dykes have intruded along major prominent fractures along EW, NE and SW direction. The vertical joints in granites are also aligned in the major direction of fractures and lineaments. Phosphate rocks containing fluoride-bearing minerals are the main source of fluoride in groundwater. The geological map of Andhra Pradesh is presented in Fig. 3.

Fig. 3 Geological Map of Andhra Pradesh



Source: Department of Groundwater, GoAP, 1988.

Table 1. Per capita availability of water (cum) in A.P. compared to India

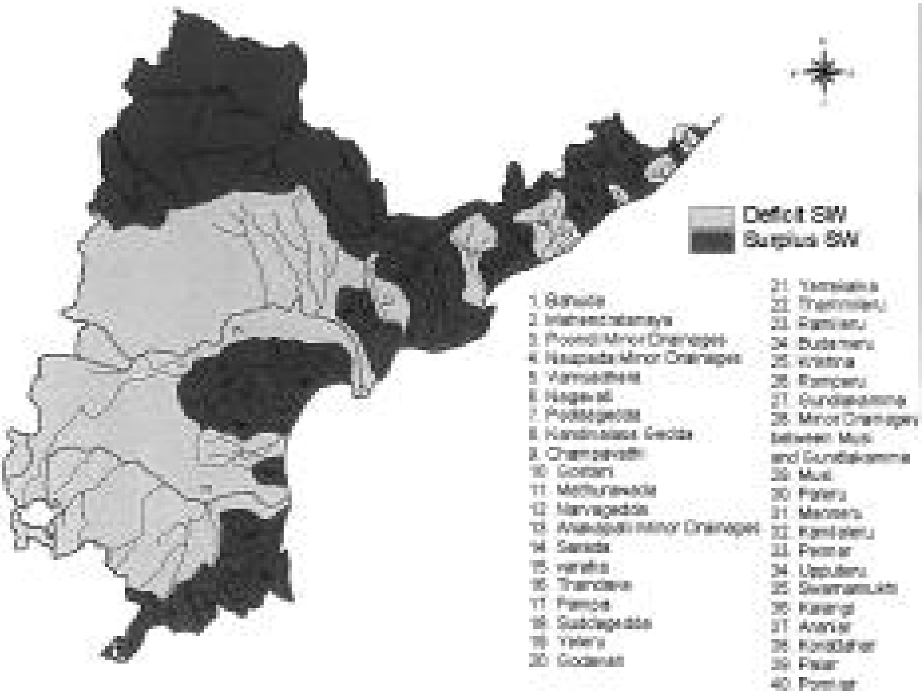
Period	Andhra Pradesh	India
1951	3600	5000
1991	1600	2100
2001	1400	1750
2050	912	1140

(Source: Water Conservation Mission, GoAP, 2003)

Soils

Soils play an important role in groundwater recharge. The soils of the state are broadly classified into red, black and alluvial soils. Red sandy soils cover the largest area in the state (67%) and occur widely in Telangana and Rayalaseema regions. The black soils are, in general, transported by rivers. The deltaic alluvial soils, coastal alluvial soils and coastal sandy soils are formed by the riverine system. Changes in land use can have

Fig. 4 River Basins of of Andhra Pradesh



Source: Water Conservation Mission, GoAP, 2003.

significant effects on rate of infiltration through the soil surface, water retention capability of soils, and subsurface transmissibility of water.

Water Resources

The total water resources (both surface water and groundwater)of the state are estimated at 108.15 bcm (3820 tmc), out of which about 62.29 bcm (2200 tmc) are currently being utilized for domestic purposes, agriculture, industry and power generation. The per capita annual water resource in the state works out 1400 cum, and annual utilization is about 800 cum. Countries or regions with annual per capita availability of water between 1000 and 2000 cum are considered "water-stressed", those with availability below 1700 cum "water-scarce" and areas with availability less than 1000 cum "severely water-scarce". If the withdrawal of available water is more than 40 per cent a country or region is considered to be "water-scarce", warranting appropriate water-governance techniques. According to GEC Report 2007, in Andhra Pradesh 171 mandals covering 6160 revenue villages are categorized as water-stressed.

The average per capita water availability in Andhra Pradesh as against that in India during the period 1951 to 2001 and estimated requirements for the year 2050 are given in table 1. The data presented indicate that the state is likely to be severely water-stressed and efforts need to be made to prevent this through efficient management supported by appropriate policy framework.

Surface Water

The State is drained by 4 major rivers – Godavari, Krishna, Pennar and Vamsadhara - and their tributaries. The riverine system divides the state into 40 river basins and further into 81 sub-basins ranging in size from 90 sq. km to 15,699 sq. km (Fig. 4).

Godavari and Krishna are interstate rivers contributing almost 90 per cent of the surface water resources of the state. The rivers are seasonal with the bulk of the flow taking place during the monsoon (June to October). The state's share of dependable flows at 75 per cent dependability from the river system is estimated at 77.75 bcm (2746 tmc) of which 49.63 bcm (1753 tmc) are currently utilized.

According to the existing information (CAD, 2006), the Godavari river basin has about 21.52 bcm (760 tmc) surplus water, while the other river basins together have about 6.51 bcm (230 tmc). The water resources of Krishna and Pennar are completely utilized in years of normal rainfall. Further development in the basins will mainly depend on flood-water management plans. Significant imbalance in water utilization among the river basins is prevalent due to local needs, development restrictions and priorities.

Table 3. Groundwater estimates in different years Groundwater Estimates and Stage of Groundwater Development Andhra Pradesh From 1985 to 2007

Ground water Assessment Year	Annual Groundwater availability MCM	Ground-water Utiliza-tion MCM	Ground-water Balance MCM	Stage of Devel-opment %	Assess-ment units	Methodology adopted	Category	No of Over Exploited villages proposed for notification
1985	25303	7074	18229	28	Taluk Wise	Water table fluctuation method	Red (24 Taluks) Dark (8 Taluks) and Grey (15 Taluks)	
1993	35292	10132	25160	29	Mandal wise	Water table Fluctuation and Rainfall infiltration method	Red,Dark and Grey	
2002	30562	12972	17590	43	1157 Ground water	GEC 1997 Methodology	Over Exploited (118), Critical (79), Semi-Critical(188) and Safe(772)	
2004	32758	14855	17903	45	1229	GEC 1997	Over Exploited (215), Critical (85), Semi Critical(208) and Safe(721)	4190
2007	34700	14112	20588	41	1229 Watersheds	GEC 1997 Methodology	Over Exploited (132), Critical(89), Semi Critical (175)and Safe(833)	3449

Source: Groundwater Department, GoAP, 1985 – 2007.

Groundwater Resources

The total groundwater resources as estimated by the State Groundwater Department (2007) are 34,700 MCM (17,886 in non-command area + 16,814 in command area) and utilization is 14,112 MCM (10,526 in non-command area + 3,586 in command area), leaving a balance of 20,588 MCM (7,360 in non-command area + 13,228 in command area). According to the report of the Groundwater Estimation Committee,

Table 2. Status of groundwater in A.P. compared to India

G.W Resource	A.P.	India	A.P. share in India,%
Annual groundwater availability (MCM)	32578	398700	8
Utilization (MCM)	14835	230440	6
Balance available (MCM)	17903	168260	11
Stage of GW development (%)	45	58	

Source: Groundwater estimations, 2004, CGWB, GoI.

the average stage of groundwater development for the state is 41 per cent during the year 2007. The stage of Groundwater development in Non command areas is 59 per cent whereas it is 21 per cent in command area (GEC-2007, GWD, GoAP).

The annual groundwater availability in Andhra Pradesh during 1985 to 2004 has increased from around 25,000 MCM to 32,000 MCM. The groundwater resources are estimated at 34,700 MCM in the year 2007and the increase is due to normal and above-normal rains during 2004 to 2007 coupled with conservation measures adopted by government during droughts. However, at the micro-level the draft has increased due to intensification of agriculture under well-irrigation resulting in lowering of groundwater levels as evidenced by increase in number of overexploited and critical villages. The overall draft increased from around 7,000 MCM to 14,000 MCM in 2007. The groundwater resource estimated during 2004 for A.P. and utilization *vis-à-vis* India is furnished in table 2. The groundwater availability and utilization on time scale is presented in table 3.

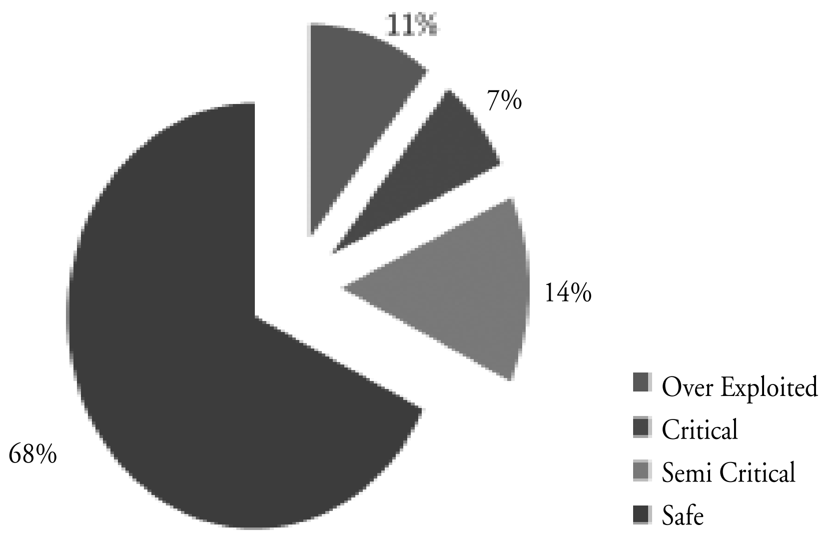
Stage of Groundwater Development

About 85 per cent of domestic water supply for rural areas is met from groundwater resources, and 85 per cent groundwater is being used for irrigation purposes. Groundwater is also the main source of urban water supply in India. The number of power pumps in Andhra Pradesh increased from less than one million in 1990 to almost 2.8 million in

2008. The continuously increased use of groundwater for irrigation has severely impacted drinking-water sources in rural areas and is becoming a great concern. The installation of over 3.5 million India Mark II hand pumps and over 0.12 million piped water supply schemes for drinking water purposes and 2.8 million power-driven pumps for irrigation purposes and industrial needs has resulted in depletion of groundwater and consequently decreased well yields. As a result of the above, the concentration of chemicals in the groundwater is increasing making it unfit for consumption; wells may be expected to dry up ultimately leading to environmental degradation.

Andhra Pradesh has 23 districts with 1108 blocks and 26,011 villages. In 2004, The Groundwater Department divided the state into 1229 micro-basins, having an average area of 220 sq. km and classified them according to stage of groundwater development. This classification was based on groundwater levels recorded from selected observation wells and secondary information available on the pumping intensities and cropping patterns in each micro-basin. In the state 132 micro-basins were classified as over-exploited (groundwater development > 100%); 89 in critical condition (groundwater development 90–100%) and another 175 semi-critical (groundwater development 70–90%) out of the total 1229 micro-basins (Fig. 5).

Fig. 5 Classification of Micro-Basins in Andhra Pradesh



Source: Groundwater Department, GoAP, 2006.

It is reported that groundwater levels were lowered by 1.9 m on average, during the period 1998-2006 in Andhra Pradesh (GEC Report, Groundwater Department, GoAP, 2007). This decline could, obviously, be much more in over-exploited and critical basins.

At present it is estimated that about 5096 villages and 111 mandals are categorized as over exploited. The number of mandals and villages falling into various categories are given in table 4.

Table 4. Mandals and villages in different categories

Category	Number of watersheds	Number of mandals	Number of Villages
Over-exploited	132	111	5096
Critical	89	60	1064
Semi-critical	175	160	2632
Safe 833	777	17219	

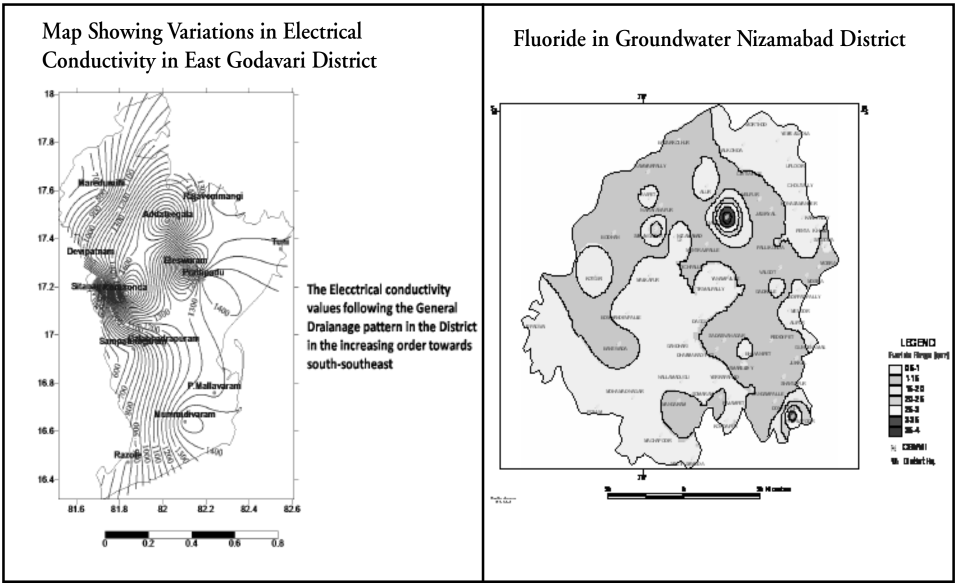
Source: Groundwater Department, GoAP, 2007

Water Quality

Groundwater is the major source for drinking and irrigation. The chemical quality of groundwater varies from place to place. The geological environment, climate, drainage, land use and engineering structures have profound influence on groundwater quality. Groundwater in Archaean crystalline rocks is in general neutral and chloride content ranges from 30 to 525 ppm. The quality of groundwater in Cuddapah and Kurnool formations is generally poor and TDS exceeds 1000 ppm in some places. In Gondwanas the quality is generally good except in some local patches. In Deccan traps, the TDS of groundwater ranges from 200 to 300 ppm in upland areas and 400 to 700 ppm in valley portions. Groundwater is often brackish to saline in black cotton (clay) soils.

Quality of groundwater is a major concern especially for drinking as it affects the health of rural people and, if poor, may deprive them of their livelihood. Thus not only the quantity but also the quality will continue to be a major threat in future. The concentration of fluorides, salinity and nitrates in drinking water will affect its quality. The presence of fluoride in excess of permissible limits is a major health problem and new "excess-fluoride" habitations are emerging mostly due to over-exploitation of groundwater. Fluoride concentrations are often found in waters having TDS concentration higher than 1500 mg/l. The pH of groundwater ranges from 7.0 to 9.0, bicarbonate content from 160 to 500 mg/l and electrical conductivity from 260 to 5700 microsiemens/cm.

Fig. 6 Water quality maps



Source: Groundwater Department, GoAP

The fluoride concentration in groundwater is highly variable in space and time and ranges from 1.5 ppm to 11.0 ppm and is related to extraction of groundwater as well as occurrence of associated minerals.

Analysis of about 1000 water samples collected in May from piezometers since 2005 indicate that the electrical conductivity (E.C.) is above the permissible limit in 16 per cent of the samples, fluoride in 12 per cent and nitrates in 33 per cent of the samples. The results suggest that 30 mandals are partly or fully saline and about 400 villages are fluoride-affected. Over-abstraction in coastal areas carries with it the additional hazard of salt water ingress. The spatial variations of electrical conductivity and fluoride concentrations based on the available data from limited samples in the districts of East Godavari and Nizamabad respectively are presented as an example in Fig 6.

Groundwater Sustainability

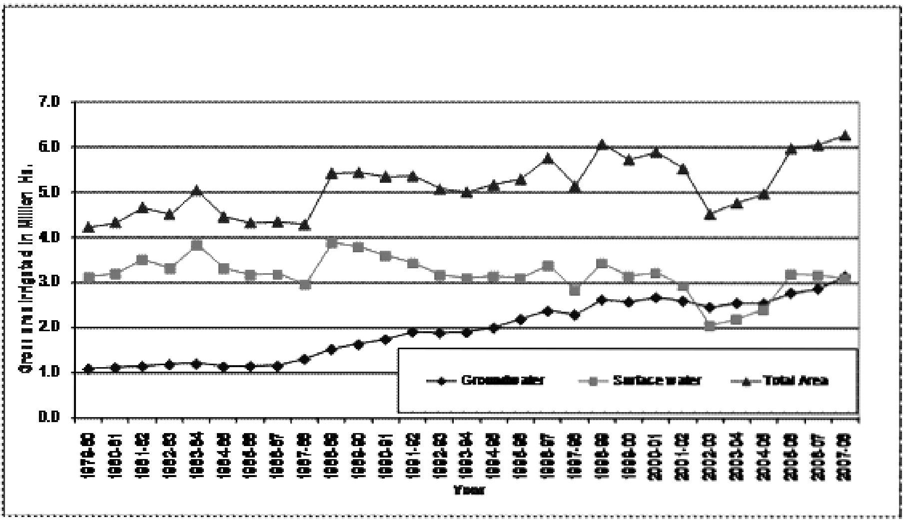
The area irrigated by groundwater is nearly equal to the area irrigated using surface water sources (Fig. 7). The over-all increase seen in areas irrigated from groundwater is only a macro-picture and does not reveal the variations in micro-trends across the state. While area irrigated from dug wells has been decreasing, the area irrigated by shallow

Table 5. Number of wells in Andhra Pradesh between 1995-96 and 2000-01

Type of Well	1995-96				2000-2001			
	Total number of wells	Wells in use	Gross area irrigated (ha)	Area irrigated per well (ha)	Total number of wells	Wells in use	Gross area irrigated (ha)	Area irrigated per well (ha)
Dug wells	1,216,412	1,018,370	1,245,166	1.02	1,185,216	946,393	1,04,0644	0.9
Shallow tube-wells (Less than 70-m deep)	317,197	304,358	617,978	1.95	6,56,359	6,37,003	1,01,0388	1.53
Deep tube-wells (more than 70-m deep)	31,216	29,839	121,969	3.9	87,482	85,601	2,42,505	2.8
Total	1,564,825	1,352,567	1,985,113	1.26	19,29,057	16,68,997	22,93,537	1.18

(Source: Directorate of Economics and Statistics, GoAP, 2001)

Fig. 7 Gross area irrigated by groundwater and surface water



Source: Directorate of Economics and Statistics, GoAP, 2007-08 and deep tube-wells has increased rapidly over the last decade. In over-exploited and critical areas, due to exponential increase in well density, the yield and area irrigated per well has been reducing. Table 5 presents temporal variations in number of different types of wells and net area irrigated from each type.

The total number of wells and number of wells in use have reduced with corresponding decrease in gross area irrigated. The number of shallow tube-wells more than doubled between 1995-96 and 2000-01, but the gross area irrigated area only increased by 63 per cent. Deep tube-wells increased three-fold and the corresponding irrigated area doubled.

Area irrigated per well reduced from 1.02 to 0.9 ha for dug wells, from 2.03 to 1.53 ha for shallow tube-wells and from 3.09 to 2.80 ha for deep tube-wells. The reduction in area irrigated per well is significant for shallow and deep tube-wells. These are average values across over-exploited, critical, semi-critical and safe areas, and the values will obviously be higher when semi-critical and safe areas are omitted.

Data presented in Table 6 indicate an alarming increase in number of shallow and deep tube-wells with low water discharge between 1995-96 and 2000-01.

Reduction in number of dug wells and increase in number of tube-wells with low discharge is due to further slippage of wells as dry wells over this period. Most of the shallow and deep tube wells with low water discharge might be located in over-exploited, critical and semi-critical areas. On an average, the density of wells increased from 5 wells per sq. km. to over 10 wells per sq. km. But in hard rock areas it is over 20 wells

Table 6. Status of wells in 1995–96 and 2000–01

Type of Well	1995-96		2000-2001		Change in wells with low water discharge (%)
	Wells in use	Wells with low water discharge	Wells in use	Wells with low water discharge	
Open wells	10,18,370	4,40,016	9,46,393	3,76,303	–14.5
Shallow tube-wells	3,04,358	68,204	6,37,003	1,77,967	+160.9
Deep tube-wells	29,839	8,020	85,601	34,216	+326.6
Total	13,52,567	5,16,240	16,68,997	5,88,486	+13.99

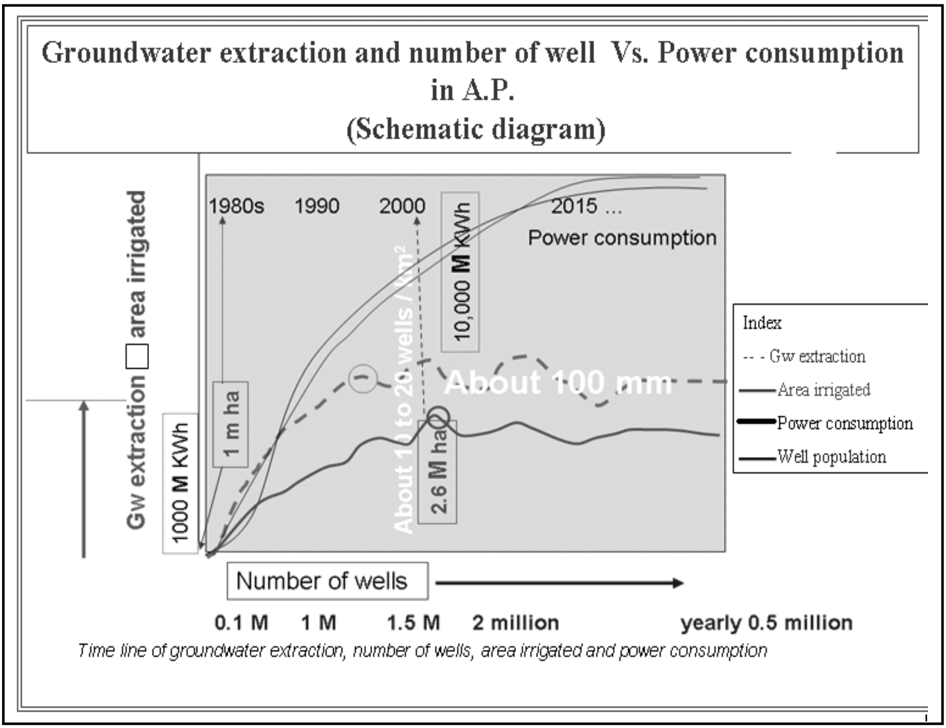
(Source: Ministry of Water Resources, GoI, 2000–01)

per sq. km and in some pockets it is as high as 100 wells per sq. km. Consequently, the yields from wells have decreased considerably and water levels dropped consistently, increasing tenfold the power requirements for irrigating the same area.

Total installed capacity for electricity generation in Andhra Pradesh is 12,330 MW (as on 31st January 2008) with 26,027 MU of cumulative energy generation. Maximum electricity consumption takes place during the post-monsoon period when agricultural consumption peaks go as high as 200 MU per day. Most of the wells in Andhra Pradesh are energized with free electricity supplied for about 7 hours per day. As per the reports of Central Electricity Authority, consumption of electricity for agriculture in Andhra Pradesh has reached 14,160 Gigawatt-hours during 2004-05, which is about 36 per cent of the total electricity consumed in the State.

The Central Power Distribution Company Limited, one of the four electricity distribution companies in Andhra Pradesh, reported an increase of 33 per cent in demand for power for agriculture between 2003-04 and 2006-07 (CPDCL, Andhra Pradesh, 2008-09).

Fig. 8 Ground Water Extraction and Number of Wells Vs. Power consumption in A.P



Source: Department of Groundwater, GoAP, 2008

Table 7. Status of agricultural service connections in 2007–08

Agricultural services	As on 31.03.2007	Added in 2007-08 (to Jan 2008)	As on 31.01.2008
Distribution Companies (DISCOMs)	2,439,632	48,844	2,488,476
Rural Electricity Service Corporations (RESCOs)	88,168	1,578	897,46
Total	2,527,800	50,422	2,578,222

Source: A.P.TRANSCO, GoAP, 2008

Purchase of power from other sources and states contributes to the huge revenue deficit of the company. The company projected a revenue deficit of Rs. 11,503 million for the year 2008-2009. Table 7 gives the number of agricultural service connections in the state and increase in the number in 2007-08. The table reveals that there was an increase of around 50,000 connections per year partly due to addition of new wells and partly through regularization of unauthorized connections.

In many areas, distribution transformers are overloaded due to increasing number of wells, unauthorized connections, use of non-standard motors and use of higher capacity pumpsets. Low voltages at pumpsets are affecting the discharge and life of pumpsets. The low energy efficiency in transmission and at the pumpset level is also a major contributing factor to the slippage of wells to lower discharge condition and finally to dry condition.

Initiatives by the Government to improve groundwater recharge

Repeated droughts and alarming depletion in groundwater resources during the late 1990's prompted the AP State Government to lay emphasis on efficient water conservation and management. The last decade has witnessed promulgation of various Acts and guidelines related to water management. One such measure is the enactment called Andhra Pradesh Water, Land and Trees Act (APWALTA) in 2002. This Act repealed earlier legislations such as Andhra Pradesh Ground Water Act (Regulation for drinking water purposes), 1996, and Andhra Pradesh Water, Land and Tree Ordinance, no.15 of 2000. Table 8 gives the chronology of events in evolution of water-related policy in Andhra Pradesh.

In March 2005 the Government of Andhra Pradesh introduced well failure insurance scheme for bore-well owners. As per this provision, farmers who take permission from the concerned authority and drill a bore-well, are eligible to claim insurance subjected to a maximum limit of Rs.10,000 in case the well turns out to be dry. Farmers were required to pay Rs. 1,200 towards insurance premium, in addition to the geological survey charges of Rs. 1,000 (Rs.500 for small and marginal farmers) towards the cost of site investigation by a qualified hydrogeologist.

From 2006–2007, the Government decided to revise the insurance scheme for failed bore-wells through the Commissioner, Rural Development, by maintaining a corpus fund instead of tie ups with insurance companies. All those bore-wells which were drilled after obtaining necessary permissions under APWALTA became eligible for insurance compensation of Rs.10,000 or actual expenses, whichever is less. In the new system, the farmers were not required to pay any premium for obtaining the insurance cover (Government of Andhra Pradesh, 2006).

In June 2005, realizing the importance of sustaining groundwater resources for improving economy of the state, the State Government through a notification defined the minimum spacing to be maintained from existing drinking and irrigation wells. As per this rule, a

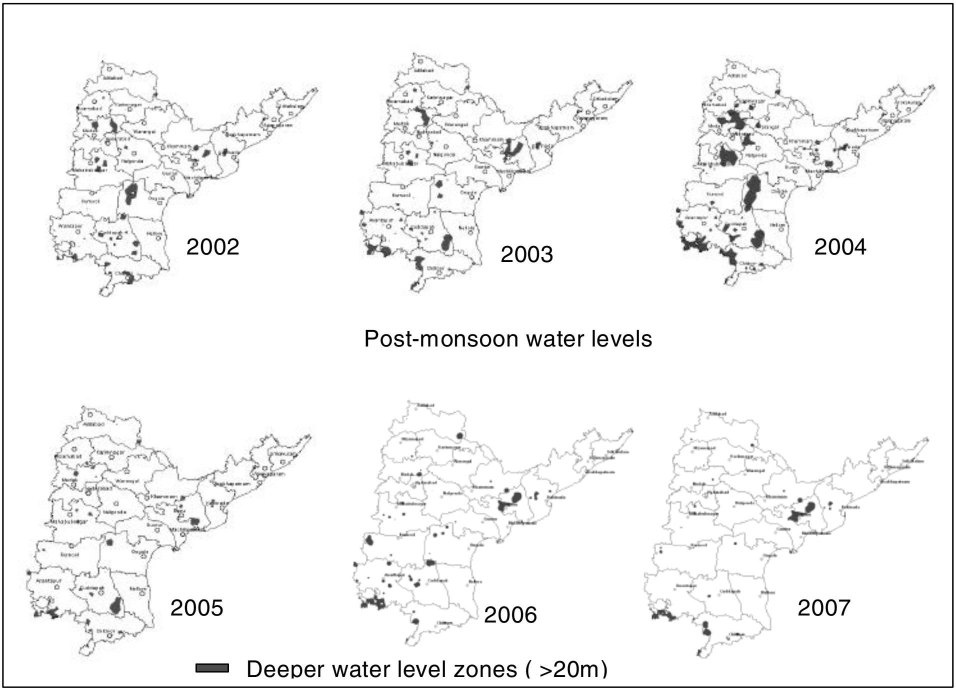
Table 8. Key events in water policy evolution in Andhra Pradesh

1996	Enactment of Andhra Pradesh Groundwater Act (Regulation for drinking water purposes)
1997	Enactment of Andhra Pradesh Farmers' Management of Irrigation Systems Act to promote participatory management of irrigation systems in the state
1999	Spelt out Vision 2020, emphasizing the importance of water management and participatory approaches to irrigation management for sustainable growth in the agriculture and fisheries sectors
2000	Andhra Pradesh Water, Land and Tree Ordinance (no. 15)
2002	Enactment of Andhra Pradesh Water, Land and Trees Act (APWALTA)
2002	Release of Guidelines for Watershed Development in Andhra Pradesh based on the national guidelines (1994) and recommendations of the reviews done from time to time
2003	Andhra Pradesh Water Vision defining a broad policy framework for water in the state

farmer who sought permission for drilling a new well would not be allowed to do so, if the proposed location is inside the specified minimum distance.

In addition to the above watershed-development programmes, desilting of water bodies and rain-water harvesting in arable and non–arable lands were initiated at the state level by establishing a water conservation mission to improve groundwater recharge. Consequent on these activities groundwater recharge has been improved. Seepage from canals and water bodies contributes the equivalent of 4 to 5 per cent of the annual rainfall and natural infiltration contributes 9 to 10 per cent of the annual rainfall towards groundwater recharge. Other large-scale recharge measures implemented have increased groundwater recharge by an additional 1.0 per cent of the annual rainfall. Temporal water level zoning maps for 2002 to 2007 indicate diminishing trends in depth to water table zones of 20m and above in post monsoon from 2002 to 2007 and the same trends are being continued in pre- monsoon (Figs. 9a and 9b).

Fig. 9a Post-monsoon temporal water level zoning maps



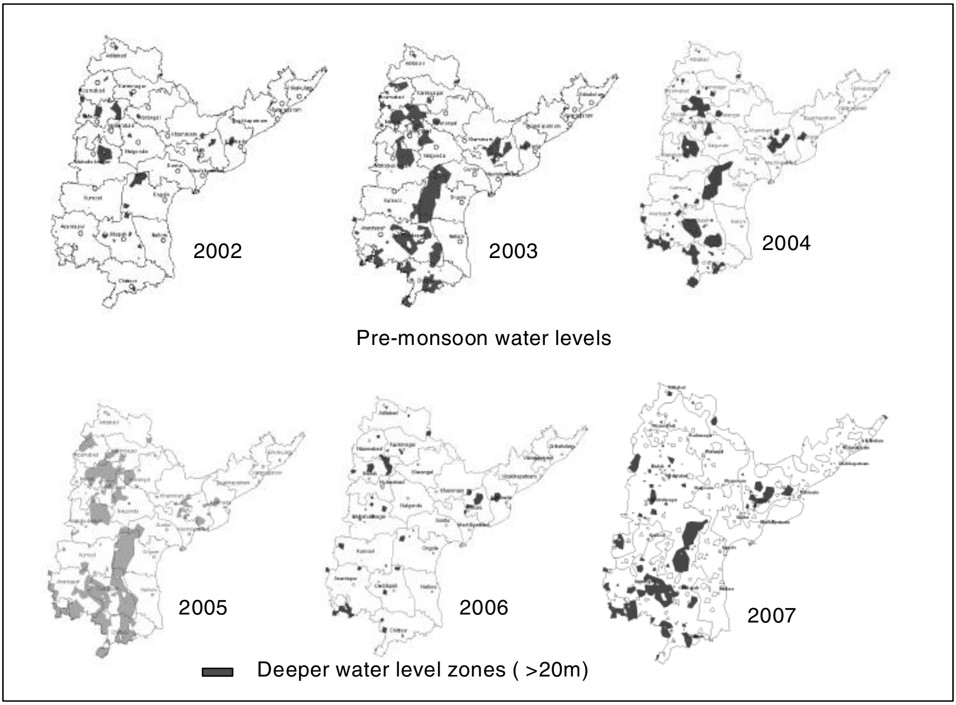
Source: Groundwater Department, GoAP, 2007

Urban hydrographs clearly show the impact of urbanization on groundwater levels, especially in and around Hyderabad. The groundwater levels show a tendency to rise because of domestic piped water supply from surface water sources reducing the dependence on groundwater for domestic consumption.

Future Challenges

The present rate of groundwater development in non-command areas will possibly result in higher depth to groundwater and reduced well yields, especially in hard rock terrain; there, consequently, is a threat to drinking water sources in terms of quality as well as quantity. Furthermore, the situation also leads to increase in number of over-exploited villages. In command areas, due to shallow water table, more areas are likely to become prone to water logging, thus reducing crop productivity. Over-exploitation of groundwater in coastal areas may result in sea-water ingress. Other main threats to aquifers include anthropogenic pollution and pollution caused by minerals in the aquifer. Once the water resources are polluted the costs and time scale for remediation of an

Fig. 9b Pre-monsoon water levels with deep water level zones



Source: Groundwater Department, GoAP, 2007 aquifer vastly exceed those for surface water resources. Thus the water challenges are manifold - improving and safeguarding the existing water sources, increasing water-use efficiency through effective water management and prevention of pollution without causing environmental degradation are the major concerns for the future.

In order to sustain the groundwater and its economy, several measures need to be initiated. The important measures will be (i) improving groundwater recharge, (ii) improving water-use efficiency in intensively irrigated areas by promoting conjunctive use, (iii) promoting less water-intensive crops and crops that give higher net returns per unit of water.

GoAP's Initiatives and Policies

The Government of Andhra Pradesh have initiated the following measures to overcome the challenges.

a) Improving the recharge of groundwater

There are many technologies and practices for recharging aquifers. But the potential for artificial recharge in the semi-arid regions is very low due to low rainfall as well as its erratic distribution, low infiltration rate of soils, poor storage potential of hard rock aquifers and high rates of evaporation. The Government has initiated programmes to harvest rainwater by establishing the Water Conservation Mission (WCM) in the year 2000. The efforts under WCM are concentrated on engineering measures such as contour trenching, gully control works, construction of sub-surface dikes, check dams, percolation tanks and farm ponds, cleaning of feeder channels and desilting of water bodies. In addition, the Government of Andhra Pradesh has fully utilized centrally sponsored watershed development programmes to conserve rainwater over an area of about 10.0 m ha by 2007. These programmes have resulted in raising the groundwater levels by 9 per cent, reducing drinking water well failures from 12,633 to 4,111 and bringing down the number of habitations requiring transportation of drinking water from 817 to 537.

b) Improving water-use efficiency

Improving the efficiency of application of surface water through increased reliability in delivery and better control over its application could help to reduce the amount of its depletion and improve its consumptive use and productivity. Government of A.P., to ensure the above, introduced participatory irrigation management by making farmers responsible for management of the irrigation systems by passing the APFMIS Act in 1997. In all, 10,292 Water Users Associations at the tertiary level, and 170 Distributory Committees covering 10.0 million farmers and more than 2.0 million ha of irrigated land started working since 1997. The water charges collected are ploughed back to WUAs, Distributory Committees and Project Committees to improve operational performance through effective maintenance. The functioning of the farmers' associations and committees are reviewed to enhance their effectiveness. The experiences so far are quite impressive. Improved maintenance has stabilized water availability at the tail end, which was earlier deprived of canal irrigation. This has increased crop yields, cropping intensity and farm income.

c) Regulatory approach to managing groundwater

At present anyone who has a piece of land has access to the underlying resource. A land owner can legally abstract any amount of water unless the geohydrology limits it. The lack of well-defined rights, the invisibility and indivisibility of groundwater and its complex flow characteristics make monitoring of its use difficult. The only institutional approach left to manage groundwater for arresting over-development of groundwater and for mitigating environmental consequences is through establishment of a regulatory framework. Towards this end the Government introduced the Andhra Pradesh Water, Land and Trees Act (APWALTA) in 2002 to promote water conservation and tree cover.

Under the Act all groundwater users must register their wells and seek permission to construct new groundwater extraction structures. No well shall be sunk in over-exploited areas already notified, except for drinking purpose. Guidelines are issued on well spacing and depth to prevent over-exploitation and to safeguard drinking water sources.

To ensure sustainable water use, there is a need for policy changes facilitating a paradigm shift from designing strategies for increasing supplies to changing the socio-economic system to manage the demand for water by effective water use. Such policy changes should include the following:

- creating awareness of occurrence, distribution and limitations to exploitation of groundwater to ensure whole-hearted participation of the people;
- prioritizing management of water resources efficiently by integrating development of water across various sectors and geographies;
- planning management and regulating the use of groundwater should be in consultation with groundwater scientists;
- Only 20 per cent of the area should be irrigated through groundwater for irrigated dry crops in order to avoid over-exploitation. The proportion can be increased to 40 per cent by introducing micro-irrigation practices; however such a shift might not result in saving water;

- keeping the future in view, groundwater should be utilized for giving wettings to rainfed crops during long dry spells;
- APWALTA is not applicable to extraction of groundwater from existing sources use of which has been responsible for over-exploitation in the area; therefore a mechanism be to be devised in order to control draft from existing sources.
- artificial recharge should be site- and objective-specific and should specially taken up to solve drinking water problems;
- the outcome of artificial recharge for irrigation purpose should be to stabilize the existing area rather than to increase the area irrigated;
- recharging through defunct dug wells is a good concept of artificial recharge and may prove to be effective and needs proper planning;
- certain pockets in every village have to be identified for creation of drinking water sanctuaries where no groundwater exploitation is allowed except for drinking purpose during emergencies;
- there is scope for increasing groundwater exploitation in command areas and efforts should be made to reach 70 per cent exploitation of available resource by way of conjunctive use. In these areas certain pockets should be allotted for exploitation to tackle drinking water problems in neighboring areas.
- creating mass awareness among the people about the quality of the water and health hazards especially in areas having industries, mining and aquaculture activities, etc.;
- sources of pollution affecting the water quality should be identified and remedial measures should be taken to safeguard water quality. Appropriate remedial measures should also be taken in areas having high fluoride and nitrate concentrations;
- regulations on sand mining for protection of drinking water sources and preventing release of industrial effluents into streams more so near drinking-water sources should be enforced effectively;
- research and development projects should focus on the land/water interface to recognize and build on land and water linkages by making coordinated management interventions.

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