Lecture Delivered at the 23rd Induction Training Program (ITP) for the new appointees of the Central Water Engineering (Group ‘A’) Services, National Water Academy (NWA), Pune from 11:30 AM to 1:00 PM on 4th November 2009

CONJUNCTIVE USE OF SURFACE WATER AND GROUND WATER

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ABOUT MYSELF

- I have taken up the task of making available good quality water in adequate amounts for public supplies, irrigation and industrial uses to all those who approached me since 1965.
- I have taken up this work as a teacher, researcher, extension worker and consultant and produced several theses and technical reports.
- My studies initially had a bias towards groundwater. In course of time, I realised that conjunctive use of surface and ground waters by making use of the latest advances in science and technology can alone save India from water shortages.
- I also find the need for a radical change in the policies pursued by the various Government Departments to achieve this goal.
- I have been shaping my views on the subject by participating extensively in several web-based forums since 1999.
- My messages to the Water Voice Project of the 3rd World Water Forum fetched me a Water Voice Messenger Award at Kyoto, Japan in March 2003.

Received Water Voice Messenger Award from the Former Prime Minister of Japan at the 3rd World Water Forum, Kyoto in March 2003

INDIA'S DEMAND FOR FRESH WATER

India's demand for fresh water has been growing at an alarming rate because of:

- Relatively high birthrate over death rate making India presently ranking second in the world after China to become No. 1 with population reaching 1.6 billion by 2050,
- Rapidly growing economy with Gross Domestic Product (GDP) ranking presently ninth in the world and going to become third after USA and China by 2040,
- High industrial growth,
- Growing migration of people from rural to urban areas, and
- Improved style of living.

WATER INDIA'S SUPPLY OF FRESH

India is unable to meet the country's demand for fresh water because of:

- Government Departments in water sector unable to meet the country's water needs due to various reasons including paucity of funds,
- People at large pumping groundwater through deep wells to meet their water needs and demanding Government for low-interest loans, subsidies and free/subsidised power,
- Water activists demand to ban both large projects and deep wells and make it mandatory for people to construct and maintain small community-based water structures and individual shallow wells besides practising community-based traditional rainwater harvesting,

All this has led the Government to dissipate resources to please all the stakeholders rather than evolve a unified policy in the water sector.

ALWAR MODEL OF GROUNDWATER MANAGEMENT

- Because of low and erratic rainfall and absence of sustainable sources of irrigation water, the farmers of Alwar District in Rajasthan were leading a miserable life.
- Rajendra Singh with no background knowledge on water could take up construction of around 9 thousand check dams across the Arvari and four other rivers both in the forest and non-forest areas at close intervals through people's participation since 1985.
- This had led to arrest of some 3% of the total surface runoff of the rivers to give a perennial look to the rivers.
- Because of the influent or losing nature of the streams, the surface water seeps slowly into the underground round the year to make available small quantities of groundwater to the innumerable shallow dug wells constructed on either side of the rivers to irrigate their small land holdings.
- This has led to some improvement in the living conditions of the farmers.

REASONS FOR THE SUCCESS OF RAJENDRA SINGH

- He could successfully defy the prevailing laws in the functioning of the Forest, Irrigation and other Government Departments that came in his way for execution of various works.
- He could also successfully implement certain stringent rules of water conservation that include:

(I) Ban on deforestation and cutting of green trees,

(ii) Ban on hunting and fishing,

(iii) Ban on mining and industrial activities,

(iv) Ban on grazing by outside cattle,

(v) Ban on rearing buffaloes,

(vi) Ban on growing water-intensive crops

(vii) Ban on pumping river water

(vii) Ban on sinking deep wells

BENEFITS ACCRUED THROUGH THE WORK OF RAJENDRA SINGH

- The work of Rajendra Singh received recognition not only by the local activists but also by the then President of India.
- He received Ramon Magsaysay Award for Community Leadership in 2001, which is widely seen as the Asian version of the Nobel Prize.
- All the court cases against him for defying the laws of the land were withdrawn.
- He was recognised as the Water Man of India and could tour all over India and the world to propagate how his methodology can solve India's water problems.
- Government has initiated many projects in the water sector involving community participation.
- There has been however no attempt by the Government to study critically the reasons for the government schemes not bringing spectacular results of the type achieved by Rajendra Singh so as to change the laws and policies that were hindering development.

HARM DONE THROUGH THE WORK OF RAJENDRA SINGH

- Implementation of stringent rules of Rajendra Singh such as ban on mining of marble deposits has hindered development of non-farm sectors with loss of livelihood for non-agricultural workers.
- Although millions of check dams were constructed all over India, no success story of the magnitude of the Arvari model has been so far reported anywhere from India.
- Many water activists warned the Government that India's surface water resources became unsustainable because of constructing major dams and canals, while groundwater became unsustainable because of deep wells.
- They further declared that the only way sustainability of water supplies could be achieved is through revival of traditional community-based water works that depend on rainwater, local runoff and shallow dug wells.
- All this, if strictly implemented, will further enhance water shortages and bring India back to the bullock-cart age..

GOVERNMENT OF INDIA'S PROGRAM TO USE DUG WELLS TO RECHARGE GROUNDWATER

- One recent example of a populist scheme taken up by the Government in 2007 is to artificially recharge groundwater by diverting floodwaters into 44.5 lakh dug wells with well owners as partners at a cost of Rs. 1800 crore.
- The scheme aims to facilitate improvement in the groundwater situation, increase the sustainability of wells during lean period, improve ground water quality, and involve the well owners in water management.
- The major snags in the program include:

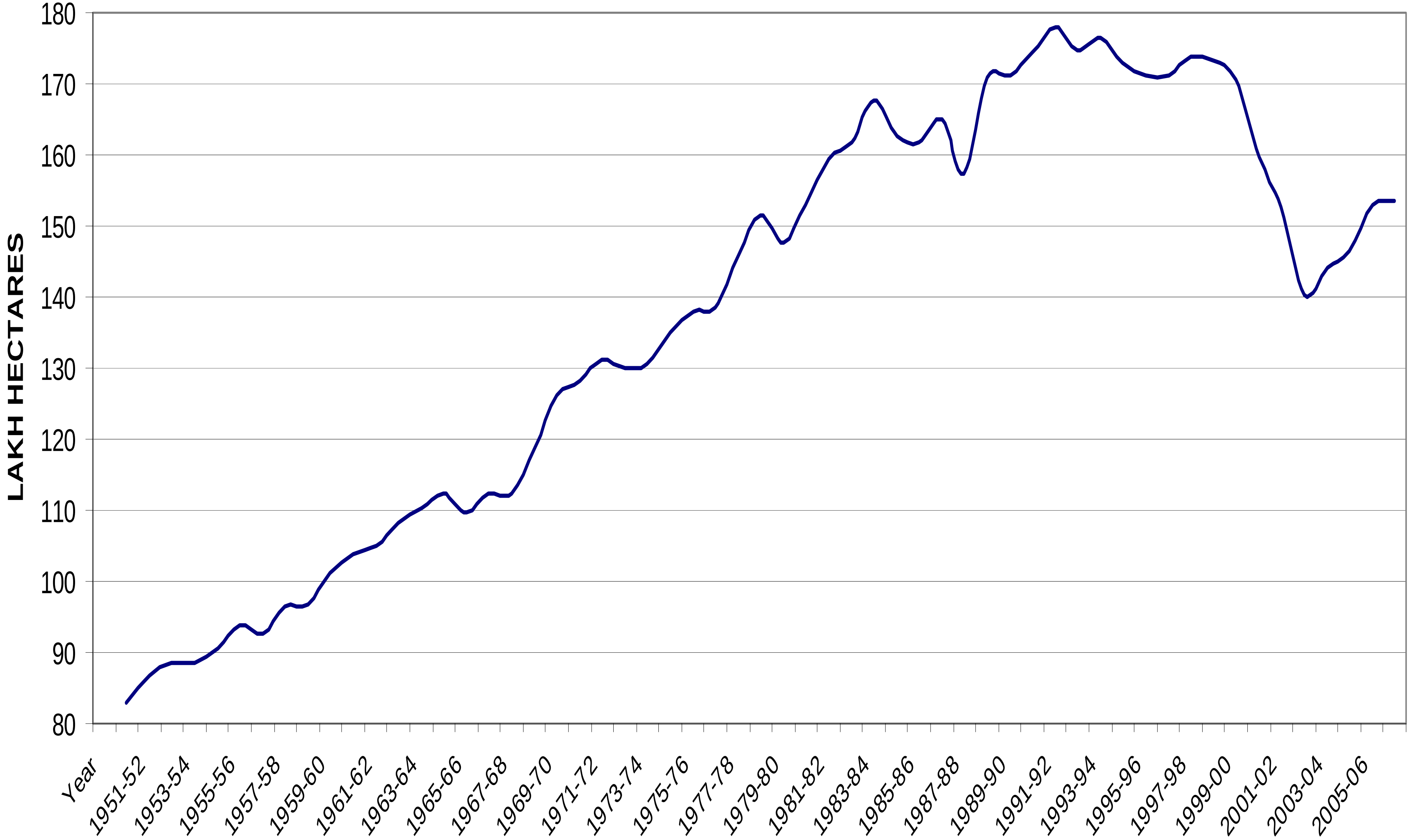
i. The danger of pollutants entering into the wells to ruin the water quality because of ignorance and carelessness, and

ii. The possibility of groundwater yields improving in the nearby deep wells rather than in the owners' dug wells resulting in loss of interest in the recharge program by the well owners .

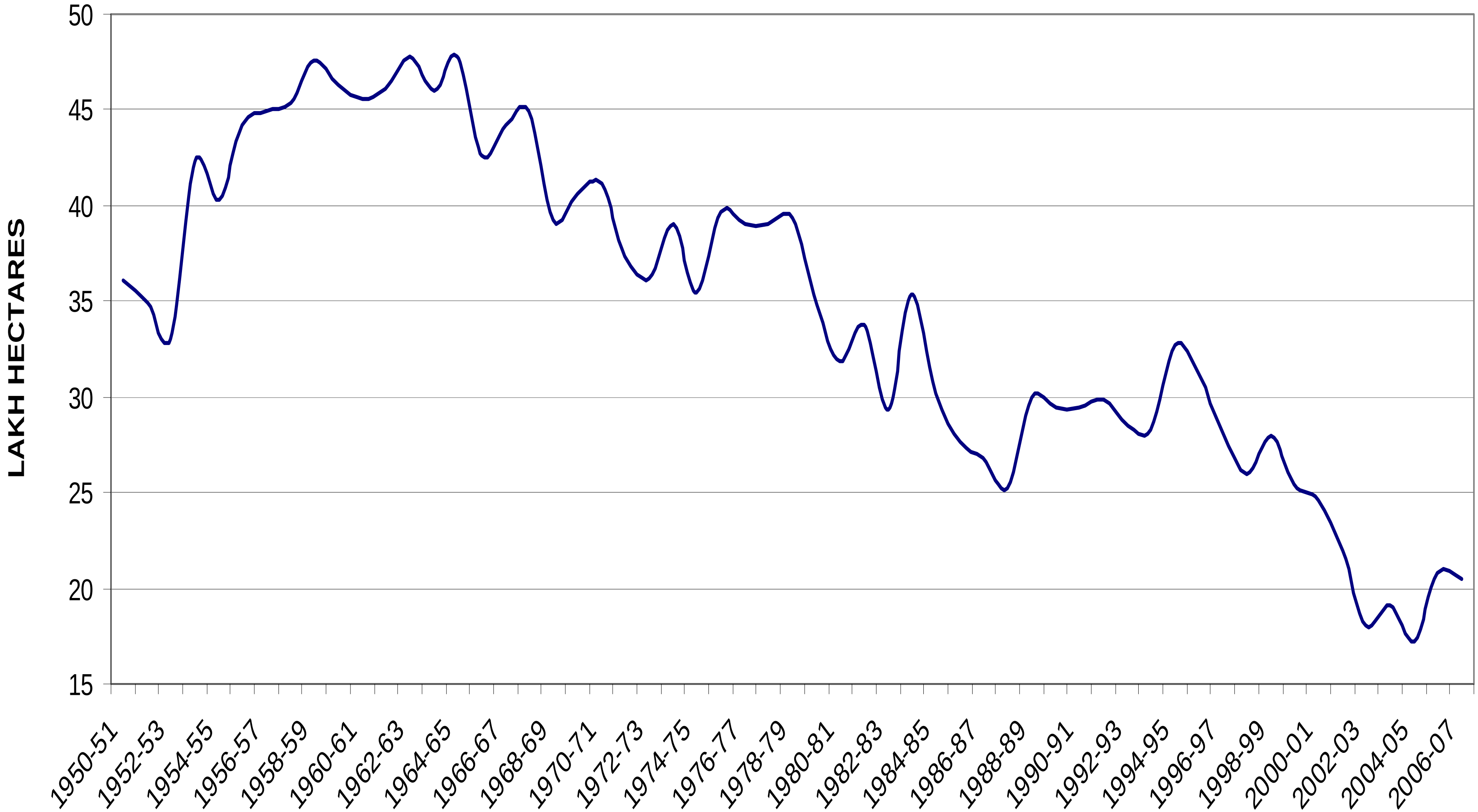
UTILIZATION OF WATER RESOURCES OF INDIA

- After India became independent in 1947, the Government took up the entire responsibility of harnessing water resources through major, medium, and minor projects to provide surface water primarily for irrigation and public supplies at highly subsidised rates.
- Pending availability of surface water from the Government projects, people have taken up large-scale harnessing of groundwater to meet their water needs.
- This has led to construction of over 19 million irrigation wells and very large number of domestic and other wells to extract over 186 cu km of groundwater per year. Of the groundwater so extracted, 92% is used for irrigation, 3% for domestic use and 5% for industrial use.
- The slides that follow give an idea of the role played by groundwater in enhancing the net area under irrigation since 1950-51 (http://dacnet.nic.in/eands/LUS-2006-07/Summary/tb2.11.pdf).

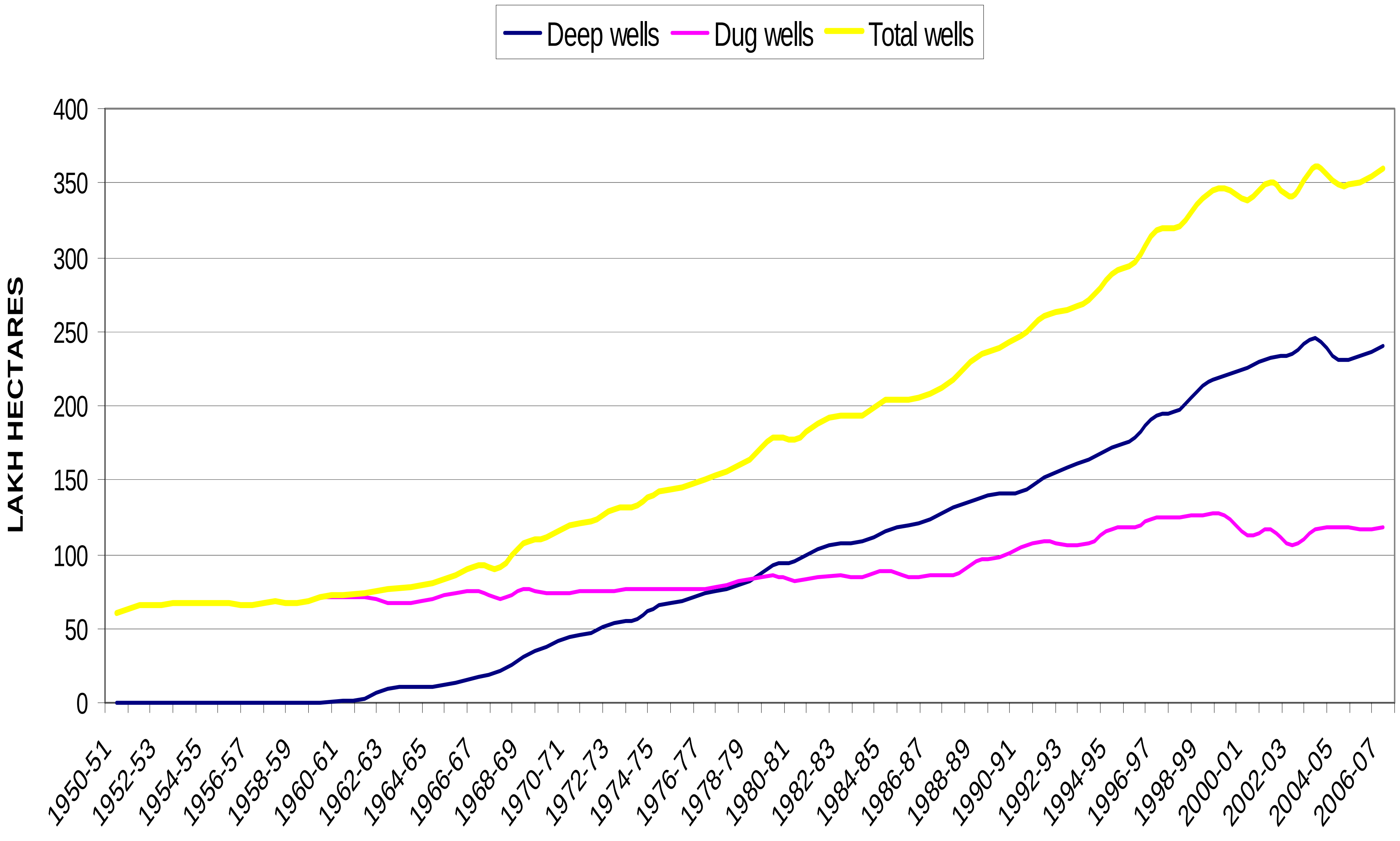
YEAR-WISE NET AREA IRRIGATED IN INDIA THROUGH CANALS (1950-51 to 2006-07)



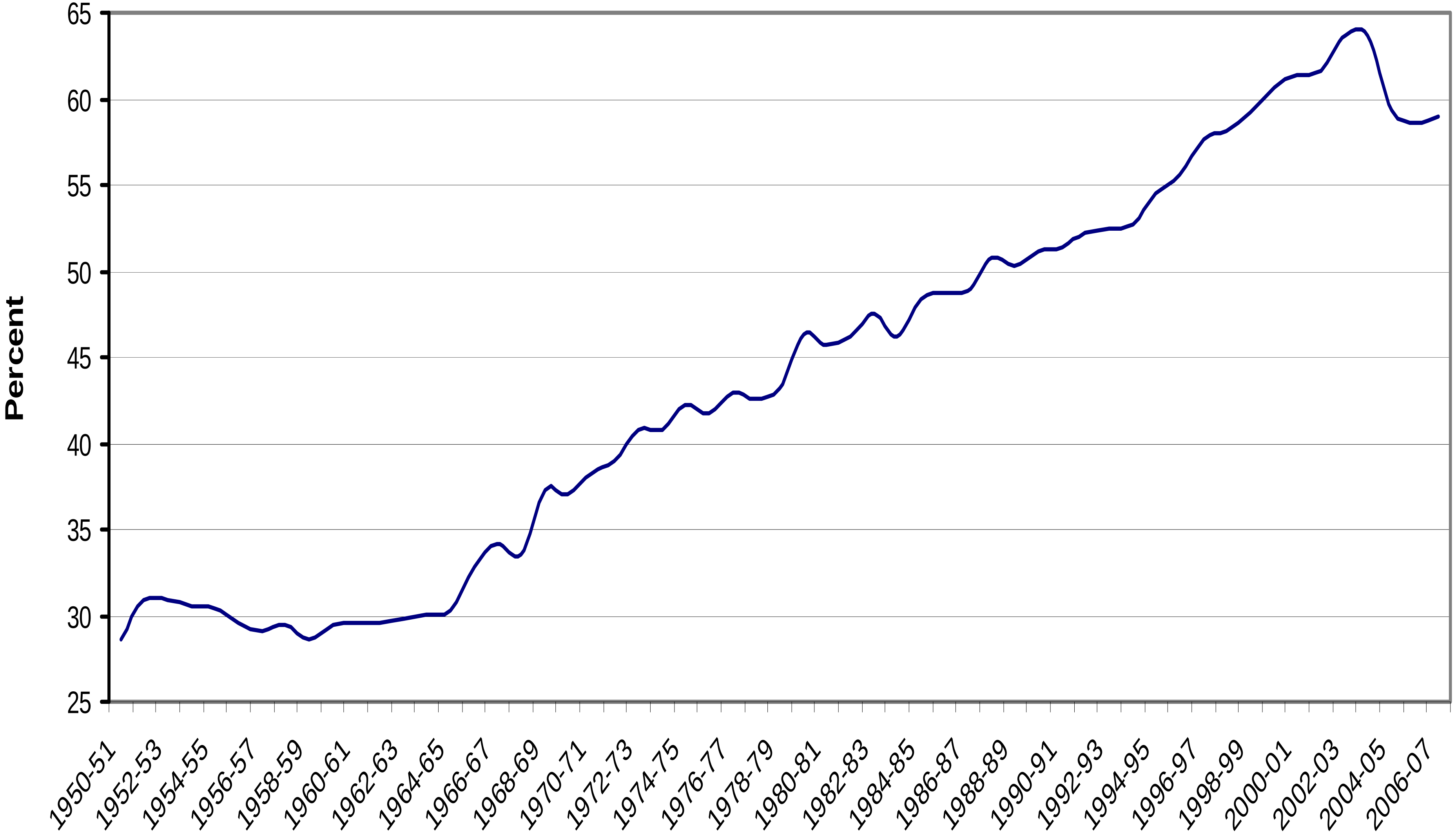
YEAR-WISE NET AREA IRRIGATED BY TANKS (1950-51 to 2006-07)



YEAR-WISE NET AREA IRRIGATED BY WELLS (1950-51 TO 2006-07)



YEAR-WISE % NET AREA IRRIGATED BY GROUNDWATER TO THAT IRRIGATED BY ALL SOURCES (1950-51 TO 2006-07)



LESSONS LEARNT FROM THE IRRIGATION STATISTICS

- The year-wise net area irrigated under tanks has shown a remarkable decrease, despite water activists proclaiming that minor water bodies alone can solve India's water problems.
- The near stagnation in the net area irrigated by shallow dug wells dispels the argument that dug wells alone can solve India's water problems.
- Absence of increase in the net area irrigated under canals does not justify heavy expenditure on major and medium irrigation projects. The only way benefits from canals could be enhanced is through conjunctive use of surface water and groundwater.
- The primary purpose of this lecture is to outline how conjunctive use of surface water and groundwater alone can provide sustainable irrigation water for more land.

Utilisable Surface Water & Groundwater Resources in River Basins of India in Cubic Km per Year

River Basins	Average Monsoon Runoff & % Available as flow	Replenishable Groundwater & % Available as flow (1999)
Indus	58.6 (21.5%)	25.5 (15.6%)
Ganga	401.3 (37.7%)	171.7 (52.3%)
Brahmaputra-Meghna	477.5 (95.0%)	29.7 (73.7%)
Godavari	107.1 (28.8%)	46.8 (63.7%)
Krishna	61.0 (4.9%)	26.6 (52.8%)
Cauvery	18.9 (100.5%)	13.6 (41.8%)
Pennar	6.2 (0%)	5.0 (51.7%)
Between Mahanadi & Pennar	15.3 (14.4%)	22.8 (65.4%)
Between Pennar & Kanyakumari	16.0 (0%)	20.9 (40.9%)
Mahanadi	60.2 (16.9%)	21.3 (72.3%)
Brahmani-Baitarni	32.6 (43.9%)	5.9 (71.7%)
Subarnarekha	9.7 (29.9%)	2.2 (68.9%)
Cambay	14.1 (64.5%)	7.9 (52.7%)
Kutch-Saurashtra-Luni	13.6 (0%)	13.9 (43.9%)
Narmada	36.9 (25.5%)	11.9 (63.9%)
Tapi	16.2 (0.4%)	8.2 (54.1%)
Western Ghats	178.1 (79.7%)	18.3 (60.3%)
India as a whole	1,523.3 (55.1%)	452.2 (54.3% - 51% in 2004)

GEOGRAPHICAL DISTRIBUTION OF INDIA'S RIVER BASINS

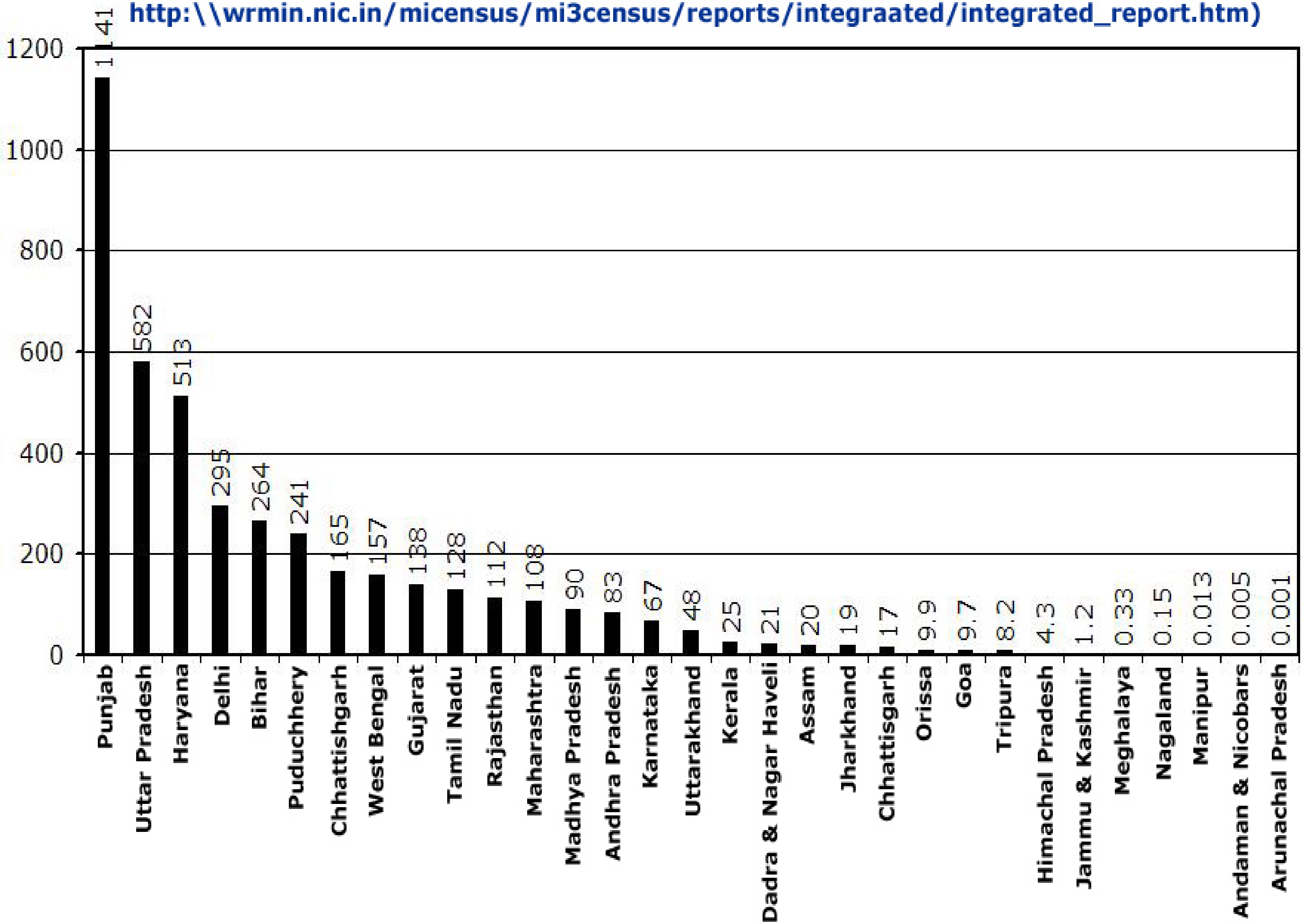
Basin-wise availability of groundwater to the replenishable ground water is highest in the Brahmaputra & Meghna basins at 82% and lowest in the Indus basin at 20%. Other basins with less than 50% water availability include Madras and South Tamil Nadu (36%), Cauvery (38%), Kutch & Saurashtra Composite (41%) and Tapi (48%). More details can be obtained from the next Slide.

BASIN-WISE UTILISABLE SURFACE WATER AND GROUNDWATER

- Water in riverbeds flows as both surface and ground water runoff with considerable interaction between the two types of waters.
- The ultimate average flow as surface runoff in a river is the difference between the average monsoon runoff and water that could be harnessed. While these flows are highest in the Brahmaputra & Meghna rivers, they are almost zero in the rivers of Kutch-Saurashtra-Luni, Pennar, those between Pennar & Kanyakumari, and Cauvery.
- The difference between the replenishable groundwater and groundwater so far harnessed in a river basin can be taken as almost equal to the average flow of groundwater runoff beneath the riverbed. While these flows are highest in the rivers of Brahmaputra-Meghna, Mahanadi, and Brahmani-Baitarni, it is lowest in the rivers of Indus, those between Pennar & Kanyakumari, Cauvery, and Kutch-Saurashtra-Luni.
- The slide that follows gives the details.

State-wise Gross area Irrigated with groundwater/1000 ha in India (2000-01)

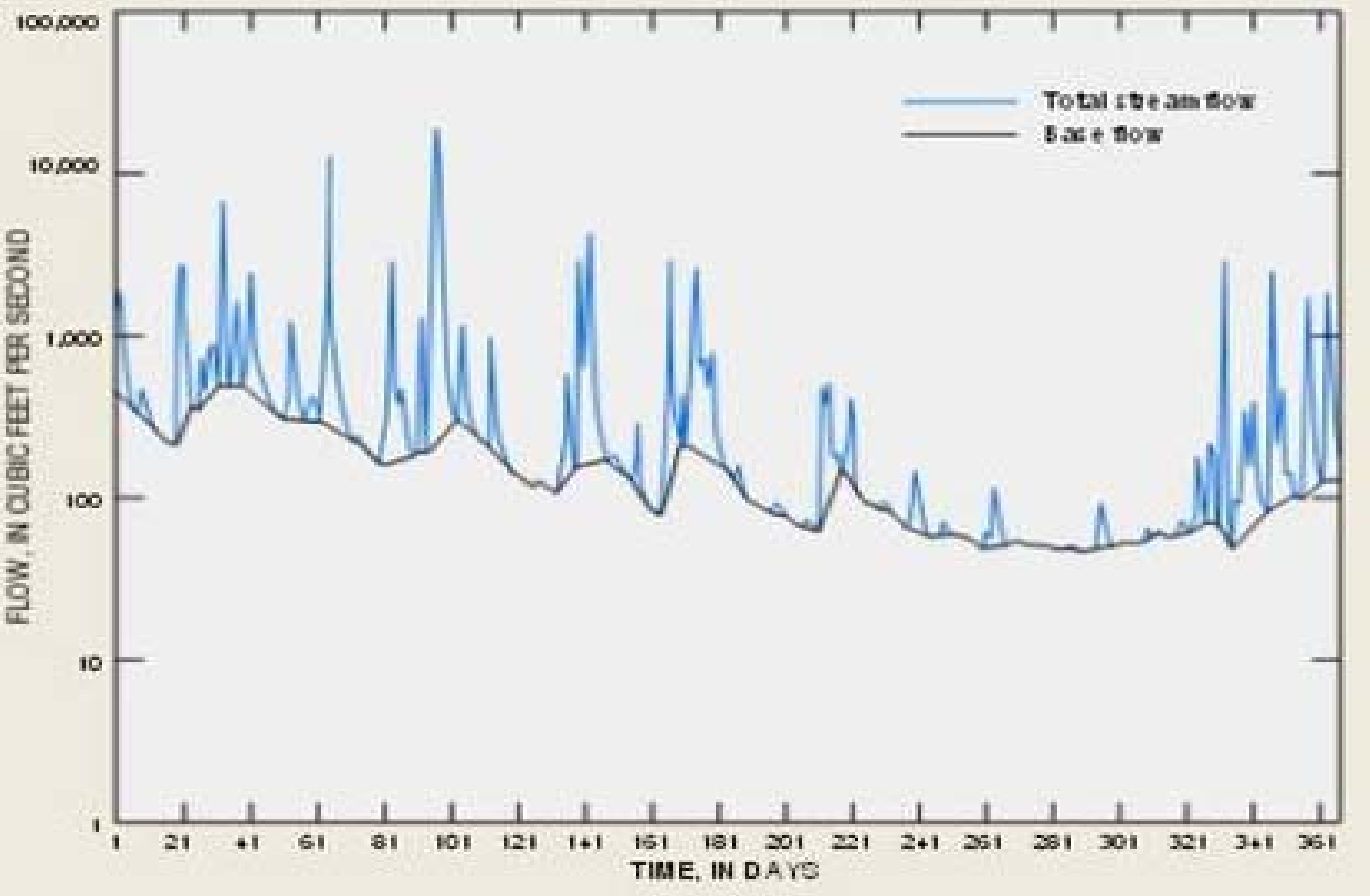
(http:\\india.gov.in/knowindia/state_uts.php &
http:\\wrmin.nic.in/micensus/mi3census/reports/integraated/integrated_report.htm)

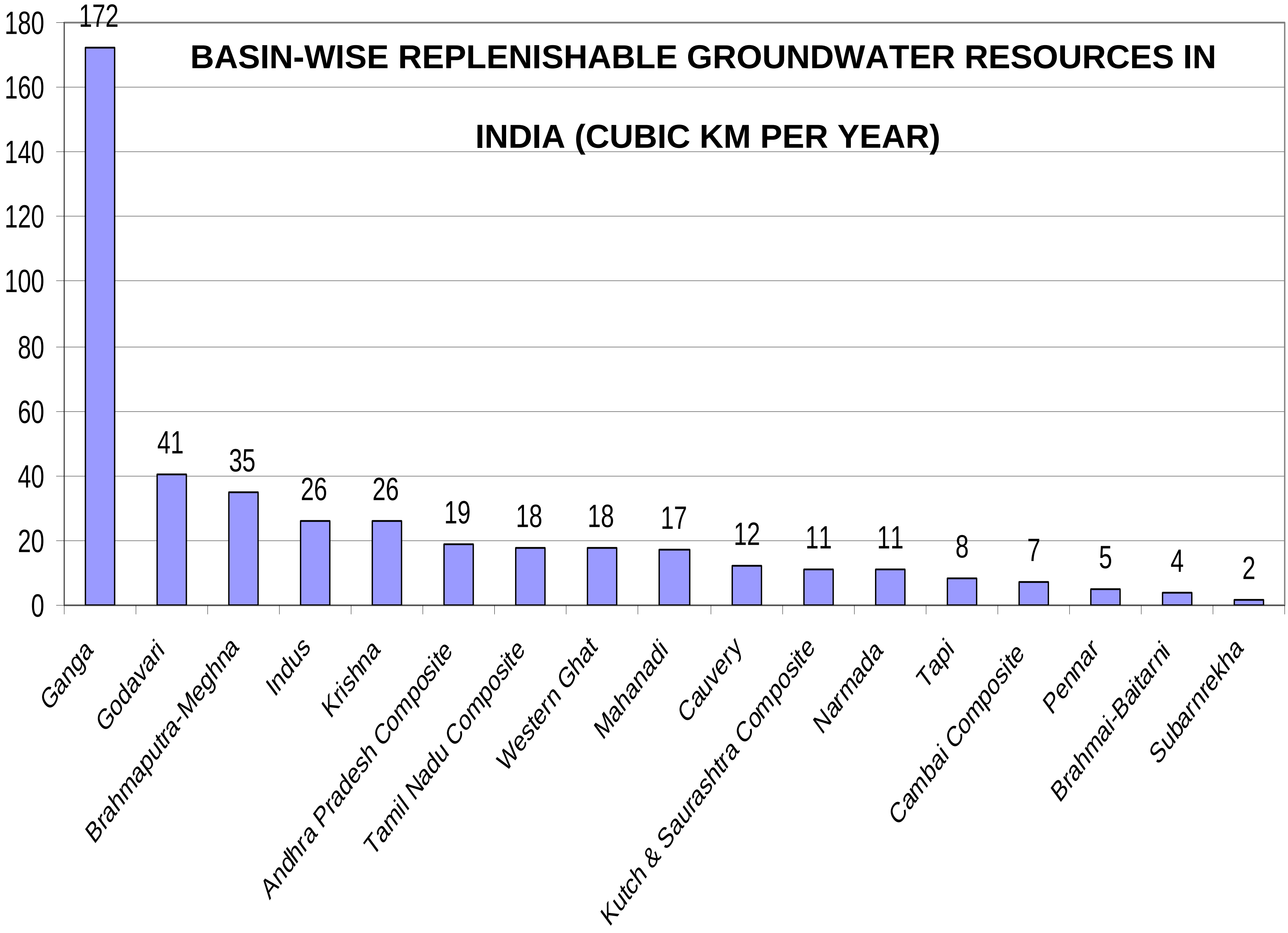


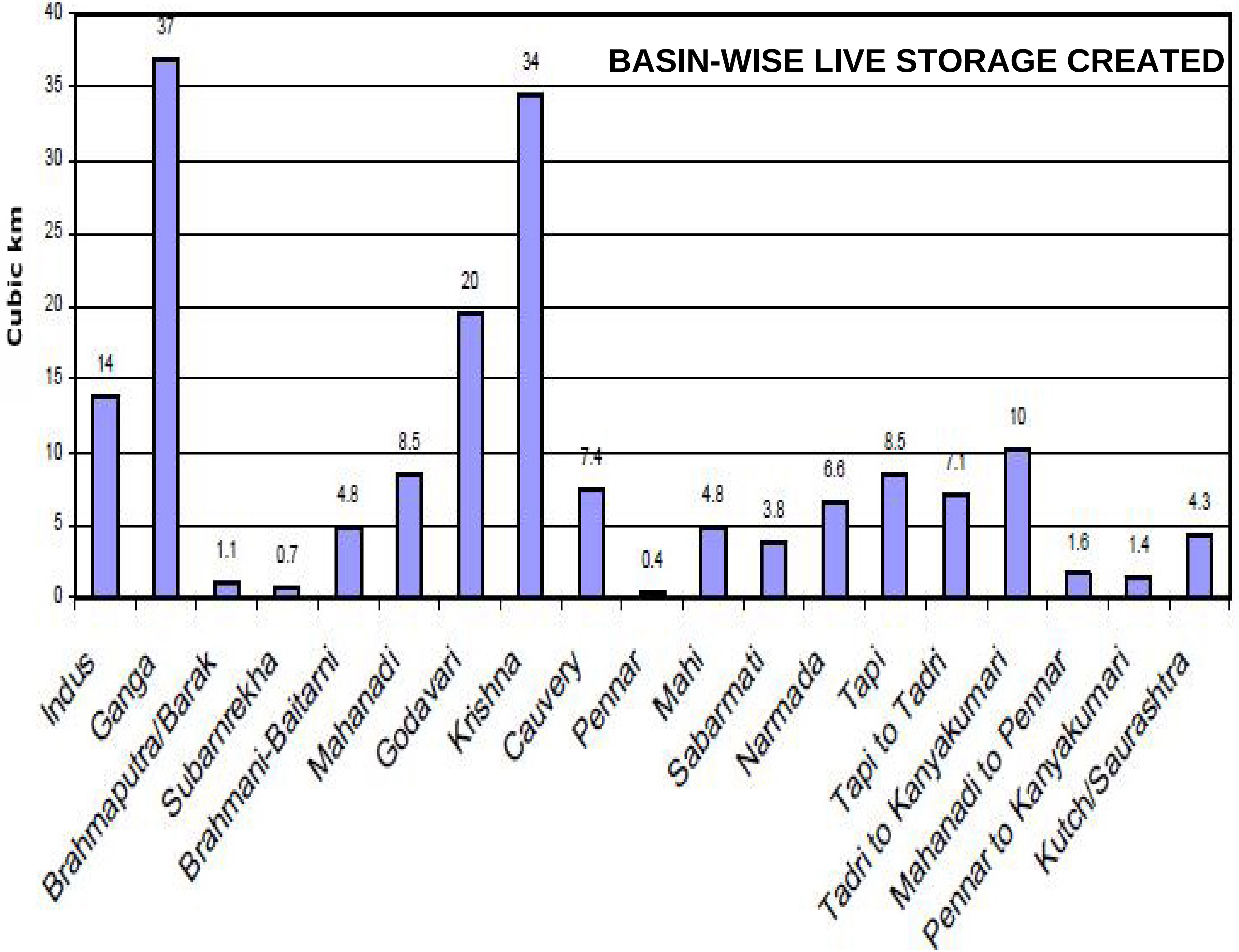
INTERACTION BETWEEN SURFACE WATER AND GROUNDWATER

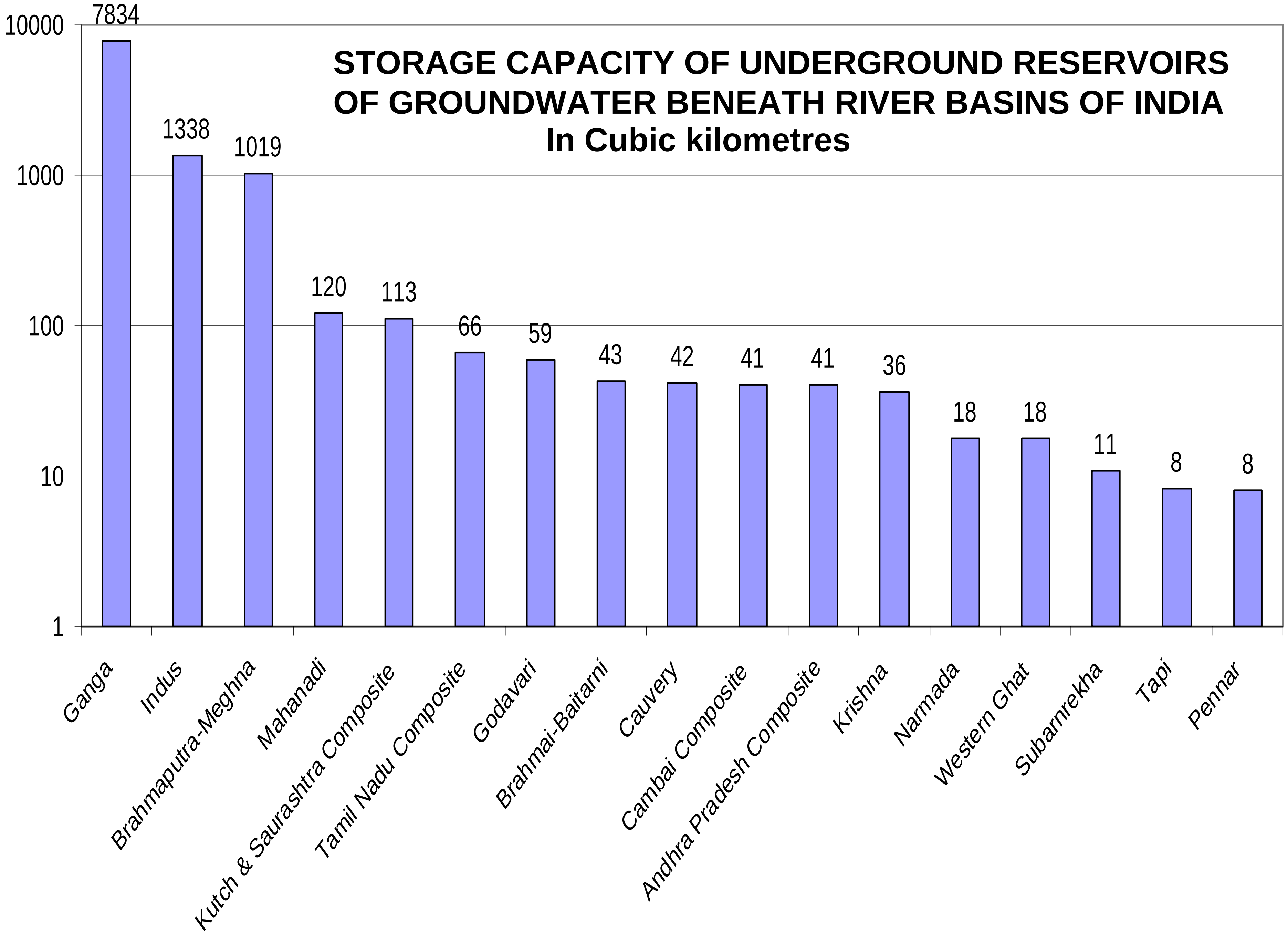
- The interaction between surface water and groundwater is best understood from a study of streams and rivers.
- In the early part of the journey of a stream, a portion of the runoff infiltrates into the underground to join groundwater. Such a stream is called ***losing or influent stream***.
- In the later part of its journey, groundwater emerges as base flow into the stream. It is then called ***gaining or effluent stream.***
- The slide that follows illustrates the losing and gaining streams
- The Institute of Hydrology in UK has a developed a method of isolating the surface water and groundwater components of runoff in gaining streams.
- The surface water and the groundwater components of the Homochitto River in Mississippi, USA as determined by the above method are shown in another slide.

TOTAL STREAM FLOW AND BASE FLOW COMPONENTS OF HOMOCHITTO RIVER, MISSISSIPI, USA




BASIN-WISE REPLENISHABLE GROUNDWATER RESOURCES IN INDIA (CUBIC KM PER YEAR)
0
20
40
60
80
100
120
140
160
180
172
41
35
26
26
19
18
18
17
12
11
11
8
7
5
4
2
Ganga
Godavari
Brahmaputra-Meghna
Indus
Krishna
Andhra Pradesh Composite
Tamil Nadu Composite
Western Ghat
Mahanadi
Cauvery
Kutch & Saurashtra Composite
Narmada
Tapi
Cambai Composite
Pennar
Brahmai-Baitarni
Subarnrekha


BASIN-WISE LIVE STORAGE CREATED
Cubic km
0
5
10
15
20
25
30
35
40
14
37
1.1
0.7
4.8
8.5
20
34
7.4
0.4
4.8
3.8
6.6
8.5
7.1
10
1.6
1.4
4.3
Indus
Ganga
Brahmaputra/Barak
Subarnekha
Brahmani-Baitarni
Mahanadi
Godavari
Krishna
Cauvery
Pennar
Mahi
Sabarmati
Narmada
Tapi
Tapi to Tadri
Tadri to Kanyakumari
Mahanadi to Pennar
Pennar to Kanyakumari
Kutch/Saurashtra

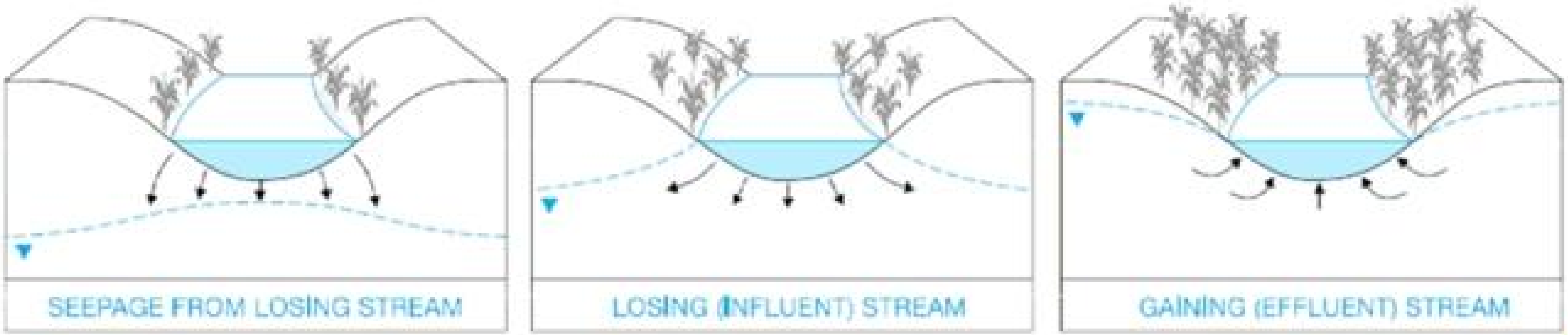

STORAGE CAPACITY OF UNDERGROUND RESERVOIRS
OF GROUNDWATER BENEATH RIVER BASINS OF INDIA
In Cubic kilometres
10000
1000
100
10
1
7834
1338
1019
120
113
66
59
43
42
41
41
36
18
18
11
8
8
Ganga
Indus
Brahmaputra-Meghna
Mahanadi
Kutch & Saurashtra Composite
Tamil Nadu Composite
Godavari
Brahmai-Baitarni
Cauvery
Cambai Composite
Andhra Pradesh Composite
Krishna
Narmada
Western Ghat
Subarnrekha
Tapi
Pennar

SUPERIORITY IN THE USE OF STATIC GROUND WATER RESERVOIRS OVER SURFACE RESERVOIRS

- The live storage so far created in India as a whole is hardly 176 cubic km.
- There is difficulty to increase the live storage primarily because of absence of suitable reservoir sites.
- The storage available in the naturally formed underground reservoirs holding fresh groundwater is computed by the Central Ground Water Board (CGWB) is 10,815 cubic km (i.e., over 60 times the live storage so far created).
- The rainfall and runoff show such high temporal variations that it is necessary to store water in reservoirs before putting it to effective use.
- It would be worthwhile to take up research to examine the feasibility of storing a portion of floodwaters in these aquifers to adopt a groundwater-oriented storage and recovery.

RECHARGE STRUCTURES FOR AQUIFER STORAGE

- Check dams, subsurface dams and sand dams are the three principal types of recharge structures taken up across streams.
- Direction of groundwater flow is away from losing streams, while the reverse is true with the gaining streams.
- Check dams are best suited for losing streams, while subsurface dams are best suited for gaining streams having thick accumulation of sand in their beds. Wells away from losing streams yield more water, while wells within the riverbeds of gaining streams yield more water.
- Sand dams are best suited to conserve both sand and groundwater in the upstream, besides reducing evapotranspiration.



Source: http://siteresources.worldbank.org/EXTWAT/Resources/4602122-1210186362590/GWM_Briefing_2.pdf

AQUIFER STORAGE OF GROUNDWATER THROUGH CHECK DAMS

A NATURAL SUBSURFACE DAM FUNCTIONING FOR CENTURIES

Papagni river in the Pennar basin, while passing through a rocky gorge, shows the characteristics of a subsurface dam with groundwater emerging as surface runoff used for drinking and irrigation round the year since historic times.

SUBSURFACE DAMS TO ENHANCE AQUIFER STORAGE

- A subsurface dam is an obstruction created below the bed level across a gaining stream to prevent the entire groundwater flow occurring in permeable sand underlying the stream.
- It is essential to conduct detailed scientific investigations to select suitable sites for their construction.
- It is also essential to execute construction of such dams under scientific supervision to ensure that no water obstructed escapes downstream through its sides or bottom
- It has been known from our experience that such dams are best constructed using cement or concrete rather than puddle clay.
- Once such a dam is properly constructed, groundwater after saturating the upstream sand emerges as surface runoff to flow to benefit the downstream users.
- Groundwater stored is recovered through shallow infiltration wells or shallow tube wells constructed for the benefit of the upstream users.

SUBSURFACE DAMS TO MAKE USE OF GROUNDWATER JOINING THE SEA

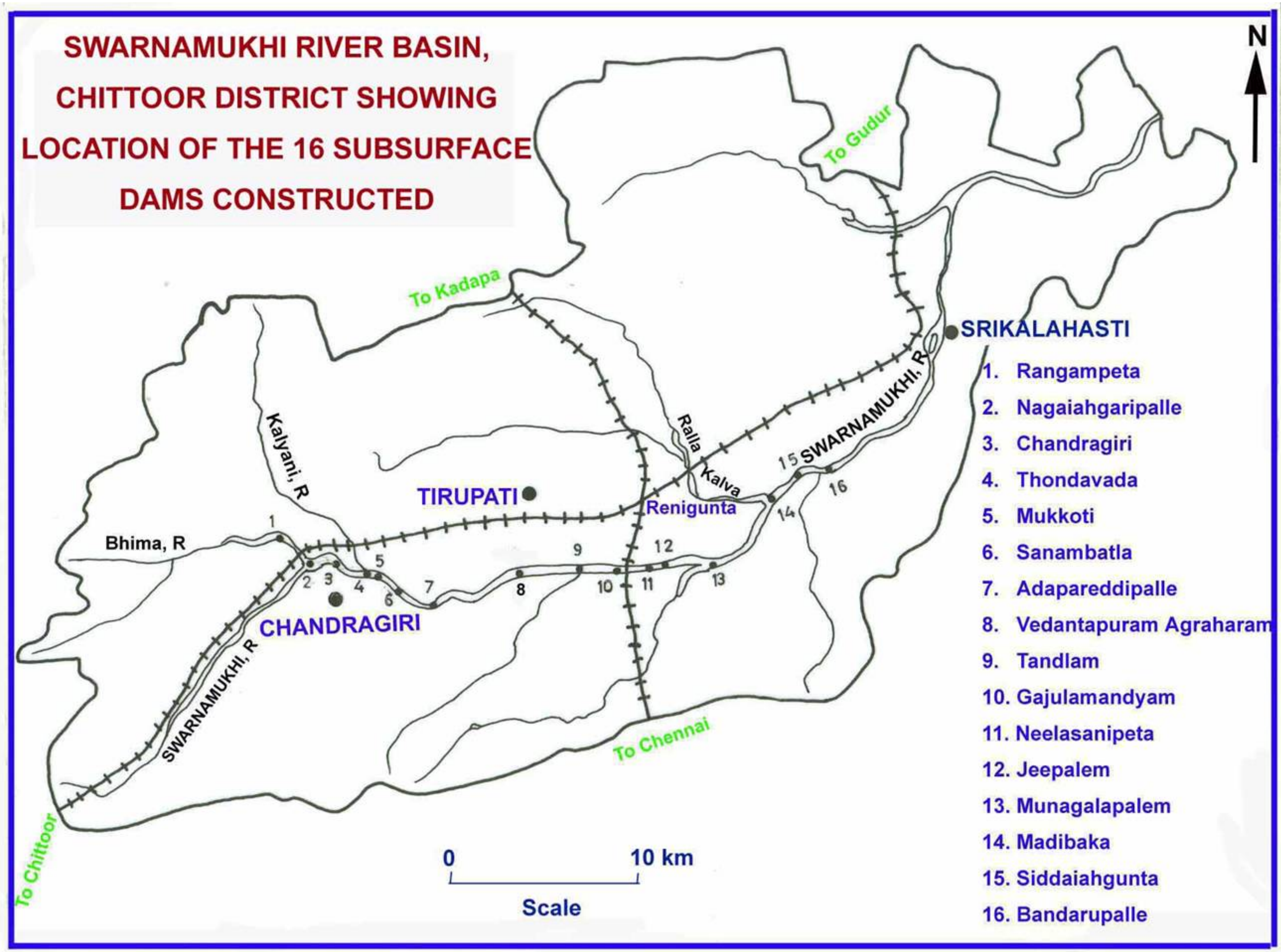
- Construction of subsurface dams across major rivers all along the coastal tracts of India can arrest enormous groundwater presently joining the sea without involving any submergence of new land.
- Groundwater so conserved contributes substantial base flow to boost up the river flows without the need to resort to pumping of ground water.
- These waters could be diverted into canals for irrigation by gravity flow.

SOMASILA SUBSURFACE DAM & SURFACE DAM

Somasila reservoir across the Pennar River could hold surface water because of the successful construction of a subsurface dam that prevents over two BCM of groundwater beneath the reservoir from flowing downstream and remain static.

CONSTRUCTION OF SUBSURFACE DAMS ACROSS SWARNAMUKHI RIVER IN CHITTOOR DISTRICT, AP

- Because of over-exploitation of groundwater, the once perennial Swarnamukhi river in Chittoor District of Andhra Pradesh looks dry for most part of the year.
- As the river is a gaining stream, subsurface dams were considered to be superior to check dams.
- A consortium of 11 NGOs constructed 16 subsurface dams across the river at a cost of over Rs. 4 crore to transform it into a perennial river.
- The success of a subsurface dam depends on arresting the entire groundwater flowing through sand beneath the river. As this could not be achieved, the river could not become perennial..

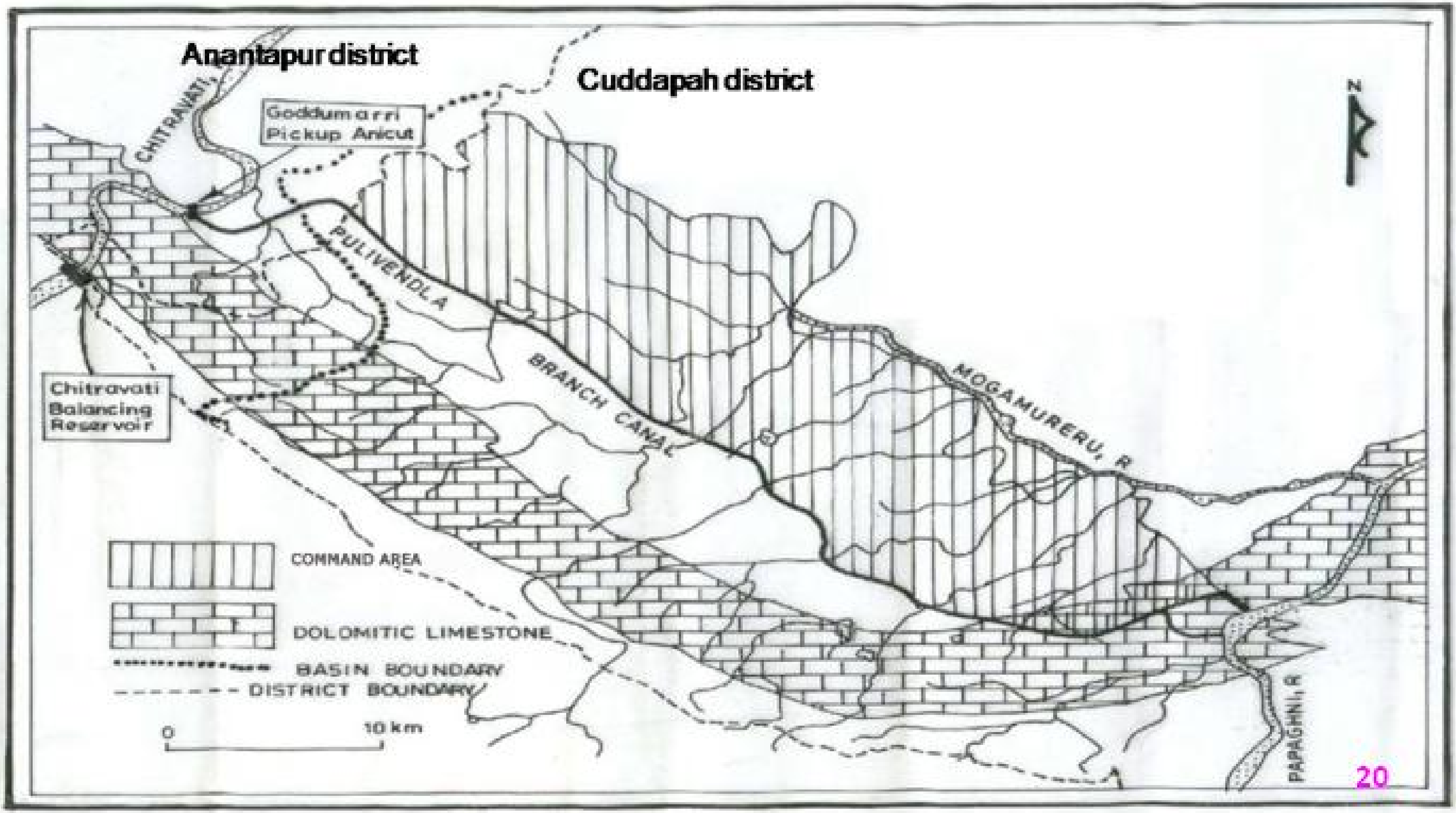

SWARNAMUKHI RIVER BASIN,
CHITTOOR DISTRICT SHOWING
LOCATION OF THE 16 SUBSURFACE
DAMS CONSTRUCTED
N
To Gudur
To Kadapa
SRIKALAHASTI
Kalyani, R
Ralla
Kalva
SWARNAMUKHI, R
TIRUPATI
Renigunta
Bhima, R
CHANDRAGIRI
SWARNAMUKHI, R
To Chennai
To Chittoor
0
10 km
Scale
1. Rangampeta
2. Nagaiahgaripalle
3. Chandragiri
4. Thondavada
5. Mukkoti
6. Sanambatla
7. Adapareddipalle
8. Vedantapuram Agraharam
9. Tandlam
10. Gajulamandyam
11. Neelasanipeta
12. Jeepalem
13. Munagalapalem
14. Madibaka
15. Siddaiahgunta
16. Bandarupalle

CONSTRUCTION OF A SUBSURFACE DAM ACROSS SWARNAMUKHI – A GAINING STREAM

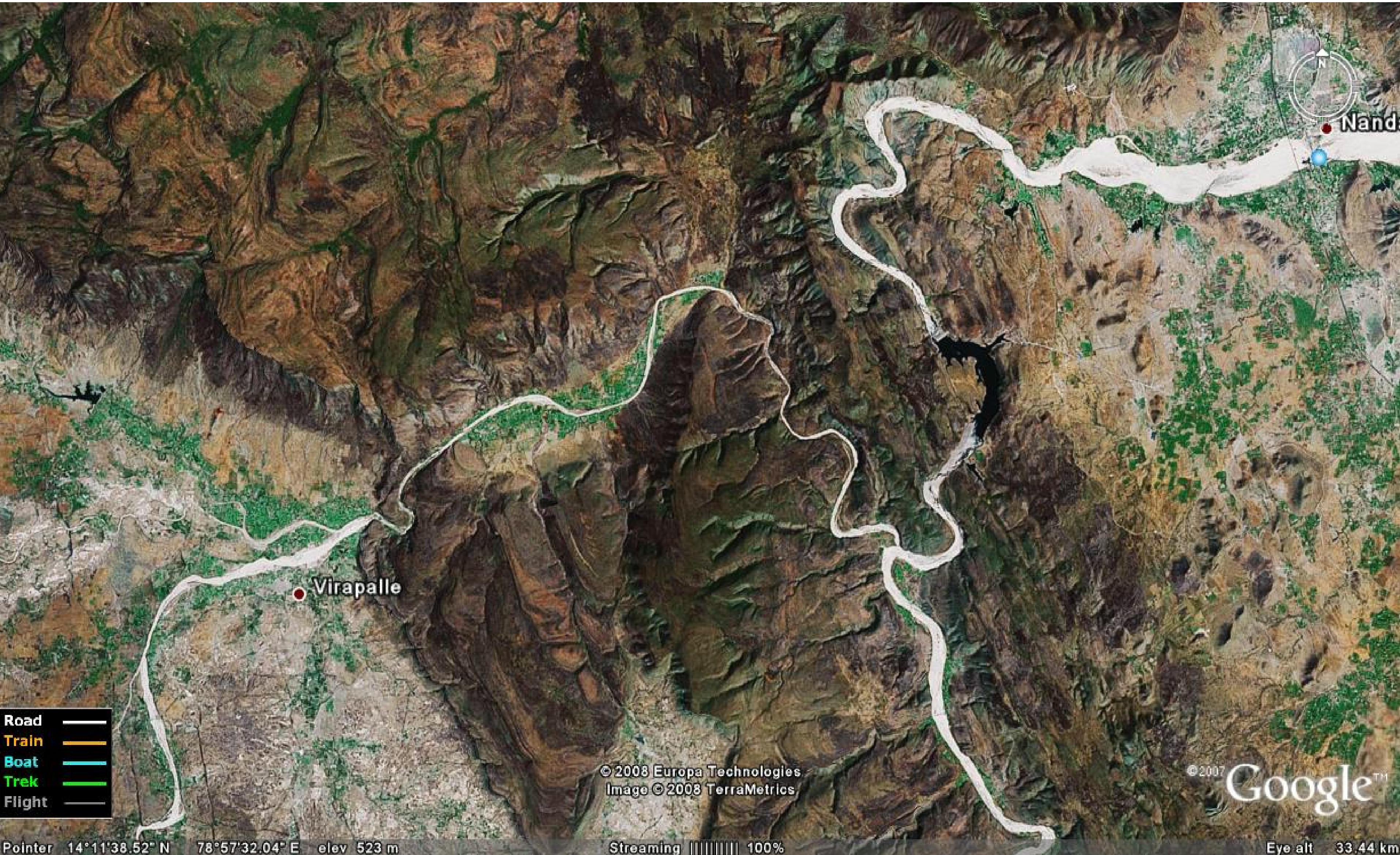
Sixteen subsurface dams were constructed in 2001 across the Swarnamukhi river using puddle clay at a cost of US$ 1 million. The dams have not served any useful purpose because of the extensive river meandering that did not prevent groundwater flow from the bottom and the sides of the river.

A SUBSURFACE DAM RECHARGING GROUNDWATER IN CAVERNOUS DOLOMITIC LIMESTONES

A subsurface dam constructed underneath the Parnapalle balancing reservoir across the Chitravathi River failed to provide irrigation water to the command area. But, large scale leakage of water from the reservoir into the cavernous dolomitic limestones has enriched groundwater in the karst region to allow extensive well irrigation.



MANDAVI RIVER BORDERED BY IRRIGATED FIELDS AND ANNAMAYYA RESERVOIR ACROSS CHEYYERU RIVER WITHOUT IRRIGATED FIELDS



CHEYYERU RESERVOIR IN PENNAR BASIN HOLDING NO WATER BECAUSE OF DEFECTS IN THE CONSTRUCTION OF ITS SUBSURFACE DAM

•The subsurface dam across the Cheyyeru river in the Pennar basin constructed in 1976 failed to arrest groundwater leaking into the cavernous dolomitic limestones in and around the dam.

•As the command area under the reservoir could not get any irrigation water through canals, efforts are being made to make the foundation impervious and thereby plug the leakage.

•Had a groundwater-based storage and recovery formulated, the command area under the project would have got irrigation water round the year long ago.

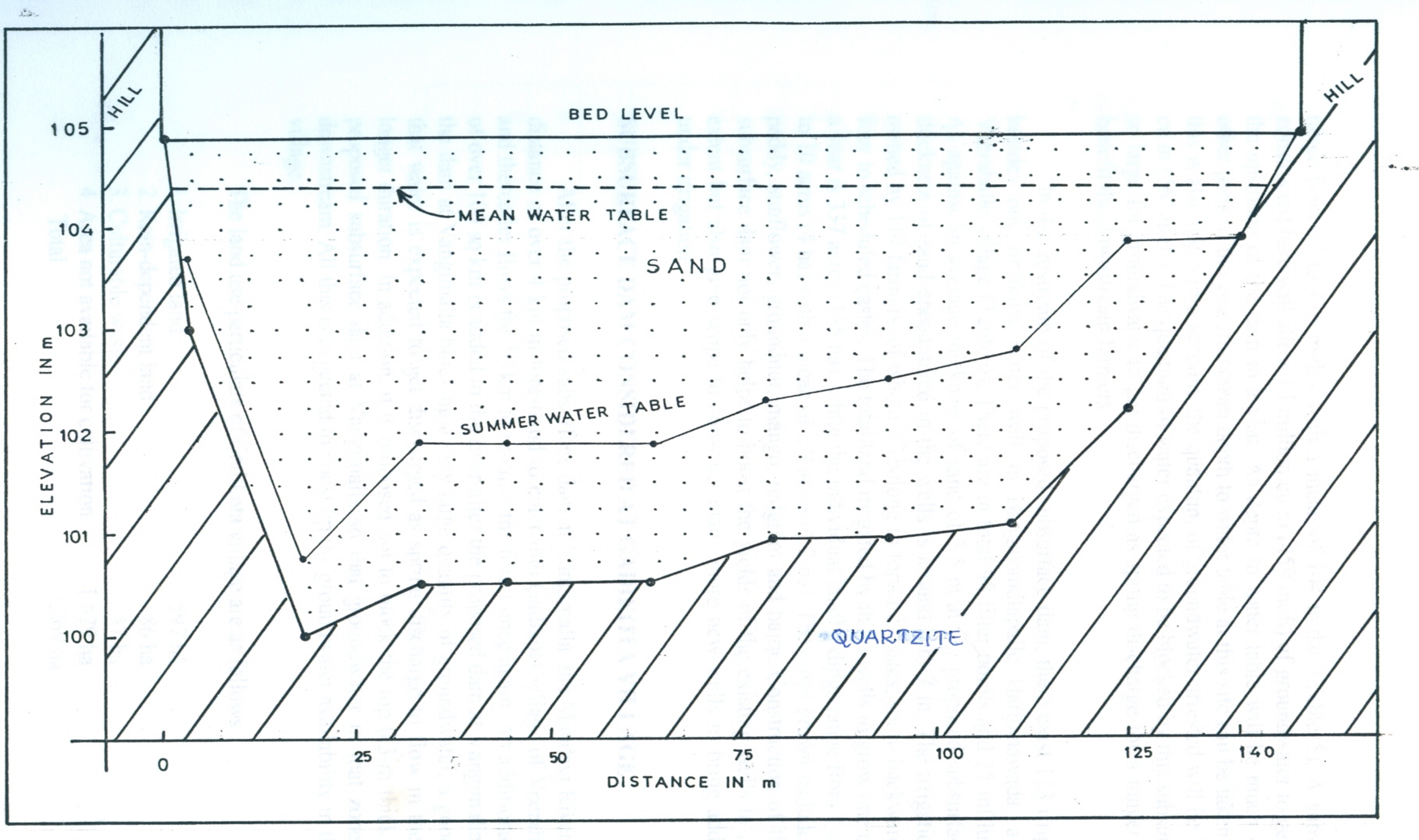
FLOW OF MANDAVI RIVER ACROSS A NARROW GORGE AT VANGIMALLA, VEERABALLE MANDAL

- The entire surface water of the Mandavi River in the Pennar basin generated in a drainage area of 1254 sq km flows at Vangimalla through a narrow gorge in the Palakonda hill ranges.
- Based on detailed studies carried out by us in 2003, we computed the quantum of groundwater flowing through coarse sand beneath the riverbed to be 15 million cu m.
- A subsurface dam constructed at this site failed to serve the intended purpose because of not arresting the entire groundwater flowing through sand beneath the riverbed.
- Although the cost of construction of the dam is hardly Rs. 20 lakh, the District Administration could not take up the work, as they have provision to take up construction of check dams, but not subsurface dams.

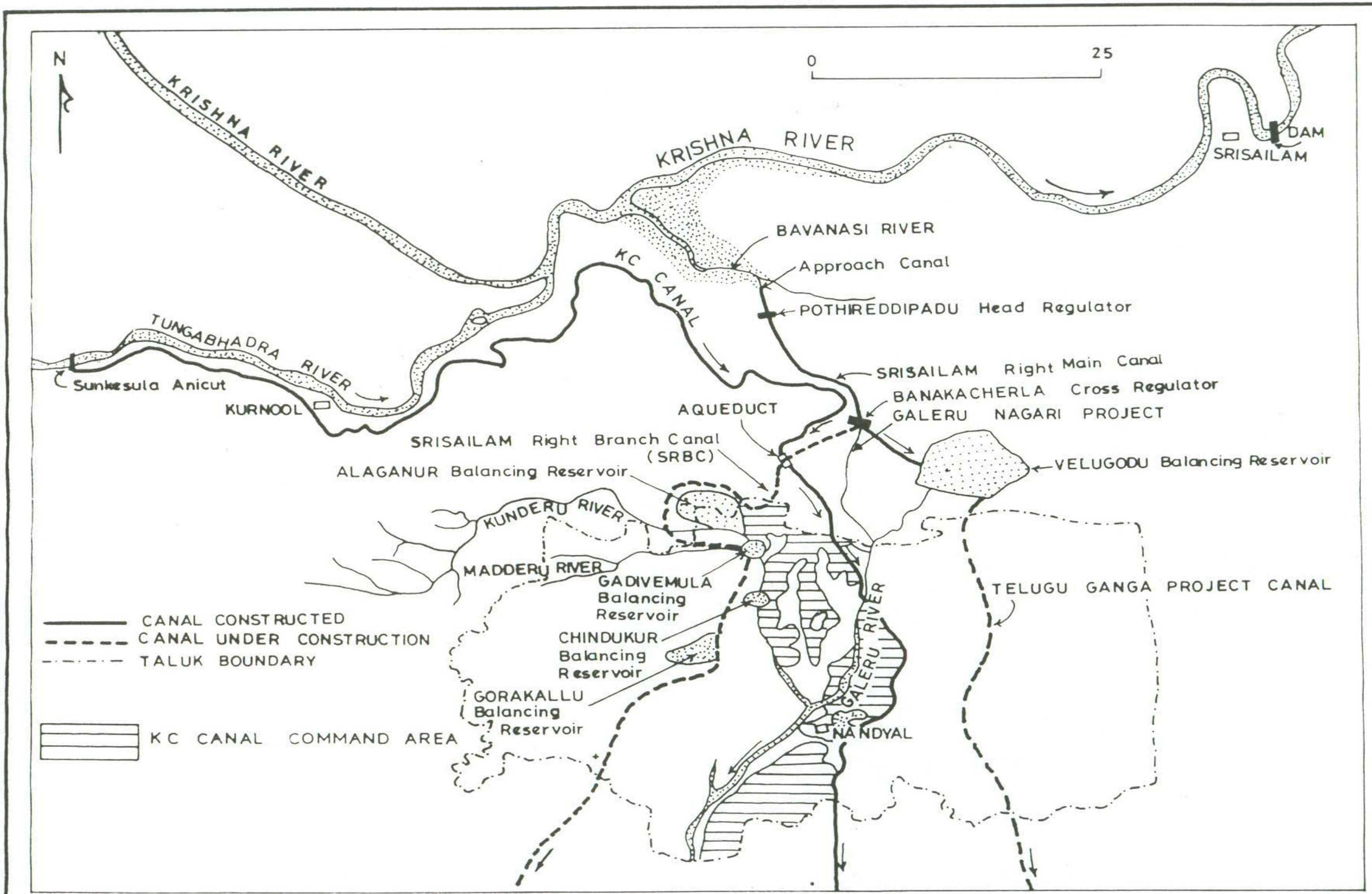
A SUBSURFACE DAM CONSTRUCTED ACROSS THE MANDAVI RIVER IN THE PENNAR BASIN BY THE IRRIGATION DEPARTMENT FAILED TO SERVE THE INTENDED PURPOSE BECAUSE OF IMPROPER CONSTRUCTION

GROUNDWATER DISCHARGE DOWNSTREAM OF THE SUBSURFACE DAM INDICATINH THAT IT IS NOT ARRESTING GROUNDWATER

A PROFILE SHOWING THE SUBSURFACE FORMATIONS ACROSS THE MANDAVI RIVER AS OBTAINED BY EXPLORATORY BORING



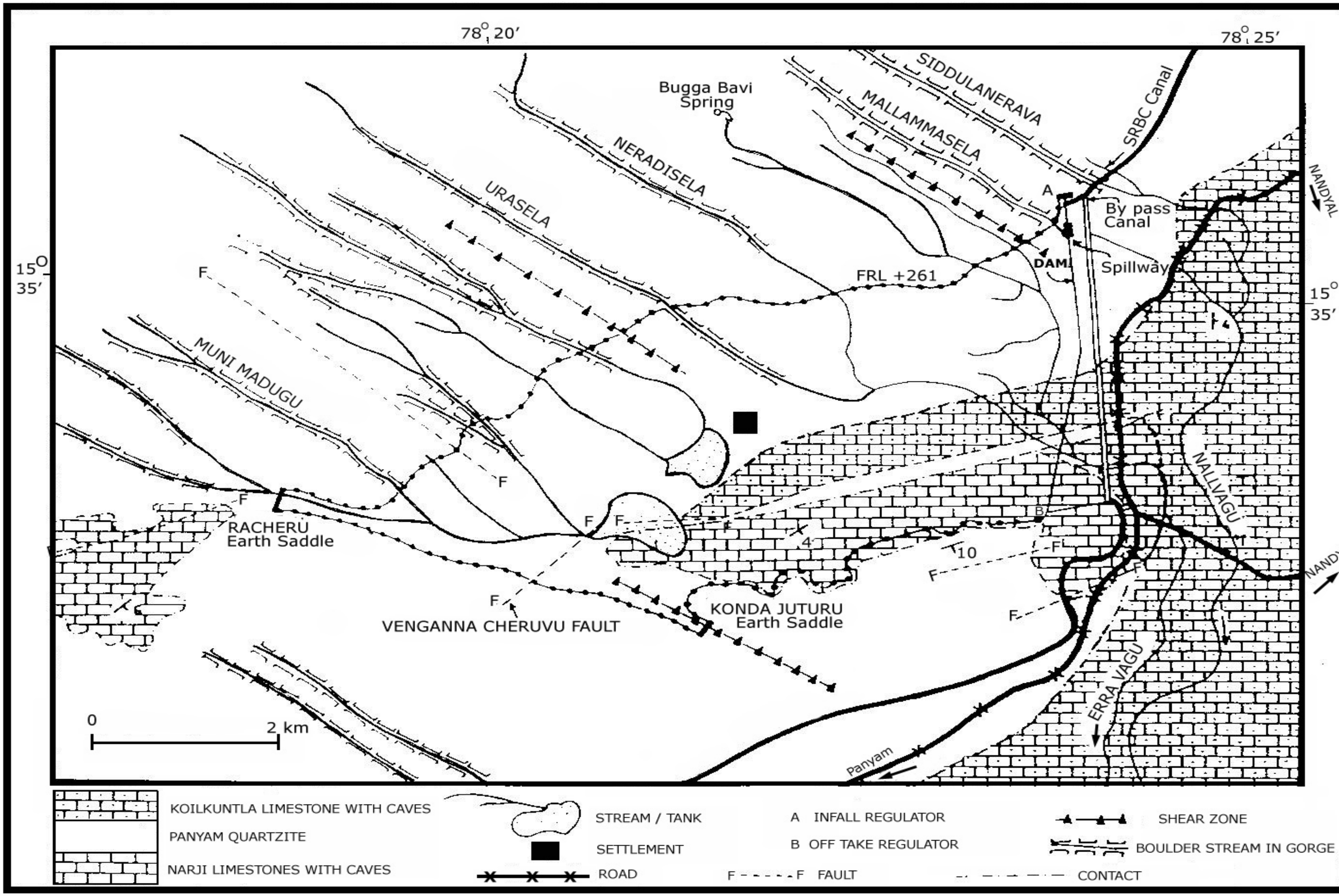
GORAKALLU RESERVOIR AWAITING COMPLETION SINCE 1981



PROBLEMS WITH GORAKALLU RESERVOIR, KURNOOL DISTRICT, AP

- For want of taking a decision to take up conjunctive use of surface and ground waters, the Gorakallu reservoir, a component of the Srisailam Right Branch Canal (SRBC) Project taken up for construction in 1981 to irrigate 58,000 ha for one crop a year could not be so far completed for want of a decision to take up conjunctive use of surface and ground waters.
- Despite Geological Survey of India (GSI) not recommending the site for reservoir construction owing to occurrence of cavernous limestones and faulty nature of formations, the AP Government wants to construct the reservoir at any cost.
- Had a decision to store water in the underground at the reservoir site was taken up, the project would have been completed long ago with the command area getting irrigation water for two crops a year through shallow wells.

GEOLOGICAL MAP OF GORAKALLU RESERVOIR AREA WITH LIMESTONE CAVES & FAULTS



GORAKALLU RESERVOIR UNDER CONSTRUCTION SINCE 1981

THE LINED BYPASS CANAL ABUTTING THE PROPOSED GORAKALLU RESERVOIR

BEST EXAMPLE OF CONJUNCTIVE USE OF SURFACE AND GROUND WATERS

- The Madhya Ganga Canal Project (MGCP) area between the Upper and Lower Ganga Canal commands in Uttar Pradesh was long depending on groundwater leading to steep decline of groundwater levels.
- It could not be provided canal water for irrigation for want of suitable reservoir site.
- The Irrigation Dept. and the WALMI in consultation with IWMI and WRD of Roorkee University took up the construction of MGCP in 1989 to convey flood flows in unlined canals to store water in aquifers. .
- A study by IWMI and WRD in the Lakhoti Branch system of the MGCP found the system working well with two crops a year without water logging, groundwater depletion and excessive pumping costs.
- Similar spectacular results are expected through replication of this strategy all over India.

SAND DAMS TO CONSERVE BOTH SAND AND GROUNDWATER

While sand dam is similar to a check dam as far as creation of an obstruction across a stream rising above the bed level is concerned, they differ from each other in the following ways.

- The primary purpose of a check dam is to collect surface water, while a sand dam collects both sand and groundwater within sand. While a check dam is constructed in one installment across a stream, the height of a sand dam is increased progressively during a period of around four years.
- The sediment accumulated upstream of a check dam consists of a mixture of sand, silt, and clay. While the sediment allowed to be accumulated upstream of a sand dam consists of only uniform sand of high hydraulic conductivity, the finer particles get transported as suspended solids in the running water.
- Water losses through evaporation are minimized; while sand depletion caused by legal and illegal mining of sand is compensated by the accumulation of additional sand in a next flood.

VIEW OF A SAND DAM CONSTRUCTED IN NAMIBIA, AFRICA DURING FOUR FLOOD SEASONS

Surface runoff in the downstream of the sand dam can be enhanced for use in the downstream by driving a horizontal pipe into the dam. Groundwater can also be recovered for use in the upstream through infiltration wells and shallow tube wells constructed directly on the sand dam (After Thomas Diettrich, 2003)

AQUIFER STORAGE & RECOVERY (ASR) THROUGH DEEP BORE WELLS

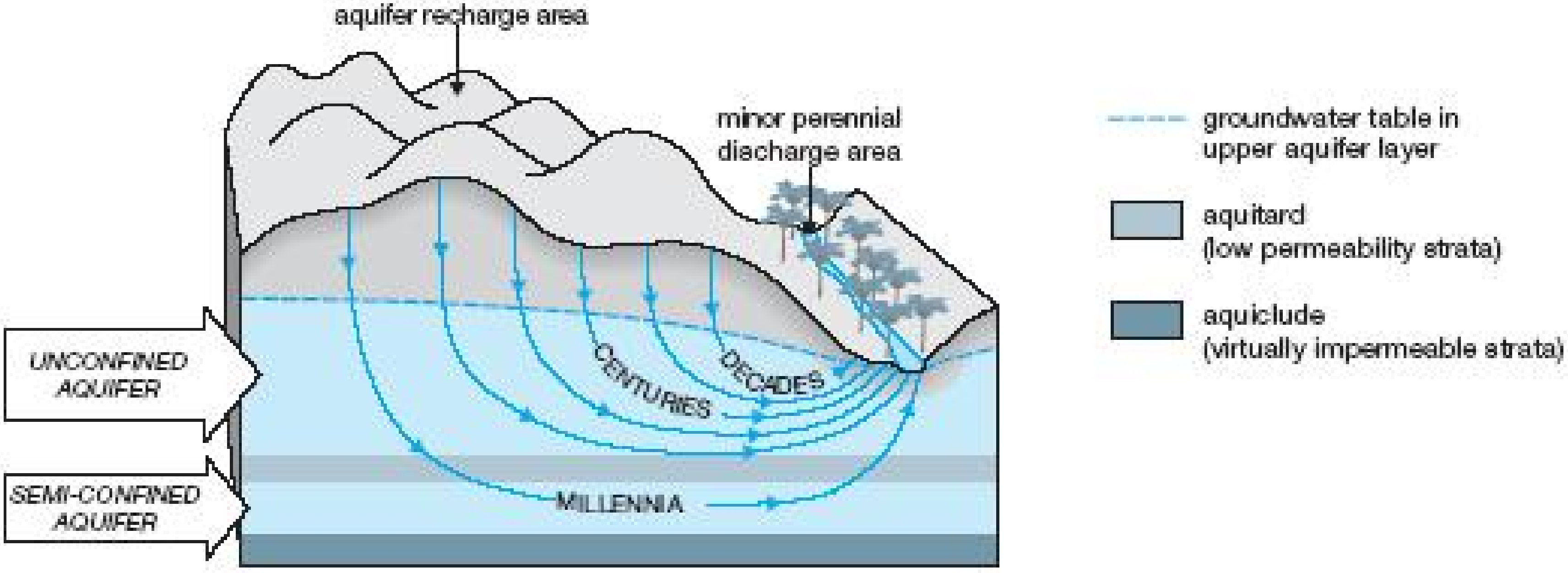
- The vast majority of structures used to recharge groundwater in India aim at arresting surface water from flowing downstream through a variety of structures such as ponds and check dams.

- As it takes inordinate time for surface water to enter into the underlying aquifer, emphasis has been laid to inject treated surface water directly into groundwater under water table conditions through shallow wells.

- As it again takes inordinate time for groundwater under water table conditions to join deep groundwater under artesian conditions, greater emphasis has been laid to inject treated surface water directly into groundwater under artesian conditions through deep wells.

- The following slide indicates the inordinate time taken for groundwater recharge to take place in semiarid areas under natural conditions.

Typical groundwater flow regime and residence times of major aquifers under semi-arid climatic regimes



AN EXAMPLE OF INJECTION OF GROUNDWATER INTO A DEEP BORE WELL IN INDIA

- ✓ The Andhra Pradesh Farmer Managed Groundwater Systems (APFAMGS) was a Project taken up by a consortium of nine NGOs at a cost of around US$ 7 million in 2003-08 and monitored by the Food & Agriculture Organization (FAO) of the United Nations to enable farmers in 650 habitations in seven drought prone districts of Andhra Pradesh State to manage their groundwater systems by demystifying the science for sustainable development.

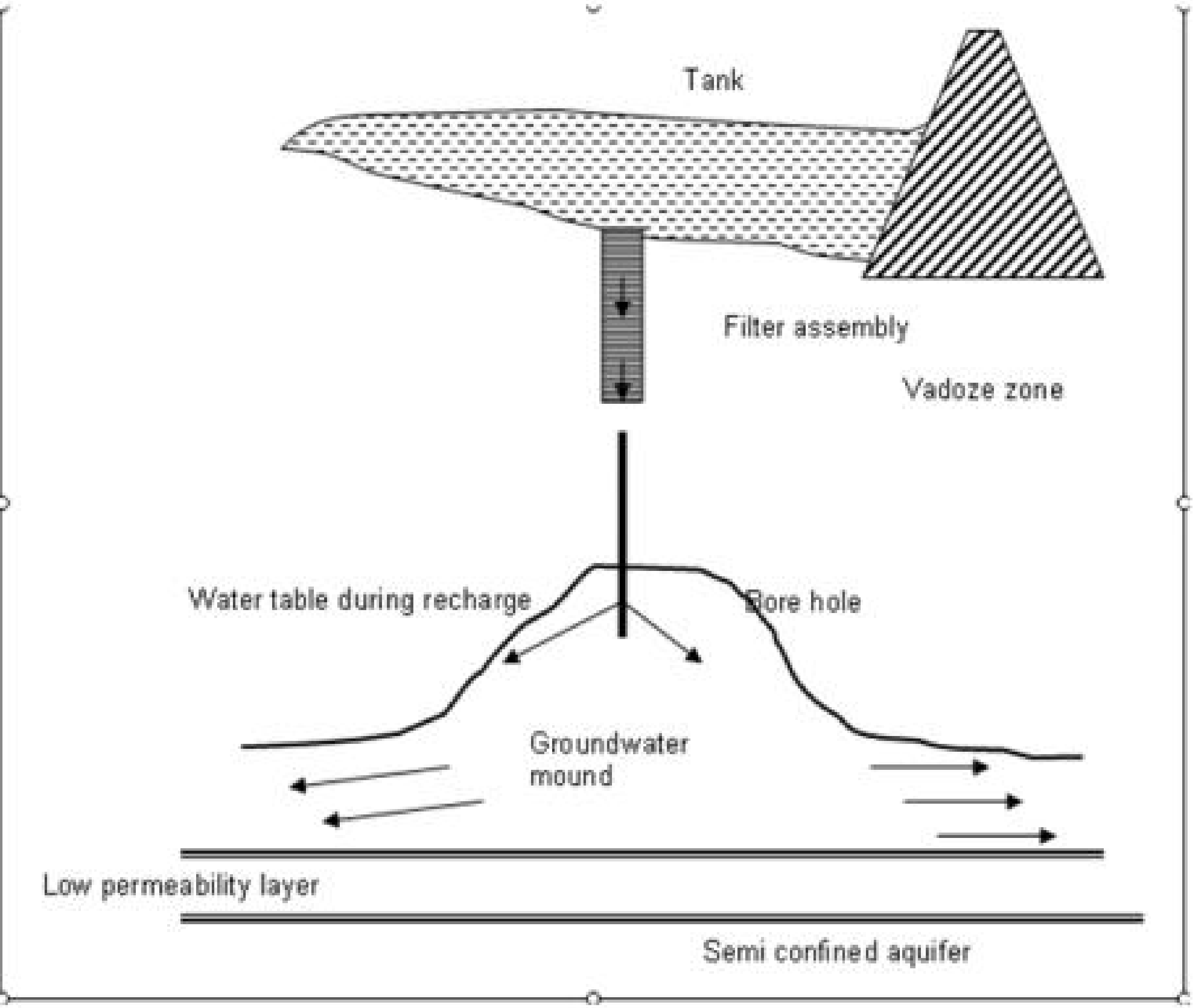
- ✓ As a part of this programme, GVS - an NGO has constructed in 2007 three recharge bore wells at Nariganipalle revenue village, Ramasamudram Mandal, Chittoor District. Of these, the 122-m deep bore well constructed in the Kothakunta minor reservoir south of an east-west extending hill north of Pulakuntlapalle village helped to recharge adequate groundwater into five dry bore wells of farmers to enable them to irrigate their limited land holdings even when there was just one heavy rain once in three years.

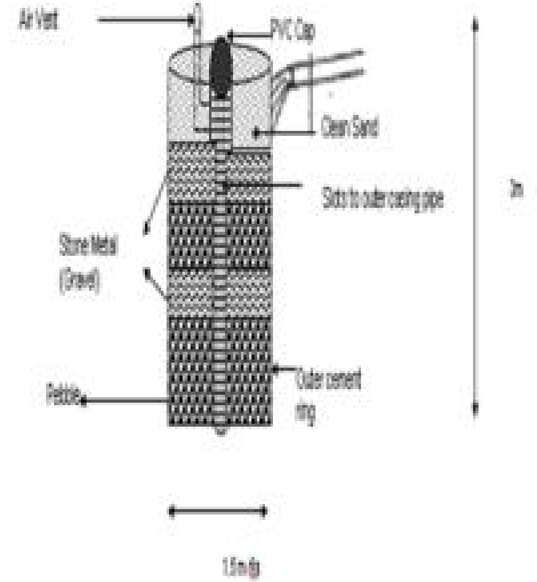
- ✓ The results of the APFAMGS project would have been more spectacular had more number of such deep injection wells were constructed all over the project area under the technical supervision of experts in the field.

THE DEEP RECHARGE BORE WELL CONSTRUCTED IN A TANK BED UNDER THE AFAMGS-FAO PROJECT

Details of the method used to recharge groundwater along with the filter assembly used are shown in the following slide.

DETAILS OF THE METHODOLOGY AND FILTER ASSEMBLY USED BY THE APFMAGS





Filter Assembly

SUMMARY OF CONCLUSIONS

- The successful exploitation of groundwater from individual wells by millions of farmers has led to a spectacular increase in the net area irrigated by wells.
- The plan to entrust the task of artificial recharge of groundwater to recharge the depleted aquifers by farmers under the guidance of NGOs will not produce useful results.
- Aquifer storage & recovery (ASR), which allows for large scale artificial recharge of groundwater when carried out under the supervision of professionals, will make groundwater sustainable.
- Construction of subsurface dams across rivers allows for usage of good portion of surface runoff and underground runoff presently joining the sea.
- Modification of irrigation projects allowing for conjunctive use of both surface and ground waters maximises benefits from irrigation projects of India.


Thank You