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MOBILISING TECHNOLOGY FOR SUSTAINABILITY

History stands witness to man's use of varied forms of technology and science, ranging from the simplest to the most complicated, for storing and extracting water. India has a particularly strong tradition of water harvesting – communities have met their minimum water requirements effectively by collecting rainwater locally, diverting and storing water from local streams and springs and tapping sub-surface water. However, these traditional technologies and methods have fallen prey to inattention and ignorance over time, and need to be revived and rejuvenated.

On the other hand are the most modern, state-of-the-art technologies and practices which could make a lot of difference in these water-stressed times. This chapter offers today's water managers a range of choices which will enable them to make their own water security plans in an effective manner – by taking from the best practices of both the worlds and adopting them viably for best results.

Traditional structures such as the tankas and khadins of Rajasthan, baoris (step-wells) of western India, the ooranis, cheruvus and temple tanks of south India, and the bamboo-split pipe harvesting method practised in the north-east still serve as lifelines for local people. Communities can combine and converge this knowledge with modern technologies and scientific tools such as satellite imaging. Emphasizing on the urgent need for rainwater harvesting, replenishing and restoring existing surface water bodies and creating new ones, and recharging groundwater, this segment urges practitioners to think beyond the conventional and look for innovative solutions.

1.1 AGRO-CLIMATIC ZONE WISE RECOMMENDED WATER HARVESTING AND WATERSHED MANAGEMENT WORKS

Based on the requirements of agricultural development, the country has been demarcated into 15 agro-climatic regions. However, for promoting rainwater harvesting with particular reference to augmenting drinking water availability in rural areas, these regions have been slightly modified and an additional region viz. "Himalayan foot hills" has been added. Broad features of these 16 regions and the recommended water harvesting measures for each region are discussed in the following paras.

HUMID NORTHWESTERN HIMALAYAS (Hilly areas of Jammu & Kashmir, Himachal Pradesh and Uttarakhand)



Water harvesting measures recommended for the region are:

- (i) Roof water harvesting
- (ii) Diversion of perennial springs and streams water in storage structures
- (iii) Village ponds
- (iv) Collection from hill slopes

HIMALAYAN FOOT HILLS (foothill areas of Jammu & Kashmir, Himachal Pradesh, Punjab and Uttarakhand in the west and parts of West Bengal, Assam and Arunachal Pradesh in the east)

The recommended structures are:

- (i) Collection from hill slopes
- (ii) Village ponds
- (iii) Contour trenching

HUMID HIGH RAINFALL NORTH EASTERN ZONE (Sikkim, Darjeeling hills, Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Tripura, Mizoram, Assam, and Jalpaiguri and Cooch Behar districts of West Bengal)

The recommended measures are:

- (i) Roof top harvesting
- (ii) Diversion of perennial springs and streams in storage structures (tanks)

HUMID ASSAM BENGAL PLAINS (Assam, and West Bengal)

The recommended water harvesting measures are:

- (i) Tanks
- (ii) Check dams/ Anicuts
- (iii) Gully plugging
- (iv) Contour bunding

SUB-HUMID AND HUMID SATLUJ-GANGA ALLUVIAL ZONE (Punjab, Haryana, Uttar Pradesh and Bihar and is served by middle reaches of the Satluj basin and the lower and middle reaches of the Ganga basin)

The recommended water harvesting measures for the region are:

- (i) Ponds
- (ii) Check dams
- (iii) Gully plugging
- (iv) Contour bunding



NORTH-WESTERN SEMI-ARID AND ARID ZONE (Western Rajasthan)

The rainwater harvesting measures recommended for this zone are:

- (i) Nadi/ Talab
- (ii) Tanka
- (iii) Khadin
- (iv) Percolation tanks
- (v) Anicuts
- (vi) Gully plugging
- (vii) Contour bunding

CENTRAL SEMI-ARID VINDHYAN ZONE (southeastern districts of Rajasthan, southern districts of Uttar Pradesh and central parts of Madhya Pradesh)

The water harvesting and watershed development measures recommended are:

- (i) Ponds
- (ii) Check dams
- (iii) Contour bunding
- (iv) Gully plugging
- (v) Sub-surface dykes

HIGH RAINFALL HIGH RUNOFF CHHOTANAGPUR PLATEAU (Jharkhand, adjoining hilly areas of Bihar, West Bengal and Orissa)

The recommended water harvesting practices, are:

- (i) Tanks/ Ponds
- (ii) Check dams/ Anicuts
- (iii) Gully plugging
- (iv) Contour bunding

MALWA PLATEAU & NARMADA BASIN (Gujarat, western parts of MP and northern parts of Maharashtra)

The water harvesting methods recommended for the region are:

- (i) Ponds
- (ii) Check dams
- (iii) Sub-surface dams



SOUTH-CENTRAL DECCAN PLATEAU ZONE (parts of Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra)

The recommended water harvesting structures are:

- (i) Ponds
- (ii) Check dams
- (iii) Percolation tanks
- (iv) Bandhara
- (v) Gully plugging
- (vi) Sub-surface dams
- (vii) Contour bunding

CHHATTISGARH PLATEAU ZONE (Chhattisgarh & South-western Orissa)

The recommended water harvesting structures are :

- (i) Ponds
- (ii) Check dams
- (iii) Percolation tanks
- (iv) Bandhara
- (v) Gully plugging
- (vi) Sub-surface dams
- (vii) Contour bunding

SOUTH-EASTERN BROWN/ RED SOIL ZONE (Pachamalai and Kadavur hills and pediplain areas of Tamil Nadu and Veligond hills and part of the plains (excluding the 4-5 km wide coastal belt) of Andhra Pradesh)

The recommended water harvesting structures for the zone are the traditional ponds/ tanks. Besides percolation tanks and sub-surface dams are suggested in the vicinity of drinking water sources like dug wells, hand pumps and tube wells.

SOUTHERN VARIABLE RAINFALL, MIXED SOIL ZONE (southern parts of Maharashtra and west-central parts of Tamil Nadu)

The recommend water harvesting and watershed development measures are:

- (i) Ponds/ Tanks/ Kunta
- (ii) Nadi



- (iii) Check dams
- (iv) Percolation tanks
- (v) Sub-surface dams
- (vi) Gully plugging

SOUTHERN BI-MODAL RAINFALL ZONE (southern most parts of Kerala, Karnataka and Tamil Nadu)

The recommended water harvesting and watershed development measures are:

- (i) Ponds/ Tanks
- (ii) Percolation tanks
- (iii) Check dams
- (iv) Gully plugging
- (v) Contour bunding

EASTERN COROMANDAL (entire coastal belt of Orissa, Andhra Pradesh and West Bengal)

The recommended measures for water harvesting, ground water recharge and watershed development are:

- (i) Ponds/ Tanks/ Kunta
- (ii) Nadi
- (iii) Check dams
- (iv) Percolation tanks
- (v) Sub-surface dams
- (vi) Gully plugging

WESTERN MALABAR (western Malabar area of Kerala and coastal areas of southern Karnataka)

The recommended measures for water harvesting, ground water recharge and watershed development are:

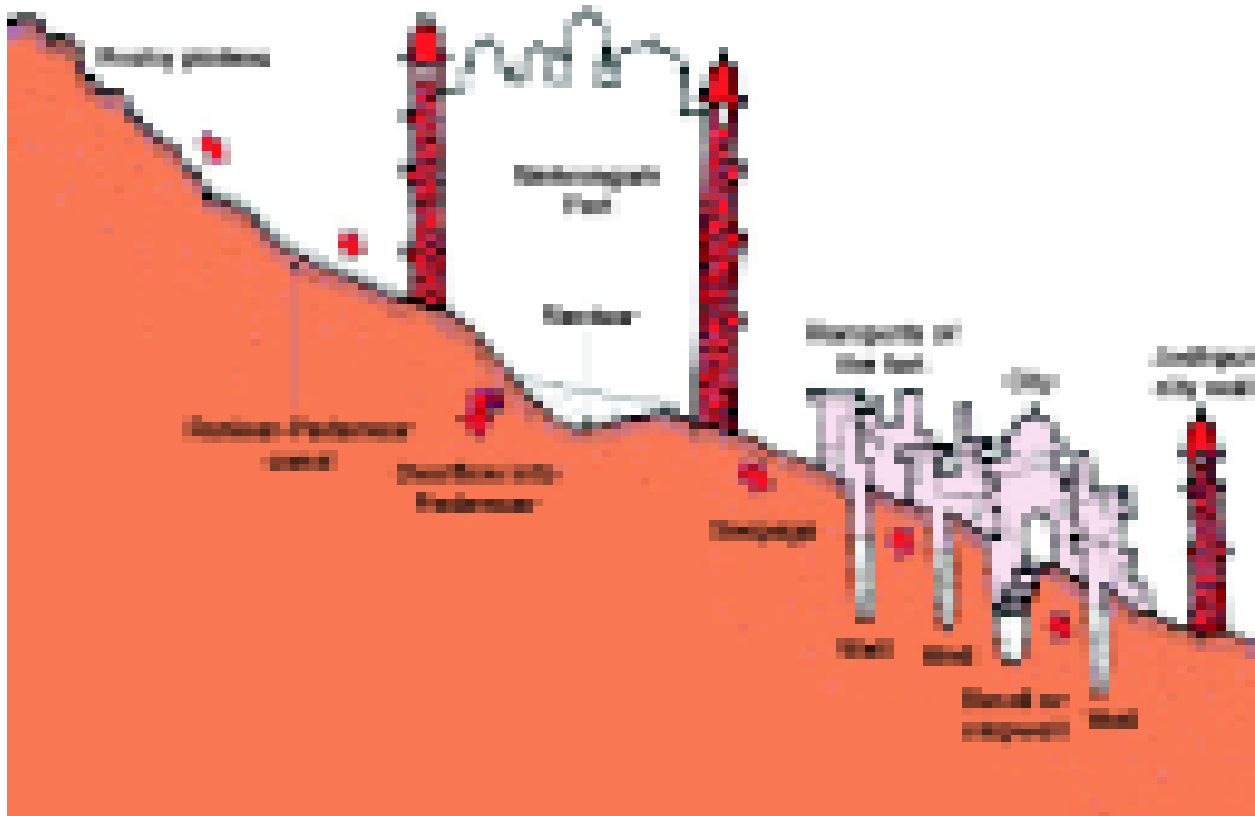
- (i) Ponds/ Tanks/ Kunta
- (ii) Check dams
- (iii) Weirs
- (iv) Bandhara
- (v) Percolation tanks
- (vi) Sub-surface dams
- (vii) Contour bunding



1.2 SUSTAINABILITY THROUGH GROUND WATER RECHARGE METHODS

1.2.1 Ancient Practices

1.2.1.1 Integrated ground and surface water harvesting on hill slopes



Integrated groundwater and surface water systems of hill forts of Jodhpur

These are structures primarily diffusion ditch type located on hill slopes wherein, the excess run-off is collected into a main tank while the permeable surface below the main tank allow seepage to recharge the water table to the downstream structures.

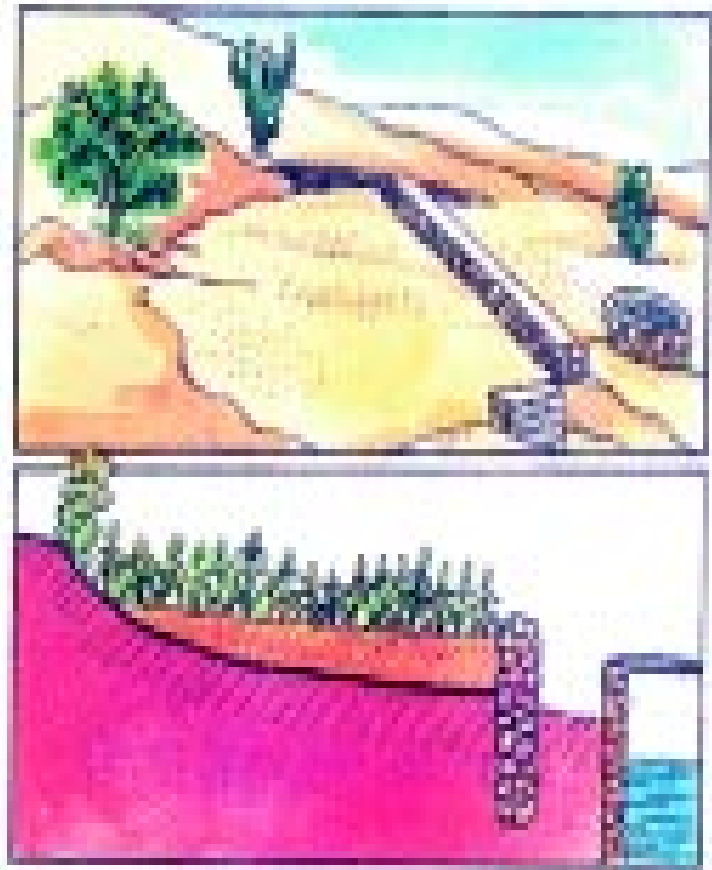
1.2.1.2 Khadin

Khadin is a system basically innovated for run-off farming and to increase agricultural productivity even where the annual rainfall is as low as 40mm. Rocky-hill terrain around a valley slope constitute the catchment area of a Khadin. The details of Conventional Khadin system adopted in Western Rajasthan are below :-

The system is site specific needing a large natural, high runoff potential catchment in proximity of plain valley land. The ratio of Khadin area to catchment area, depending on type of catchment, is minimum i.e. 1:12 to 15. Figure-1 given in Annexure shows plan and section of a typical Khadin. However, these need proper management.



Before starting the construction of Khadin, bund position is aligned and then about 15 cm layer of natural ground surface is scrapped out. The earth work is done in layers of 30 cm thickness and then compacted by ramming with hand hammer, sheep foot roller or road roller. For providing shape to the bund, a profile at every 20 m length of bund is erected. Provision is made for over flow by providing cement-concrete spill-over structure with stone pitching, downstream to check erosion. Pipe outlet is also provided at centre of bund to drain out standing water. After completion of Khadin, leveling of land near bund is done for uniform spreading of water. Seeding of grass on bund during rainy season is done for its stabilization.



In big Khadins, making small dug wells outside Khadin bund is an innovative method developed by ancient people to have conjunctive use of water as also to encourage seeping out of saline water to prevent salinity development in Khadin in course of time. Following improvements in construction of Khadin are suggested:

- (i) Khadin is basically a runoff agricultural system. Though site specific, with good management it can make arid wasteland productive. Modern experience is however limited to few isolated projects. Intensive techno-economic evaluation in several regions with different climates, soils and crops are needed to identify its potential for the future.
- (ii) To make runoff agriculture more effective, there is a need to develop crops better suited to this system.
- (iii) Though it is primary runoff agriculture, a lot of water gets stored on the land, partly going down deep, side ways and much is lost through evaporation. For conservation and conjunctive use of such collected water, research work on models of suppression of evaporation losses, is needed.

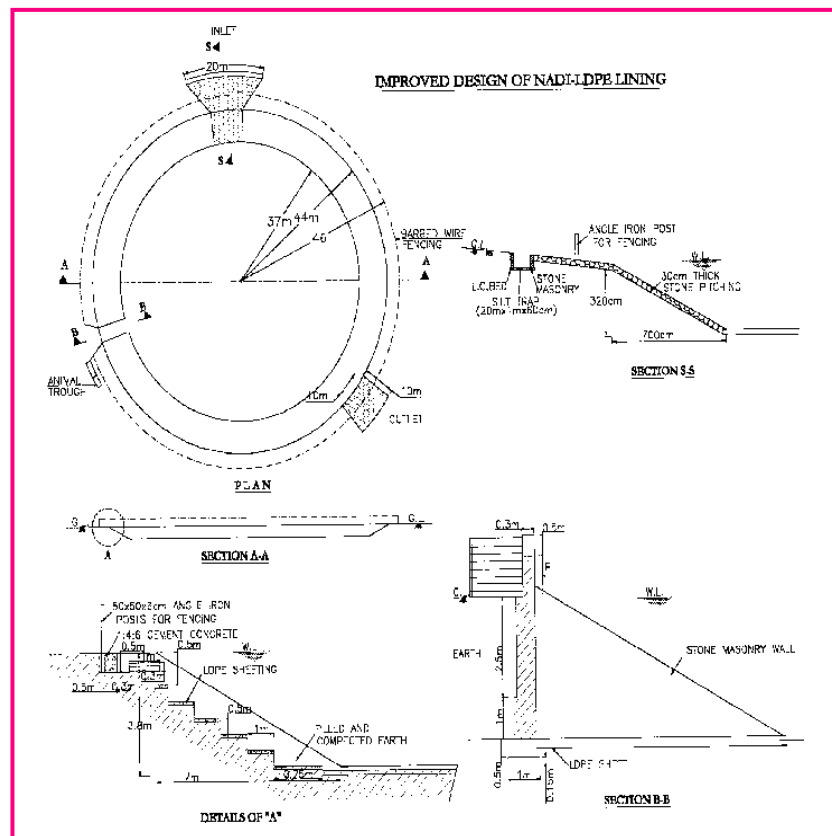


1.2.2 Nadi/Johad

Nadis are small excavated or embanked village ponds for harvesting water in deficit rainfall area to meet the demand of drinking water. The storage capacity is provided for 2 months to one year depending upon the catchment characteristics, amount of rainfall received and its intensity. This is an ancient practice and is the vital water source for drinking water needs.

The first recorded masonry Nadi was constructed in 1520 A.D. near Jodhpur during the regime of Rao Jodhaji. Since Nadis are the vital water sources in the Indian arid zone, each village has one or more of these, depending on the water demand and availability of sites.

Location and size of a Nadi depends on the catchment area it commands. It should be located in areas with lowest elevation to have the benefit of natural drainage and need for minimum excavation of earth. Surface of catchment area should preferably be impermeable. If necessary, the catchment area may be prepared artificially by soil conditioning wherever possible. Silt Trap should be provided at the inlet point to prevent sediment load from entering the Nadi. The size of the silt trap should be designed keeping in view the site conditions, duration and intensity of rainfall. Silt Trap should be cleaned regularly. The inlet should be stone pitched to prevent soil erosion. A mesh should be provided at the inlet to prevent



floating material from entering the Nadi. The slope of the sides shall depend on the soil condition. In order to prevent seepage losses through sides and bottom, these are lined with LDPE sheeting. This should be embedded properly. The outlet should be stone-pitched to prevent soil erosion. An extraction well should be constructed at a suitable point of Nadi to facilitate withdrawal of water. The well has to be constructed by raising two masonry wing walls and one front wall. A suitable platform fitted with iron fixtures for Pulley and Hand Pumps is necessary.



Table 1: Effect of Rainfall in mm on Nadi Volume/ Catchment Area Ratio under different Physiographic Settings

Physiographic Setting	Nadi Volume in m ³ per ha of Catchment Area for Various Rainfall Figures (mm/yr)				
	250-300	300-350	350-400	400-450	450-500
Dune Complex	55.3	110.5	53.0	37.1	-
Sandy plain	120.4	128.0	131.1	137.3	-
Younger alluvial plain	-	-	-	349.9	1066.9
Rocky/ gravel pediment	491.7	518.9	785.5	1644.7	2264.7

The traditional Nadis are affected by heavy sedimentation, high evaporation and seepage losses and water pollution.

The highest Nadi volumes per unit of catchment areas were observed on dunes and sandy plain area with slopes of 1-2%. In younger alluvial plains, rocky/ gravel pediments, Nadi volumes per unit of catchment area, increase with increasing slope. Similarly, the Nadi volumes per unit of catchment area under different rainfall zones are given in Table-1. In dune complexes, the Nadi volumes were highest in the 300-350 mm rainfall areas because of stabilisation of the sands with grass.

Nadis usually have large surface areas compared to the volume of water stored and heavy losses occur since evaporation is a function of surface area. On the other hand, seepage increases with the depth of the stored water. LDPE lining was found to be useful in avoiding seepage losses.

Table 2 : Effect of Ground Slope on Nadi Volume/ Catchment Area Ratio under different Physiographic Settings

Physiographic Setting	Nadi Volume m ³ per ha of Catchment Area in Different Slope Groups (%)					
	<-1	1-2	2-3	3-4	4-5	>-5
Dune complex	54.3	108.2	45.7	29.0	-	13.8
Sandy plain	110.6	154.2	121.1	-	-	-
Younger alluvial plain	466.4	578.5	731.8	-	-	-
Rocky/gravel pediment	51.4	421.5	724.7	945.9	-	1236.5

1.2.3 PERCOLATION TANKS

These are quite popular in the states of Maharashtra, Andhra Pradesh, Madhya Pradesh, Tamil Nadu, Karnataka and Gujarat. Percolation tanks are artificially created surface water bodies, submerging



a land area with adequate permeability to facilitate sufficient percolation of impounded surface runoff to recharge the ground water.

These have come to be recognized as a dependable mode for ground water recharge in the hard rock terrain covering two-third of the country. The hard rock areas with limited to moderate water holding and water yielding capabilities often experience water scarce situations due to inadequate recharge, indiscriminate withdrawal of ground water and mismanagement. The percolation



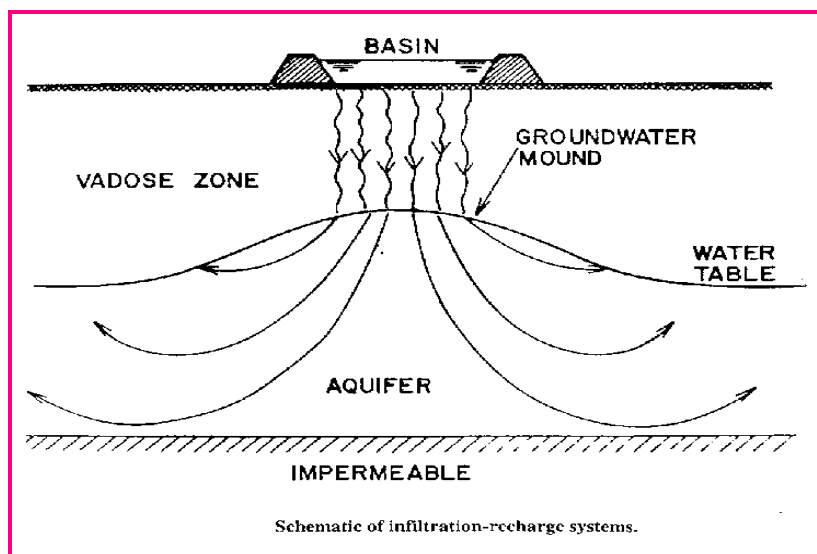
tank is more or less similar to check dams or nala bund with a fairly large storage reservoir. A tank can be located either across small streams by creating low elevation check dams or in uncultivated land adjoining streams, through excavation and providing a delivery canal connecting the tanks and the stream. General Guidelines are as follows :

- (i) Percolation tanks should normally be constructed in a terrain with highly fractured and weathered rock for speedy recharge. In case of alluvium, the boulder formations are ideal.

However, the permeability should not be too high that may result in the percolated water escaping in the downstream as regenerated surface flow.

- (ii) The aquifer to be recharged should have sufficient thickness of permeable Vadose zone to accommodate recharge. The Vadose

zone should normally be about 3 m below the ground level to minimise the possibility of water logging.





- (iii) The benefited area should have sufficient number of wells, hand pumps etc. A minimum well density of 3 to 5 per square kilometres is desirable. The aquifer zone should extend upto the benefited area.
- (iv) Submergence area should be uncultivated as far as possible.
- (v) The nature of the catchment is to be evaluated based on Strange's Table for classification under good, average and bad category. It is advisable to have the percolation tank in a good/ average catchment.
- (vi) Rainfall pattern based on long-term evaluation is to be studied so that the percolation tank gets filled up fully during monsoon (preferably more than once).
- (vii) Soils in the catchment area should preferably be of light sandy type to avoid silting up of the tank bed.
- (viii) The location of the tank should preferably be downstream of runoff zone or in the upper part of the transition zone, with a land slope gradient of 3 to 5%.
- (ix) The yield of a catchment area is generally from 0.44 to 0.55 MCM/sq.km in a low catchment area. Accordingly, the catchment area for small tanks varies from 2.5 to 4 sq.km and for larger tanks from 5 to 8 sq.km.
- (x) The size of percolation tank is governed more by the percolating capacity of the formation under submergence rather than the yield of the catchment. Therefore, depending on the percolation capacity, the tank may be designed. Generally, a percolation tank is designed for a storage capacity of 2.25 to 5.65 MCM. As a general guide the design capacity should normally not be more than 50 percent of the total quantum of utilizable runoff from the catchment.
- (xi) While designing, due care should be taken to keep the height of the ponded water column about 3 to 4.5 m above the bed level. It is desirable to exhaust the storage by February since evaporation losses become substantial from February onwards. It is preferable that in the downstream area, the water table is at a depth of 3 to 5 m below ground level during the post monsoon period, implying that the benefited area possesses a potential shallow aquifer.
- (xii) Construction-wise, there is not much difference between a percolation tank and a minor irrigation tank, except for providing outlets for surface irrigation and the depth of the cut-off trench. The cut-off trench is to be provided below the earthen bund with depth limited to one fourth of the height between bed level and full storage level.



The design of percolation tanks involves detailed consideration of the following aspects:

- (i) The catchment yield is to be calculated for long-term average annual rainfall, using Strange's Table. Appendix-III gives the yield from 1 hectare of Catchment for different values of monsoon rainfall.
- (ii) The design of the dam is to be done on the basis of (a) the topographical setting of the impounded area, to calculate the height and length of the dam wall, its gradient, width and the depth of the foundation, taking into account the nature of the underlying formation; (b) details of the cut-off trench, to reduce seepage losses; (c) height of stone pitching on the upstream slope to avoid erosion due to ripple action and on the down stream slope from rain by suitable turfing; (d) upstream and downstream slopes to be moderate so that shear stress is not induced in the foundation beyond a permissible limit; and (e) stability of the dam.
- (iii) Percolation tanks are normally earthen dams with masonry structures only for the spillway. Construction materials consist of a mixture of soil, silt, loam, clay, sand, gravel, suitably mixed and laid in layers and properly compacted to achieve stability and water tightness. The dam is not to be over-tapped, by providing adequate length of waste weir and adequate free board.
- (iv) A waste weir is provided to discharge surplus water when the full pond level is reached. Maximum permissible discharge from the catchment is to be calculated using the formula approved by the local authority based on local conditions. In the absence of such a formula, Inglis, or Dicken's formula may be used based on the observed or design discharge and catchment areas for local culverts under road or railway bridges. Once the discharge is known the length of the waste weir is decided depending on the maximum flood discharge and permissible flood depth the crest of waste weir.
- (v) Finally, measures indicated for the protection of catchment areas of rock dams hold good in the case of percolation tanks also.
- (vi) The percolation tanks in a watershed may not have enough catchment discharge though a high capacity tank is possible as per site conditions. In such situations stream from nearby watershed can be diverted with some additional cost and the tank can be made more efficient. Such an effort was made in Satpura Mountain front area at Nagadevi, Jalgaon



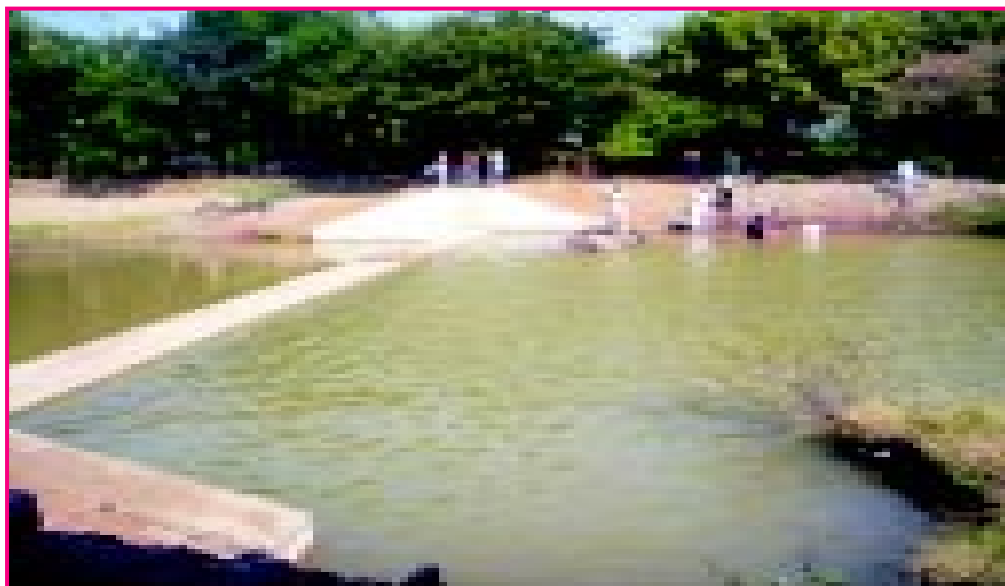


district, Maharashtra. The existing capacity of the tank of 350 TMC was never utilized after its construction. This could however be filled by stream diversion from adjacent watershed.

The Design Example of Percolation Tank with Drawings is given in Appendix-IV

1.2.4 CHECK DAMS/ CEMENT PLUG/ NALA BUNDS

Check dams are constructed across small streams having gentle slope and are feasible both in hard rock as well as alluvial formations. The site selected for check dam should have sufficient thickness of permeable bed or weathered formation to facilitate recharge of stored water within short span of time.



The water stored in these structures is mostly confined to stream course and the height is normally less than 2 m. These are designed based on stream width and excess water is allowed to flow over the wall. In order to avoid scouring from excess run off, water cushions are provided at downstream side. To harness the maximum run off in the stream, series of such check dams can be constructed to have recharge on regional scale.

A series of small bunds or weirs are made across selected nala sections such that the flow of surface water in the stream channel is impeded and water is retained on pervious





soil/ rock surface for longer body. Nala bunds are constructed across bigger streams of second order in areas having gentler slopes. A nala bund acts like a mini percolation tank.



Site Characteristic and Design Guidelines

For selecting a site for Check Dams/ Nala Bunds the following conditions may be observed.

- (i) The total catchment of the nala should normally be between 40 to 100 Hectares though the local situations can be guiding factor in this.
- (ii) The rainfall in the catchment should be less than 1000 mm/annum.
- (iii) The width of nala bed should be atleast 5 meters and not exceed 15 metres and the depth should not be less than 1 metre.
- (iv) The soil downstream of the bund should not be prone to water logging and should have pH between 6.5 and 8.
- (v) The lands downstream of check dam/ bund should have irrigable land under well irrigation (This is desirable but not an essential requirement).
- (vi) The Nala bunds should be preferable located in area where contour or graded bunding of lands have been carried out.





- (vii) The rock strata exposed in the ponded area should be adequately permeable to cause ground water recharge through ponded water.
- (viii) Nala bund is generally a small earthen dam with a cutoff core wall of brick work, though masonry and concrete bunds/ plugs are now prevalent.
- (ix) For the foundation for core wall a trench is dug 0.6m wide in hard rock or 1.2 metres in soft rock of impervious nature. A core brick cement wall is created 0.6 m wide to stand atleast 2.5 metres above nala bed and the remaining portion of trench is back filled on upstream side by impervious clay. The core wall is buttressed on both sides by a bund made up of local clays and on the upstream face, stone pitching is done.
- (x) Normally, the dimensions of the Nala bund are : length 10 to 15 metres, height 2 to 3 metres and width 1 to 3 metres, generally constructed in a trapezoidal form. If the bedrock is highly fractured, cement grouting is done to make the foundation leakage free.
- (xi) Dams should be built at sites that can produce a relatively high depth to surface area so as to minimise evaporation losses.
- (xii) Rocky surfaces should not be fractured or cracked, which may cause the water to leak away to deeper zones or beneath the dam.
- (xiii) Dam foundation must be of solid impermeable rock with no soil pockets or fracture lines.
- (xiv) Convenient location for user groups.
- (xv) No soil erosion in the catchment area.
- (xvi) Dams should be sited along the edges of depressions or directly across the lower ends of deep gullies into the rock.

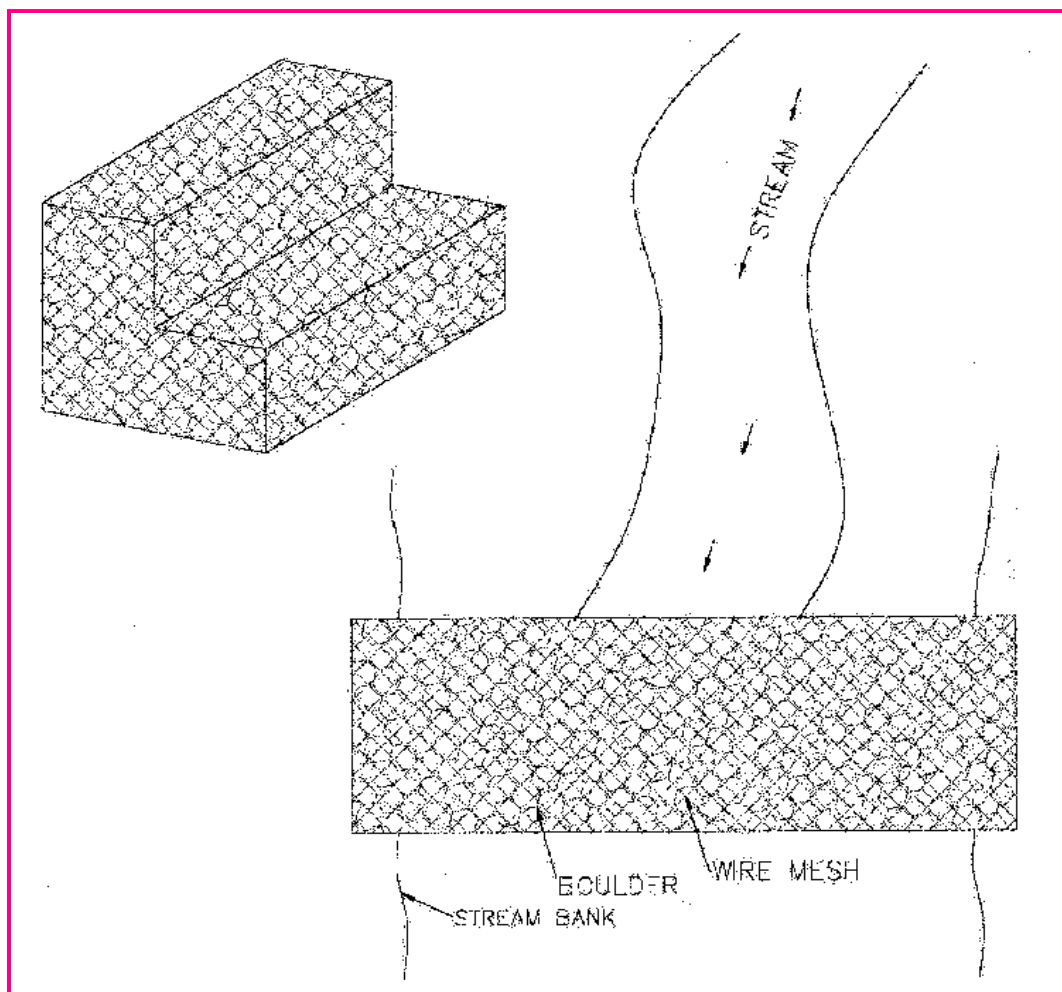




The check dams are also popular and feasible in Bhabar, Kandi and other areas of Uttar Pradesh, Punjab and Maharashtra and have had substantial impact on augmentation of ground water. The Design Example of Check Dam with Drawings is given in Appendix-V.

1.2.5 GABION STRUCTURE

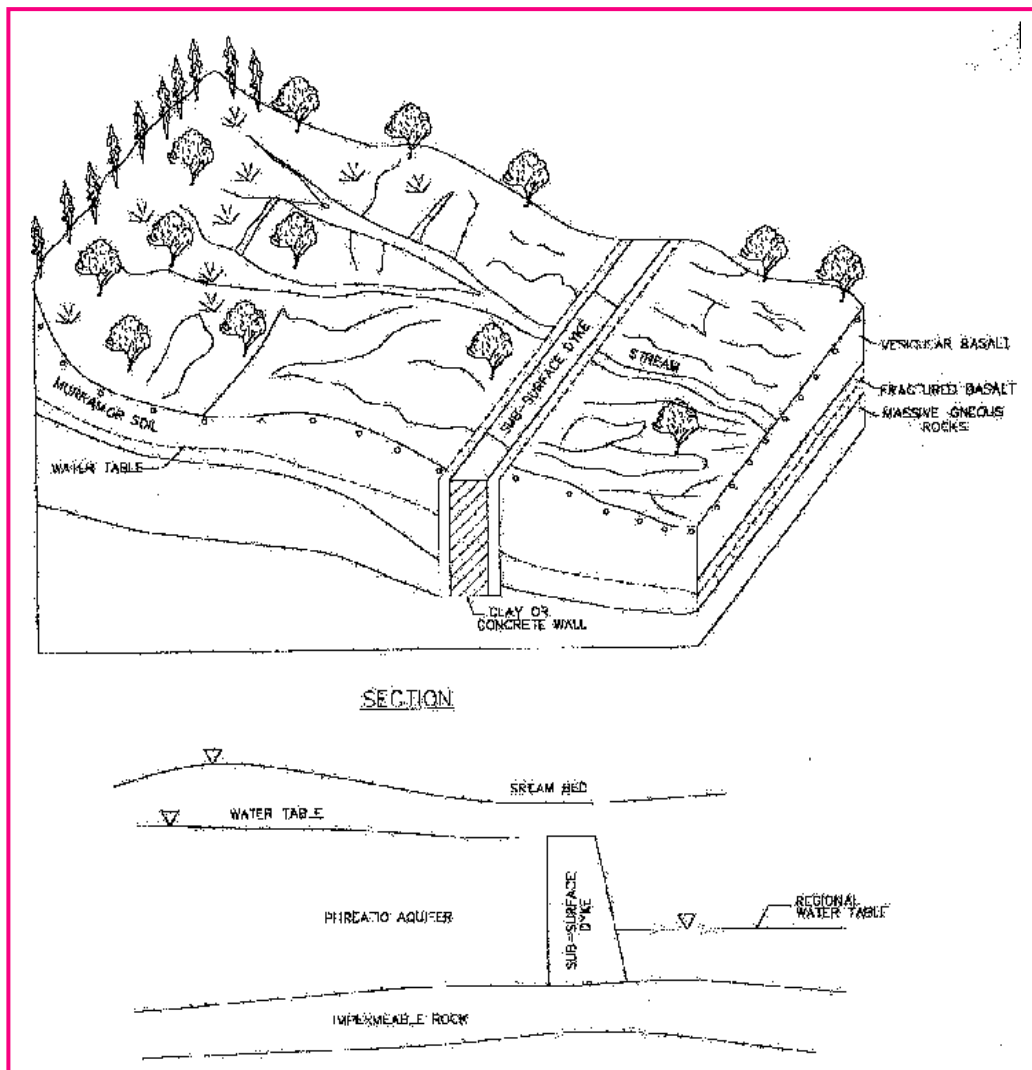
This is a kind of check dam being commonly constructed across small stream to conserve stream flows with practically no submergence beyond stream course. The boulders locally available are stored in a steel wire mesh and are tied up in the form of rectangular blocks. This is put up across the stream to make it as a small dam by anchoring it to the stream banks. The height of such structures is around 0.5 m and is normally used in the streams with width of about 10 to 15 m. The excess water overflows this structure storing some water to serve as source of recharge. The silt content of stream water in due course is deposited in the interstices of the boulders to make it more impermeable. These structures are common in Maharashtra, Madhya Pradesh, Andhra Pradesh etc. Typical drawing of a Gabion structure is given below :





1.2.6 GROUND WATER DAMS OR SUB-SURFACE DYKES OR UNDERGROUND BANDHARAS (UGB)

These are basically ground water conservation structures and are effective in providing sustainability to ground water structures by arresting sub-surface flow. A ground water dam is a sub-surface barrier across stream, which retards the natural ground water flow of the system, and stores water below ground surface to meet the demands during the period of need.



The main purpose of ground water dam is to arrest the flow of ground water out of the sub-basin and increase the storage within the aquifer. By doing so the water levels in upstream part of ground water dam rises saturating the otherwise dry part of aquifer.

The underground dam or dyke has following advantages:

- Since the water is stored within the aquifer, submergence of land can be avoided and land above reservoir can be utilized even after the construction of the dam.
- No evaporation loss from the reservoir takes place.



- No siltation in the reservoir takes place
- The potential disaster like collapse of dams can be avoided.

Such dykes are also useful across the perennial streams. Dykes of 30 cm thick brick-cement or stone cement, extending down to the compact bedrock, with mud or clay fillings in excavated portions on both sides of the wall provide a perfect impermeable barrier.



Management and Maintenance

The quality of water in groundwater dams is generally better than water from other water harvesting systems since water here is stored in the ground and filtered as it moves through the sandy soil. However, the shallow groundwater risks contamination from seepage of surface pollutants.

Once the clay wall groundwater dam is built, it demands very little maintenance. However, the user community should check the dam site for erosion after each large flood. Any erosion should be corrected by refinishing the clay wall and protecting it with large rocks, which cannot be moved by smaller flows. With masonry groundwater dams, any channel erosion that might undermine or expose the dam should be arrested by filling it with large boulders and using silting traps to catch sandy materials. It is a similar prescription for raised dams. With the raised dam, the gravity pipe should be checked frequently along its length for signs of damage or leaks and the tapping station should be kept in good order. Also with groundwater dams there may be a need to control water use, thus requiring supervision, clear agreements among the users and monitoring of the available storage. For the latter, a piezometer may be installed, which allows a caretaker or watchman to estimate how much water is left and if rationing has to be made more strict.

The precautions to manage and maintain water quality and reliability in sub-surface and sand dams and to reduce the risk of contamination are:

- Ensure there is no open defecation in/ near the river bed upstream
- No tethering of donkeys at the well
- Check bathing/ laundry upstream of the dam
- There must be no pit-latrines on upstream of the bank



- There must be no unprotected wells in the river bed near the protected well
- Regular maintenance of the protected well-site and the hand pump must be assured
- Ensure use and maintenance of a downstream gravity out-take
- Avoid use of pesticides/chemicals upstream of the dam site

1.2.7 FARM PONDS

Farm ponds are basically small size rectangular trenches will collect run-off water in agricultural fields. Inter-connectivity of farm ponds could not only result in effective ground water recharge but also dilute the contaminants in ground water. Dug wells would also serve similar purposes.



View of typical farm pond

1.2.8 RECHARGE SHAFTS

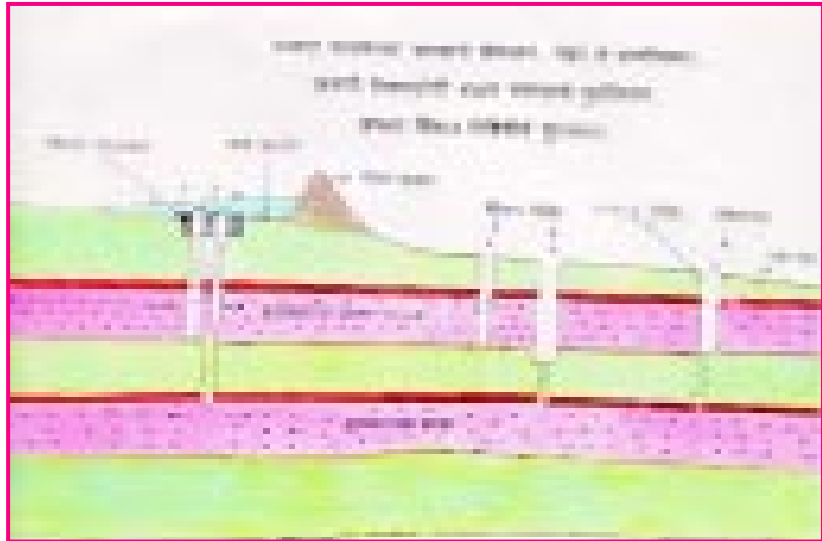
In areas where phreatic aquifer is overlain by poorly permeable strata, the recharge to ground water storage by water spreading method becomes ineffective or have very low efficiency. This situation also occur in ponds/depressions where due to siltation an impermeable layer or lens is formed which affects hydraulic connection of surface water and phreatic aquifers. Recharge shaft is an artificial recharge structure which penetrates the overlying impervious horizon and provides affective access of surface water for recharging the phreatic aquifer. These structures are ideally suited for areas with deep water levels. In areas where low permeable sandy horizon is within shallow depths, a trench can be excavated to 3 m depth and back filled with boulder and gravel. The trench can be provided with injection well to effectively recharge the deeper aquifers.

1.2.9 INJECTION WELLS

The aquifer to be replenished is generally one which is already over exploited by tubewell pumping and the declining trend of water levels in the aquifer has set in. Because of the confining layers of low permeability the aquifer can not get natural catchment from the surface and needs direct injection through recharge wells. Artificial Recharge of aquifers by injection well is also done in coastal regions to arrest the ingress of sea water and to combat the problems of land subsidence in areas where confined aquifers are heavily pumped. In alluvial areas injection well recharging a



single aquifer or multiple aquifers can be constructed in a fashion similar to normal gravel packed pumping well. The only difference is that cement sealing of the upper section of the well is done in order to prevent the injection pressures from forcing leakage of water through the annular space of borehole and well assembly. In hard rock areas casing and well screens may not be required.



An injection pipe with opening against the aquifer to be recharged may be sufficient. However, in case of number of permeable horizons separated by impervious rocks, a properly designed injection well may be constructed with slotted pipe against the aquifer to be recharged. In practice the injection rates are limited by the physical characteristics of the aquifer. In the vicinity of well, the speed of ground water flow may increase to the point that the aquifer is eroded, specially if it is made up of unconsolidated or semi-consolidated rocks. In confined aquifer confining layers may fail if too great pressure is created under them. If this occurs, the aquifer will become clogged in the vicinity of the borehole and/or may collapse.

1.2.10 GULLY PLUGGING/ CONTOUR BUNDING/CONTOUR TRENCHING/ HALF-MOON TERRACES

Contour bunding is a watershed management practice to build up soil moisture storage. It is to arrest run-off through bunds connecting equal ground elevations referred to as contours. Contour trench is the reverse of the bund. Trenches are excavated at different contour levels to conserve the run off in trenches, facilitating percolation of stores water underground.



View of half-moon terracing



In sloping/ hilly areas, these contours bunds/trenches can be inter-connected by masonry chutes to allow smooth flow of excess run-off water from the hill tops to the hill base wherein necessary ground structures could be constructed to contain water. Use of half-moon trenches would be highly useful in slope stabilization and also allowing percolation of rainfall into the ground.



Gully Plugging on hill slopes



View of contour trenching

1.2.11 UNCONVENTIONAL METHODS OF GROUND WATER RECHARGE

Unconventional methods for ground water recharge are being adopted in Maharashtra and Gujarat, with an aim to create :-

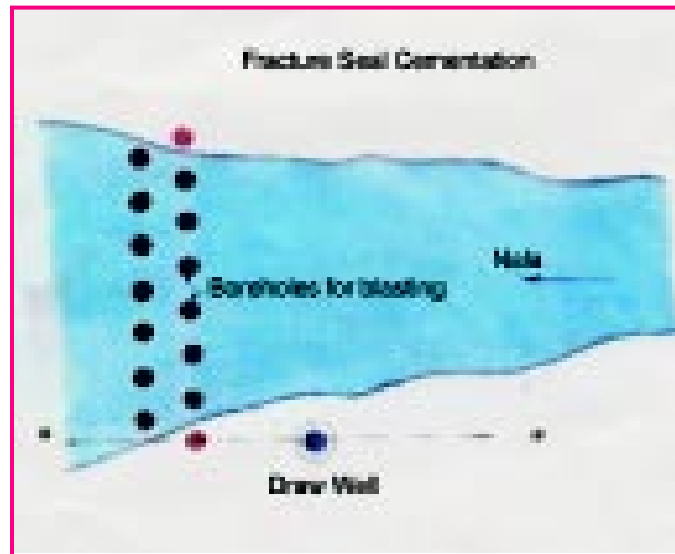
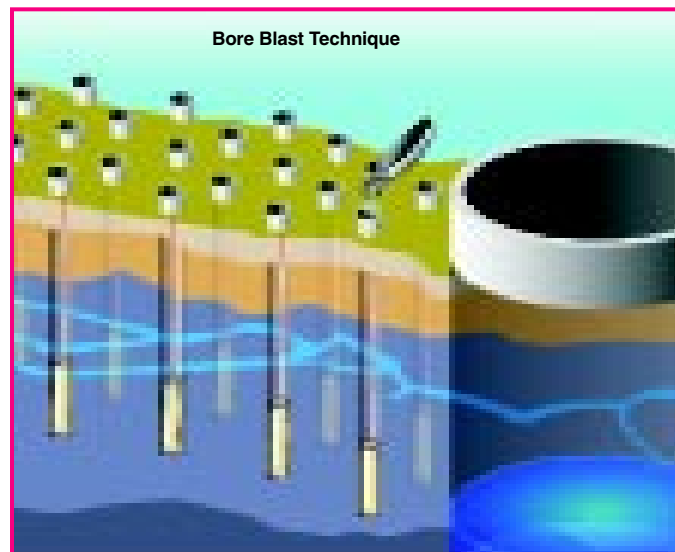
- (a) Rise in ground water table
- (b) Formation of secondary aquifer in otherwise massive hard rocks
- (c) Diversion of nearby stream/sub-surface water to drinking water sources which are otherwise not recharged due to specific geological conditions.



The methods used are :

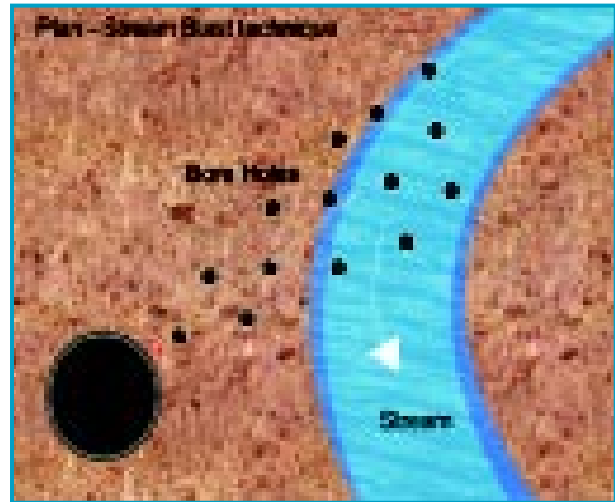
- Fracture Seal Cementation (FSC) – This is a method where cemented seals are made across the stream, near to a drinking water source. These act as sub-surface dykes and restrict movement of sub-surface water and thereby recharge the nearby drinking water sources.
- Bore Blast Technique (BBT) – This is a method of drilling zig-zag placed blast holes and adopt controlled blasting techniques so that the fractures and fissures in the hard rocks get widened and allow recharging the nearby drinking water sources
- Jacket well Technique (JW) – This is also a similar technique like Bore blast technique except that a particular drinking water source like an open well is already identified and the surroundings are blasted appropriately for allowing more recharge.
- Stream Blasting (SB) – This is a method of serial blasting so as to inter-connect a stream/ surface body to a nearby drinking water source, which otherwise does not get recharged due to local hydro-geological conditions.

The unconventional methods of ground water recharge adopted by Government of Maharashtra and Gujarat could suit to specific geological conditions and therefore, States have to study the local conditions very carefully before





implementing the same. Hydro-fracturing, one of the known methods of improving the recharging conditions by widening the underlain cracks is also applicable only in specific locations. Uncontrolled blasting could lead to fly rock and its impact on the surrounding environment has to be studied. Use of explosives may attract the provisions the Explosives Act, 1884, Mines Act, 1952 and Environment (Protection) Act, 1986. Specific licenses are required to handle explosives and storage of explosives, require a designated “buffer zone”.



1.2.12 SITING OF RECHARGE STRUCTURES THORUGH LATEST TECHNIQUES OF REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEMS

As mentioned earlier, about 85% of the rural drinking water supply schemes are dependent upon ground water as its source. Rural water supply is executed by State PHEDs/ Board, PRIs predominantly through hand pumps and some schemes through dug wells, energizing tapping of ground water for piped water supply systems, etc. These Departments have an established drilling & Maintenance unit, where experienced hydro-geologists are posted.



Varied geological formations



Over exploitation

Due to work pressure, these Hydro-geologists are often not able to conduct systematic hydro-geological studies for site specific investigations be it for tapping or identification of sustainability structures. Further, lack of scientific data on case –specific basis, leads to improper identification of sites for tapping and/or recharge. Over-exploitation of ground water for irrigation, industries, etc. have also resulted in inducing various water quality problems. Therefore, the RGNDWM way back



in the year 1998-99 decided to prepare ground water prospect maps on 1:50,000 scale incorporating geological (lithological and structural), geo-morphological (land use, forest cover, soil map, slope & aspect, etc.), hydrological information (rainfall, trend and pattern) and socio-economic base maps (population, habitations, water quality problem areas, SC/ST trends, etc.).

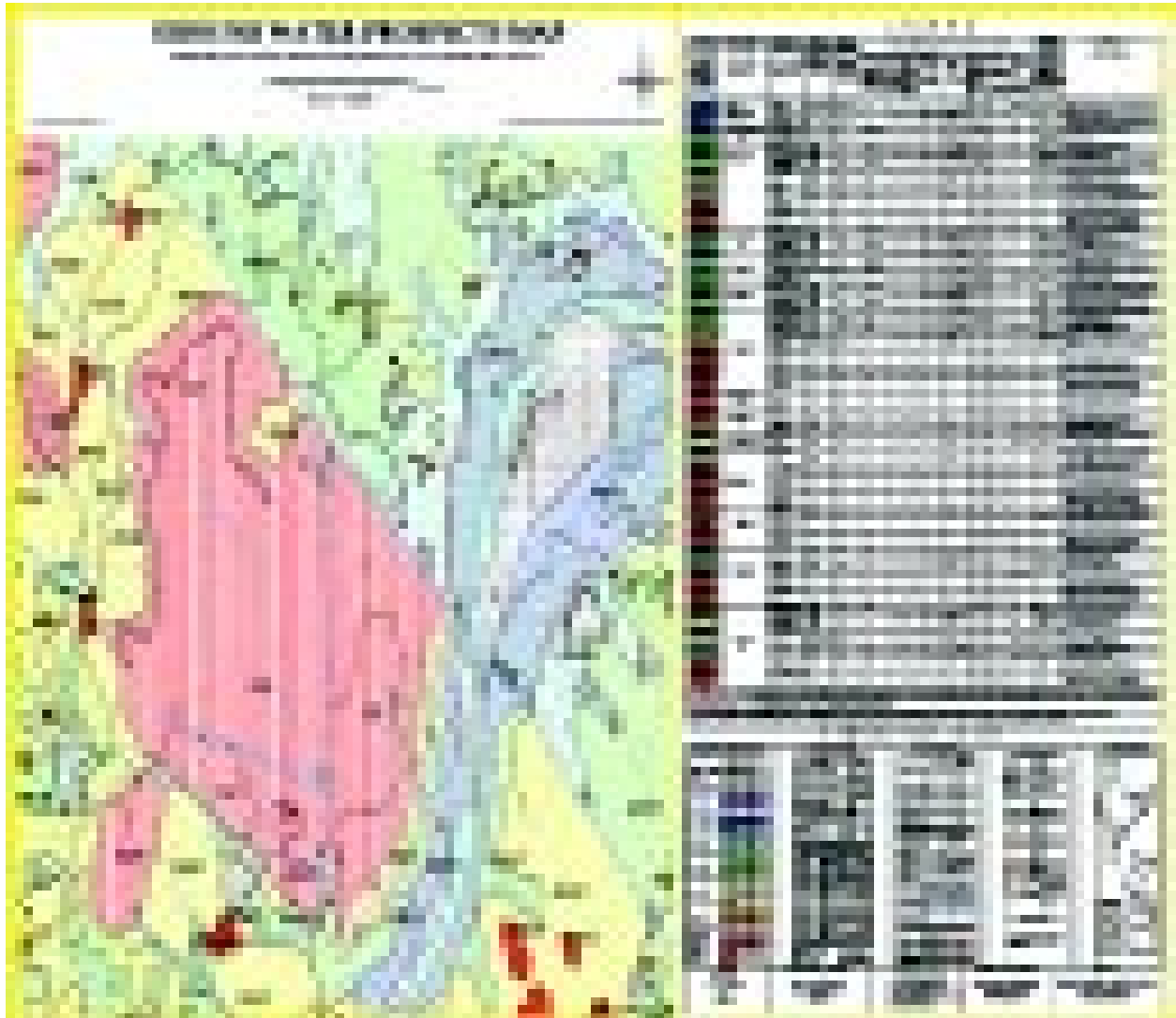
Such integrated approach led to “ground water prospect maps” with suitable data base for narrowing down the target zones and systematic selection of sites after follow-up groundwater surveys.

Methodologies available for using Satellite data ::

- In the year 1974, hydromorphological maps were prepared through aerial photo-interpretation on 1:50,000 scale indicating the hydromorphic unit-wise ground water potential in quantitative terms ie., very good, good, poor and none.
- In the year 1978, Geomorphological maps were prepared based on visual interpretation of Landsat-1 imagery on 1:2,50,000 scale and geomorphic province –wise ground water potentials were evaluated taking into account the landform, lithology, drainage and lineament density and the ground water potentials indicated in qualitative terms ie., very high, high, moderate and low.
- In the year 1984, Ground water potential maps were prepared on 1:2,50,000 scale based on visual interpretation of Landsat-MSS data wherein the ground water potentials were evaluated by combining the geology, geomorphology, terrain conditions, depth of weathering, etc. Ground water potential maps were prepared on 1:50,000 scale using high resolution Landsat-TM data in 1985 taking into account the lithology, landform and structural information. Ground water potential maps were also prepared by Departemnt of Space for the states of Maharashtra, Karnataka and Rajasthan by adopting a common legend.
- Hydro-geomorphological maps were prepared on 1:2,50,000 scale using Landsat-TM and IRS-1A/1B data for all the 447 districts of the country by the Department of Space. Subsequently, NRSA prepared 1:50,000 scale maps under the Integrated Mission for Sustainable Development.
- RGNDWM engaged the services of NRSA, Hyderabad to prepare Hydro-geo-morphological (HGM) or ground water prospect maps on 1:50,000 scale using IRS-1C/1D FCC satellite imagery and burning various thematic layers on the corrected and geo-coded satellite data. Preparation of 1654 maps out of 1723 maps completed in Phase-I in 6 States (AP, Karnataka, MP, Kerala, Chattisgarh & Rajasthan) at a cost of Rs 13.09 crore has been completed and these maps were handed over to the respective State Governments. (69 maps along the International border along Rajasthan state could not be taken up). Preparation of 650 maps out of 724 maps completed in Phase-II in 4 States (Himachal Pradesh, Jharkhand, Orissa and Gujarat) a cost of Rs 8.01 crore was also completed and handed over to the concerned State Governments. (74 maps in Gujarat State were not done as they were already completed by Gujarat WR Department).



Another 1290 HGM maps preparation in Six more states viz., Andhra Pradesh (remaining part), Assam, Punjab, Jammu & Kashmir, Maharashtra and Uttarakhand has been taken up during the current year with a project cost of Rs 15.98 crore.



Objectives of Ground water Prospecting Maps ::

The main objectives are-

- (i) Preparation of ground water prospecting maps on 1:50,000 scale is to identify
 - (a) Prospective ground water zones,
 - (b) Prioritization of areas of planning recharge structures,
 - (c) Tentative sites for taking up recharge structures to improve the sustainability of drinking water sources in the problematic habitations.



- (ii) Creation of a digital database which
 - (a) would form an excellent data bank for all ground water studies and related applications
 - (b) will facilitate easy updation, editing, archival, data integration, analysis, generation of derivative maps etc.

Maps considered by NRSA while preparing Ground Water Prospecting maps for RGNDWM

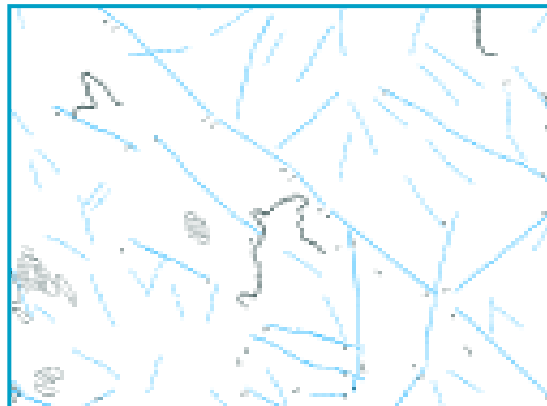
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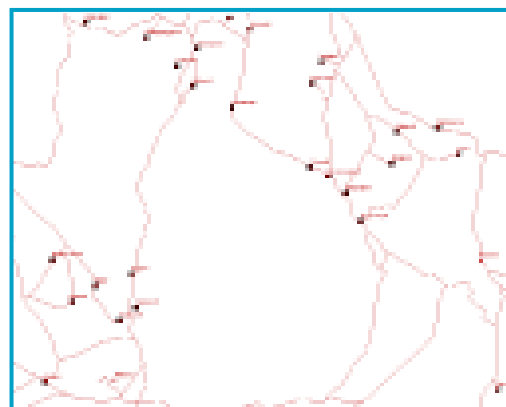
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(4)



(5)





Legend ::

- 1) Lithological map layer
- 2) Geomorphological map layer
- 3) Structural map layer
- 4) Hydrogeological map layer
- 5) Base map layer

Feedback received from State Governments on usage of Satellite data

Out of 10 States that were taken up for preparation of HGM maps, 8 States viz., Andhra Pradesh, Karnataka, Madhya Pradesh, Kerala, Chattisgarh, Rajasthan, Gujarat and Orissa are getting benefited by using HGM maps for siting bore wells and recharge structures. The remaining two states viz., Himachal Pradesh and Jharkhand have started using these HGM maps, as per feedback received by NRSA from various States.

Based on the feedback received from States, more than 2 lakh wells have been drilled in 6 states and achieved more than 90% of success rate, on average. Similarly, 9,744 recharge structures have been planned out of which, 7030 structures have been constructed which have significantly improved the sustainability of drinking water sources.

With the help of the ground water prospecting maps in Karnataka 34,688 wells were drilled (92.7 % success) and 2,574 recharge structures were implemented. In Madhya Pradesh 18,608 wells were drilled(90 % success) and 3361 recharge structures were constructed. In Andhra Pradesh 34,698 wells (92.8% % success) and 440 recharge structures were constructed. In Kerala, 7730 wells (92% success) and 8 recharge structures have been constructed. In Chattisgarh, 33413 wells (92.5% success) and 327 recharge structures have been constructed. In Gujarat and Orissa, 50 wells and 3 wells respectively were drilled using HGM maps and the success rate found was 100%.

In the very difficult terrain of Rajasthan, 75,733 wells have been drilled and success rate achieved is between 85-95% while all the 320 recharge structures planned have been constructed.

Latest technologies now available

Satellite data from IRS-2A/2B/2C/2D with PAN merged data would result in a high resolution of about 5.7m to 10m. Use of Google-Earth data is also being done by some of the agencies as tools for water conservation. Very powerful GIS softwares like Erdas Imagine, Arc Info, MapInfo, etc. are available in the market today for synthesizing digital data of various forms.



Case study of Chattisgarh State (Umara Nalla Sub-Water shed)

- Umara Nalla" (part of Kulherba sub basin) sub watershed is described to demonstrate the utility of RS & GIS tool to generate an action plan of suitable water harvesting structures to enhance ground water recharge in the area. Umara Nalla sub watershed is part of Mohkheda block. Watershed Boundaries are shown here.
- The said watershed lies between north latitude of 21°50'30" to 22° and east longitude of 78°43' to 78°57' sprawling over a total geographical area of 130 sq. km. consisting of 38 villages.



General Information (layers) considered for Mapping ::

- Social Profile
- Demographic Profile
- Cultural Profile
- Economic Status
- Health Status
- Wild Life
- Bio diversity
- Flora Fauna
- Education
- Agricultural Status
- Farming System
- Pollution Studies
- Industries



Specific data considered for ground water recharge studies

- Land use pattern
- Irrigated & Non Irrigated Area
- Water bodies status
- Soil Cover Condition
- Forest Status
- Toposheets
- Drainage System
- Physiography
- Slope conditions
- Soil Map
- Geology
- Ground Water Status
- Ground Water Prospects
- Climatic Data
- Hydrogeomorphology
- Water Quality Maps
- Watershed consisting of moderate drainage texture with drainage density of approx. 1.95.



The main characteristics of the said watershed is erratic and uneven distribution of rain fall spatially and temporally which results into frequent water shortage, flash floods and soil loss. On the other hand area receives average rainfall of 1027 mm annually. It has been observed that approx. 90% of the water goes as surface runoff of the watershed as unused.



Slope/Aspect Map

- The said watershed is fern shaped. It controls the time taken for run off to concentrate at outlet.
- The watershed has been divided into three zones ie. Recharge Zone, Transition Zone and Discharge Zone.
- Higher the slope, higher the run off.



Soil map

- Soil is the most important component to be considered for ground water Recharge.
- Factor affecting the GW recharge are :
 - a. Soil Profile
 - b. Soil Texture
 - c. Soil Structure
 - d. Infiltration
 - e. Moisture
- Depth of weathering on basalts is quite deep resulting in development of considerable thick soil and residual weathering material. The soils derived from the deccan trap in the Umra Nalla watershed are vertisole, predominantly dark coloured, very deep, silty swelling clays which are popularly known as “black





cotton soil". These have generally developed on yellow silty clay derived from weathering of the basalt. but at some places where the weathered basalt is within 2m of the soil surface, the black cotton soil is directly overlying the basalt.

Geological Map

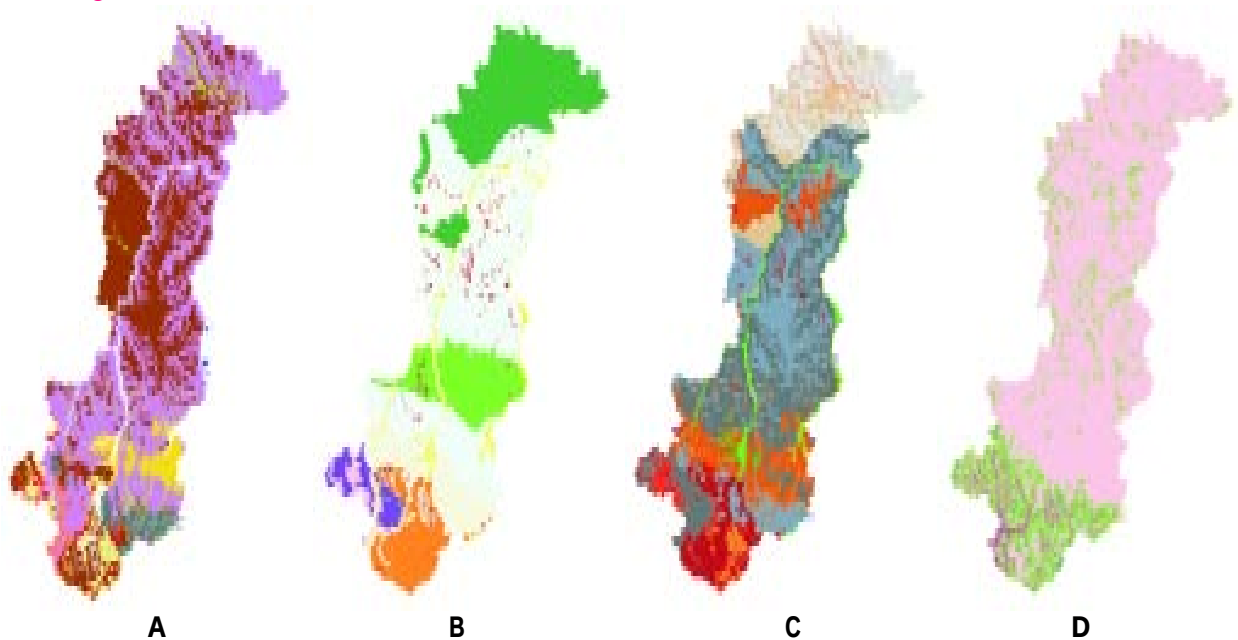
- Area mainly consists of Deccan trap formation. The ground water occurs under semi confined to confined conditions in the weathered, vesicular, joints and fractured basalts. The potential yield ranges between 1.5-8 lps. In the phreatic aquifer water bearing capacity is reduced to large extent because of non availability of vegetation cover and deforestation.

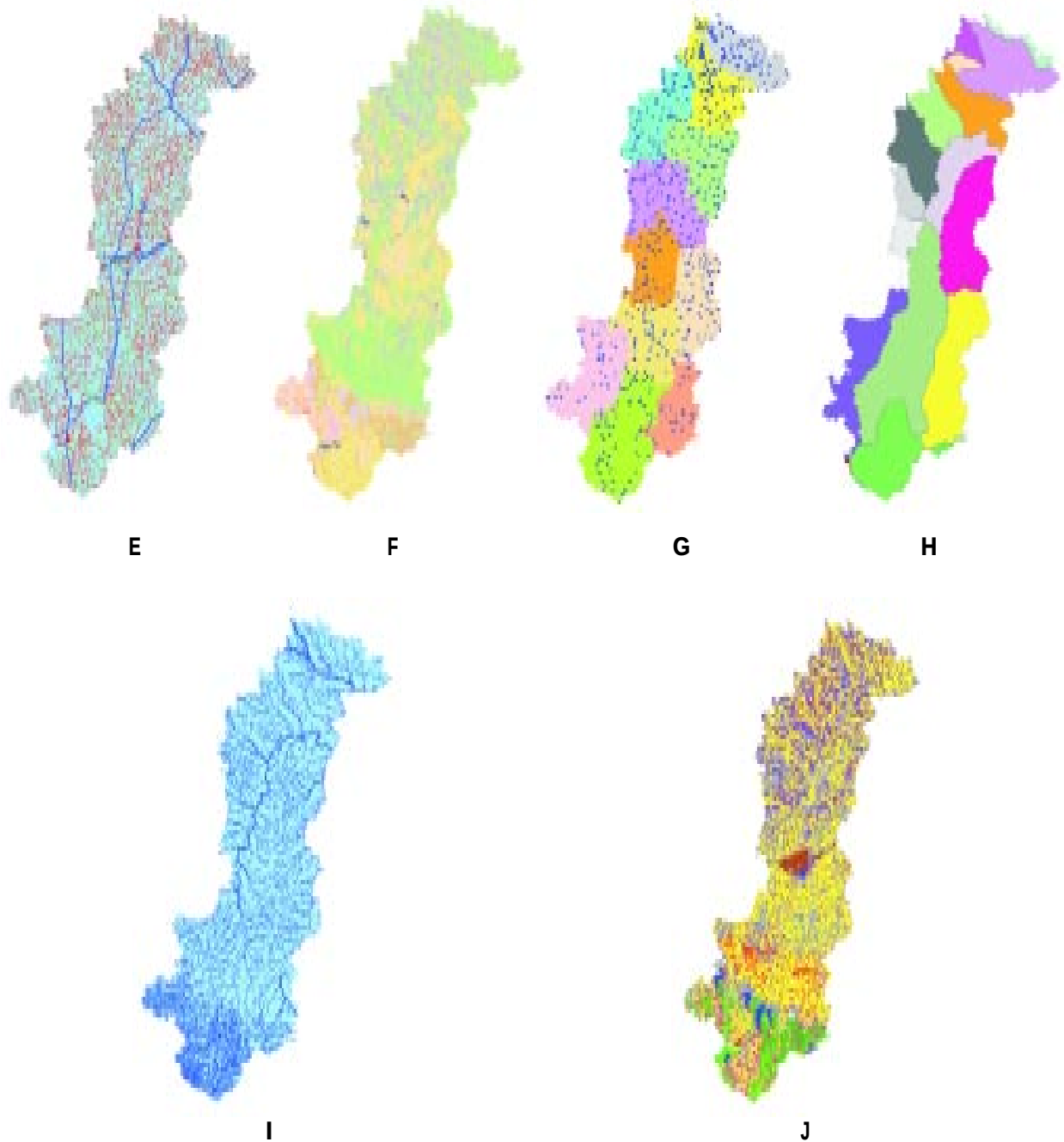


Hydro-morphological Map

Indicates four geomorphic units in the area i.e. valley fill, buried plains, Pediplains and Lineaments. HGM indicate the area is very good for ground water recharge.

Case Study of Integrated Water Management for Sustainability of drinking water sources – Chattisgarh State





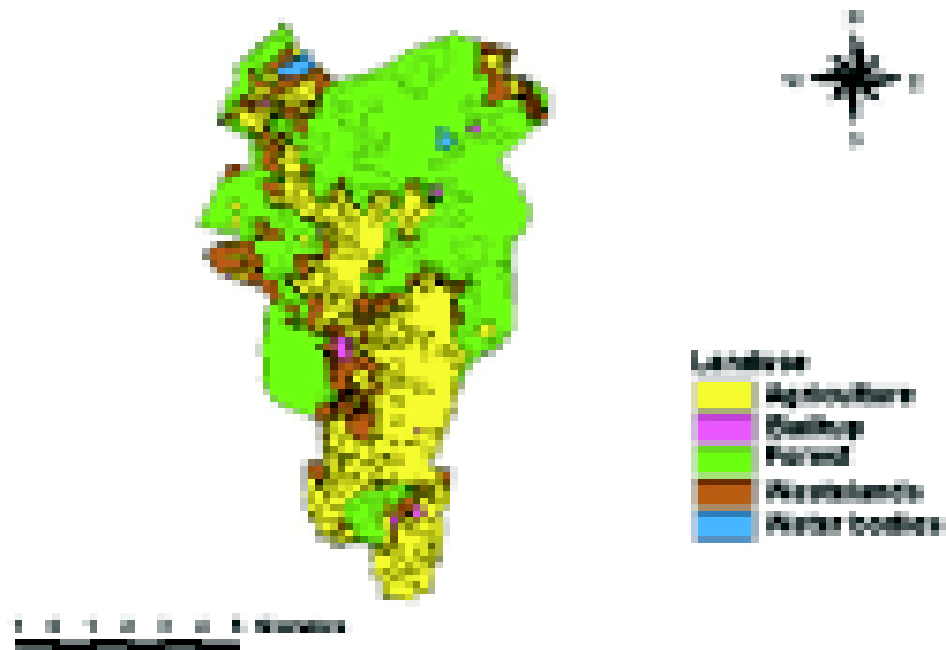
List of Thematic maps considered for Integrated Water Resource Management

A	Morphology	F	Soil profile
B	Lithology	G	Well Inventory
C	Ground water potential	H	Watershed
D	Slope	I	Drainage
E	Transportation Network	J	Land Use/Land Cover



Step -3 :: Preparation of Land Use Map

Landuse Map of Amravati Pilot



Step - 4 :: Preparation of Geological Map





Step – 5 :: Integrating various layers on Village Raster Map



Village map with all surface features in the digital form would then be superimposed over all other layers to generate the final Hydrogeo-morphological map.

1.3 SUSTAINABILITY THROUGH SURFACE WATER HARVESTING/ COLLECTION METHODS

1.3.1 Ancient practices

Rainwater harvesting structures are a part of a strategy for water conservation. People in all parts of country have a long standing tradition of rainwater harvesting by designing different types of structures and management systems.

The Indus Valley Civilization, that flourished along the banks of the river Indus and other parts of western and northern India about 5,000 years ago, had one of the most sophisticated urban water supply and sewerage systems in the world.

The fact that the people were well acquainted with hygiene can be seen from the covered drains running beneath the streets of the ruins at both Mohenjodaro and Harappa. Another very good example is the well-planned city of Dholavira, on Khadir Bet, a low plateau in the Rann in Gujarat.

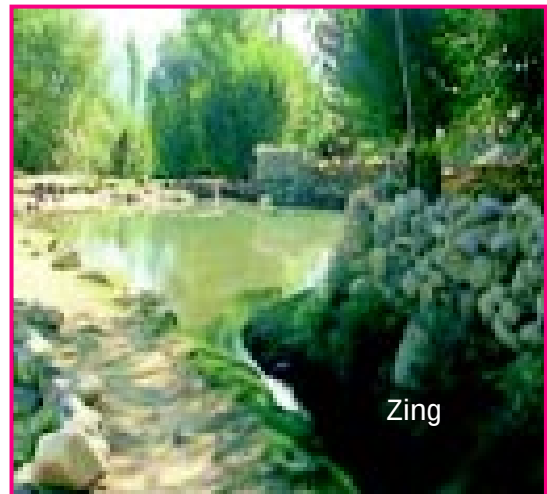
One of the oldest water harvesting systems is found about 130 km from Pune along Naneghat in the Western Ghats. In ancient times, houses in parts of western Rajasthan were built so that each had a rooftop water harvesting system. Rainwater from these rooftops was directed into underground tanks. This system can be seen even today in all the forts, palaces and houses of the region. Underground baked earthen pipes and tunnels to maintain the flow of water and to transport it to distant places, are still functional at Burhanpur in Madhya Pradesh, Golkunda in AP, temple tanks in Tamil Nadu, Bijapur in Karnataka, and Aurangabad in Maharashtra.



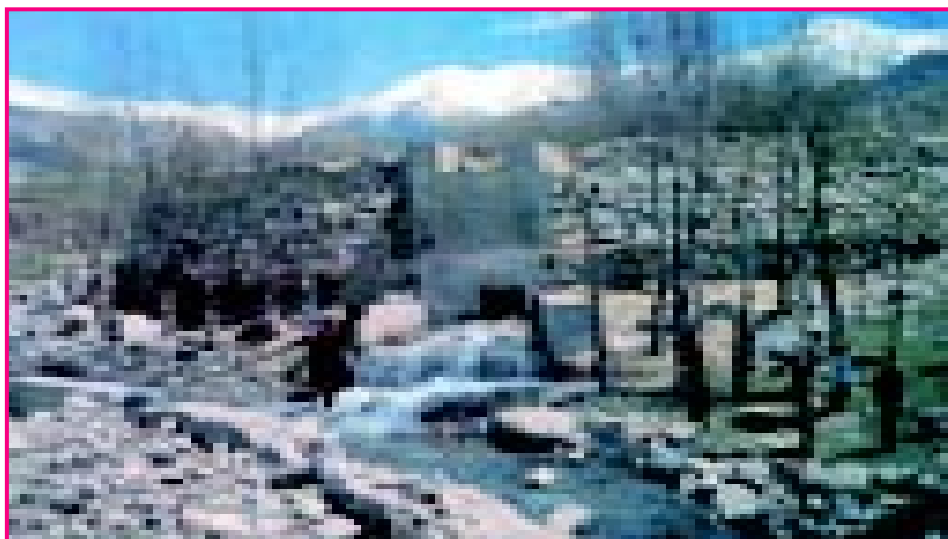
In Rajasthan, wherever any space is available, people made a sloping courtyard there. The slope can be from one side to the others but if the courtyard is big enough, it can run from the four sides and converge towards the middle portion. In this portion, a kund is made according to the shape and size of the courtyard and according to the amount of rain, which falls. The inside of the kund is lined in such a way that not a single drop from the water collected within is lost through seepage, and throughout the year the water remains clean and protected. Integrated surface and ground water systems in forts hills of Jodhpur, Zings of Ladakh, Ahar Pynes in Bihar, lakes of Udaipur, are all good examples of rainwater harvesting methods. People in different parts of country innovated such structures, with improvisation based on local condition and needs and gave them different names. Such structures are time tested and were the sustainable source of drinking water to all.

1.3.1.1 Ancient methods adopted in Trans Himalayan Region

Water from melting snow and ice is the only source of water here. Nearly 68% of Ladakh lies 11000 ft above mean sea level. The people made intelligent use of their limited resources and made agriculture possible in this dry and barren land. The snow and ice melt slowly through the day and water is available in the streams only in the evening, when it is too late for irrigation. The water in the streams was hence led by channels to storage tanks called **zing** and used the next day.



In the Spiti area of Himachal Pradesh, diversion channels called **kul** were used to bring the melting snows from glaciers to circular tanks, from where the water was distributed.



View of Kul



1.3.1.2 Ancient Methods adopted in Western Himalayas

The farmers of this region built canals along the contours to collect water from hill streams, springs and melted snow. Since the first millennium A.D., there has been extensive rice cultivation in Kashmir, aided by an elaborate irrigation system consisting of irrigation canals bringing water from the melting snows. Water wheels (araghatta) were used to lift water from the Jhelum.

Ponds were the main source of drinking water in Jammu. Ponds in the Kandi region were dug beside rivers. During floods the river waters were diverted into them. In Himachal Pradesh a temporary headwall of boulders called **kuhl** was constructed across a ravine to divert the waters of natural flowing streams (khud) through a canal to the fields. About 20 ha could be irrigated by a community kuhl. The water would flow from field to field and surplus water would drain back to the khud. The kohli or water tender distributed and managed the water.



View of Guhl

In Uttar Pradesh contour channels called **guhls** were used extensively. Streams were dammed by temporary barriers to divert water into these channels.

1.3.1.3 Ancient Method adopted in Eastern Himalayas

Streams are the only dependable source of water here. Bamboo pipes are used to divert the water for irrigation.

The apatani system of Arunachal Pradesh was practised by the Apatani tribes. They harvested both ground and surface water for irrigation. The stream water was blocked by constructing a wall 2 to 4 m high and 1 m thick near forested hill slopes. This water was taken to the agricultural fields through channels. The valleys were terraced into plots separated by 0.6 m high earthen dams with inlet and outlet channels (to the next plot) that help to flood or drain the plots as and when required.

1.3.1.4 Ancient Methods adopted in North Eastern Hill Ranges

Rainfall and groundwater are the main sources of water in this region. But the terrain makes it difficult to capture the surface water. Natural springs are used for drinking water purposes.

Zabo, meaning 'impounding run-off', is practised in Nagaland. When rain falls on terraced hill slopes, the runoff collects in ponds in the middle terrace. The runoff then passes through slopes where there are cattle yards, and finally reaches the paddy fields at the foot of the hills.



Rapidly flowing water from streams and springs was captured by bamboo pipes and transported over hundreds of metres to drip irrigate black pepper cultivation in Meghalaya. Many bamboo pipes of varying diameters and lengths were laid to manipulate and control the flow of water.



1.3.1.5 Ancient Methods adopted in Brahmaputra Valley

This region has many natural depressions along the banks of the Brahmaputra and Barak rivers. Floodwaters accumulate in these depressions, which are used for cultivation when the waters recede.

Dongs or ponds were constructed by the Bodo tribes of Assam to harvest water for irrigation. In the Jalpaiguri district of West Bengal, small irrigation channels called dongs or jampoies were used to bring water from streams to rice fields.





1.3.1.6 Ancient Methods in Indo-Gangetic Plains

The rivers and their floodwaters are the main source of water here. Ahar-pyne is a traditional floodwater harvesting system indigenous to south Bihar. Here the terrain has a marked slope, the soil is sandy, groundwater levels are low and rivers flood their banks only during the monsoon. The ahar is the catchment basin embanked on three sides, while the fourth side is the natural slope. Pynes or artificial channels start out from the river, and meander through fields to end up in an ahar.

Inundation canals were an efficient irrigation system in Bengal. Floodwaters rich in silt entered the inundation canals, and were carried to the fields. The canals were broad and shallow and long and continuous. Channels cut into their sides distributed water to the fields. They were closed once the floods ceased.

1.3.1.7 Ancient Methods adopted in Thar Desert

The Thar Desert receives very little rainfall. Hence rainwater was captured and stored in ponds and underground tanks.

Tarais (reservoirs) were built in the valley between sand dunes by constructing bunds at the two ends. When it rained the rainwater was collected in the reservoir. The tarais dried up in a few months owing to the highly porous soil. But the region around it remained wet and moist. Wells were usually dug close to the tarai.

Individual homes and farms in Bikaner built tankas. They were round or rectangular underground rooms that functioned as water tanks. Rainwater from the roof or terrace was directed towards an opening in the floor which led to the tanka.

Stepwells are India's most unique contribution to architecture. They are called vav or vavadi in Gujarat, and baolis or bavadis in Rajasthan and northern India. The stepwells of Gujarat consist of a vertical shaft in the middle from which water is drawn. This shaft is surrounded by corridors, chambers and steps, which provide access to the well. They were profusely carved and served as a cool resting place in summer.

Mata Bhavani's vav at Ahmedabad, built in the eleventh century, is one of the earliest stepwells, while the Rani Vav (Queen's well) at Patan, built during the late eleventh century, is the grandest. The Dada Harir's vav at Ahmedabad, and the octagonal vav at Adalaj, are some of the finest examples of stepwells.

Kunds or kundis in Western Rajasthan and Gujarat harvest rainwater for drinking in the sandy tracts of the Thar Desert. The saucer-shaped catchment area gently slopes towards the pit in the centre, which has a dome-shaped cover, to protect the water. The water inlets are covered with mesh. The depth and diameter of kunds depend on their use (drinking or domestic water requirements).



Kuis or beris were deep pits dug near tanks to collect the seepage. They were also used to harvest rainwater in areas with scanty rainfall. From a narrow mouth a kui gets wider to prevent evaporation of collected water but at the same time facilitates more water collection.

1.3.1.8 Ancient Practices in Southern India

The Satvahanas (1st Century B.C.-2nd Century A.D.) introduced the brick and ring wells. Lake and well irrigation was developed on a large scale during the time of Pandya, Chera and Chola dynasties in south India (1st-3rd Century A.D.) and large structures were built across Cauvery and Vaigai rivers. Irrigation tanks were built, many of these by developing large natural depressions. Water resources development on a large scale took place during the Gupta era (300-500 A.D.). In the south, the Pallavas expanded the irrigation system in the 7th Century A.D. The famous Cauvery anicut was built during this period. Large-scale construction of tanks for tapping rain water was also done in Tamil Nadu. The Chola period (985-1205 A.D.) witnessed the introduction of quite advanced irrigation systems, which brought about prosperity in the Deccan region. This included not only anicuts across rivers and streams but also chain-tanks i.e. a number of tanks with connecting channels. This new system was more reliable in terms of water availability and provided better flexibility in water distribution.



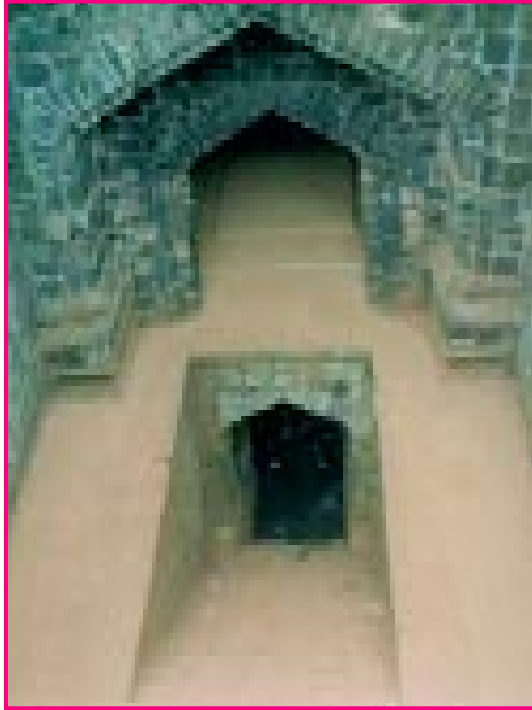
View of Cauvery Anicut

1.3.1.9 WATER FOR FORTS AND PLACES OF WORSHIP

All forts, built in different terrains and climatic conditions, had elaborate arrangements for drinking water. Those built on hilltops or in rocky terrain depended mainly on rain water harvested from surrounding hills. The Amber Fort near Jaipur built about three centuries ago is a classic example of such a system. It has an automatic arrangement for desilting and aeration of harvested rain water before its entry into the large storage tank. The Jodhpur fort in western Rajasthan had water harvesting arrangements to tap both rain water and groundwater. The Panhala Fort of



Maharaj Shivaji built on a hillock near Kolhapur in Maharashtra had Baolis and wells to tap underground springs originating in nearby higher hill slopes. The fort at Chittor on top of a hill has a large reservoir formed from the harvested waters of springs.



Baolis to tap underground springs in Panhala Fort

At the Buddhist site of Sanchi (Madhya Pradesh) dating back to the 3rd Century B.C., there are three ancient tanks to store rain water from the hill slopes.

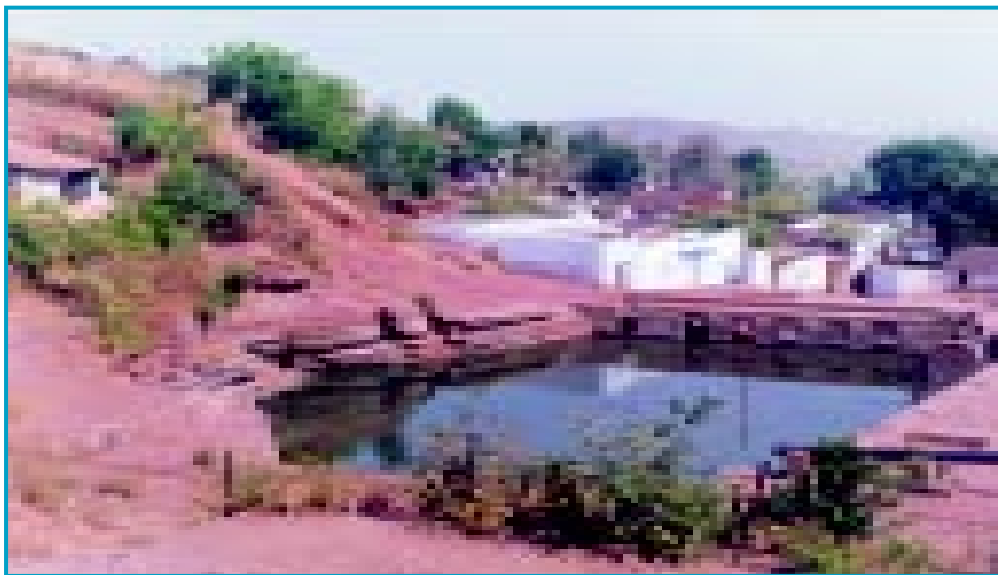


Ancient Tanks on the Buddhist site of Sanchi dating back to the 3rd Century B.C.

Most of the old temples in south India built centuries ago have large tanks in their premises. These tanks are either fed by harvested rain water or by tapping underground springs. In Tamil Nadu alone there are 39 temple tanks with areas varying from 0.25 to 3 hectares. These are all fed by rain water. Though these were used mainly for bathing and religious purposes, these also recharged the drinking water wells.



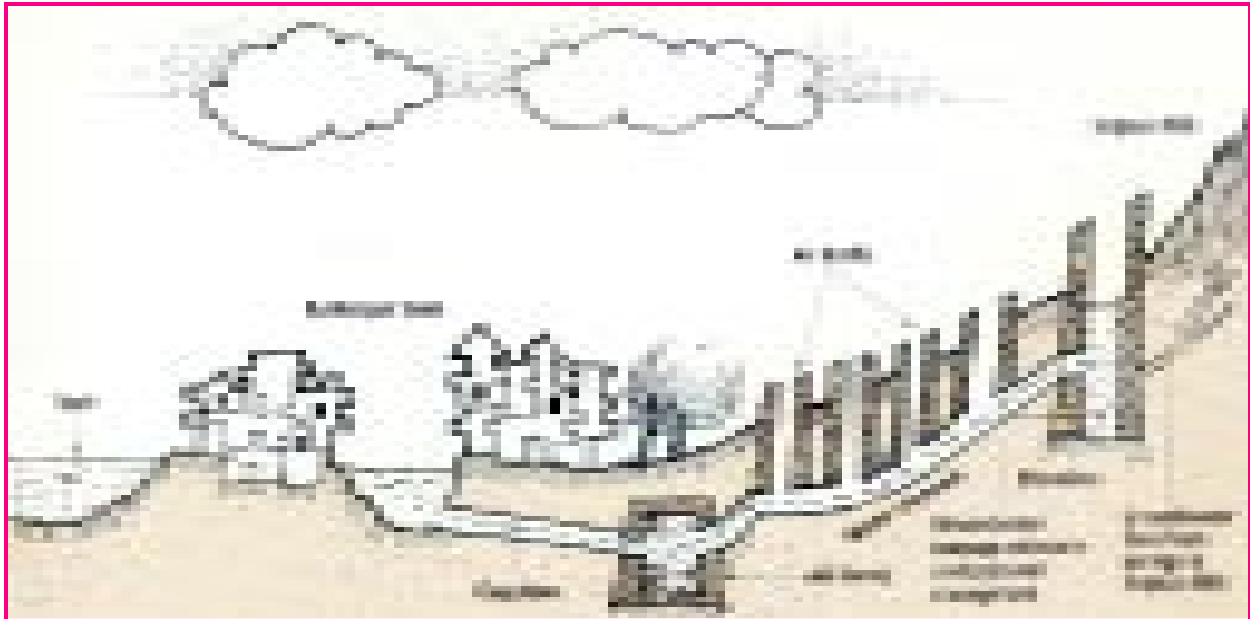
Spring Water Harvesting in Fort of Chittor



Baori Constructed in the Fort of Raisen

Unique example of Burhanpur Fort

In 1615, during the Mughal rule, Abdul Rahim Khan built a unique water supply system of the Burhanpur town (Madhya Pradesh). The system involved construction of long lines of underground tunnels with vertical airshafts to tap the underground water flow from the nearby Satpura hill ranges to the Tapi river lower down. The system is still functioning well and is adequate to meet the entire water requirements of the town.



Engineering Marvel of Burhanpur



Air Shaft in Original Condition (left) and after repair (right)



Series of Air shafts



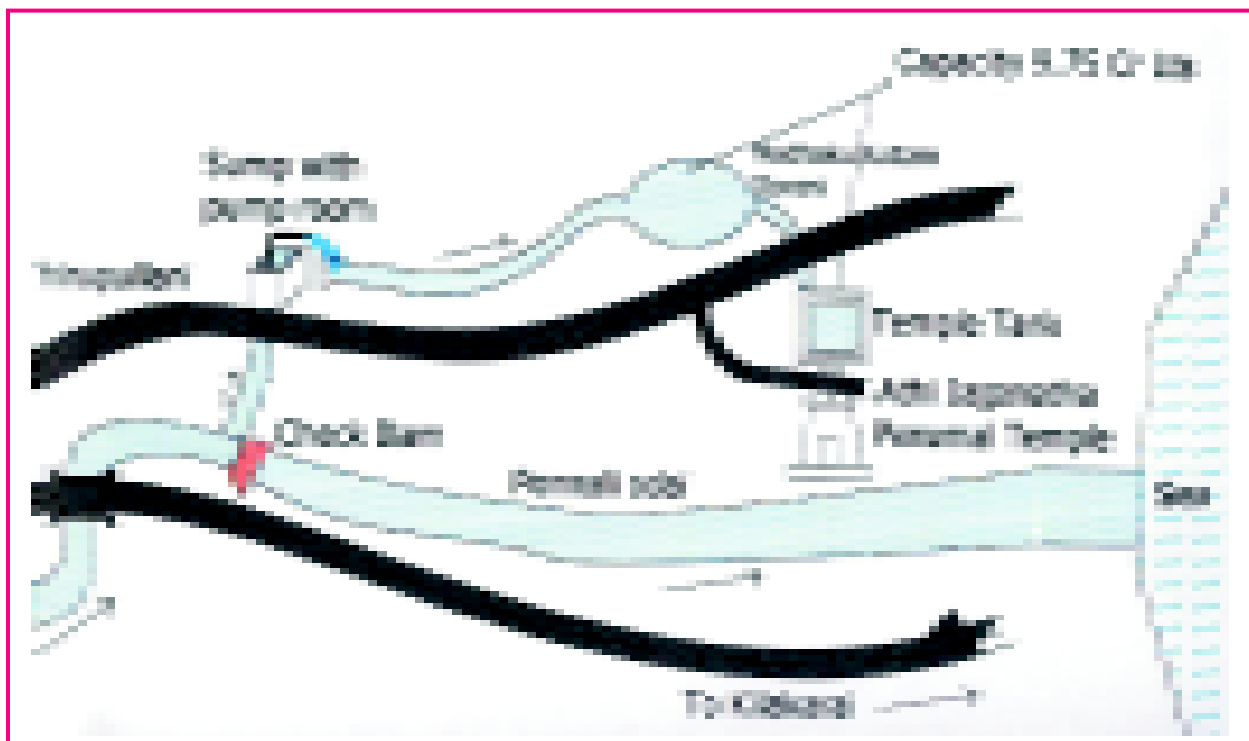
Horizontally Dug Water Channels (Tunnels)



Villagers use these Air Shafts like wells as water flows through the tunnels throughout the year



1.3.1.10 Renovation/Restoration of Temple Tanks





The Athi Jaganatha Perumal temple in Thirupplani village of Ramanathapuram district has a temple tank, which was getting dried up during summer seasons. Adding to the woes, the sea water intrusion was also high as the temple lies very near to the coast. Therefore, the Ponnali Odai rivulet which was joining the sea was diverted by constructing a check dam and pumping the water to Madhaku Kuttam Oorany. From this Oorany, the temple tank is connected

During 4th and 8th Century Dasmatisagar was built near Titlagarh in Orissa. During the same period two large reservoirs were built in Mayurbhanj district. The erstwhile Patna state also had 6 major reservoirs for water supply. All these were zealously maintained and cattle grazing and agriculture were not permitted in their vicinity.

Under the Nizam Shahi Kings (1490-1635 A.D.) 15 channels were built to supply water to the city of Ahmadnagar from deep wells at the foot of the nearby hills. Similar systems were built by various Kings for the towns of Vadgaon, Junnar, Karad etc.

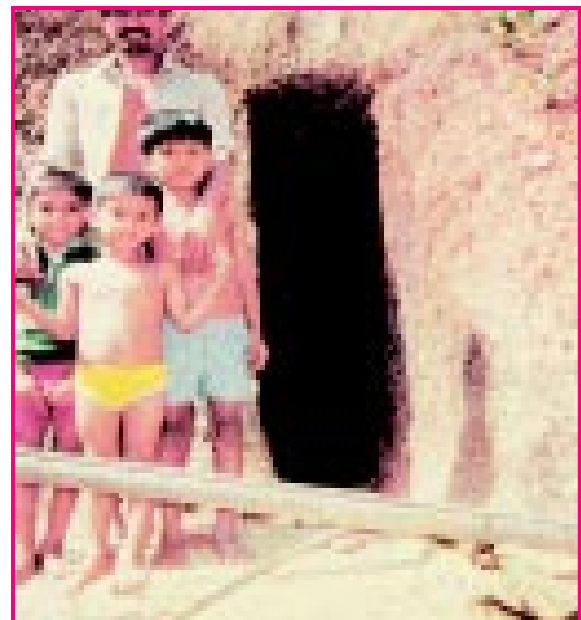
In the low rainfall areas of present-day Karnataka a large number of tanks were built during the 15th Century for both irrigation and drinking water, prominent among these were the Kempambudhi, Dharmambudhi, Sampangi and Siddikatte Kere tanks built by Kempe Gowda.

The city of Hyderabad (Andhra Pradesh) has a glorious tradition of tanks built by its ruler Mohammad Quli Qutub Shah in the 16th Century. The first source of water supply to the town was the Hussain Sagar lake built by Hussain Shah Wali in 1562. In the hills near Daulatabad, two reservoirs were built by the Hindu Kings, in ancient times to meet the water requirements of the city.

A number of tanks were built in Palanpur, Ahmedabad, Bharuch, Surat and Vadodara areas of Gujarat during the 15th Century for both irrigation and drinking water.

In hilly areas of Uttarakhand, the people harvest ground water by making stonewall across ground water streams. These are called Naula or Hauzi. For various reasons, there has been a steady decline in the construction of these structures, the main reason being drying up of underground streams due to large-scale deforestation and increased human activity in the hills. Similar practice is in vogue in parts of **Kerala** where the ground water is collected by excavating long deep trenches across a gentle slope. These are called Surangam.

In Punjab shallow wells called Jhalars are dug near streambeds to trap seepage water. In Rajasthan





these are called Beris. In earlier times, Baolis were built by kings but now these are not in vogue. In Gujarat shallow wells dug in depressions to tap ground water are called Virdas. In Tamil Nadu Ooranis were built earlier but are not built any more.

1.3.2 TANKA/ KUND/ KUNDI

Tanka is generally circular in shape and is constructed in stone masonry in 1:3 cement-sand mortar. While small Tankas of 3 to 4.22 m diameter and about 21-59 cum capacity are built by individual households, larger ones of 6 m diameter and 200 cum capacity are built for the village communities. In both the cases the depth is kept equal to the diameter. The catchment of the Tanka is treated in a variety of ways to increase the rain water collection.



The commonly used materials are murrum, coal ash, gravel, pond silt, Bentonite, soil-cement mix, lime concrete, sodium carbonate etc. Because of the constraints of availability of large open areas around the Tanka and the unit cost of treatment, a circular strip of land of 12 m width around the Tanka is usually treated, the slope of which is kept as 3% i.e. a fall of 3 cm in a length of 1 m.

This provides bulk of the requisite amount of water to fill the Tanka. Remaining water is received from the natural catchment outside the treated area.

Tanka of about 21 cum capacity for an individual household should preferably be built in front of the house in an open area of about 10 m x 10 m size. Since the rainwater from this area is to be collected in the Tanka, the area should be such that human activity and cattle grazing may be prevented during the monsoon season to prevent pollution of water.



For community Tanka of about 200 cum capacity the size of the open area should be at least 30 m × 30 m.

In both the cases the land surface should be firm and sandy with gentle slope of about 3 % i.e. with a fall of 3 cm in 1 metre length.

Planning and Design Criteria

1. Water Requirement

A Tanka of 21 cum capacity is usually adequate to meet the minimum drinking water requirements of a family of 6 persons for one year. Community Tankas, however, have only a supplemental role since these can only partially meet the requirements depending upon the size of the community and the availability of land for constructing the Tankas. Viewed in this light, water requirement of the community is not necessarily a governing criterion for design of a Tanka scheme. Instead, conservation of available water and its proper distribution and use are of crucial importance.

2. Water Availability

(a) Untreated Catchment

Some part of the rainwater is lost due to evaporation and seepage into the ground. This loss varies with the amount of rainfall. For low rainfall the losses are high and for high rainfall these are low. Availability of rainwater for a Tanka from a natural catchment can be computed from the Appendix-II.

(b) Treated Catchment

Volume of rain water that can be collected from a treated catchment around the Tanka can be worked out from the Appendix-II.

3. Structural Design

For 21 cum capacity :

- (i) Foundation excavation: Area 3.9 m diameter and 3.5 m deep
- (ii) Foundation concrete: 1:3:6 CC 250 mm thick over an area of 3.9 m diameter
- (iii) Tanka Wall: 1:2:4 CC Wall 150 mm thick with 5 mm Cement Plaster
- (iv) Tanka Cover: Stone slab roof, at height of 1.0 m from G.L.
- (v) Apron around Tanka: 1:3:6 CC Apron, 1.0 m wide and 100 mm thick
- (vi) Deep Catch Pit at the bottom of Tanka: Size 1000 x 250 mm
- (vii) Slope of artificial/ treated catchment around Tanka: 3% to 4% - a fall of 3 cm in a length of 1 m



- (viii) 3 Inlets and 1 Outlet in Tanka wall at apron level: Size 0.6 x 0.3 m with Iron Bars and Expanded Metal
- (ix) Opening at the top (for drawing water): Size 1.0 x 1.0 m
For 200 cum capacity :
 - (i) Foundation excavation: Area 9.15 m diameter and 6.32 m deep
 - (ii) Foundation concrete: 1:3:6 CC 230 mm thick over an area of 9.15 m diameter
 - (iii) Tanka Wall: RR masonry 1.45 m thick at bottom in 1:3 cement-sand mortar gradually reduced in steps to 0.38 m at the top
 - (iv) Tanka Cover: Stone slabs over 3 Nos. R.S. Joists of size 0.20 x 0.15 m
 - (v) Apron around Tanka: 1.6 m wide and 115 mm thick
 - (vi) Deep Catch Pit at the bottom of Tanka: Size 915 x 230 mm
 - (vii) Silt Collecting Gutter: Size 305 x 305 mm, bottom 75 mm thick 1:2:4 Lime Concrete and 230 mm thick RR masonry, sides 230 mm thick RR masonry
 - (viii) Slope of treated catchment around Tanka: 3% to 4% - a fall of 3 cm in a length of 1 m
 - (ix) 3 Inlets and 1 Outlet in Tanka wall at apron level: Size 0.6 x 0.3 m with Iron Bars
 - (x) Opening at the top (for drawing water): Size 0.9 x 0.9 m

Note:

- (i) For rain water yield from natural catchment outside the treated area refer Table A-3.1 of Appendix-III.
- (ii) Catchment should be treated for increasing rain water collection into the Tanka.

1.3.3 POND/ TANK

Size

Size of a pond is usually dictated by the availability of adequate land in the vicinity of the village. In rare cases do we have the option to design and build a pond of a desired size to meet the water requirements of the community. Where we have such an option, the first step is to work out the water requirement for various needs. The next step is to determine the catchment area, above the pond site, from where the monsoon run off would be available to fill the pond. Thereafter the location, alignment and height of the earthen bund are decided, as also the location and size of the spillway to evacuate the surplus monsoon discharge.



Water Requirement and Gross Storage

Unless otherwise prescribed for an area, following general guidelines may be used to determine the water requirements of a village community and the gross storage capacity of the pond.

- a. Animal Needs : Provide at the following rates:

Beef Cattle : 54-68 litres/day

Dairy Cows : 68 litres/day (drinking)

Dairy Cows (drinking + barn needs) : 158 litres/day

Pigs : 18 litres/day

Sheep : 9 litres/day

- c. Domestic Water Needs : 40 litres per head per day

- d. Fish Culture : Ensure about 1.85 m depth to provide proper temperature environments. Fish culture will also ensure that minimum Dissolved oxygen levels are maintained in the pond.

The storage capacity should be at least double the total water requirement to take care of evaporation and seepage losses. As a rough guide, 10 per extra storage may be provided for sediment deposition. For example if the total annual water requirement is 10,000 cum and pond will have only one filling, its gross capacity should be 22000 cum ($2 \times 10,000 + 10\%$).

Runoff and Storage Volume

A detailed survey is usually required to estimate the size of the catchment area and the reservoir storage for different water levels. Where the surveys are likely to be expensive or otherwise not feasible, catchment area can be roughly computed from Survey of India toposheets to the scale of 1:25,000 or 1:50,000. However, for computing approximate reservoir storage volumes certain rudimentary field surveys have to be carried out using inexpensive equipment and ordinary local skills.

Since a pond is usually built by putting a bund (earthen or masonry) across the flow path of a natural drainage, the parameters required for computing approximate storage volumes, for different pond levels are :

Channel width B (meters) at bund site

Bank slopes of the channel – n : 1 (Fall of 1 metre in a length of n metres)

Bed slope of the channel – S : 1 (Fall of 1 metre in a length of S metres along the channel bed)

Depth of water above the channel bed at the bund site – D (metres)



Storage volume is approximately computed by using the formula

$$V = \frac{SD^2}{2} (B + nD)$$

For ready reference, storage volume for different values of S, D, B and n are given in Appendix-V

Traits of a Good Pond Site

A good pond site should possess the following traits:

- (i) It should be a narrow gorge with a fan shaped valley above: so that a small amount of earthwork gives a large capacity.
- (ii) The capacity catchment area ratio should be such that the pond can fill up in about 2-3 months of rainfall. The capacity should not be too small to be choked up with sediments very soon.
- (iii) The pond should be located where it could provide adequate drinking water security throughout the year.
- (iv) Junction of two tributary, depressions and other sites of easily available fill material and favourable geology should be preferred.
- (v) The site should not have excessive seepage losses.
- (vi) The catchment area should be put under conservation practices.

Spillway Dimension for the Mechanical Spillway

In low rainfall areas peak discharges during rainy season are too meagre to required evacuation through a concrete or masonry spillway. Instead a pipe spillway may be provided. Normally the pipe should be large enough to pass the peak monsoon discharge without considering any moderation due to the reservoirs. Storage effect of small ponds of capacity of 0.123 to 0.246 is usually neglected. However, where the reservoir is large with considerable storage capacity the moderation effect may be considered using the following formula:

$$\frac{Q_0}{Q} = 1.25 - \left(\frac{1500 V}{RA} - 0.06 \right)^{1/2}$$

Where,

Q_0 = Rate of outflow when the pipe first flows full in cumecs

Q = Peak rate of inflow in cumecs

V = Available storage in ham

R = Runoff in mm, and

A = Drainage area in hectares (same as watershed area)



The above equation provides a rough guide to estimate of the size of the mechanical spillway pipe required.

For ready reference Appendix-VII may be used to determine the diameter of the pipe for known values of Q, V, R and A.

Structural Design

The following general guidelines are kept in view for the structural design and construction of the pond:

- (i) Angle of repose is less for wet soil than for dry soils: so provide for flatter gradient on the waterside of the earthfill. For very small ponds uniform slopes on both upstream and downstream sides can be provided ($2\frac{1}{2}$:1). For other provide a minimum slope of 3:1 on the waterside.
- (ii) Remove all vegetation, roots, and organic matter from the fill area: scrape the upper 30 cm of the soil to get rid of the excessive roots: remove all tree stumps at the construction site (to come under the fill).
- (iii) Provide a 1.5 m wide bottom key trench with 2:1 side slopes, to give a good bondage with the original earth.
- (iv) Lay the earthwork in horizontal layers of not more than 8 centimetres at a time: water them to have a 14% moisture content: use sheep-foot roller for maximum compaction. Bulldozers fill earth in heaps, which cannot be easily compacted. Use them for site clearance but not for earth fill.
- (v) Place the conduit pipe of the mechanical spillway before starting the earthfill.
- (vi) Use topsoil and fertilisers to establish a quick grass cover on the earthfill. Do not let trees or bushes come up on the embankment.
- (vii) At the inlet of the inflow runoff provide a measuring structure (triangular weir), drop structure, or a sod chute so that when the pond is low, the inflow does not cause gullying. Cut all excavation on 2:1 or at least 1:1 side slopes.
- (viii) The road on the crest should be provided with a gravel metal, middle camber and drains on sides (lead the road runoff safely down the slope in pipes or masonry/ concrete flumes or chutes. This can be otherwise a cause of gullying).
- (ix) Provide for constant level livestock watering tank.

1.3.4 SPRING WATER HARVESTING

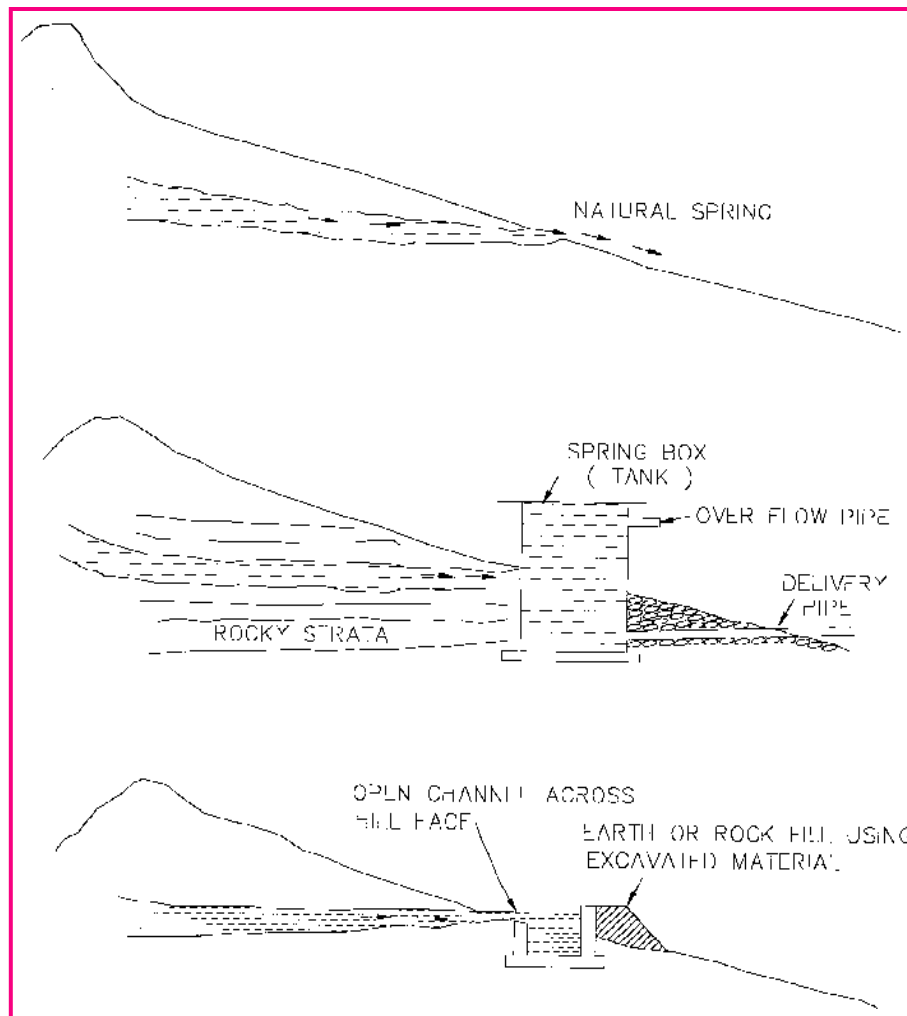
In the Lahaul and Spiti areas of Himachal Pradesh, water from hill streams are diverted through small excavated channels, called Kuls, for domestic use and irrigation. In Jammu region



they pronounce it as Kuhals. This practice can also be seen in Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Sikkim and Darjeeling area of West Bengal, where the springs are merely in the form of water trickling through layers and joints in rocks, split bamboo channels are used to trap and convey water upto the village/ hamlet for drinking purposes.

Spring water is a highly desirable source of community water supply. Since the water emerges at the ground surface through cracks and loose joints in rocks under internal pressure of the ground water system, no pumping is required. More over the water is fresh and free from pollution obviating the need for artificial purification. However, such sources are available mostly in hilly terrain, foothill areas or intermontane valleys.

A typical spring water harvesting system is shown below :-



One relatively easy means of storing and distributing spring water is through a device known as a spring box. Built usually into a hillside and deep enough to access the spring-water source, this device allows water to enter from the bottom (as depicted above) and fill upto a level established by an overflow or vent pipe. Hydraulic pressure then maintains the level in the spring



box. The outflow pipe near the base of the device may be connected via pipe to a larger storage system (such as a tank) closer to the point of use or tapped directly at the location of the box. This device can be constructed using local materials, and if built carefully and protected can provide many years of reliable operation. Depending on local water requirements and conditions, a number of these spring boxes may be constructed to provide year-round supply or used to recharge other community water storage systems.

Alternatively, a variation on the spring box concept may also be employed known generally as an infiltration gallery. A long perforated pipe or box (3 to 6 inches or more in diameter) may be placed across the water-bearing layer of the hillside to gather spring water. Back-filled with gravel or another sufficiently porous medium, the pipe or box is connected to an outflow pipe(s).

1.3.5 Oorani

Drinking water ponds (Ooranies) are basically surface water collection ponds from an improved catchment. These are suitable especially when the vadoze zone is too narrow with or without an unconfined aquifer and massive hard rock underlying the sandy overburden. Tamil nadu has the maximum number of Ooranies in the country. The depth of the ponds are kept at 3-5 m. Many





villagers maintain separate Ooranies for drinking, washing and bathing and cattle consumption. The main components of a Oorany harvesting structure are the pond with well dressed rip-rap on the slopes, hard and impervious bottom, a channel leading run-off water from a specified catchment, a filtering unit, a draw well attached to a hand pump to collect drinking water. Ooranies meant for drinking purposes are normally fenced on all the sides.

Designs of basic Oorani units

There are basically seven technical design units for an Oorani system, these are:

1. Catchment area
2. Inlet (combined grit chamber with baffle wall)
3. Oorani (storage chamber)
4. Emergency or recharge well
5. Horizontal roughing filter system
6. Draw or storage well
7. Vertical upflow fine sand filter system

The detailed technical designs are given in the following.

Catchment area

The catchment area is the extent of land surface that would add to the surface run-off/ ground water recharge in a sub-basin with respect to a particular stream or source. With the help of physical information (i.e. soil condition, geology, vegetation, slopes and drainage system) a catchment can be sufficiently designed. In combination with hydrological data the surface runoff can be simulated to find out about the runoff potential of the catchment. The supply channel allows the controlled drainage of sheet flow runoff from the catchment and supplies the water towards the design point, which is par definition the grit-chamber of the Oorani. It has to be designed and constructed for most economical condition (trapezoidal or rectangular) by taking the maximum intensity of rainfall during a year. The suitable size and gradient of the channel has to be decided based on the volume of runoff generated from the catchments. This will enable to divert the water from catchments to the Oorani without any flooding/abstraction and with minimum loss.

Inlet Arrangement (Grit chamber)

As inlet arrangement, silt trap and stilling basin has to be designed as per the velocity of flow in the channel, soil type and particle size. Grit chambers are required to remove gravel, sand and mineral particles from the raw-water and to protect following units from silting and abrasion.



Hydrological data

The amount of raw-water very much depends on the size of catchments (see chapter above) and the rainfall intensity. First is very much a site specific factor. The rainfall intensity is to be evaluated from available database, which covers 30 years data. Climatic data mostly follow Pearson distribution, which is related to Gauss distribution. Latter requires a data pool of at least 30 to guarantee its statistical quality. The rainfall intensities to be used for further calculation derive from the highest rainfall peaks within (1959-1988) as shown in the table below:

Table on Probability of rainfall intensities

Rank	Year	Max. rainfall in mm	Duration in min.	Intensity in mm/h	Empirical return interval in year	Empirical return interval in month	Probability in %
1	1982	34	380	5	1.0	12.4	97
2	1978	39	300	8	1.1	12.8	94
3	1972	43	280	9	1.1	13.3	90
4	1980	93	590	9	1.1	13.8	87
5	1969	41	280	9	1.2	14.3	84
6	1970	68	415	10	1.2	14.9	81
7	1986	56	340	10	1.3	15.5	77
8	1964	38	230	10	1.3	16.2	74
9	1968	39	220	11	1.4	16.9	71
10	1987	50	280	11	1.5	17.7	68
11	1965	43	240	11	1.6	18.6	65
12	1988	36	200	11	1.6	19.6	61
13	1959	75	410	11	1.7	20.7	58
14	1971	56	300	11	1.8	21.9	55
15	1973	56	300	11	1.8	23.3	52
16	1974	62	330	11	2.1	24.6	48
17	1966	50	260	12	2.2	26.6	45
18	1963	87	430	12	2.4	28.6	42
19	1981	47	220	13	2.6	31.0	39
20	1984	61	280	13	2.8	33.8	36
21	1979	36	160	14	3.1	37.2	32
22	1983	56	240	14	3.4	41.3	29
23	1987	52	230	14	3.9	46.5	26
24	1977	70	280	15	4.4	53.1	23
25	1985	213	600	21	5.2	62.0	19
26	1976	134	375	21	6.2	74.4	16
27	1990	149	300	30	7.8	93.0	13
28	1975	116	200	35	10.3	124.0	10
29	1961	51	55	55	15.5	186.0	6
30	1962	92	80	69	31.0	372.0	3

*Source: Rainfall intensities of SW and NE monsoons in Central 1959-1998 (JULIUS, PhD-Thesis Anna Univ. Chemnitz 1992)



The rainfall peaks have been ranked and the return period calculated. According to the results following assumption have been made, which are underlined in grey in the above table:

The rainfall intensity, which is used for the design of the grit chamber, should have a return period of 5 years equal to 20 % probability. The return period selected is much lower to what is commonly used for draining water in urban areas (here 50-100 years return period is common). Reason for that is the fact that there is no damage to be expected in the case of Oorani systems. In the worst case scenario of a failing grit-chamber some grit >200 μm will enter the Oorani. Compared to the increase of cost for designing a higher capacity grit-chamber, this should be acceptable. The requirement for a 5 year return period is fulfilled for an intensity of around 20 mm/h (see table above). The quantity of water to be drained from the catchments is:

$$Q = I * A;$$

for, I = intensity in mm/h

A = catchments are in m^2

Baseline data for the grit-chamber

Particle size

In general grit-chambers will be dimensioned for particle sizes not less then 200 μm . The theory of sedimentation follows Stoke's Law for laminar flow, Newton's Law for the transmission towards turbulent flow Allen's Law can be applied. With the help of these three laws the velocity of settlement of a round shape particle with a density of 2.65 g/cm^3 will be according to the below given table:

Table on Settling velocity of sand (Bretschneider et al, 1993)

Particle size	Settling velocity, v_s in cm/s			Turbulence
	$v_h=0$	$v_h=0.30$	$v_h= v_{krit}$	$>v_{krit}$
0.05	0.2	0	0	15
0.20	2.3	1.7	1.6	27
0.50	7.2	5.0	6.0	42
1.0	15	11	13	60
5.0	47	33	45	130
10.0	74	-	65	190



The design of grit-chamber for an Oorani system should allow a particle from 200 μm size to settle, which means that the settling velocity for laminar flow should be around 1.7 cm/s.

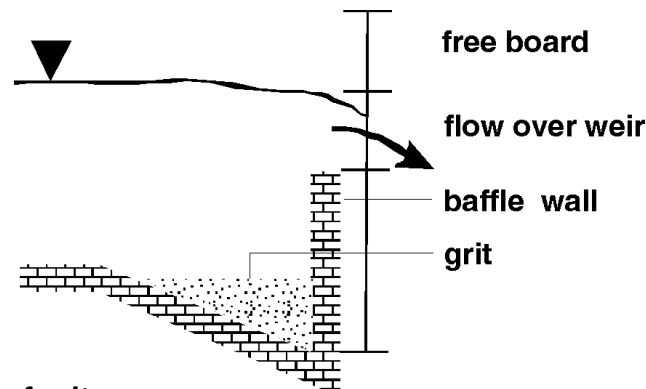


Figure 1 : Settlement of grit

The grit has to settle within the grit-chamber for a distance of maximum 20 cm until it will be caught at the baffle wall (see Fig. 1). The horizontal flow velocity will be estimated with 0.3 m/s (Metcalf&Eddy 2003). The settlement time will be calculated as follows:

$$T_s = h_s / v_h$$

for, h_s = height to be settled

v_h = horizontal flow velocity

To make the grit settle the time T_s have to be provided, which depends on the length and the flow velocity in the grit chamber. The flow velocity can be calculated by using following continuum-equation:

$$Q = v_h * A$$

Q is known from interpretation of hydrological data. 'A' can be put empirically to calculate v_h :

$$v_h = Q / A$$

In general the horizontal flow velocity should be = 0.3m/s. The length of the canal can be estimated by:

$$L = v_h * T_s$$

The retention time of the water in the canal is:

$$T_R = L * H * W / Q$$

Volume of the grit chamber:

$$V_{Gr} = D_{Gr} * W_{Gr} + D_R / 2 * W_R$$

for, D_{Gr} = Depth of the grit-chamber

W_{Gr} = Width of the grit-chamber

D_R = Depth of the ramp

W_R = Width of the ramp



Special arrangement

The grit-chamber was provided with two baffle walls, one for preventing floating material to enter the Oorani, second for keeping grit outside. The first baffle wall will also cause the grit-chamber overflowing in the case, that the storage has not been cleaned.

Note: It is advisable to clean periodically in upstream side of the silt trap in order to maintain the depth for settlement of silt.

Oorani (Water Storage)

The runoff obtained from the catchment for 365 days should meet the total annual water requirement of the people or the total required storage capacity of the Oorani. Earthen bund has to be provided at the periphery of the Oorani to meet the annual water demand. The Oorani system has the capacity to store water in two different ways. Around 75 % of the storage capacity is infiltrated into the ground to recharge the ground water. This water can be made accessible by providing a recharge or emergency well in the middle of the storage tank. During dry season after the surface water dried out it can be used for drinking water supply.

The surface storage of the Oorani will provide water for about 10 month of a year. This requires the exact calculation of the volume of water to be stored. The basic storage equation to be followed is:

$$Q = D + R + E$$

For, Q- Volume in m³

D-Demand in m³

R-Recharge in m³

E-Evaporation in m³

After defining the volume of the storage it is to be decided, which shape is to be chosen. An Oorani can be either round, square or rectangular type. To save construction material it is always recommended to choose round shape Ooranes as cost can be saved up to 20 % compared to square type shapes.

The recommended depth should be 5 m as it has been proofed that the evaporation loss can be reduced significantly. To stabilize the sidewalls of the storage and to reduce the infiltration capacity of the Oorani it is highly recommended to provide stone revetment. The revetment should be build in several steps as shown in the cross-section below with a general slope of 1:1.5. If no revetment is chosen, the side slope should not be less than 1:2.5. At the bottom of the revetment a foot wall is to be provided for stabalization.



Table : Volume assessment for Ooranies based on the basic requirements

Designation/Order	Unit	Months												Total _{max}	Total _{min}
		January	February	March	April	May	June	July	August	September	October	November	December		
Evapotranspiration	mm/d	3.81	4.27	4.81	5.38	5.87	6.44	6.87	4.77	4.28	3.78	3.27	2.71		
Evapotranspiration	mm	118	131	152	165	181	193	213	148	131	116	101	84		
Area of the Canal	m ²	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040		
Volume of Evapotranspiration	m ³	1181	1369	1582	1737	1892	2017	2213	1443	1267	1116	1010	844	1040	1040
Permeability*	m/s	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07		
Height of Canal	m	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0		
Bottom area of the Canal	m ²	876	876	876	876	876	876	876	876	876	876	876	876		
Volume of Seepage	m ³	876	876	876	876	876	876	876	876	876	876	876	876	876	876
Infiltration	mm/d	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45		
Percent of Water per day	EDD	5	5	5	5	5	5	5	5	5	5	5	5		
Percent of Water	m ³	134	112	134	138	134	138	134	134	131	134	131	134	1328	1485
Requirement	m ³	544	551	555	557	744	743	725	559	549	521	545	555	10785	7945
Req. Requirement	m ³	544	551	555	557	744	743	725	559	549	521	545	555	10785	7945

Designation/Order	Unit	Months												Total _{max}	Total _{min}
		January	February	March	April	May	June	July	August	September	October	November	December		
Evapotranspiration	mm/d	3.81	4.27	4.81	5.38	5.87	6.44	6.87	4.77	4.28	3.78	3.27	2.71		
Evapotranspiration	mm	118	131	152	165	181	193	213	148	131	116	101	84		
Area of the Canal	m ²	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040		
Volume of Evapotranspiration	m ³	1211	1251	1581	1737	1892	2017	2213	1443	1267	1116	1010	844	1040	1040
Permeability*	m/s	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07		
Height of Canal	m	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0		
Bottom area of the Canal	m ²	876	876	876	876	876	876	876	876	876	876	876	876		
Volume of Seepage	m ³	876	876	876	876	876	876	876	876	876	876	876	876	876	876
Infiltration	mm/d	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45		
Percent of Water per day	EDD	5	5	5	5	5	5	5	5	5	5	5	5		
Percent of Water	m ³	134	112	134	138	134	138	134	134	131	134	131	134	1328	1485
Requirement	m ³	757	581	744	738	777	821	808	713	718	581	584	605	11657	8738
Req. Requirement	m ³	757	581	744	738	777	821	808	713	718	581	584	605	11657	8738

To define the optimal size of the Oorani the total requirement, which is deriving from the demand, the evaporation loss and the infiltration should be as equal as possible compared to the actual volume of the Oorani.

At the top of the bund and all round of the Oorani have to be fenced and a gate must be provided at the entry. The above arrangement will help to protect the Oorani from the pollutions such as wastewater from the houses, cattle's and from the adjacent agriculture field. Fencing material and type has to be decided based on the site condition and it should be economically viable. A step will be provided to allow maintenance work inside the Oorani as well as collection of water from the recharge well, in the case the Oorani is dry.

Design parameter for the filter system

Oorani systems are already in existence since hundreds of years. The traditional system provided water without filtration. Turbidity has been removed by using gypsum or a natural seeds which functions as flocculants. With the technical development in rural areas new pollutants like artificial fertilizers, pesticides and aromatic hydrocarbons entered the supply chain of Ooranis. In many cases Ooranis got polluted and became neglected. Therefore the design of filter system



becomes of crucial meaning for the development of the new generation of Oorani systems. Boundary conditions for the design filters are:

- simple-technology
- Low-cost
- Low maintenance
- No energy consumption

To fulfil these criteria's a number of studies have been done to get an optimized filter system for Ooranis.

Filter design for Ooranis

Advanced treatment systems incorporate filter system for removal of one of the following groups:

1. Residual organic and inorganic colloidal and suspended solids
2. Dissolved organic constituents
3. Dissolved inorganic constituents
4. Biological constituents

A filter technology provided for Oorani system could only serve group 1 and partially 4 in other terms the removal of suspended and colloidal solids and probably protozoan cysts and oocysts, which are of larger size. Out of the three basic kind of filtration, which are:

1. Depth filtration
2. Surface filtration
3. Membrane filtration

only depth filtration will be feasible for Oorani systems. Others are not competitive due to inappropriate complicated technologies causing high cost and which are maintenance intensive.

Depth filtration

Depth filtration involves the removal of particulate material suspended in a liquid by passing the liquid through a filter bed comprised of a granular or compressible filter medium. Apart from inorganic particulate material a supplemental removal of suspended particulate BOD can be achieved. Following technologies of depth filtration are distinguished:

1. Slow sand filter
2. Rapid porous and compressible medium filter
3. Intermittent porous medium filter
4. Recirculating porous medium filter



Among these slow and rapid sand filter are adequate systems to apply and adapt for Oorani structures.

Table : Filtration rates for rapid and slow sand filter (METCALF & EDDY, 2003)

Filter type	K_f -value in m/s	Filtration rate in l/m ² /min	Filtration rate in l/m ² /d
Slow sand filter	$3.5-7.0 \times 10^{-7}$	0.021-0.042	30-60
Rapid sand filter	$1.3-3.3 \times 10^{-3}$	80-200	115,200-288,000

The filtration rate of a slow sand filter is 4000-5000 times slower than this of a rapid sand filter why often the use of slow sand filters becomes inadequate for many applications.

The waterworks of Zurich using slow sand filter of $k_f=2.0 \times 10^{-4}$ m/s. The speed for rapid sand filters should not exceed 2.2×10^{-3} m/s (Bretschneider et al 1999).

General features of conventional rapid and slow sand filters systems

Strainer - Supporting layer (sieving layer)

Filtering medium – Substrate of the filter

Drainage layer – Filter underdrain system, which is also used to reverse the flow for backwashing

Filtering medium characteristics

The grain size is the decisive parameter affecting the filter behaviour and the clean-water headloss. To describe the filter medium the **d_{10} -value** and the **d_{60}/d_{10} -ratio** (or **uniformity coefficient**) must be known by conducting sieve analysis. Both, the **effluent quality** and the **headloss** have to be equalized by achieving an acceptable headloss for the required effluent quality. Accordingly the **surface** and **length** of the filter has to be selected.

Following processes supporting the removal of particulate matter:

1. **Straining** (particle size related)
2. **Sedimentation** or inertial impaction (grain is outside the particle trajectory, loss of transport energy)
3. **Interception** (similar sedimentation but particle is still in the streamline of the particle trajectory and only settler due to low transport energy)
4. **Adhesion** (contact with medium)
5. **Flocculation** (agglomerate of particulate matter, then straining, sedimentation or interception)

Sedimentation, interception and adhesion are increasing with the continuous clogging process of the filter. The case might happen that there is a **break through** of the filter indicated by a



sudden increase of turbidity in the effluent. This happens when a sudden remove of (especially adhesive bounded particles) particles take place which increases the velocity in the medium causing additional remobilization (snow-ball effect). At this moment usually the backwash or change of filter material is required.

Some of the big threads for filters are chemical reactions like **formation of salts or oxides/hydroxides** and **biological growth**. Both processes might lead to **irreversible clogging** of the filter medium if the particulates are growing too big.

Rapid sand filter

Rapid sand filter comprises of a bed of sand serving as single medium granular matrix supported on gravel overlying and underdrainage system.

Design of slow sand filter

Table: CPHEEO (1999): Manual on Water Supply and Treatment- Ministry of Urban Development (New Delhi)

Description	Recommended design value	Description	Recommended design value
Design period	10 years	Depth of supernatant water	1.0 m
Filtration rate		Free board	0.2 m
Normal operation	0.1 m/h	Depth of filter sand	
Max. overload	0.2 m/h	initial	1.0 m
Number of filter beds		final	0.4 m
minimum	2	Size of sand	
Areas upto 20 m ²	2	d ₁₀	200-300 µm
Areas upto 20-249 m ²	3	Uniformity	<5
Areas upto 250-649 m ²	4	Gravel (3-4 layers) depth	0.3 m
Areas upto 650-1200 m ²	5	Underdrains (made of bricks or perforated pipes)	0.2
Areas upto 1201-2000 m ²	6	Depth of filter box	2.7 m
Effluent weir level above sand bed	20-30 mm		

Filter sand

Basically four parameter have to be distinguished to describe filter sand. The effective particle size (or effective filter corn size) is reflected by the particle size which permits 10 % (d₁₀) of weight fraction to pass the sieve. This value will be divided by the 60 % weight fraction (d₆₀) to



get the uniformity U of the sand ($U = d_{60} / d_{10}$). The Uniformity tells to which degree the sand is sorted and it should never exceed 5. The mean value of 50 % of weight fraction to pass the sieve represents the average particle size, which gives the name of the sand (fine, middle or coarse). According to IS: 8419 (Part I), 1977 and CPHEEO (1999) Manual on Water Supply and Treatment, Ministry of Urban Development, following factors for a sand are required:

- Sand shall be of hard and resistant quartz or quartzite and free of clay, fine particles, soft grains and dirt of every description
- Effective size shall be 0.45-0.7 mm
- Uniformity coefficient shall not be more than 1.7 or less than 1.3
- Ignition loss should not exceed 0.7 per cent by weight
- Silica content should be not less than 90 %
- Specific gravity shall be in the range between 2.55-2.65
- Wearing loss shall not exceed 3 %

Selection of filter sand

To find the filter sand following criteria's should be fulfilled:

- Filter capacities
- Availability
- Low cost

For matching with criteria b and c river sand is the optimal solution for South India as river beds are everywhere available and mostly adjacent to the construction side. Latter reduce the cost for transport tremendously. The filter characteristics for river sands are the most important factor. To find out about these parameters a number of sediment samples from rivers all over Tamil Nadu have been taken and analysed.

Figure 3 : Particle Size distribution for river sand

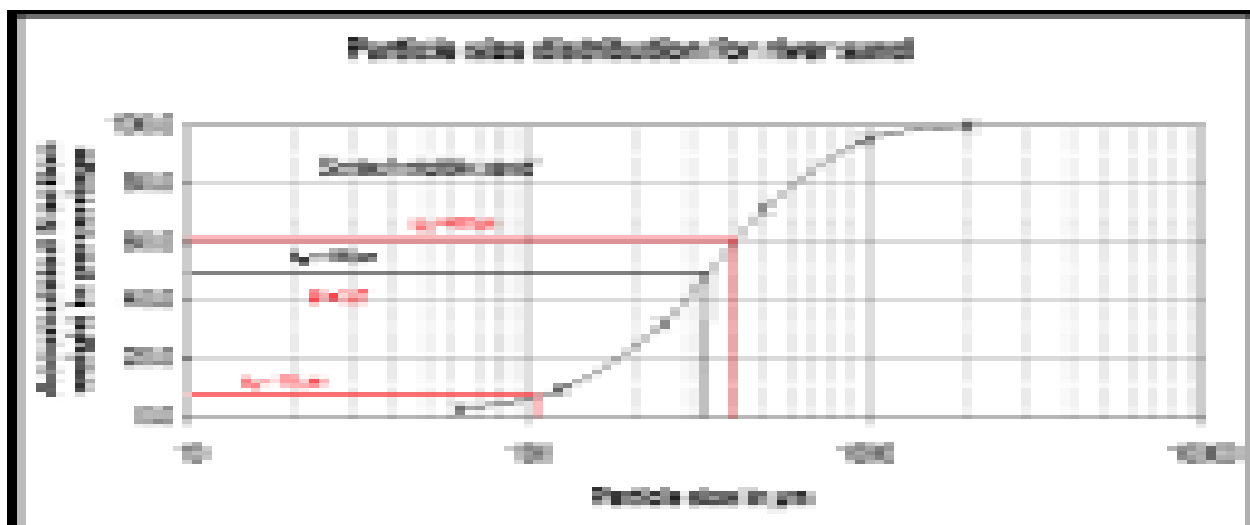




Figure : Average particle distribution curve and basic parameter of river sediments in South India

The distribution curve reveals that the uniformity of most river sands is insufficient ($U > 1.7$). To overcome this problem it is recommended to wash the material before using it for the filter. Washing can be done either by using a sieve or just by pouring water over the sand, which is lying on an inclined surface. The basic parameters of Fig. 3 can be used to estimate the hydraulic permeability according to the empirical HAZEN-equation:

$$k_f = C * d_{10}^2 \text{ for}$$

$$C = (0.7 + 0.03t)/86.4$$

t = water temperature in °C

The average water temperature in Ooranis is 28°C and the d_{10} as it is mentioned above 110 μm why $k_f = 2.2 \cdot 10^{-4} \text{ m/s}$. The effective porosity of middle sand is estimated **25%** (Hölting 1998). The filtration follows DARCY-equation:

$$V = k_f * h/l * A \text{ [m}^3\text{]}$$

for V = Volume

k_f = hydraulic permeability

h = height

l = length of filter

A = area of filter entry

The term h/l reflects the inclination of 1 reflecting the worst case of Δh (pressure head) = l (length of the filter) why the formula will be simplified to:

$$V = k_f * A \text{ [m}^3\text{]}$$

For the above given values of the hydraulic permeability and the effective porosity the volume for each square meter surface of filter will be:

$$V = 2.2 \cdot 10^{-4} * 0.25 = 0.55 \cdot 10^{-4} \text{ m}^3/\text{s} = 4.75 \text{ m}^3/\text{d}$$

One square meter of natural river sand filter provides 4.75 m^3 of filtered water per day.

This value reflect only the optimized condition without considering the effect of filter blocking which will be discussed in the following chapter.

Filter blocking

One of the most unwanted effects is the blocking of filter, which on the one hand causes headloss and a decrease of filter capacity. In addition it could cause filter breakthrough which means a sudden release of fine fraction held by the filter itself (snow-ball effect). The dimension of the filter should be designed in that way that it can take up enough filter-material within a period of one year. As limiting factor we consider the uniformity of 5, which often express the



switch from laminar to turbulent flow within porous filter. During the investigation the Turbidity has been measured in NTU. For better calculation the turbidity will be expressed as Total Suspended Solid (TSS) by applying a conversion factor of 1.5 (Metcalf&Eddy, 2003)

Following kind of Ooranes is to be distinguished:

Table : Total suspended solids for different Ooranes in Tamil Nadu

Total suspended solids in Oorani mg/l	Name of the Oornai	TSS mg/l
<100	Nenmeli ^{a)}	13
	Keerapakkam ^{a)}	21
	Edaiyur ^{a)}	67
<1000	Kandilan ^{b)}	341
	Nallur ^{a)}	541
	Pushpavanam ^{b)}	767
	Pattikadu ^{a)}	793
>1000	Kodarendal ^{b)}	3376

a) Kancheepuram district

b) Ramanathapuram district

There are no guidelines or recommendation available for calculating the blocking of filters on a theoretical base. Usually the moment for cleaning a filter system will be decided either on time base or more commonly depending on the headloss. Following theoretical approach is proposed to estimate the minimum size of a filter depending on the amount of total suspended solids in the water. Basic assumption is that the accumulated weight percentage of the suspended solid per year should not exceed 10 % of the total weight of the filter material. The d_{10} -value is considered as effective particle size, which is influencing the hydraulic conditions in the filter. Changing conditions of flow (from laminar to turbulent) could cause filter breakthrough.

The size of the filter depending on the average TSS in the Oorani can be estimated according to the following table:

Table : Filter size depending on the total suspended solids of Oorani water

Filter size	Side length	Weight of filter sand	Weight % for TSS 100mg/l	Weight % for TSS 1000mg/l
m^2	m	2.2 mg/l conversion kg	(116.8 kg/y) %	(1168 kg/y) %
1	1.00	1100	10.6	106.2
2	1.41	2200	5.3	53.1
3	1.73	3300	3.5	35.4
4	2.00	4400	2.7	26.5
5	2.24	5500	2.1	21.2
7.5	2.74	8250	1.4	14.2
10	3.16	11000	1.1	10.6



Résumé

The design of the Oorani filter system is mainly influenced by two factors: the hydraulic conductivity of the filter sand and by the clogging process of the filter system. In most of the cases for Oorani systems the clogging of the filter is the limiting factor for the sizing of the filter due to high amounts of suspended solids in Oorani water. By providing two filter systems, one inside the Oorani, which is a rapid sand filter and another one at the outlet of the Oorani, which is a slow sand filter, the risk of clogging is reduced to a minimum with equal functioning of the filter system.

Hydrochemistry & Importance of water quality

Intensive studies have been undertaken to find out about the water quality of Oorani water before and after filtration. The results revealed that the pollution in Oorani was generally low. Problems mostly derive from high turbidity and pathogen contamination. Some parameter is listed as indicator for the quality status of Oorani systems. As there are Turbidity (Total Suspended Solids), E-coli, Nitrate, Phosphate and BOD₅/COD. Apart from this pesticides are a very abundant problem. Due to a huge variety of pesticides no analysis for checking is proposed rather than preventing pesticides of entering the Oorani system

Turbidity (Total Suspended Solids)

High turbidity in Oorani derives from the catchments and is very much a site specific parameter. According to investigation the relationship between Turbidity and TSS corresponds in the following way (Metcalf&Eddy, 2003):

- a) for settled secondary effluent, $TSS \text{ (mg/l)} = 2.0-2.4 * \text{Turbidity (NTU)}$
- b) for filter effluent, $TSS \text{ (mg/l)} = 1.3-1.5 * \text{Turbidity (NTU)}$

For drinking purposes according to Indian Standards the value should not exceed 10 NTU. This can be achieved by providing membrane and depth filter systems or by enhancing flocculation.

E-coli

The most important species of the family Enterobacteriaceae is Escherichia or E-coli which can be described as a specification of faecal coliforms. Why faecal coliforms can also contain intermediate species E-coli is a real proof for an source of faecal pollution. Pathogen bacteria and viruses are a real threat to human health and can be prevented from by two measures, the control of catchments and the treatment of the water when it is taken from the Oorani source. Latter is partly possible by providing a filter system to a degree of 90 % for rapid sand filter and 95-99% for slow sand filter. The requirements according to drinking water standards are zero counts/ 100 ml.



Nitrate

Nitrate is the most common nitrogen species in Oorani water depending on oxygen rich conditions. It is a strong indicator for contamination either deriving from faecal or from an excess in use of fertilizers. Latter can be dealt with improving measures in the catchments area. The maximum value should not exceed 45 mg/l according to Indian Standards. The cleaning potential of filter systems as observed in the field is negligible due to high solubility of nitrate in the water.

Total phosphate

Similar like nitrate, phosphate is a strong parameter indicating pollution from anthropogenic sources. The level should be kept as low as possible and according to CPHEEO Standards not exceed 5 mg/l. The concentration of phosphate generally increases during the monsoon period but decreases then very fast due to its adsorption at suspended matters. Filter media can further reduce the phosphate concentration depending on its adsorption capacity.

BOD/COD

The BOD/COD ration is an important indicator for industrial pollution or presence of pollutants which are not easily biodegradable. The general relationship between BOD and COD has a range of ratio BOD/COD between 0.3 and 0.8. If the ratio is below 0.3 either the waste may have some toxic components, the organic compounds are difficult to digest or acclimated microorganisms may be required. Naturally the BOD level in Ooranies should not exceed much more than 5 mg/l.

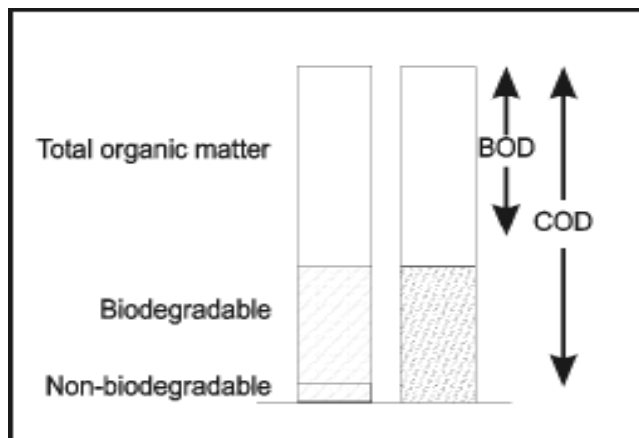
Table 1: BOD/COD relationship

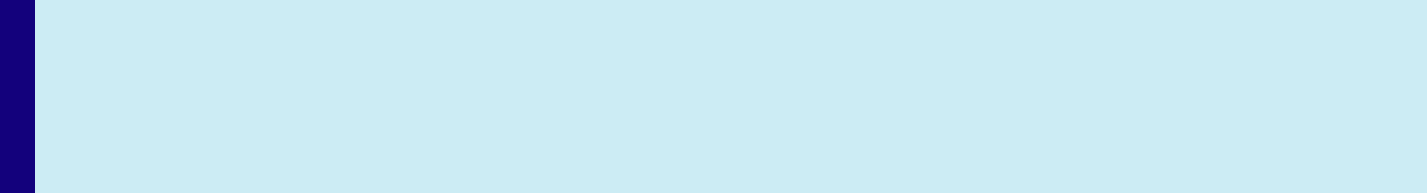
Type of water	BOD/COD	BOD/TOC
Untreated	0.3-0.8	1.2-2.0
After primary settling	0.4-0.6	0.8-1.2
Final effluent	0.1-0.3	0.2-0.5

Metcalf and Eddy (2003): Wastewater Engineering- 4th ed, p. 1819; ^Tata McGraw-Hill Ed. (Delhi).

Figure : Relationship of BOD and COD in water

Measurement of quality of drinking water supplied from the Ooranies is of utmost importance as quantity without appropriate quality never become a Sustainable and safe drinking water supply requirement. Many guidelines from WHO, CPHEEO, USEPA, EEC, ICMR, etc. are available but the mandate of





Multi-barrier system of controlling contaminants in Ooranies

Treatment steps

- 1) Silt chamber to collect particles > 150 µm and floating materials outside
- 2) Doser storage, which mainly functions as a sedimentation pond
- 3) Horizontal roughing sand filter, reducing turbidity and pre-treatment for coagulation
- 4) Fine sand filter, main biological treatment and fine screening for turbidity

70



The basic idea of the multibarrier system is to address various kinds of pollution, which may require different forms of treatment. The above mentioned system is the result of a process with very strict boundary conditions given by the State government of Tamil Nadu as there are:

- No use of energy
- Use of local available materials
- Use of local know-how

It provides treatment up to a degree to encounter pollution problem, which have been identified during 3 year study on Ooranies in Tamil Nadu. The system is considered to be flexible and allows the addition of further treatments if required. However it should be considered as the absolute minimum to be provided to assure a safe water supply.

1.4.1 Polluting sources of Ooranies and desired catchment treatment

A number of misuses and malpractices cause severe pollution problems:

- Ooranis are used to collect domestic sewage from villages
- Water from catchments is passing through rice fields which are highly treated with fertilizers and pesticides or the water from the catchments is polluted by organic waste
- The banks of Ooranis are used for washing clothes (MAS, detergents and phosphates)
- Cattle is brought into the Oorani for washing and feeding
- The bunds are misused as public toilets or dumping sites
- Waste like plastic and other non-degradable substances are lying scattered around

If pollution aspects are considered for Oorani projects it has to be considered in two ways. One are the “End of pipe” measures including the treatment of water others the “Beginning of pipe” measures, which are prevention measures to minimize the degree of pollution. The possible pollution sources of Ooranies in villages are:

- Agricultural run-off (plant nutrients fertilizer and pesticides Plants and animals debris, etc.)
- Human bathing (phosphate, tensides, bacterial and viruses)
- Washings of animals (nutrients, bacterial and viruses)
- Washing of vehicles (aromatic compounds)
- Sewage and domestic wastes (oil & soap, detergents, rubbish)
- Human and animal excreta
- Others like bird dropping, decomposition of leaves and wood



- Small scale industries (aromatic compounds. Detergents, oil, etc.)
- Hazards (any kind of pollution)
- Bury ground (nitrogen, bacterial and viruses)

To deal with pollution problems following steps are to be undertaken:



Careful identification of probable sources of pollution is part of the field study, which is taking place during the survey of catchments. The second step of segregation covers prevention measures.

Zoning of catchments (pollution prevention)

The experiences have shown that awareness among local bodies to protect the catchment area has major impact on the quality of water in particular for concerning the reduction of organic loads and excessive input of nutrients and germs.

There are three kind of protection zones available for Ooranies:

1. **Zone 1**, Oorani storage zone
2. **Zone 2**, inner protection zone
3. **Zone 3**, outer protection zone

Zone 1 (Storage zone)

The Oorani storage zone comprises the direct environment of the Oorani inside its bund or fencing. This area should not be entered by any unauthorized person, any kind of activities are forbidden.

Zone 2 (Catchments zone)

The inner protection zone includes the total catchments of the Oorani. In this area no activity should take place causing any form of contamination like spraying of pesticides, use of artificial fertilizers, misuse of natural fertilizers or any kind of human activities causing contamination (washing, defecation, etc.).

Zone 3 (Outer catchments zone)

The outer protection zone delimits that area which is outside the catchments but could contaminate the catchments due to transportation (e.g. aerosols by spraying of pesticides) or animals. In general it forms a frame around the outer limit of the catchments of 5 m.



Figure : Protection zones of Oorani catchment

Zone definitions/restrictions

Zone 1

No unauthorized person is allowed to enter the Oorani storage zone. This is to prevent the Oorani from direct contamination. Cattle are not allowed to stay within this protected zone. No kind of human activities is supposed to take place.

Zone 2

Following activities should not take place in the catchments protection zone:

- ☐ Use of pesticides
- ☐ Use of artificial fertilizers
- ☐ Uncontrolled use of natural fertilizers
- ☐ Public toilet
- ☐ Feeding ground for livestock
- ☐ Washing place
- ☐ Washing of car, auto or any kind of vehicle
- ☐ Industrial activities
- ☐ Solid waste disposal place
- ☐ Burial ground

Zone 3

Following activities should not take place in the outer catchments protection zone:

- ☐ Spraying of pesticides
- ☐ Spraying of fertilizers



1.4.3 Simulation Models for drinking water security in surface water collection systems like Ooranies

For any surface water collection system be it a check dam, percolation pond, village pond, tank or a Oorany, it is essential to understand the degree of water collection and ground water recharge. While traditional ponds and Ooranies are basically impervious ponds which reduce/eliminate seepage losses, the other collection systems are combined systems of collection and recharge. The SWMM (Storm water management model) developed by USEPA is one of the very good softwares to analyse and design storm water management effectively. This software is now compatible to Civil Designer Version 6.4 to generate detailed engineering designs, drawings and estimates.

Simple to use software could be generated locally based on the hydrological, soil profile, porosity characteristics of the strata, extent of the upper vadoze zone, degree of unconfinity of the top most aquifer, etc. Software could be initially developed for providing design solutions and later on can be up scaled on to a GIS platform with various inputs from different segments of the State/ Country.

Simulation model for designing a Oorany need to consider the following aspects:

Assessment of baseline data

The following chapter explains which data are required for comprehensive approach to develop Oorani systems and about their importance.

Hydrology

Frequency Analysis of Rainfall Data

In general, rainfall data of a particular place of interest may not be available. In case if it is not, the data of the nearest rainfall station can be used. At least thirty years data have to be used for the analysis. The values are arranged in descending order of magnitude and each value is given a number termed as 'order of magnitude, m' starting with 1 for the highest value and increasing it by 1 for the next smaller value and so on.

Recurrence interval (T) of magnitude of an event is defined as the period in which, the event has occurred with the set magnitude equalled or exceeded at least once in that period. The probability of occurrence (P) of this magnitude is taken as the reciprocal of T and expressed in terms of percentage. With the data arranged in descending order and order numbers assigned, T and P can be calculated as indicated below.

The design and simulation modeling of Ooranies along with catchment treatment procedures is a product of sincere efforts and hardwork done by the Rural Development Department of Government of Tamil Nadu in association with Anna University, Panchayati Raj Institutions, NGOs and Community. This information is reproduced in its contents for wider dissemination. Efforts of Mr. Dirk Walther of Centre for Environmental Studies, Anna University, Chennai is gratefully acknowledged.



Table 2: Frequency analysis of rainfall

S.No.	Values arranged in descending order	Order number (m)	Recurrence interval ($T = N/(m+1)$)	Probability of occurrence ($P = (1/T) \times 100$)
1	Highest value	1		
2	Next highest value	2		
..				
..				
..				
N	Smallest value	N		

The rainfall data subjected to the above analysis will help one to find out the probability of occurrence of different magnitudes of rainfall at the place of interest. The yield estimation can be carried out for such of those magnitudes of rainfalls as needed for the design. For example, 95% dependable rainfall can be used for the yield estimation to have 95% dependable water supply by the Oorani.

The most important hydrological parameter is the rainfall, which can be expressed in two different ways, the **total amount of rainfall in mm** and the **rainfall intensity in mm/hr**.

Evaporation

Besides the size of the catchment area of the Oorani, the slope and due to that the percentage of run-off water is required. This is to find out about the storage behaviour of the Oorani. In addition it has to be studied if water is infiltrating from the Oorani into the ground water, why infiltration test (e.g. with a Guelph permeameter) have to be conducted. Infiltration loss and evaporation loss will be added to total loss of water of the Oorani within a year. The total loss is to be added to the yearly demand for the sizing of the Oorani pond.

Hydraulics

Yield Estimation

There are several methods available for the yield estimation from a catchments. The most popular one frequently used by the engineers in the state of Tamil Nadu is 'Strange Table Method'. It is also popularly known as 'Dry - Damp - Wet Method':

Strange's table and curves give runoff for daily rainfall for good, average and bad catchments and surface conditions viz., dry, damp and wet prior to the rain. This classification based on the degree of slope and type of soil condition. The following table gives daily runoff for average catchments:



Table 3: Daily runoff for average catchments

Daily rainfall (mm)	Runoff percentage and yield when the original state of ground is					
	Dry		Damp		Wet	
	%	Yield (mm)	%	Yield (mm)	%	Yield (mm)
6.25	-	-	-	-	8	0.5
12.50	-	-	6	0.75	12	1.5
18.75	-	-	8	1.5	16	3.0
25	3	0.75	11	2.75	18	4.5
31.25	5	1.56	14	4.37	22	6.88
37.5	6	2.25	16	6.0	25	9.37
43.75	8	3.5	19	8.31	30	13.1
50	10	5.0	22	11.0	34	17.0
62.5	15	9.37	29	18.25	43	26.9
75	20	15.0	37	27.75	55	41.25
100	30	30.0	50	50.0	70	70

As well as for good or bad catchments, add or deduct up to 25 % of yield.

SCS Method

The runoff obtained from the catchments can be calculated using SCS method. The general mathematical equation for computation of runoff from any catchments is as follows;

$$Q = (P - I_a)^2 / P - I_a + S$$

where Q = Actual runoff

P = Rainfall in mm

I_a = Initial abstraction (range varies 0.1 to 0.3)

S = Potential maximum retention after runoff begins

The above equation can be used to calculate the daily yield from the catchments using the daily rainfall data. This equation is function of land use, antecedent moisture condition, soil group and curve number. The yield obtained for 365 days from the above equation is known as annual runoff.

Evaporation Loss (E)

The evaporation due to the difference between vapour pressure of the air and film above a liquid. The movement between film and air is ruled by diffusion, convection and mechanical transport (wind). The rate of evaporation depends on the pressure gradient which is expressed by the "Dalton's Law":



$$E = C (p_w - p_a)$$

For E = rate of evaporation m/d

C = coefficient

p_w = vapour pressure in the film

p_a = vapour pressure in the air

As this process is endotherm it will cause a cooling effect.

Collection of data

Daily Pan Evaporation data has to be collected from the India Meteorological Department (IMD) to estimate the Evaporation loss for the Oorani. Evaporation loss can be calculated by plotting the graph Depth vs Water spread area of the Oorani. From this graph, daily evaporation can be calculated and multiplying the daily value with 365 will result annual evaporation.

In the case that proper data material is not available following rates can be assumed for locations with similar conditions as Chennai.

Table 4: Evaporation loss Red Hills lake (Central Water commission, 1990)

Month 5 year data	Average loss in mm	Total loss in mm
January	5	155
February	6	168
March	6.8	211
April	8	240
May	7.8	242
June	6.4	192
July	5.7	176.7
August	5.4	167.4
September	4.2	126
October	3.5	109
November	3.4	102
December	4.1	127
Total		2015 mm

Recharge (R)

Soil samples have to be collected at the bed and sides of the Oorani using the hand augur. These soil samples have to be analyzed by sieve analysis in order to obtain the per day seepage loss from the bed as well as side of the Oorani. This value multiplied by 365 to obtain the annual seepage loss. For various types of soil the seepage losses given in the table:



Table 5: Infiltration capacity of various soils

Material	Hydraulic Conductivity (cm/s)
Clay	10^{-9} - 10^{-6}
Silt, Sandy Silt, Clayey sand	10^{-6} - 10^{-4}
Silty sand, fine sand	10^{-5} - 10^{-3}
Well-sorted sand, glacial outwash	10^{-3} - 10^{-1}
Well-sorted gravel	10^{-2} - 1

1.5.1 ROOF TOP RAIN WATER HARVESTING

Roof-top rainwater harvesting structures could be constructed in any part of the Country. It is a simple mechanism of collecting the rainfall, allow it to pass through a sand filter and store in a tank. The excess water could be drained into the recharge pit. There should be a provision to drain out portion of the first rainfall, as it would flush out the dirt. This water can also be connected to the recharge pit.

1.5.1.1 Estimating the Size of the Required Systems

In actual field conditions, the size of the collector and storage system is dictated by the available roof area and the rainfall. Both these factors are beyond our control except that some modifications can be made in the type of roof covering to improve runoff. The water harvested from the available roof area, therefore, is more or less fixed and has to be judiciously used. In rare cases we have the real option of building enough roof area to meet the pre- determined per capita requirement of a given family or community. However, for the purpose of illustration, the planning and design procedure for such a system is discussed in the following paragraphs.

Types of Roof-top rainwater harvesting





Collection from simple sloping sheets



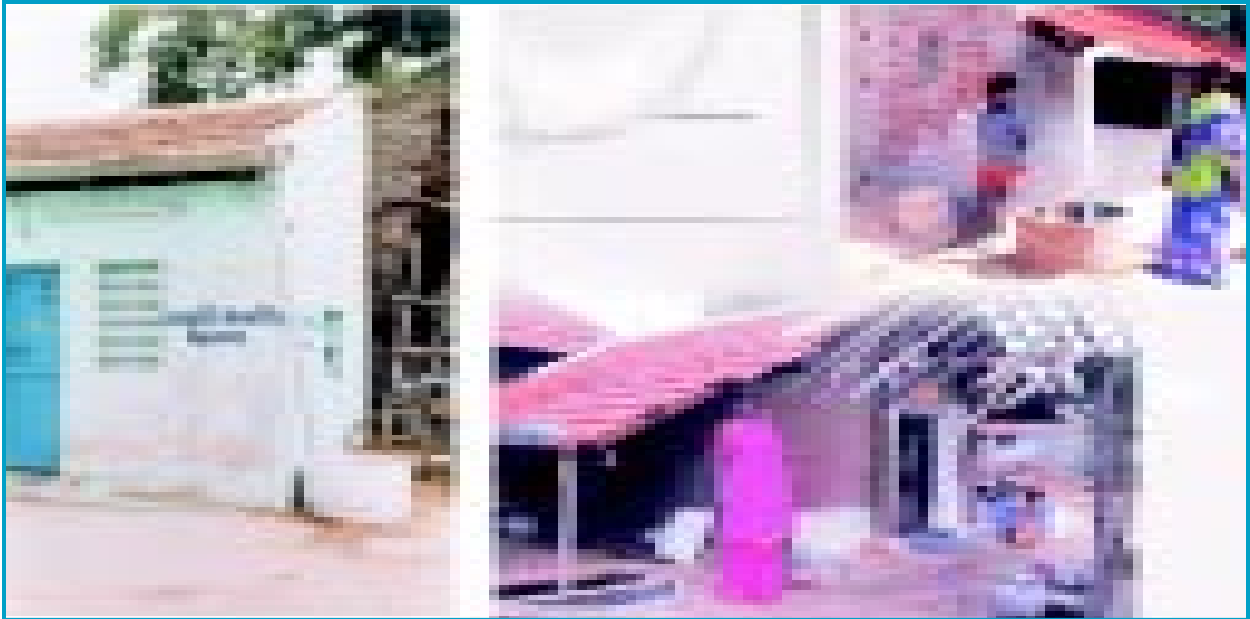
Collection from thatched roofs



Thatched roof covered with a gunny bag
In a cycle shop



Direct collection & recharging



Collection from slopes/tiled roofs



Roof-top rainwater harvesting in School buildings



The size of the catchment area and tank should be enough to supply sufficient water for the users during the dry period. Assuming a full tank at the beginning of the dry season (and knowing the average length of the dry season and the average water use), the volume of the tank can be calculated by the following formula :

$$V = (t \times n \times q) + et$$

Where,

V = Volume of tank (litres)

t = Length of the dry season (days)

n = Number of people using the tank

q = Consumption per capita per day (litres)

et = Evaporation loss during the dry period

Since evaporation from a closed storage tank is negligible, the evaporation loss (et) can be ignored (=zero)

Design Example

If, for example, 40 lpd (q) is agreed upon and a dry period of 80 days (t) is normally not exceeded, a storage volume of 16 m³ would be required for a family of 5 members (n).

$$[V = 80 (t) \times 5 (n) \times 40 (q) = 16,000 \text{ litres or } 16 \text{ m}^3]$$

The required catchment area (i.e. the area of the roof) can be determined by dividing the volume of the tank by the accumulated average rainfall volume (in litres) per unit area (in m²) over the preceding wet months and multiplying this with the runoff coefficient, which can be set at 0.8 for galvanized iron or tiled roofs.

Experience shows that with the water storage tanks next to their houses, people use between 20-40 litres of water per person per day (lpd). However, this may rise in time as people relax their water use habits because of easy access. This contrasts with a maximum of 10 lpd consumption levels under similar environments with people fetching water from distant sources. Together with





the community/ family, a decision must be taken on how the water will be used or what affordable service level can be provided.

Rooftop water harvesting systems can provide good quality potable water if the design features outlined below are taken into account.

- The substances that go into the making of the roof should be non-toxic in nature.
- Roof surfaces should be smooth, hard and dense since they are easier to clean and are less likely to be damaged and release materials/ fibres into the water.
- Roof painting is not advisable since most paints contain toxic substances and may peel off.
- No overhanging trees should be left near the roof.
- The nesting of birds on the roof should be prevented.
- All gutter ends should be fitted with a wire mesh screen to keep out leaves, etc.
- A first-flush rainfall capacity, such as detachable down pipe section, should be installed.



RWH in Panchayat building



RWH in IAY scheme



- A hygienic soak away channel should be built at water outlets and a screened overflow pipe should be provided.
- The storage tank should have a tight fitting roof that excludes light, a manhole cover and a flushing pipe at the base of the tank (for standing tanks).
- There should be a reliable sanitary extraction device such as a gravity tap or a hand pump to avoid contamination of the water in the tank.
- There should be no possibility of contaminated wastewater flowing into the tank (especially for tanks installed at ground level).
- Water from other sources, unless it is reliable source, should not be emptied into the tank through pipe connections or the manhole cover.

Design aspects of Roof-top rainwater harvesting are provided at Appendix-I.

1.5.1.2 Threshing floors for water collection

Another innovative method of harnessing rainwater is to make use of the slope of the threshing floors to direct the run-off into the cattle trough/ any half-cut tanks. The excess water can also be diverted to the recharge pit which would meet the aquifer. Alternatively, the entire water harvesting on the threshing floors could be directly fed to the recharge pits.



Rainwater harvesting from threshing floors



1.5.1.3 Rainwater harvesting Calculator ::

Rainfall Calculator

Try & calculate the advantages of Rainwater Harvesting

Select your District*	1290	is average rainfall
Type of Building*	Individual House	
Investment for RWH setup Rs.	5000	
Roof Top Area*		(Sqr.ft)
Number of Persons*		
Actual Requirement per Day		Litres
Quantity can be Collected		Litres
Actual Requirement per year		Litres
Number of Days the Water could be used		Days
Cost of RWH water saved		Rs.

[Cost of 5000 litres is Rs.500(Market Price)]

The above mathematical calculator would give the amount of water that could be stored from a selected catchment (roof) and also give insight of money saved vis-à-vis if this amount of water is to be brought by a tanker or from piped water supply from long distances. For details, TWAD Board site at www.aboutrainwaterharvesting.com could be visited.



2 MOBILISING HUMAN RESOURCES FOR SUSTAINABILITY

The local community is the key human resource involved here. It will be the primary user of the facility which is being developed. It will also be the manager of this facility and therefore, must be empowered to take measures for its sustainability.

Community participation, thus, refers to the involvement of village households — both men and women — in water resource management by working for rejuvenation of traditional water bodies and building new structures. Community participation should lead to a feeling (among the households) of owning these structures and water resources, and therefore motivate them to work for their conservation and protection, and contribute monetarily (according to capacity) for the use of water. It should also encourage the households to identify problems if any and find solutions, take care of sanitation in the village, help in the reducing the drudgery of women and facilitate equitable distribution of resources to all.

In short, the community should have control over its resources, and should feel responsible for their upkeep. It should take the initiative to build sustainable drinking water sources, share some of the costs in construction and accept responsibility for operation and maintenance of the system(s).

The State, of course, has 'facilitate' this process and may use local NGOs to mobilize community participation.

Despite an investment of about Rs 65,000 crore and application of various technological solutions, sustainability in the drinking water supply sector has remained a chimera. It only underscores the management principle that without proper utilization of human resources, financial and technical resources fail to yield the desired results on a sustainable basis.

Having grasped this, the national government has been advocating a paradigm shift in the rural drinking water supply sector for the past one decade. Under Swajal Dhara, sectoral reform principles were introduced with the aim to involve the community in planning, management and maintenance of their drinking water supply systems through the institutional mechanism of Village Water and Sanitation Committees. Principles of sharing capital costs and demand-driven approach were applied. The programme was upscaled subsequently across the nation.

As a facilitator, the key role of the national and state governments is that of intensive awareness generation amongst the masses regarding issues ranging from over-extraction of groundwater and what it is doing to local water security, to contamination of drinking water and water quality



monitoring. Training for water conservation, rainwater harvesting, artificial recharge and in the use of modern technologies is also being conducted under various programmes.

The department has derived the lessons emerging from these and other government programmes, and evolved a road map for mobilizing human resources. Effective community participation, according to it, can be ensured only when



Effective community participation, according to it, can be ensured only when

- states, besides providing the PRIs with funds, functions and functionaries, also act as facilitators;
- the community takes full responsibility for the operation and maintenance (O&M) of the assets created; the state, of course, will provide support in situations of crisis or for building larger systems. PRIs/local communities/Village Water and Sanitation Committees can be empowered to generate resources for O&M and other uses;
- the community is provided capacity-building training to equip it to plan, implement, use and maintain new water supply schemes. These trainings could range from hand-pump repair and O&M of tubewells to construction of structures etc.

In this context, community involvement consists of the following four steps or 'S's':

1. Understanding or **Samajhna**
2. Making others understand or **Samjhaana**
3. Conservation or **Sahejna**
4. Accepting and internalizing the truth or **Sweekruth**

Samajhna: Understanding the Resource, Developing Capacity

The first step is that of understanding water as a natural resource and its importance for all forms of life. Our ancient cultural traditions do provide this knowledge; however, over time, this understanding has been reduced to ritualistic acceptance and performance of practices that are not internalized by the community.



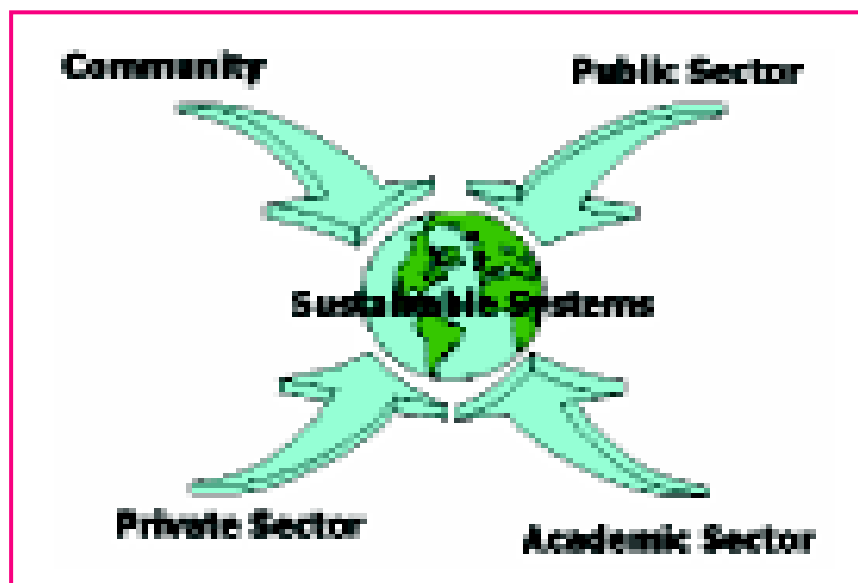
Four distinct areas have been identified where capacities need to be developed for sustainability:

- **Capacity to educate and train**, including community awareness building, adult training and formal education, so as to provide sufficient numbers of competent human resources to develop and apply enabling systems
- **Capacity to measure and understand water resources and systems** through applied research, monitoring and technology development, so that reliable data is generated and used for analysis and decision-making
- **Capacity to legislate, regulate and achieve compliance** through effective governmental, non-governmental and private sector institutions and through efficient enforcement and community acceptance
- **Capacity to provide appropriate, affordable water infrastructure, services and products** through sustained investment and management by both private enterprises and public agencies



Figure 3.1: Stakeholder Help in Community Participation

‘Samajhna’ should also be an effort towards recognizing all stakeholders who could be helpful in empowering the community in managing its assets





Samjhaana : Generating Awareness, Disseminating Knowledge

Understanding, naturally, has to be followed by the second step — making others understand or samjhaana. This step involves three key components: Information, Education and Communication (IEC). Various tools of IEC such as inter-personal communication, PLA/PRA exercises like drawing resource maps or village transects, and different audio-visual and mass media modes can be utilized depending upon the cultural habits of the community.

Awareness generation, on its part, can be done through multiple means of involving the community, mobilizing it and empowering its weaker sections (such as women).

Community Involvement

Community involvement is required at each stage viz. planning, design and O&M activities. Involvement in technical activities can be ensured by:

- Conducting water budgeting exercises in each village
- Finalizing sources with community participation and indigenous knowledge
- Strengthening existing sources and utilizing the existing infrastructure
- Conducting yield tests for each new source before developing it
- Involving the community in preparing village action plans for water supply
- Prompting the community to keep a vigilant eye on the quality of works
- Involving women SHG groups in O&M of the facilities
- Installing rain gauges in each village, and making the local school teacher responsible for recording daily rainfall
- Giving the community hands-on training for maintaining water quality
- Ensuring community participation through labor contribution

Community Contribution

Communities can also be encouraged to contribute monetarily or in kind. This contribution can be ensured by:

- Introducing innovative ideas for collecting community contribution
- Mobilizing community members for collecting contributions
- Promoting those villagers who can afford to contribute for those who cannot; later, these villagers can retrieve their contributions in kind
- Maintaining receipt books for community contributions



Community Mobilization

The basic goals of a rural water supply scheme should be to improve villagers' access to water and to decentralize the planning, implementation and maintenance of water supply to local government institutions. This can be achieved by mobilizing the community through these means:

- Encouraging villages to conduct regular informal sessions on project planning and decision making
- Activating the gram sabha as a decision-making forum in the village, and for ensuring active participation of women; conducting regular meetings for monitoring project implementation
- Promoting a cadre of village-level motivators for community mobilization
- Ensuring that district teams provide necessary guidance and facilitation
- Focusing especially on capacity building of the service providers
- Ensuring representation of women and weaker sections in the committees
- Capturing feedback and learning regularly, and taking corrective actions
- Building a process of external audits for regular feedback
- Conducting cross-learning review sessions regularly for interaction
- Ensuring that decision-makers make field visits
- Activating block teams and regional hubs to provide necessary support
- Ensuring visits of district staff to the villages at regular intervals
- Encouraging participation of youth clubs to sensitize the community

Women's Empowerment and Vulnerability Reduction

Drinking water affects women more than any other members of a rural household. The responsibility for fetching water from sources located outside the home (at times, at large distances), its storage and adequate provision is largely the concern of women. It is, therefore, imperative that women become active participants in the process. Community participation activities must, therefore, include initiatives that

- Involve women in decision-making and thus, help develop leadership qualities in them. A growing number of GPs now have women as their Panchayat Presidents or Sarpanches. Women's involvement right at the planning stage is also essential as they understand the utility of water more than men.
- Allow women in the gram sabha to play the major role in decision-making. Guidelines issued by the RGNDWM already indicate that at least 1/3rd of the members of Village Water and Sanitation Committees (VWSCs) should be women.



- Encourage and help women to come forward and put forth their views. Destitute women, disabled persons, etc. are largely neglected by the community in any decision-making process. If drinking water has to reach the poorest of the poor, it is essential to eliminate this vulnerability element.

Sahejna: Conserving Water, Ensuring Water Security

Conservation of water is an essential component of drinking water security. The practise of harvesting rainwater dates back to ancient times when the need to create water sources that would remain both clean and provide plentiful supply was recognized. Over the years, rising populations, growing industrialization and expanding agriculture have pushed up the demand for water.

Efforts have been made to collect water by building dams and reservoirs and digging wells; some countries have also tried to recycle and desalinate (remove salts) water. The idea of groundwater recharging by harvesting rainwater is gaining importance in many cities. In forests, water seeps gently into the ground as vegetation breaks the fall. This groundwater, in turn, feeds wells, lakes and rivers.



Protecting forests, therefore, means protecting water 'catchments'. In ancient India, people believed that forests were the 'mothers' of rivers and worshipped the sources of these water bodies.

Sweekruth: Accepting, Internalizing the Truth

It is important to understand water as a resource, and not as a commodity which can be controlled by market forces. It is also as important to realize that it is not a resource that will last for ever – unless we use it prudently. It is a gift of nature that needs to be treated with respect and caution. Sustainable use of water calls for self-discipline and an understanding of the resource in this light, and communities need to accept and internalize this truth.

Two Studies in Effective Community Participation

Water Budgeting at village level, Demand and Supply Management

A Case study of bringing Drinking Water Sustainability in Arid Kachchh

Our thirst for developing drinking water solutions, which were ecologically more sustainable, and socially more empowering in arid Kachchh began with Rupakaka – a 70 year old man living in a village on the borders of India. In 1994, he took us half a kilometer from his village, Khari, and told our geologist, "Help us dig a well here, and we will find water". The hills around Khari village, (Khari literally means saline), have salinity in their rocks, and the inhospitable Rann of Kutch surrounds them, bringing salinity into every crevice of their landscape. It was hard to imagine how sweet water could be found here. Our geologist, Yogesh, asked Rupa kaka, "How are you so sure there is sweet water here?" Rupa kaka explained that of all the 8 rock formations in his village, only Rati Dawdi (laterite) had the potential to yield sweet water.



Yogesh knew that laterite was a formation that developed on the surface of the Kachchh region after the Jurassic period, when the entire region was submerged under the sea. Therefore Rupa kaka was probably right!

A well was dug, and a pump put on the well, to carry the 'nectar' to village taps. However, this excitement was short lived. The next year was a drought year and the water used to make tea, made the milk sour; By the time summer arrived, even the green gram in the traditional 'Khichdi' would refuse to soften in spite of continuous boiling. We realized that the salinity had claimed the well too, and the total dissolved salts had risen first to 2000 and then to 2400. However, that year, understanding the laterite stretch led to the village constructing a check dam above the well, to recharge it, increase the sweet water, dilute the salts and not allow the salinity to rise. Below the well, a subsurface check dam was made to check the runoff into the Rann. Typically, as in Khari village, which has a catchment of 125 ha, the rainwater inflow is 4,25,000 cum, while the outflow is 3,82,500 cum; With the runoff at 60% (2,55,000cum), and the evaporation at 30% (1,27,500 cum), the **water balance** indicated that 5-10% rainwater harvesting in the aquifer, for groundwater recharge, could match the drinking water demand of 140 households even in a three year, consecutive, drought period. Thus, the existing demand for drinking water which was 21,600 cum was in fact, met by 5% of the total rainfall.

Fortuitously, the rains arrived and since that day in 1995, Khari village which had learnt to integrate traditional wisdom with a more professional understanding of water balance/water budgeting and geo-hydrology, has never had a drinking water problem. More important, it is not dependant on an 'outside' source. However they have a thumb rule, that if the water level in the well drops beyond the 18 feet mark, the water gets rationed. Today, the village, which has inspired a framework for decentralized, local, sustainable drinking water solutions in a region like Kutch, is considering changing its name from Khari to Leelpar, which means- green village.

Typically, as in Khari village, which has a catchment of 125 ha, the rainwater inflow is 4,25,000 cum, while the outflow is 3,82,500 cum, with the runoff at 60% (2,55,000cum), and the evaporation at 30% (1,27,500 cum), the **water balance** indicated that 5-10% rainwater harvesting in the aquifer, for groundwater recharge, could match the drinking water demand of 140 households even in a three year, consecutive, drought period. Thus, the existing demand for drinking water which was 21,600 cum was in fact, met by 5% of the total rainfall.

In the past two decades, the younger generation of rural, arid Kutch, has lost the regional wisdom that the 'Rupa kaka's' of the region have traditionally possessed. In the past 40-50 years, the focus shifted from traditionally managed water sources, to centralized, pipe line solutions - making the need for local knowledge and village self sufficiency irrelevant, depending exclusively on a single pipeline system and the loss of an access to drinking water which could have contributed to Sustainability.

Out of 18 rock formations found in Kutch, only four have the potential of working as sweet water aquifers – Laterite, Basalt, Alluvium and Sandstone. After the 'Khari' experiment, we discovered that if the geological search is rigorous, any one of the four aquifers is to be found in every village of Kutch. In fact that is precisely why the villages have settled where they have. The success of Khari, led to 52 more villages developing their own drinking water source, by understanding their geology and developing structures appropriately. To ensure that the skills of finding the elusive aquifer are not lost, amidst the complicated geology of this region, we developed a training program for the rural youth of the region. Today, there are 90 young Para Water Professionals, all less than matriculates, who help Gram Panchayats and their Pani Samitis, identify the water source of their villages.

In Dador village, on the edge of the Banni grasslands, one of the sangathans of the Kutch Mahila Vikas Sangathan collective, developed their well in a sandstone patch, with Valji Ahir, the local Para Water Professional, and our geologist. However, the well was one and a half kilometers from their village. As no electricity was available, the diesel pump made the operational cost expensive. Each family in the village had to contribute Rs 50/- every month. The village soon began to consider handing over the well to the Water Supply Board, as they could not cover the operation costs. However, the women were not happy with this solution. They were aware of the experience of Jam Kuneria village that had handed over their well too to the government. The result was, that, within a year, the source was connected to supply water to five other surrounding villages. Consequently, in the subsequent drought, the well turned saline, and Jam Kuneria was unable to yield sweet water again.

Having learnt from Jam Kuneria village, a unique solution was developed with the community of Dador village. A solar pump was installed on the well. The operation cost became completely viable despite the initial capital cost of Rs. 2.5 lakhs. From a monthly running cost of Rs. 6,700 with a diesel pump, the running cost with the solar pump came down to Rs. 1,300 per month. Today the women's sangathan runs and maintains the pump with a contribution of Rs 15/- per family, which the village is happy to contribute. To achieve sustainability the village not only has to manage the demand



and supply from their aquifer, they also have to ensure that the control of the management remains with the people themselves. This also ensures that the water is carefully used and not wasted. Today in collaboration with WASMO (The Water and Sanitation Management Organization set up by the Gujarat Government to work exclusively on water and sanitation), villages are converting their diesel pumps to solar, and thereby taking control and responsibility of their village water supply.

Encouraged with these results, in 2006 WASMO sponsored a project to develop a plan for 163 villages and towns of Abdasa taluka. Supported by Sahjeevan and ACT, 12 Para Water Professionals of the region set up a service organization called 'PARAB' (The word has a traditional connotation which refers to the public facility of every village in earlier times, which would serve water to travelers/guests.). Parab services the Panchayats/Pani Samitis, to develop their water plans and help them implement it. The complete information of the aquifer, the water demand and the cost of the project is provided to the village on a single page. A community radio program will regularly report^{©15} on the panchayats that have developed their water sources. It is now not uncommon to find a group of villagers sitting around a tea stall inquiring about the aquifer in each other's village!

Nalia town, the taluka headquarters of Abdasa taluka, has a population of 15000 people. As their wells had gone saline, families were buying drinking water from the private operators; or alternately, the Panchayat provided water by purchasing water from a near by company that had installed a reverse osmosis plant.

Inspired by the campaign to develop their own drinking water source, the Gram Panchayat developed a recharge structure on their old, saline wells. Within a year the water quality improved. Today the Panchayat supplies rationed drinking water to the whole town. And has initiated a growing confidence that decentralized local drinking water source solutions, owned and managed by the local governance mechanisms, is not only appropriate, and possible, but in fact the only sustainable way - even for growing villages, and our mofussil towns.

Village drinking water plans of Chhadura and Sujapar of Abadasa Taluka of Kachchh (Gujarat) along with photographs is given in Appendix-VI.

Rejuvenating the Ooranis of Tamil Nadu

A government effort for renovating the Ooranis of Kancheepuram and Ramnathpuram districts

The rejuvenation of the Ooranis was conceived as a project by the Rural Development department of the state government. A Special Task Force (STF) was constituted at the state, district and block levels for the implementation of the project; the STF included representatives from the government, technical institutions, NGOs and the community.

The project began with the collection of baseline information from the villages. Awareness generation amongst the community was done by the state-based NGO, Dhan Foundation. Water users' associations were formed, bank accounts opened and community contribution was collected.

On basis of the demand from the water users and PRIs, design estimates were prepared. The project was executed by the water users' associations with the assistance of the PRIs and other stakeholders. A periodic evaluation of the project by experts from district-level technical institutions was initiated.



The impact of the project was impressive. Storage capacity increased three/four-fold. Even in only 50% rainfall conditions, the Ooranis supplemented the drinking water demand for 10 months. Groundwater was recharged, the water level in borewells and open wells increased, and the quality of the water improved.



3 MOBILIZING FINANCIAL RESOURCES FOR SUSTAINABILITY - CONVERGENCE AND ROLE OF THE STATE

Numerous government programmes on soil and water conservation and for augmentation of groundwater are being undertaken by various ministries at the Central and state levels. There is a need to converge these efforts at the district, block, village and habitation levels as well to optimize the benefits of the range of technical options and financial outlays in a synergistic manner. The role of the State and planners — as ‘facilitators’ — becomes important in bringing about such convergence.

The State also has a central role to play in providing the legislative framework for protection of water bodies, regulating indiscriminate extraction of groundwater and in the arbitration of competing interests for water. Additionally, the State has a facilitating role to create institutional mechanisms for community ownership and management of water supply systems, as well as for monitoring strategies and devising new ways to move ahead on the journey of continued sustainability.

This chapter features a selection of programmes which have a strong sustainability component — states could work towards convergence at the district level with respect to these programmes.

The National Water Policy (2002) adopted by the Government of India enunciates that “water is a scarce and precious national resource to be planned, developed, conserved and managed as such, and on an integrated and environmentally sound basis, keeping in view the socio-economic aspects and needs of the states. It is one of the most crucial elements in developmental planning. As the country has entered the 21st century, efforts to develop, conserve, utilize and manage this important resource for sustainability have to be guided by national perspective.” The policy has assigned the highest priority to drinking water supply needs, followed by irrigation, hydro-power, navigation, industrial and other purposes.

For sustainable drinking water supply, a convergence of all watershed-based schemes is essential at the district level. The water cycle can be shown schematically as:

It is estimated that in India, 80% of the drinking water is based on groundwater resources. The schemes based on surface water also depend on continued and secure supply from the catchment. Efforts should be made to manage the water right from the catchment, conserving all the run-off and using the natural filter systems to ensure safety of water.



There has been increasing recognition over the years of the need for water conservation and water management. Consequently, there have been a number of schemes initiated by different departments, which have as their critical component, water conservation and water management issues. There is the need, therefore, for a convergence of related activities under these schemes — especially at the district level — to optimize their benefits. Some of the schemes of the various departments of the government of India, which have a strong sustainability component and may be converged at the district level, are as follows:



NATIONAL AFFORESTATION PROGRAMME

Under this programme, all afforestation schemes of the Ministry of Environment and Forests have been brought under a single umbrella scheme being implemented through decentralized Forest Development Agencies (FDA) set up at the district level. The FDAs have a strong linkage to the District Panchayat and Village Forest Protection Committee.



Objectives:

The overall objective of the scheme is to develop the forest resources with people's participation, with focus on improvement in livelihoods of the forest-fringe communities, especially the poor. Financial support under the scheme is provided for soil and moisture conservation.



Funding Pattern

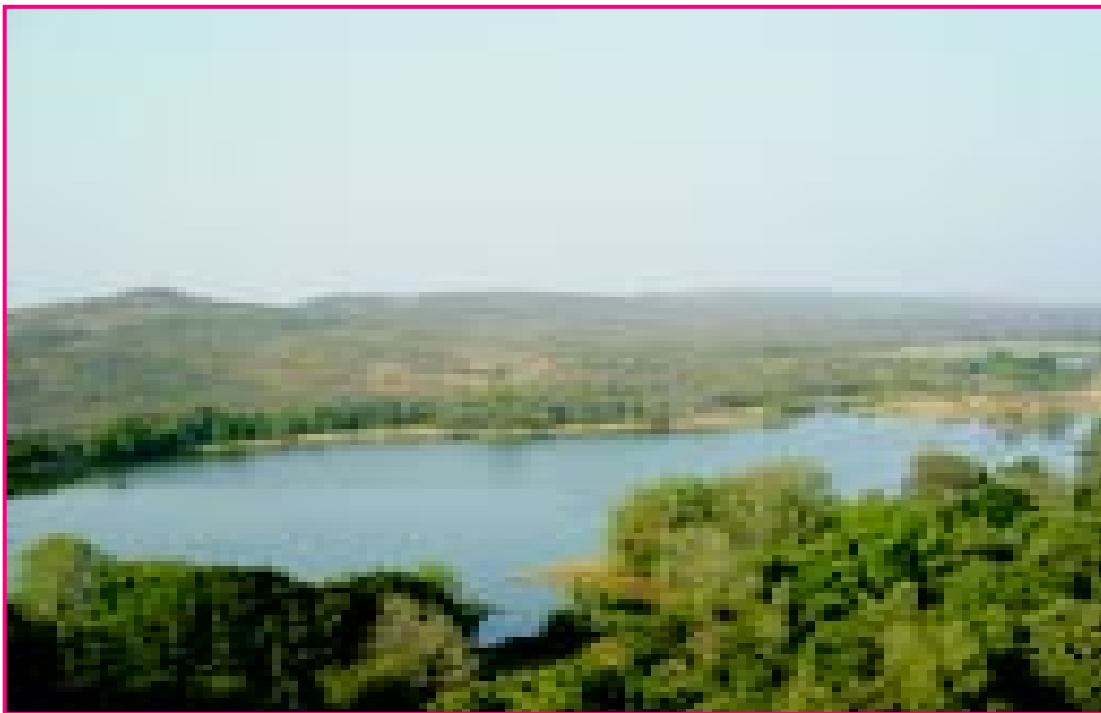
The scheme is operated by the National Afforestation and Eco-Development Board, Ministry of Environment and Forests as a 100% Central Sector/ Centrally Sponsored Scheme. In the participatory mode, the scheme is being implemented by involving two-tier set up namely the Forest Development Agencies (FDA) and Joint Forest Management Committees (JFMC).

Implementation

The NAP is being implemented through a 2-tier structure of Forest Development Agency (FDA) at the forest division level and Joint Forest Management Committee (JFMC) at the village level. Thus, FDA is the confederation of JFMCs in that forest division. FDAs are registered under the Societies Registration Act. JFMCs are registered either with the Forest Department or under Statutory provisions. The district-level officers of relevant line departments of the State Govt. and Panchayat Raj Institution are members of FDA.

NATIONAL PROJECT FOR REPAIR, RESTORATION AND RENOVATION OF WATER BODIES

This scheme was announced by the Union Finance Minister in his Budget Speech 2004-05 with the aim to repair, renovate and restore all the water bodies directly linked to agriculture. Managed by the Ministry of Water Resources, the project envisages active community participation



Objectives

Under the scheme, projects are to be taken up in one or two districts each in the states. The states are to take up restoration of water bodies having original irrigation culturable command



area of 40 ha upto 2000 ha to revive, augment and utilize their storage and irrigation potential. Priority is to be accorded by states to areas, which are arid, drought-prone, tribal-dominated, backward while selecting districts.

Funding Pattern

This is a state-sector scheme and the proposed funding pattern is Centre: State 75: 25. The projects are to be completed within a period of two years. Detailed project Reports are to be prepared by the states as per the guidelines and submitted for approval of Ministry of Water Resources and consideration for funding. 10% of the project cost will be kept for related capacity building & people's participation and survey for collect of baseline data.

Implementation

There will be a district level implementation committee, chaired by the District Collector for deciding all implementation management issues and supervision. The Panchayati Raj Institutions and Water Users Associations (WUA) and representative of all stakeholders will be actively involved in the Committee. WUAs will include representative of all stakeholders including those from landless and vulnerable groups and women.

RIVER VALLEY PROJECT AND FLOOD PRONE RIVER PROGRAMME

The centrally sponsored programme of soil conservation for enhancing the productivity of degraded lands in the catchments of River Valley Project and Flood Prone River, in the present form, is being implemented since November 2000 by the Ministry of Agriculture and Cooperation.



Objectives

The main objectives of the programme are:

- Prevention of land degradation by adoption of a multi-disciplinary integrated approach of soil conservation and water shed management in catchment areas



- Improvement of land capability and moisture regime in the watersheds
- Promotion of land use to match land capability
- Prevention of soil loss from the catchments, to reduce siltation of multipurpose reservoirs and enhance the in situ moisture conservation and surface rainwater storages in the catchments to reduce flood peaks and volume of run off.

Funding pattern

The financing pattern of the programme after amalgamation is in the ratio of 90:10 between centre and state governments. The funds are provided to state governments as 80% grant and 20% loan.

Implementation

In this programme all types of lands viz. agriculture, waste and forest are treated in an integrated manner with suitable package of treatment. The catchments included under RVP and FVR programmes are surveyed by the All India Soil & Land Use Survey Organisation by conducting Priority Delineation Survey and categorized into five categories i.e. Very High, High, Medium, Low and Very Low using Silt Yield Index methodology. As per the norms stipulated in the Guidelines only priority watersheds (very high and high watersheds) are taken for treatment.

NATIONAL RURAL EMPLOYMENT GUARANTEE SCHEME

The National Rural Employment Guarantee Act was notified on 7th September 2005.

Objectives

The NREGS' objective is to strengthen livelihood opportunities and create durable assets in rural areas through legal guarantee of 100 days of employment in a financial year to a rural household that demands employment within 15 days of demand. Among the works undertaken under NREGS, water conservation and water harvesting has a high priority

The kind of works permissible under the Programme and according to priority are:

- Water conservation and water harvesting;
- Drought proofing, afforestation and tree plantation.
- Irrigation canals including micro and minor irrigation works;
- Provision of irrigation facility to land owned by households belonging to the Scheduled Castes and Scheduled Tribes or to land beneficiaries of land reforms or that of the beneficiaries under the Indira Awas Yojana of the Government of India.
- Renovation of traditional water bodies including desilting of tanks,



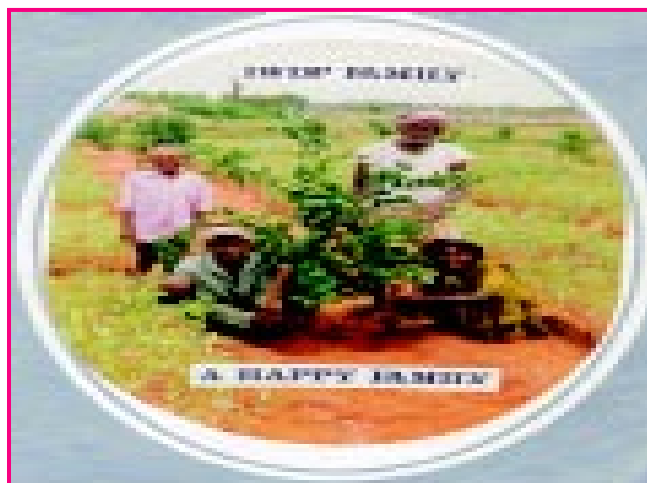
- Land development,
 - Flood control and protection works including drainage in water logged areas,
 - Rural connectivity to provide all-weather access. The construction of roads may include culverts where necessary, and within the village area culverts may be taken up along with drains.
- 
- Any other work which may be notified by the Central Government in consultation with the State Government

Implementation

The implementing agencies of these schemes are the gram Panchayats (half of EGS works), other Panchayati Raj institutions, line departments (PWD, Forest dept) and NGOs. Contractors have been banned from these schemes. The planning process is initiated by the Gram Sabha, which also recommends works. The Gram Panchayat consolidates recommendations of Gram Sabha into Village Development Plans and forwards to intermediate Panchayat level. The GP plans are consolidated into block plans with the addition of works that cut across GPs. The District Panchayat approves the plans. There is a shelf of projects at the village level. A holistic village plan is prepared from which NREGA needs are derived (inter sectoral and inter departmental needs and resources are factored in this). There is also a five-year district perspective plan.

INTEGRATED WASTELAND DEVELOPMENT PROGRAMME

This scheme is implemented by the Department of Land Resources, Ministry of Rural Development since 1989-90. Apart from the development of non-forest wastelands the scheme also provides for the development of an entire micro watershed in a holistic manner. The IWDP scheme is being implemented on the basis of new Guidelines for Watershed Development from 1.4.1995.





Objectives

The basic objective of this scheme is an integrated wastelands development based on village/micro watershed plans. These plans are prepared after taking into consideration the land capability, site condition and local needs of the people.

Activities:

The major activities taken up under the scheme are:

- In situ soil and moisture conservation measures like terracing, bunding, trenching, vegetative barriers and drainage line treatment.
- Encouraging natural regeneration.
- Encouraging people's participation through community organization and capacity building.
- Development of small water Harvesting Structures.



CHECK DAM



RECHARGING WELL UNDER IWDP PROJECT

Implementation

To make the programme successful, proper Institutional arrangement has been provided in the Guidelines from state level to village level. The State Watershed Programme Implementation



and Review Committee is an apex organisation at a state level under the chairmanship of Chief Secretary/Addl.Chief Secretary/APC. Representatives of prominent NGOs, SIRDs, Heads of Department of related Departments are also member of the Committee. The Committee undertakes monitoring, review and evaluation of Watershed Development projects. DRDA/ZP is a key institution in the programme execution. The project is sanctioned in favour of the DRDA and funds are released to it directly from Government of India. The Watershed Development Team is a multi-disciplinary team responsible for technical and financial supervision of the project activities. The team consists of field level officials drawn from various disciplines like forestry, soil conservation, horticulture, social sciences etc. Watershed Development Association (WA) consists of all members of the village whose land is situated in the watershed area called user group (UG) and all those members who derive sustenance from the watershed area called self help group (SHG). Watershed Committee (WC) is the key institution at Watershed level consisting of about 2-3 representatives, each of UG, SHG, Panchayat and women etc. Committee also appoints a Watershed Secretary preferably a local man graduate from the same area.

Funding

The IWDP Scheme is 100% Grant-in-Aid from Government of India. The projects are sanctioned on getting basic information from DRDAs about the watershed to be treated and capability of the PIA and over all situation in the area. A well laid criteria for selection of watersheds has been provided in para 27 of the Guidelines. The watersheds selected for the projects should be as far as possible contiguous and there should be preponderance of wastelands. Acute shortage of drinking water, low wage rates and non over lapping of watersheds with any other project are other requirements. Under IWDP scheme the projects are sanctioned in non DPAP/DDP areas. Normally, not more than two projects are sanctioned in a district. Funds from DRDA flow to Watershed Committees who open an account in the nearest bank to be operated jointly by WDT member and local man i.e. Secretary of WC. The Watershed Committee is the primary unit which is directly involved in implementation of the programme right from preparation of action plan and check measurements of works and payment of wages. The WC also maintains an account called Watershed Development Fund Account, where contribution realised from the members of Watershed Associations are deposited for utilisation in post project maintenance of assets. Contribution in shape of labour, cash and kind are valued and kept in interest bearing account. The projects under IWDP Scheme aim at sustainability in the long run. This is achieved through the establishment of Watershed Development Fund which takes care of post project maintenance and sustenance. This fund is meant to sustain the maintenance of the assets created during the course of project implementation so that the people in the watershed area continue to reap the benefits even after the completion of the project.



Sustainable use of Water Resources

HARIYALI

The guidelines for Hariyali were issued in 2003 with the aim to involve the Panchayat Raj Institutions (PRIs) more meaningfully in planning, implementation and management of economic development activities in rural areas. New projects under the area development programmes have to be implemented in accordance with the Guidelines for Hariyali with effect from 1.4.2003. The programmes under these guidelines have to be implemented exclusively on watershed basis. All activities relating to watershed development and management like planning, execution and maintenance of assets created are to be taken up by the local people through their own organizations specifically created for the purpose.

Objectives

The objectives of projects under Hariyali are:

- Harvesting every drop of rainwater
- Ensuring overall development of rural areas through the Gram Panchayats and creating regular sources of income for the Panchayats from rainwater harvesting and management.
- Employment generation, poverty alleviation, community empowerment and development of human and other economic resources of the rural areas.

Funding Pattern

The prevailing cost for a prescribed watershed project of 500 ha. is Rs. 30.00 lakh i.e. Rs. 6,000 per hectare. Central and State Government in the ratio of 75:25 share the cost. Funds will be released in five annual installments.



Implementation

Under the Hariyali Guidelines, the execution of watershed projects is to be carried out by Gram Panchayats. The block level or Zilla Panchayat will act as a Project Implementing Agency (PIA).

TWELFTH FINANCE COMMISSION

The Twelfth Finance Commission was appointed by the President of India on 1st November, 2002 and it submitted its report on November 30, 2004, covering the period 2005-10. The TFC stated in its report that The Panchayats are to be encouraged to take over water supply assets. The PRIs are to recover at least 50 per cent of the recurring costs in the form of user charges. The guidelines further mention that priority should be given to expenditure on the O&M costs of water supply and sanitation. This will facilitate Panchayats to take over the schemes and operate them. The Twelfth Finance Commission made a grant of Rs. 20,000 crore which is to be used for improving the service delivery by the Panchayats in respect of water supply and sanitation..

Implementation

The TFC provides for the constitution of a high level committee to ensure proper utilization of Local Bodies Grants headed by the Chief Secretary, and includes the Finance Secretary and Secretaries of the concerned departments.

This committee is responsible for the following

- Approval of the projects at the beginning of every year to be undertaken in each sector, quantify the targets, both in physical and financial terms and lay down a time table for achievement of specific milestones
- Monitoring both physical and financial targets and ensuring adherence to the specific conditionality in respect of each grant, wherever applicable
- The state Finance Secretary is required to provide a certificate every year of the percentage of grants spent on schemes of water supply and sanitation by the PRIs, details of recurring O&M cost recoverable by the PRIs.

BACKWARD REGIONS GRANT FUND

The Backward Regions Grant Fund is designed to redress regional imbalances in development. The fund aims to provide financial resources for supplementing and converging existing developmental inflows into 250 identified districts, so as to bridge critical gaps in local infrastructure and other development requirements that are not being adequately met through existing inflows.

Objectives

It aims to:

- Strengthen, to this end Panchayat and Municipality level governance with more appropriate capacity building, to facilitate participatory planning, decision making, implementation and monitoring.



- Provide professional support to local bodies for planning, implementation and monitoring their plans
- Improve the performance and delivery of critical functions assigned to Panchayats, and counter possible efficiency and equity losses on account of inadequate local capacity.

Funding Pattern

The Programme has two components namely, a district component covering 250 districts and Special plans for Bihar and the KBK districts of Orissa. A total provision of Rs. 5000 crore had been made for the two components in the Budget of 2006-07. Out of this allocation Rs. 1250 crore had been provided in the Demand for Grants of the Ministry of Finance for the Special Plans dealt with by the Planning Commission. The remaining amount of Rs. 3750 crore had been placed at the disposal of the Ministry of Panchayati Raj for the District Component, covering 250 districts. The allocation of Rs. 3750 crore consisted of two funding windows (a) capacity building fund of Rs. 250 crore and (b) development grants of Rs. 3500 crore for the financial year 2006-07.

Implementation

The Panchayats at the village, intermediate and district level, referred to in Part IX of the Constitution, will undertake planning and implementation of the programme, in keeping with the letter and spirit of Article 243 G.





4 SUSTAINABILITY - PRACTICES AND ISSUES VIEWS OF THE STATE GOVERNMENTS

Considering the vast and diverse geo-hydrological regime of India, it is almost impossible to have a uniform policy for the entire nation – and the department recognises this fact. Therefore, what this document enumerates is largely illustrative or indicative in nature, and the states have been encouraged to innovate and offer their own solutions for water security at the village level.

The draft document was widely circulated among various stakeholders for their comments, observations and suggestions. This chapter is a concise summary of observations and suggestions from state governments.

4.1 Andhra Pradesh

- ❑ 600 Roof top RWHS constructed in fluoride affected Nalgonda district. Difficulty has been faced in changing filter media every year on onset of monsoon. Awareness has been created among community for changing filter media every year.
- ❑ TANKA/ Kund / kundi are not used in A.P.
- ❑ Design aspect of percolation tanks: Uses of Geological maps for percolation tank under RGNDWM are essential for selecting suitable site for constructing percolation tanks.
- ❑ Desilting of irrigation tanks needs to be taken up under NREGP duly giving preference to augmentation of Water Supply schemes.
- ❑ Design aspects of check dam/ cement plugs/ nallah bunds. : Desilting of clay material has to be done periodically. VWSC have to be involved for these works. Priority to be given to construction of check dams in the habitations where transplants of water and hiring of bore wells is done.
- ❑ Design aspects of Gabion Structure: useful for State of Andhra Pradesh.





- ❑ Design aspects of Ground water dam sub-surface dyke are constructed: few sub-surface dykes are constructed in AP in riverbeds when infiltration wells are proposed in PWSS and they are proved to be success.
- ❑ Geo-hydro morphological condition and ground water table:-
- ❑ Geo-hydrological maps are used at field level for identifying potential zones of drinking water sources and location of suitable sites for WHS liter check dams/ percolation dam tanks..
- ❑ Over exploited, critical and semi critical blocks RWHS have to be provided in over-exploited and critical mandals.
- ❑ Use of GIS/ remote sensing & other data / local knowledge (got prepared) soft copies of ground water prospecting maps by RGNDWM to be provided to user department.
- ❑ Existing system of monitoring quantity and quality needs to be strengthened. Database for all existing sources need to be prepared.
- ❑ District water security plan is essential contribution up to 1% to 5% of cost of project may be charged from community.
- ❑ Observation wells for monitoring ground water table are essential for future planning. Wells maintained by GW Department are to be used for this purpose.
- ❑ 3800 Percolation tanks and 11,167 check dams are proposed as per CGWB Master Plan at a cost of Rs 1229 crore.



4.2 Arunachal Pradesh

- ❑ Majority of water supply schemes are dependent on gravity feed systems drawn from rivers, streams, nala or springs.
- ❑ Due to tree-felling by tribes under Jhum cultivation, the sustainability of surface streams has been endangered.
- ❑ Suggested to ban Jhum cultivation in the upstream of sources. Legislation to this extent has to be enforced by the State Government.
- ❑ Catchment protection through fencing at strategic points and banning of grazing or plantation of fruit bearing trees.
- ❑ Road construction works encourages arbitrary settlement of population along the road. This affects quality of water flowing down the hills. Clearance from PHED is required for taking up new road constructions.
- ❑ Hariyali programme should be converged with water supply department for enhancing vegetation coverage
- ❑ Construction of catch drains, check dams, dykes should be allowed as component of ARWSP. Funds from NREGS, CGWB, XII-Finance Commission, IWDP should be dovetailed.
- ❑ 500 check dams, 1000 weirs, 1000 gabion structures and 300 spring development works are proposed as per CGWB Action Plan at a cost of Rs 87 crore.



4.3 Assam

- ❑ Rainy season extends for 7 months duration in a year
- ❑ Rainwater can be stored in built-up tanks to provide source of drinking water
- ❑ State has suggested 5 months storage for the lean period
- ❑ Rainwater harvesting is not a popular technique in Assam as the ground water table lies between 0-4 m bgl and therefore quantity of ground water is never a problem. It is only the quality of ground water which is a problem.
- ❑ Recharging aquifers is feasible by means of check dam, increased vegetation cover, etc.
- ❑ Spring water harvesting as an alternative source of drinking water in hilly districts (Karbi Anglong and North Cachar Hills)
- ❑ There is no mechanism to check ground water extraction by private parties.
- ❑ CGWB/PHED may be identified as Nodal Agency for issuing No-Objection certificates to the concerned drilling agencies.
- ❑ 250 check dams, 500 weirs, 1000 gabion structures, 250 spring development works at a estimated cost of Rs 50 crore is proposed as per CGWB in rural areas of the State.



4.4 Bihar

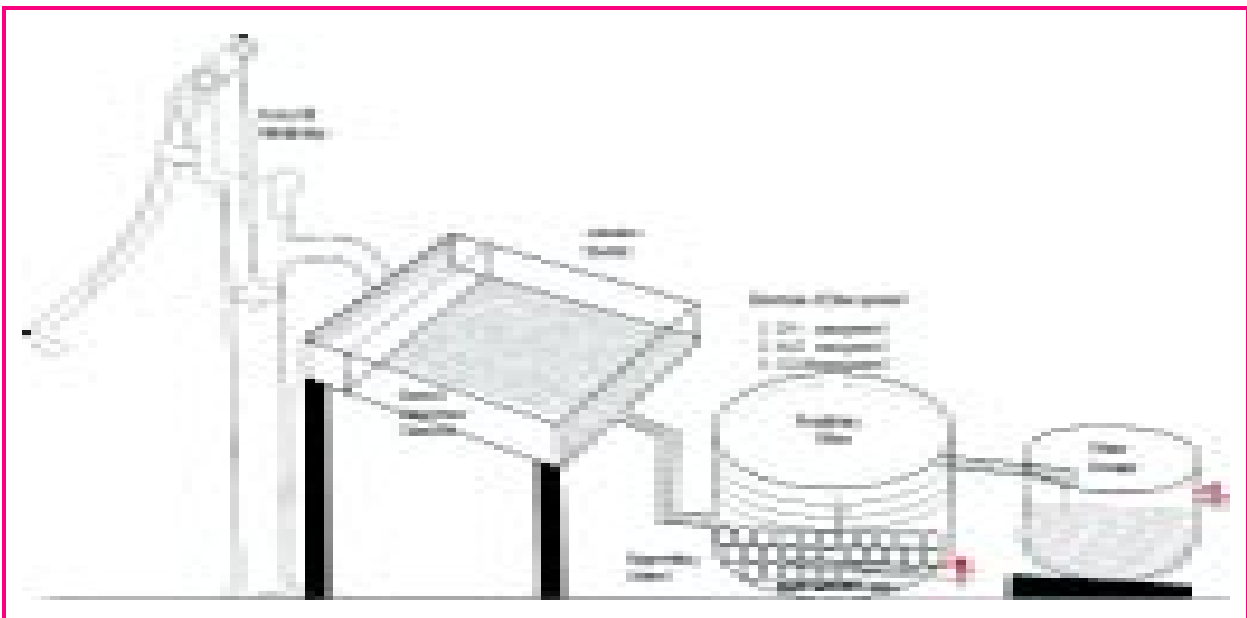
- ❑ Convergence of programmes is essential for avoiding duplicity of projects implemented in the field of Water Resources Management and Development.
- ❑ Full cost recovery should not be insisted from the beneficiary. Measures should be taken to ensure that the user community is able to generate funds for O&M.
- ❑ Habitation is undefined entity. It would be better to prepare plans at the Panchayat level or Revenue village level, while covering the Panchayat or village, the habitation would in any case be included.
- ❑ Project formulation / implementation be entrusted to Gram Panchayats / VWSCs.
- ❑ GoI should consider for 100 % funding for sustainability projects including those works where the source creation is also involved.
- ❑ Authority to scrutinize the projects should be decentralized at the State level where GoI nominee can also be authorized to participate. Funds should be released to State's SWSM which in turn can allocate to various districts on the basis of project requirement.
- ❑ Each village should have one observation well; technical details have not been given. It is not clear who would bear the cost of construction of these observation wells. GoI can incur the cost of construction of such wells.
- ❑ For Bihar & Jharkhand, 2695 percolation tanks, 9483 nala bunds, 1303 contour bunds are proposed as per CGWB Master plan at a cost of Rs 634 crore.





4.5 Chattisgarh

- ❑ Agriculture Ministry and Department of Space manual for recharge structures may be followed
- ❑ WQ mapping should be done at the block level prior to the construction of recharge structures. This can be done on the basis of GIS.
- ❑ Master Plan to be developed at the Block level with village unit using Remote Sensing and GIS techniques.
- ❑ Other parameters of thematic maps like drainage, slope, soil, geology, geo-morphology will have to be integrated with the technical design of the recharge structures.
- ❑ State of Art suggests the following structures in Chhattisgarh state:
 - Ponds, Check dams, Percolation tanks
 - Bandharas, Gully plugging, Sub surface dams/ Dykes, Contour bunding
 - Recommended structures are Flat battered tanks
- ❑ Selection of suitable sites for improvement of existing systems, better water management
- ❑ Convergence with NREGS, CGWB, MoWR, Ministry of Agriculture has already been taken up.
- ❑ Department of Space is already working with the state government for generating the maps. These maps can be transformed into the Water quality maps also.
- ❑ Studies of drainage basins/ watersheds will be conducted systematically before implementing the construction of recharge structures.
- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 223 crore in rural areas – 648 percolation tanks, 2151 nala bunds/check dams/cement plugs, 2582 gravity head/ recharge shafts, 7740 gully plugs/ gabion structures.





4.6 Gujarat

- ❑ Master plan incorporates water supply grid from Sardar Sarovar to cover 70% State population.
- ❑ In addition, local sources are also identified to find permanent solution to drinking water sustainability at habitation level.
- ❑ Various types of measures have been adopted to augment capacity of local sources viz., recharging of ground water aquifers and scientific approach combined with local wisdom
- ❑ Use of Remote sensing/ ground water prospecting maps, hydro-geological information have been effectively used for getting better results.
- ❑ Measures adopted for recharging are
 - Check dam, Percolation tank, Nala plugging
 - Injection tubewell, Deepening of village ponds
 - Inter-linking of rivers and check dams, Inter-linking of ponds
 - Filling of ponds from surface sources by pipelines
 - Revival of traditional sources like step wells and wells
 - Desilting of wells, Filtration wells on ponds
 - Roof-top rainwater harvesting
 - Linking of roof-top water to recharge wells and borewells
 - Bore blasting in hard rock areas to develop secondary porosity
 - Bori-bund (sub surface dykes), Khet talavadi (Farm ponds)
- ❑ In coastal areas specific projects have been taken up with integrated planning for sustainability in a decentralized approach which reduced salinity and fluoride levels drastically
- ❑ Water management plans were also implemented for most of the individual water supply schemes and regional rural water supply schemes.
- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 1155 crore in rural areas – 4942 percolation tanks with recharge tubewells, 13210 check dams





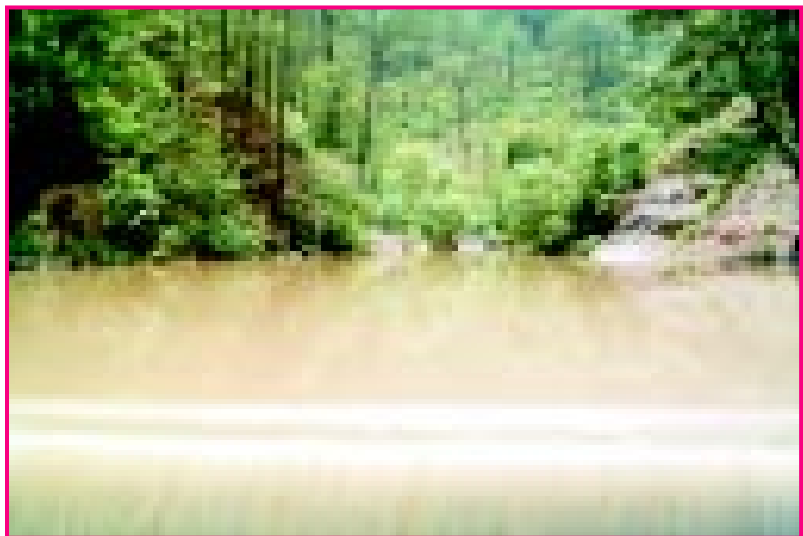
4.7 Haryana

- ❑ Traditional rainwater structures are not being provided as they do not come under the purview of this Department.
- ❑ Check dams/ tanks are being constructed by Agriculture and Irrigation Departments which are helping indirectly by recharging the ground water table
- ❑ 60% of the State are covered with canal based schemes, which reduces load on ground water.
- ❑ In Mewadh areas, 150 injection wells have been drilled for recharging the ground water table, which improved discharge in tubewells.
- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 159 crore in rural areas – 15928 recharge shafts/trenches



4.8 Himachal Pradesh

- ❑ Water supply schemes are based on springs, nala, rivers, dugwells, percolation wells and tubewells
- ❑ Traditional water harvesting is being abandoned slowly due to piped water supply schemes
- ❑ Government has made mandatory to provide roof-top harvesting structures in urban towns, office buildings, institutions, industries and hotels, along with ground water recharge structures.
- ❑ Irrigation & Public Health Department has started check dams, weirs, ponds and structures for revival of springs under Sustainability measures. Renovation of 80 water bodies has been taken up.
- ❑ Other sustainability measures are construction of ponds, check dams, percolation tanks and sub-surface dykes.
- ❑ In existing schemes, wherever shortage of water is experienced, appropriate recharge/ harvesting structures have been instructed to be built. Roof-top rainwater harvesting are practiced for individual/ cluster of households and institutional buildings.
- ❑ Interlinking of tanks and check dams. Gully plugs are taken up across small nalas on gentle slopes. Construction of ponds in waste lands and forests to be taken up. Rehabilitation of abandoned silted up old ponds, wells and Khatries to be taken up.
- ❑ Effecting point source recharge through recharging pits/ shafts
- ❑ Construction of ponds and water retaining structures on invert-saddle of dry and waste hills
- ❑ Constructing water retaining structures at the bottom of catchments of hills for collecting water through trenches and drains.
- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 458 crore in rural areas – 1000 sub-surface dykes, 500 check dams, 300 revival of ponds, 500 revival of springs





4.9 Jammu & Kashmir

- ❑ Monitoring the glacier activity and steps to minimize its melting.
- ❑ Deforestation and improper exploitation of ground water and surface water should be stopped
- ❑ Practices such as surface water harvesting, ground water recharge to be encouraged through following works:
 - ❑ Nalla bunding, Contour bunding, Check dams, Storage tanks, Gully plugging, Desilting of tanks, Aquifer modification, Rain water recharged borewell technique, revival / revitalization of wells
 - ❑ Attention to maintenance of system assets
 - ❑ Snow Check dams for snow retention
 - ❑ Traditional Roof Top Rain Water Harvesting Structures to be encouraged for drinking water sources
- ❑ State of the art suggests the following structures in the Humid North western Himalayas and Himalayan foothills:
 - Roof Top Rain water Harvesting Structures.
 - Diversion of perennial springs and streams
 - Village ponds
 - Collection from hill slopes
 - Improvement in the roof structures and use of proper material such as corrugated sheets for generating higher runoff and with arrangements of foul slush diversion system and proper storage structures for checking the water from contamination (spring protection works & diversion).
 - State of the Art for the Himalayan foothills suggests that the following structures should be implemented:
 - Collection of surface run off from hill slopes
- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 234 crore in rural areas – 1500 sub-surface dykes, 336 revival of Kandi ponds



4.10 Jharkhand

- ❑ Large number of watersheds have been created but are insufficient to meet the prospective demand
- ❑ Formulation of State Water Policy is in progress
- ❑ 1394 rainwater-harvesting structures have been constructed during last 2 years.
- ❑ Hydro-geo-morphological setting, annual rainfall, study of GIS maps by State Space Application Centre are being considered for designs.
- ❑ Gabion structures with local material are being constructed.
- ❑ Check dams will be constructed across small streams with gentle slopes
- ❑ Big diameter wells are being constructed in the downstream of check dams for piped water supply to nearby habitations
- ❑ Roof top RHW, dug-well recharge and construction/ rejuvenation of old ponds are the main sustainability measures being taken up.
- ❑ CGWB Master Plan is for combined Bihar & Jharkhand. Please refer Bihar state observations.



4.11 Karnataka

- ❑ Convergence of activities of Departments of Agriculture, watershed Development, Major & Minor Irrigation, Mines & Geology, CGWB, Remote Sensing Application Centre and RD&PR are being taken up for water harvesting structures.
- ❑ In addition to the structures already mentioned in the Reference Manual, point-recharge techniques, temporary bandharas and point recharging through defunct borewells may be included.
- ❑ The total cost of Sustainability component should be borne by Government of India
- ❑ A comprehensive plan for drinking water supply for all habitations is being prepared with compulsory inclusion of element on water harvesting.
- ❑ The State has already devised a matrix showing technologies for ground water recharge in each district, geology-wise and topography-wise.
- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 1233 crore in rural areas – 1040 sub-surface dams, 5160 percolation tanks/desilting of old tanks, 17182 check dams.



4.12 Kerala

- ❑ Technology options can be adopted in the state. Design of option can be finalized after detailed hydro-geological investigation.
- ❑ In Kerala, KWA is the most appropriate technical agency to address the quality and quantity issues. Financial and other resources would be extended to KWA by GoI for optimum design and scientific investigation of sustainability intervention.
- ❑ District Water Security Plan: Inter-district water security plan is required to be prepared in such cases, where the sources lie in one district and the habitation lies in the other district.
- ❑ Environmental issues: Fresh water should be protected with tree plantation 50 m around the lake and area within 50 m around the lake shall be declared as a free zone with afforestation plan. Construction of leading channels, grit / slit trap to avoid excess turbidity/siltation also needs to be promoted in addition.
- ❑ Draft modified policy for State with emphasis on Sustainability action is being taken up to approve draft policy.
- ❑ State is celebrating “Jal Varsham” with Action Plan for awareness, sustainability projects, implementation of projects etc.
- ❑ Action is being taken to construct / identify observation wells in each habitation under the WQ Monitoring & Surveillance programme.
- ❑ Water management initiatives under the river basin management programme
- ❑ Excess sand mining in river bed prevented by Govt. orders
- ❑ RWH made compulsory for newly constructed houses and buildings
- ❑ Ground water potential studies are in progress.
- ❑ Due to peculiar physiography, the total run-off is not being tapped as the intensity of rainfall in short periods is high. Concerted efforts amongst various departments are required for surface water harvesting.





- ❑ Limitation of funds at various sectors results in poor achievements of goals
- ❑ Technical options currently in use in Kerala:
 - Dugwells,
 - Sub-surface dykes,
 - Surface water spreading methods are being proposed.
- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 1221 crore in rural areas – 4312 check dams, 7180 sub-surface dykes, 10780 gully plugs/ nalabunds



4.13 Madhya Pradesh

- ❑ In some districts, water re-use schemes as part of Wise-water management has been implemented with the support of Unicef and NEERI in hostels, ashrams, schools and institutions.
- ❑ The Sustainability works will be implemented through the PRIs.
- ❑ Integration of efforts with “Jalabhisek” for water conservation and recharge would be taken up.
- ❑ NREGS is already being dovetailed for water conservation and harvesting works in many districts of the State.
- ❑ 100% funding is requested from Government of India for Sustainability projects.
- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 1909 crore in rural areas – 5302 percolation tanks, 20,198 nala bunds/ cement plugs/ check dams, 23181 gravity heads/ dug wells/ tube wells/ recharge shafts, 69,589 gully plugs and gabion structures (some structures are included for urban areas also).





4.14 Maharashtra

- ❑ State Government has launched Shivkalin Pani Sathvan Yojana in 2002. under this scheme, rainwater is collected on public or private buildings for its use directly or for source recharge.
- ❑ Construction of tanks in rocks and hilly areas, deepening of wells and tanks and construction of check dams are some of the rainwater harvesting techniques practiced by the States in scarcity affected habitations.
- ❑ The State Government has requested the GOI to allow to utilize more than 5% amount under ARWSP for sustainability measures.
- ❑ Guidelines have been issued in May 2004 to all Gram Panchayats for implementing rainwater harvesting structures which include :
 - Roof-top water collection from Govt. buildings and private houses
 - Construction of storage tanks in elevated areas of villages for storing rain and spring water
 - Recharging public drinking water sources by artificial recharge.
 - Unconventional methods like jacket wells, stream blasting, Bore Blasting Technique, Fractured Seal Cementation
- ❑ Women participation is ensured during source finalization





- ❑ Revival of traditional water bodies to be taken up.
- ❑ Sources are to be protected against ground and surface water contamination with respect to sewage disposal, industrial effluents, open defecation and use of chemical fertilizers in close vicinity.
- ❑ Ground water regulation Act has been enacted since 1993
- ❑ District-wise strategies have been worked out for technological options.
- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 2000 crore in rural areas – 8108 percolation tanks, 16598 cement plugs, 2300 recharge shafts, 3500 run-off harvesting.



4.15 Manipur

- ❑ All chapters in the draft Guidleiens are acceptable.
- ❑ There are no GPs in the hilly areas
- ❑ Implementation by VWSC is not practicable at this stage.
- ❑ Technological options like roof-top rain water harvesting, village pond/tank/ Oorany , spring water harvesting are suitable for implementation.
- ❑ For a family of 10 persons, 60 cum (60,000 litres) storage is being proposed for individual roof-top rainwater harvesting system for 5 months dry period.
- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 48.5 crore in rural areas – 300 check dams, 500 weirs, 500 gabion structures, 150 spring development works.



4.16 Meghalaya

- ❑ Deforestation need to be stopped immediately for preventing depletion of flow in surface water streams / sources.
- ❑ Series of impounding structures need to be created along the course of streams by outing check dams across the flow of streams at various places. These check dams will also helping arresting the silt flowing along the surface run off originating from the catchment and joining the stream flow. The impoundage thus created would not only fulfill the drinking water demand during the lean periods, but it would also help in maintaining the flow recharge in the stream and recharge in the bed.
- ❑ Ground water recharge is essential in some over-exploited areas.
- ❑ In limestone formation in Cherrapunji ground water retention capacity is lowered. In these areas, RWHS would be the most suitable option. A comprehensive Water Balance Study needs to be conducted in such areas.
- ❑ Unique situation is being faced in Khasi Hills, Jaintia Hills, Ri Bhoi Hills, where ownership of the land is directly connected with the ownership of the resources, hence works related to ground water recharge or storage ponds etc including recharge structures, projects on RWHS can not be taken up without the consent of the land owner.
- ❑ Scope for judicious and conjunctive use of surface and ground water for drinking and irrigation needs and hydel power generation needs to be studied thoroughly for assessing the shortfall in these areas.
- ❑ Off stream reservoirs are required to be planned in the flood prone areas specially in Garo Hills and other foothill areas where during the rainy season flood water can be diverted to an off shore reservoir.
- ❑ According to the State of art presented for Humid High rainfall North Eastern zone, the following structures have been prescribed for Sustainability of Drinking Water Sources:
 - Roof Top Rain water Harvesting Systems.
 - Diversion of perennial springs and streams in a storage structure
 - Recommended structures are following:
 - Improvement in roof top rain water harvesting structures and use of proper material such as corrugated sheets for generating higher run off and with arrangement of food slush diversion system and proper storage structure for checking water from contamination.
- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 53.5 crore in rural areas - 300 check dams, 600 weirs, 600 gabion structures and 200 spring development works.



4.17 Mizoram

- ❑ State Government is already implementing individual roof-top rainwater harvesting structures, impounding dams/ reservoirs and improvement of village spring sources under Sustainability component of ARWSP. 24,185 RWH structures, 1242 no.s of improvement of village spring sources and 24 impounding dams have been constructed so far.
- ❑ Mizoram Water Supply Act has been enacted in 2006 for preserving and reserving water storage with catchment areas.
- ❑ Use of HGM maps, ground water atlas maps and other technical data like vertical electrical soundings, survey instruments like Terrametre SAS 300 C make more progress in ground water investigation and development with a success rate upto 70%.
- ❑ Artificial recharge through impounding, sub-surface dykes and percolation tanks will be introduced from the present working season ie., October 2007.
- ❑ State Government requested to launch NREGS, CGWB and XII-Finance Commission programmes for accelerating progress in the field of Sustainability.
- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 82.5 crore in rural areas – 500 check dams, 1000 weirs, 100 gabion structures, 200 spring development works



4.18 Orissa

- ❑ Artificial recharge has been sanctioned by the State Committee for 2 projects in Nayagarh district to tackle 36 fluoride-affected habitations as technology option
- ❑ Potential sites for recharge structures have been identified with the help of Hydro geological, geo-physical and remote sensing studies.
- ❑ Long term and short term measures have been conceived along with People's participation in the Comprehensive programme of Implementation, Monitoring and Maintenance of Recharge structures.
- ❑ To record the improvement in ground water level and quality for atleast 3-5 years since commissioning of these structures.
- ❑ Recharge structures are maintained by Community by periodical cleaning and development of recharge borewells with air-compressors atleast once in a year
- ❑ Sand Media at the top of one metre in Recharge pits is cleaned every year during Pre-monsoon period.
- ❑ Hydro geological investigations to ascertain the controls of high fluoride in ground water.
- ❑ Recharge of ground water through in-situ recharge of defunct borewells under favourable geo-morphological conditions will be taken in the long term Action Plan.
- ❑ Maintenance of drinking water sources have been handed over to PRIs
- ❑ Revival of traditional sources is taken up by RWSS, Watershed Mission and Forest Department
- ❑ Spring based water supply schemes in hilly terrain of Koraput district have been taken up under low-cost technological options.
- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 414 crore in rural areas – 569 percolation tanks, 761 converted percolation tanks, 698 sub-surface dykes, 809 nala contour bunds, 679 check dams/ weirs, 1981 spreading basins, 668 induced recharge



4.19 Punjab

- ❑ Handing over of Operation and Maintenance of Rural Water Supply to Panchayats for 749 schemes is completed. Out of 749 schemes, 554 schemes are running satisfactorily.
- ❑ RWHS in newly constructed as well as Government buildings Rs.12.11 lakhs worth RWHS constructed in Hemkunj rest house of Punjab Government in Shimla storage capacity 135 cu.m. Each for 2 structures is created including installation of sprinklers platform for washing clothes have been constructed. Stored rainwater is used for irrigation, kitchen garden and clothes washing during dry season.
- ❑ RWHS constructed in new District Administration complex, Patiala provides storage tanks as well as ground water recharge facilities after passing it through filter bed into the shallow injunction wells. RHWS are constructed in all Government buildings.
- ❑ Irrigation Department has constructed trenches with filter beds/ shallow injunction wells in the bed of trenches in Patiala and Sangrur under the guidance of Central Ground Water Board on pilot basis.
- ❑ Department proposes to install rainwater harvesting system on all water works of Rural Water Supply schemes. Abandoned tubewells are proposed to be utilized for ground water recharge as injunction wells.
- ❑ Waste water in 122 villages is proposed to be recycled / reclaimed for its use for irrigation purpose. After treatment in Treatment plants cost of project is Rs.94 crore.
- ❑ Under World Bank project low cost sanitation components will be implemented in 150 villages for utilizing the treated waste water for irrigation purpose. In addition, 1000 village ponds are proposed to be remodeled by treating rain water in them and utilizing rain water for fish culture and cattle drinking purpose (water management).
- ❑ All the funds under various programmes are proposed to be dovetailed for achieving maximum progress in sustainability of RWS schemes.
- ❑ Institutional and M & E mechanism is supported as per draft guidelines of GOI.
- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 400 crore in rural areas – 40,030 recharge shafts/ recharge trenches



4.20 Puducherry

- ❑ Government buildings are being provided with roof-top rainwater structures and public are being motivated to construct such structures in newly constructed buildings for recharging the ground water.
- ❑ 84 tanks are constructed for storing water for irrigation and recharging of ground water. PWD is maintaining all these tanks.
- ❑ All tanks and ponds are being rejuvenated by desilting and deepening measures through “Tank Rehabilitation project” launched in 1999 with 80% financial support of European Commission, remaining through State funds and Contribution made by Water Users Association.
- ❑ All water bodies get filled up to their full capacity during NE monsoon period, which help in recharging of ground water and preventing sea-water intrusion.
- ❑ Bed dams and check dams have been constructed at many places for scaling up the ground water table.
- ❑ Agriculture Department is also implementing construction of percolation ponds and infiltration points for water sustainability. Convergence is being ensured by PWD between similar programmes being implemented by other departments.
- ❑ Sub-surface and Sand dams will be constructed to reduce the risk of contamination of ground water.
- ❑ PWD will organize programmes in association with members of local bodies to attain total water security in the larger interest of the Public.
- ❑ Cattle drinking water requirements will also be taken up with the Animal Husbandry department.
- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 2.2 crore in rural areas – 5 percolation tanks, 14 recharge pits, 20 check dams, 40 desilting ponds, 10 nala bunds and 20 desilting/ recharge wells



4.21 Rajasthan

- ❑ State Government has launched Jal Abhiyan and Jal Chetna in 2006 under convergence of Irrigation and PR Departments for sustainability of water resources.
 - ❑ For total drinking water security, approach has been proposed from smallest unit of a household to district, with use of low-cost options for harvesting the water and recharging the ground water.
 - ❑ Incentive is required to all households for promoting the programme of rainwater harvesting.
 - ❑ The tank capacity of households may be restricted to a reasonable capacity by diverting surplus water to common village tanks through pipelines for use by houses not having pucca roof. To give a legal shape, MoU has to be devised between VWSC and households.
 - ❑ Insitu dilution of contaminants in water quality affected habitations through surface water harvesting takes a very long time and cannot be treated as a short term measure.
 - ❑ 80-days storage of rainwater harvesting structure will be insufficient in most critical period of Summer season. 300-335 days dry period should be considered for working the storage capacity of water harvesting tanks.
- 
- ❑ Small water bodies with lower depths will not be able to control evaporation losses. Chemical sprays to control evaporation require special attention.
 - ❑ Surface water treatment for water stored in ponds is very costly. A thought should be given to domestic treatment, as being adopted for fluoride affected water.
 - ❑ VWSC shall be entrusted to take up Sustainability works. They require capacity building for the same.
 - ❑ Funding pattern prescribed for Pond, Khadina nd nadi needs review for making them more realistic.
 - ❑ Financial limits for IEC and HRD are conservative and needs review.
 - ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 740 crore in rural areas – 3228 percolation tanks, 1292 anicuts, 2871 recharge shafts



4.22 Sikkim

- ❑ Drinking water sources are surface sources like springs and rivers. Besides, ground water sources have been identified in the South and East districts of the State
- ❑ Water balance study to assess the availability Vs draft of water is to be carried out. Assessment of total water resources with respect to draft projected for future projects.
- ❑ Catchment treatment, surface water harvesting and spring protection measures have to be taken up.
- ❑ Slope protection measures have to be implemented.
- ❑ Types of structures suggested include:
- ❑ Soil erosion control measures.
 - Contour bunding/ Bench terracing.
 - Series of check walls.
 - Rapids along with the water courses.
 - Plantation along the hill slopes.
- ❑ Convergence with other programmes needs to be taken up. Common guidelines to be implemented for all agencies working on water sustainability works.
- ❑ Transfer of O&M in a phased manner.
- ❑ Latest mapping for delineating surface features of the catchment areas and sources
- ❑ Construction of Roof Top Rain Water Harvesting Structures. Legislative measures to include mandatory construction of Roof Top Rain Water Harvesting Structures in all public buildings/ houses.
- ❑ Source protection through catchment treatment and prevention of open defecation. Revival of traditional sources of spring water, revival of ponds. Protection of slopes from soil erosion, land slides; Proper catchment treatment measures to be taken up. Depletion of the flow in the streams can be checked by taking up of afforestation activities.
- ❑ Drinking water needs for Cattle has to be addressed.
- ❑ Promotion of household level filters for removing the bacterial contamination.
- ❑ Types of Sustainability structures suitable to the hilly terrain in North eastern states would be applicable in case of Sikkim also.
- ❑ Suitable structures for the State of Sikkim are as follows:



- Roof Top Rain Water Harvesting structures.
 - Diversion of perennial springs and streams in a storage structure.
 - Improvement of roof structures and use of proper material such as corrugated sheets for generating foul slush diversion system for proper storage structures for checking water from contamination.
- As per CGWB Action Plan, the following structures are proposed at a cost of Rs 103 crore in rural areas – 2100 spring development, 2500 cement plugs/ nala bunds, 5300 gabion structures



4.23 Tamil Nadu

- ❑ To use GIS for preparation of drinking water security plans
- ❑ For all roof-top RWH structures, suitable filter media preferably with sand, charcoal and pebbles is essential.
- ❑ Silt control devices are required for Percolation ponds with periodic desilting practices.
- ❑ Wherever large capacity ponds are to be designed, a buffer tank can be created within the percolation pond at the inlet channel, separated by an earthen bund.
- ❑ Check dams are to be constructed in the areas where the water level is moderately deep to facilitate augmentation of ground water.
- ❑ Ponds, tanks and Ooranies should be fenced appropriately.
- ❑ The Remote sensing data, satellite imagery and aerial photographs are utilized for preparation of Taluka-wise Hydro-geological maps and block-wise HGM maps. 110 out of 385 blocks in the State were identified and taken up as hard core and difficult areas.
- ❑ Overall success rate for source creation activities using HGM maps works out to 98%.
- ❑ Allocation under Sustainability needs to be enhanced to 15-20% of ARWSP funds.
- ❑ Observation of water level is done twice a year in 1286 wells.
- ❑ Ground water recharge is achieved through construction of recharge structures like check dams, percolation ponds, recharge pits and recharging trenches.
- ❑ Monthly monitoring of Impact assessment of the recharge structures constructed is being done.
- ❑ Observation of water quality and water levels are being monitored through 500 observation wells on river beds, twice a year.
- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 2086 crore in rural areas – 8612 percolation ponds, 18170 check dams





4.24 Tripura

- ❑ Sustainability projects have to be fully funded by GOI both for material and labour costs.
- ❑ Tribal population should be exempted from O&M responsibility and monitoring the quality and quantity of water in hilly areas of the State.
- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 47 crore in rural areas – 300 check dams, 500 weirs, 1000 gabion structures and 100 spring development works.



4.25 Uttarakhand

- ❑ Monthly measurement of discharges will help to understand the fluctuations and natural behaviour of surface water sources in a better manner.
- ❑ Catchment area of surface water sources should be conserved from deleterious human interference of any nature.
- ❑ Dependency of local community for fuel and fodder on catchment areas of water sources should be marginalized by managing their requirement through other sources like LPG gas cylinders and animal feeds.
- ❑ Forestry activities should be appropriately linked with conservation of soil and water.
- ❑ Afforestation of species like Banj, Buransh, Mura, Uttis should be planted for enhancing soil and water retention capacities of the catchments.
- ❑ Capacity building plan for all conserved at various stages of planning, execution of water supply schemes needs to be elaborated.
- ❑ Relaxation of Forest (Conservation) Act, 1980 should be taken up for carrying out Source sustainability and other relevant works in the forest land.
- ❑ Combined with Uttar Pradesh State – for CGWB Action Plan



4.26 Uttar Pradesh

- ❑ 141 blocks in 36 districts out of 820 blocks in the State have been identified with water table 8m bgl. Only in these blocks, ground water recharge measures are to be adopted.
- ❑ Augmenting ground water recharge through spreading technique in alluvial areas, check dams and percolation tanks and direct injection methods utilizing the abandoned structures in large number in the hard rock region are practiced.
- ❑ 37 check dams have been constructed from 5% ARWSP funds so far. Another 23 check dams, 3 ponds and 199 ground water recharging projects through borewells are under construction in problem areas.
- ❑ 3365 structures have been proposed during the Xi-plan period at an estimated cost of Rs 100 crore for sustainability of drinking water sources.
- ❑ Efforts have been made to dovetailing check dams with NREGS in the districts of Chitrakoot, Kaushambi and Mainpuri.
- ❑ Co-ordination is required at various levels as guidelines under different programmes vary. State Ground Water Board has been nominated as the Nodal department for technical co-ordination.
- ❑ UP and Uttaranchal States - As per CGWB Action Plan, the following structures are proposed at a cost of Rs 3561 crore in rural areas – 4410 percolation tanks, 12600 check dams/ cement plugs, 2,12,700 recharge shafts



4.27 West Bengal

- ❑ Average rain fall varies from 1000-1200 mm in Bankura, Bhirkhum & Purulia districts to 1500-1700mm in the gangetic plain to 3000-3500 mm in the hilly areas of Darjeeling.
- ❑ Ground water is abstracted and supplied either through hand pumps or big diameter pumps fitted tube-wells supplying piped water supply.
- ❑ Use of spring water, sub-surface water of river, impounded water in Dams and Barrages, storage and use of pond water and use of roof top rainwater have been tried and successfully implemented at different parts of the State.
- ❑ Geo-hydrological map of the State has already been prepared and enclosed.
- ❑ In the mountainous region of Himalayas at the northern part of the State, hill springs are used as main source of drinking water, and supplied to people after adequate treatment.
- ❑ In Terai region of foot hills, ground water is difficult to abstract due to boulder formation. Odex drilling is being resorted to, to improve drilling performance.
- ❑ Ground water in the alluvium region is abundant and are being tapped through spot sources.
- ❑ Arsenic affected areas of the State is fully in alluvium region and surface water, wherever available, has been tried as alternative in such areas.
- ❑ In Purulia, parts of Bankura, West Midnapur, Birbhum and Bardhaman districts, fluoride is dominant in ground water. Rig bored tube-wells constructed by DTH rigs drawing ground water from the cracks and fissures of rocks is the major source of drinking water in these areas. There are number of piped water supply schemes drawing water from sub-surface of river impoundment of Dams and Barrages. Roof top rainwater harvesting is also picking up in these areas.
- ❑ Ground water in the Southern part of the State is saline due to sea water intrusion. Pond based water supply arrangement after treatment is gradually coming up in these areas. Membrane based desalination plant has also been installed in one area of North-24 Paraganas.
- ❑ All ground water based piped water supply systems are selected after building in element of sustainability upto the design period.
- ❑ Agencies like CGWB, State Water Investigation Director (SWID) are working on improving the situation considerably. They have also constructed successfully number of Ground water recharge structures.
- ❑ Fluoride Task Force constituted by the State Government has taken up pilot project on artificial recharge in Birbhum and Bankura districts to observe the dilution effect of excess fluoride in ground water.
- ❑ Two methods of rainwater harvesting are adopted viz., Harnessing surface water from rocky formations with a rock masonry dam and semi-circular clayey earthen dam for clay-rich soils. Out of the two methods, rock masonry dam is preferred as it provides quality water.
- ❑ Impoundment of water in bandhs and dams in the districts of Bankura, Purulia, Bardhaman and Paschim Midnapore was taken up in 10 schemes at a cost of Rs 92 crore to benefit a population of 6.29 lakh.
- ❑ Roof top rainwater harvesting system is best suited to Darjeeling area where the rainfall is very heavy. The State has already sanctioned 7 schemes at a cost of Rs 34 lakh. Also, during 2005-06, execution of 8 schemes of roof top rainwater and 2 schemes on impoundment of water at a cost of Rs 2.63 crore was sanctioned by the State Government.
- ❑ West Bengal Pollution Control Board and Institute of Environmental Studies and Waste Land Management have taken up 40 projects on roof-top rainwater harvesting in various schools.
- ❑ Rural areas of West Bengal have large number of ponds ranging from smaller to moderate capacities. 11 Schemes on Pond based water supply in various districts have been sanctioned at an estimated cost of 1.7 crore to benefit a population of 31,690 (2001 census).
- ❑ PHED and Panchayat & Rural Development Department have jointly put forth an effort whereby it has been proposed that the panchayat will identify the location and creation of rain water ponds under various programme like NREGA, IWDP, Hariyali, etc. A model design and drawing on such rain water ponds and Hydrogeology and Water Quality Map are given in Appendix-VII.
- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 1333 crore in rural areas – 11,200 percolation tanks with shafts, 3606 gabion structures, 1054 nala bunds/ cement plugs, 1680 re-excavation of ponds, 500 desiltation of village ponds, 1000 spring development works, 70 sub-surface dykes.



4.28 Nagaland *

- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 82.5 crore in rural areas – 500 check dams, 1000 weirs, 100 gabion structures, 200 spring development works

4.29 Andaman & Nicobar Islands *

- ❑ However, traditional water storage structures like “Digies” as locally called in the islands still exist.
- ❑ Spring water harvesting is also practiced in Nicobar islands
- ❑ Huge water harvesting structures like “Dhanikedi dam”, “Jawahar sarovar” are existing for providing water supply
- ❑ 145 spring developments, 270 cement plugs and 38 percolation tanks, 150 sub-surface dykes are proposed as per CBWB Master Plan at a cost of Rs 23 crore.

4.30 Chandigarh *

- ❑ 597 recharge trenches, trenches and gabion structures are proposed as per CGWB Master Plan at cost of Rs 6 crore in both rural and urban areas.

4.31 Dadra & Nagar Haveli *

Specific suggestions are yet to be received from the UT

- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 2 crore in rural areas – 50 check dams/ cement plugs, 58 sub-surface dykes.

4.32 Daman & Diu *

- ❑ No recharge structures are proposed as per CGWB Action Plan in rural areas.

4.33 Delhi *

- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 232 crore in rural areas – 23 percolation tanks, 23 existing dug wells, 10 nala bunds, 19,216 lateral trench with recharge wells.

4.34 Goa *

- ❑ As per CGWB Action Plan, the following structures are proposed at a cost of Rs 63 crore in rural areas - 1410 check dams/ Kolhapur weirs,

4.35 Lakshadweep *

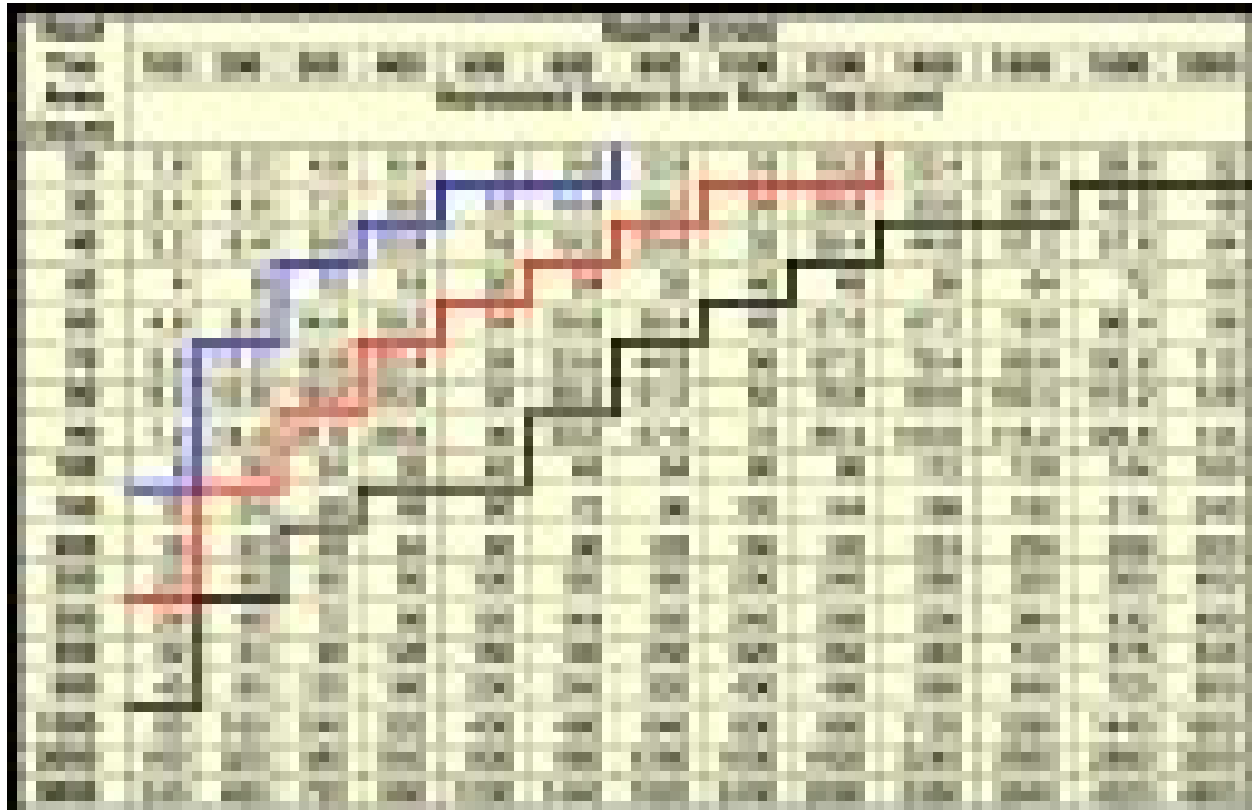
- ❑ All the islands are already having individual roof-water harvesting structures.
- ❑ Additionally, CGWB Master Plan proposes 1000 structures for urban area at a cost of Rs 10 crore.

* :: Assessment of Department of Drinking Water Supply, Ministry of Rural Development, GOI. States/ UT views were not received at the time of printing this document.



APPENDIX - I : REFERENCE TABLES AND DESIGN EXAMPLE OF ROOF TOP HARVESTING

Table A-1.1 : Water Availability for a given Roof Top Area and Rainfall



- (a) Figure A-1.1 (blue line) - 100% runoff (100% of rainfall)
- (b) Figure A-1.1 (red line) - 50% runoff (50% of rainfall)
- (c) Figure A-1.1 (black line) - 25% runoff (25% of rainfall)
- (d) Figure A-1.1 (grey line) - 10% runoff (10% of rainfall)
- (e) Figure A-1.1 (green line) - 5% runoff (5% of rainfall)
- (f) Figure A-1.1 (yellow line) - 2% runoff (2% of rainfall)
- (g) Figure A-1.1 (orange line) - 1% runoff (1% of rainfall)
- (h) Figure A-1.1 (purple line) - 0.5% runoff (0.5% of rainfall)
- (i) Figure A-1.1 (brown line) - 0.2% runoff (0.2% of rainfall)
- (j) Figure A-1.1 (pink line) - 0.1% runoff (0.1% of rainfall)
- (k) Figure A-1.1 (grey line) - 0.05% runoff (0.05% of rainfall)
- (l) Figure A-1.1 (brown line) - 0.02% runoff (0.02% of rainfall)
- (m) Figure A-1.1 (pink line) - 0.01% runoff (0.01% of rainfall)
- (n) Figure A-1.1 (grey line) - 0.005% runoff (0.005% of rainfall)
- (o) Figure A-1.1 (brown line) - 0.002% runoff (0.002% of rainfall)
- (p) Figure A-1.1 (pink line) - 0.001% runoff (0.001% of rainfall)
- (q) Figure A-1.1 (grey line) - 0.0005% runoff (0.0005% of rainfall)
- (r) Figure A-1.1 (brown line) - 0.0002% runoff (0.0002% of rainfall)
- (s) Figure A-1.1 (pink line) - 0.0001% runoff (0.0001% of rainfall)
- (t) Figure A-1.1 (grey line) - 0.00005% runoff (0.00005% of rainfall)
- (u) Figure A-1.1 (brown line) - 0.00002% runoff (0.00002% of rainfall)
- (v) Figure A-1.1 (pink line) - 0.00001% runoff (0.00001% of rainfall)
- (w) Figure A-1.1 (grey line) - 0.000005% runoff (0.000005% of rainfall)
- (x) Figure A-1.1 (brown line) - 0.000002% runoff (0.000002% of rainfall)
- (y) Figure A-1.1 (pink line) - 0.000001% runoff (0.000001% of rainfall)
- (z) Figure A-1.1 (grey line) - 0.0000005% runoff (0.0000005% of rainfall)

Table A-1.2 : Diameter of Gutter and Width of G.I. Sheet

[illegible]



Table A-1.3 : Size of Storage Tank

(Depth of live storage above the outlet pipe = 1.4 m)

Tank Capacity (in cum)	Diameter of Tank (in m)
1.60	1.21
2.40	1.48
3.20	1.71
4.00	1.91
4.80	2.09
5.60	2.26
6.40	2.41
7.20	2.56
8.00	2.70
9.60	2.95
11.20	3.19
12.00	3.30
12.80	3.41
14.40	3.62
16.00	3.81
16.80	3.91
19.20	4.18
20.00	4.26

Note: For rural areas the diameter of tank may be limited to 3 m. The tank would be adequate to meet the drinking water requirements of a family of 5 members for 6 months. For large storage two or more tanks may be provided instead of a single large tank.

DESIGN EXAMPLE

A house has a slopping roof of G.I. sheet with an area of 50 sq.m. The owner of the house has a family of 5 members. Design a roof water harvesting system. The 10 year rainfall for the areas is as follows:

Year 1	320 mm
Year 2	360 mm
Year 3	311 mm
Year 4	290 mm



Year 5	330 mm
Year 6	280 mm
Year 7	335 mm
Year 8	380 mm
Year 9	355 mm
Year 10	340 mm

The maximum rainfall intensity is 10 mm/hour. The lower edge of the roof is 3 m above the ground. Arranging the rainfall in descending order: 380, 360, 355, 340, 335, 330, 320, 311, 290, 280

The first figure if 380 mm is equalled or exceeded only once in 10 years. Therefore, its expected return period is 1 in 10 years. This is rare. On the other hand the last figure of 280 mm is equalled or exceeded in all the 10 years. Thus is the most reliable figure. So let's design the system for this figure.

From Table 1, for the roof area of 50 sq.m and rainfall of 280 mm, the available water = 11.2 cum = 11,200 litres.

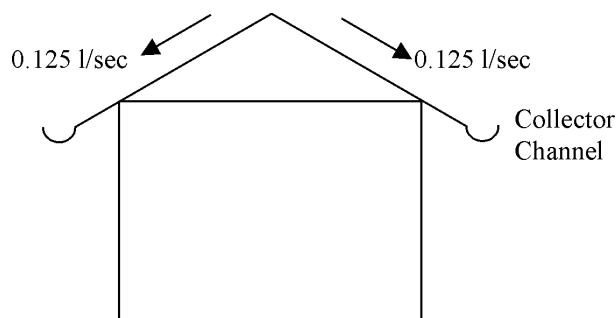
Allowing a consumption of 10 lpcd this water should be sufficient for 224 days or at least 7 months. In rural areas houses are of low height. So let's limit the height of the tank to 1.6 m with water storage upto 1.4 m height.

A tank of 3.2 m dia and 1.4 m height should be adequate. However provide an extra 0.2 m height to allow for fixing overflow pipe and dead storage below the outlet (tap). Provide a tank size of 3.2 m dia and 1.6 m height.

Size of Collector Channel (Gutter)

During heavy rains i.e. with maximum intensity of 10 mm/hr the runoff coefficient may be taken as 0.9 i.e. assuming a net loss of 10% of rainfall. Maximum rate of runoff from the roof on either side (ignoring the concentration time for runoff i.e. instant generation of runoff is considered)

$$= \left[\frac{10.0}{1000} \times \frac{50 \times 0.9}{2 \times 3600} \right] = 0.000125 \text{ cum/sec} = 0.125 \text{ litres/sec}$$

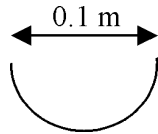


Provide a minimum slope of the collector channel of 5 cm in a length of 10 m i.e. 1 in 200



Trial - I

Providing a collector channel of 0.1 m diameter



$$\text{Area, } A = \frac{1}{2} \pi \frac{D^2}{4} = \frac{1}{2} \times \pi \times \frac{0.01}{4} = 0.003925 \text{ sq.m}$$

$$\text{Perimeter, } P = \frac{\pi D}{2} = 3.14 \times \frac{0.1}{2} = 0.157 \text{ m}$$

$$\text{Hydraulic Mean Depth, } R = \frac{0.003925}{0.157} = 0.025 \text{ m}$$

Providing a slope of 1 in 200 for the collector channel,

$$\begin{aligned} \text{Velocity of flow, } v &= \frac{1}{0.025} \times (0.025)^{2/3} \times \sqrt{\frac{1}{200}} \\ &= \frac{1}{0.025} \times 0.0855 \times \frac{1}{14.14} = 0.24 \text{ m/sec} \end{aligned}$$

$$\text{Discharge, } q = A \times v = 0.003925 \times 0.24$$

$$= 0.000942 \text{ cumecs}$$

against the design discharge of 0.000125 cumecs

The channel is too oversized.

Trial - II

Let us try a channel of 0.05 m diameter

$$\text{Area, } A = \frac{1}{2} \times \pi \times \frac{(0.05)^2}{4} = 0.00098 \text{ sq.m}$$

$$\text{Perimeter, } P = \pi \times \frac{0.05}{2} = 0.0785 \text{ m}$$

$$\text{Hydraulic Mean Depth, } R = \frac{0.00098}{0.0785} = 0.0125 \text{ m}$$

$$\text{Velocity, } v = \frac{1}{0.025} \times (0.0125)^{2/3} \times \frac{1}{14.14} = 0.152 \text{ m/sec}$$

$$\text{Discharge, } q = A \times v = 0.00098 \times 0.152 = 0.000148 \text{ cumecs}$$

O.K.

The channel may be made of plain G.I. sheet. Width of the G.I. sheet required for channel

$$= P = 0.0785 \text{ m} = 78.5 \text{ mm}$$



Providing 25 mm extra for fixing with rafters/ purlins

Total width required = 78.5 + 25 = 103.5 mm

say 104 mm

Design of Base for the Tank

Total weight of water = 11.2 × 1 = 11.2 Tonnes

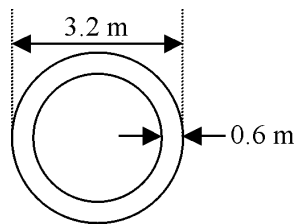
Dead weight of tank & cover (L.S.) = 0.3 Tonnes

Total = 11.5 Tonnes

Assuming bearing capacity of soil = 10 Tonne/sq.m

∴ Area of foundation = $\frac{11.5}{10} = 1.15 \text{ sq.m}$

Providing a minimum width of 0.6 m for foundation



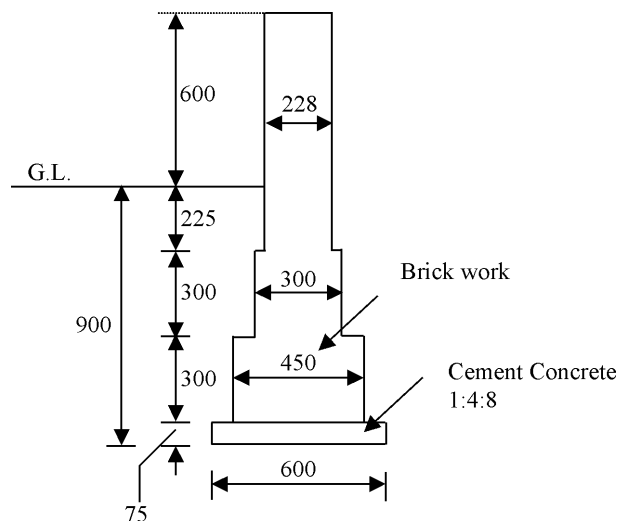
$$\begin{aligned} \text{Total area of foundation} &= \pi \times \frac{(3.2)^2}{4} - \pi \times \frac{(3.2 - 1.2)^2}{4} \\ &= \frac{\pi}{4} [(3.2)^2 - (3.2)^2 - (1.2)^2 + 2 \times 1.2 \times 3.2] \\ &= \frac{\pi}{4} \times (6.24) = 4.9 \text{ sq.m} \end{aligned}$$

Foundation is safe.

Provide 0.6 m wide circular foundation in cement concrete 1:4:8, 75 mm thick.

Depth of foundation – 900 mm below ground level.

Brick work in foundation to be provided in width of 450 mm to 228 mm in steps as shown in figure below:





Total Revenue in Millions in 2011	Best Customers		Average Customers		Worst Customers	
	Percentage of Millionaire net worth	Millionaire net worth (dollars)	Percentage of Millionaire net worth	Millionaire net worth (dollars)	Percentage of Millionaire net worth	Millionaire net worth (dollars)
\$0	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$1	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$2	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$3	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$4	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$5	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$6	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$7	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$8	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$9	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$10	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$11	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$12	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$13	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$14	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$15	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$16	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$17	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$18	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$19	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$20	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$21	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$22	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$23	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$24	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$25	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$26	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$27	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$28	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$29	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$30	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$31	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$32	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$33	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$34	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$35	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$36	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$37	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$38	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$39	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$40	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$41	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$42	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$43	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$44	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$45	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$46	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$47	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$48	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$49	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$50	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$51	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$52	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$53	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$54	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$55	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$56	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$57	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$58	0.00%	\$0.00	0.00%	\$0.00	0.00%	\$0.00
\$59	0.00%	\$0				

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APPENDIX - III

Run off from Treated Catchments (30 m dia) for rainfall range 130 mm to 317 mm

Sl. No.	Treatment	Percentage of utilisable rain water	Utilisable rain water (Cum)
1	Concrete (20% mixed)	51-87	48.30-194.38
2	Cement (8% mixed) with soil 1.20 cm thick	53-71	51.32-171.82
3	Mud Plaster (local) 1.20 cm thick	54-87	54.30-194.38
4	Lime-Concrete 5 cm thick	48-74	44.30-165.70
5	Stallum-concrete spray 40-71 kg/10sq.m over 1.20 cm thick compacted bank (H)	43-83	37.30-158.30
6	Mud Plaster - with mixture of mud, wheat husk (Ghussa) and Jandha (Pondicherry) (asphalt) - (80.00)	48-78	45.30-178.80
7	Total untreated and compacted without treatment	54-87	51.30-194.38

Note: For a given rainfall the utilisable rainwater can be suitably interpolated.

DESIGN EXAMPLE

Assuming that the average annual monsoon rainfall for a village is 220 mm and the natural catchment is flat, partly cultivated, with stiff sandy absorbent soil. Land is available only for one community Tanka with a catchment of 2 ha.

From Table A-3.1, it is seen that the catchment is "Average".

For 220 mm of rainfall the available rainwater = 2×68.58
= 137.16 cum

Assuming that we decide to treat a circular area of 30 m diameter around the Tanka with lime concrete.

From Table A-3.2, the utilisable rainwater from the treated catchment (by interpolation) = 102.58 cum.

Therefore, total amount of water from natural and treated catchment = $137.16 + 102.58 = 239.74$ cum

The site is therefore suitable for a standard community Tanka of 200 cum capacity.



APPENDIX - IV : DESIGN EXAMPLE OF PERCOLATION OF TANK

DESIGN EXAMPLE OF PERCOLATION TANK

Data

Catchment Area = 1.4 sq.km (0.549 sq.miles)

Nature of Catchment = Good

Average annual rainfall = 786 mm

65 percent dependable rainfall = 717 mm

Capacity Table for Tank

R.L. (m)	Capacity (MCM)
97.00	0.0070
97.50	0.0090
98.00	0.0105
98.50	0.0116
99.00	0.0120
99.50	0.0131
100.00	0.0139
100.50	0.0142

Yield from Catchment

From Strange's Table

Yield/sq. km for 717 mm rainfall = 0.187 MCM

Yield from the catchment = $0.187 \times 1.4 = 0.262$ MCM

Assumptions

- (i) Number of fillings per year = 2
- (ii) Utilisation of yield per filling = 5 percent

Design of Tank

Capacity of percolation tank = $0.05 \times 0.262 = 0.0131$ MCM

Total utilisation of yield per year = $2 \times 0.0131 = 0.0262$ MCM

Full Tank Level for capacity of 0.0131 MCM = 99.50 m

Crest level of spillway = 99.50 m



Providing 0.5 m head over the spillway crest

Maximum water level in tank = 100.00 m

Providing free board of 0.5 m above M.W.L.

Top of bund = 100.50 m

Design Flood

Where a formula applicable to a given situation is available viz. Dicken's or Ryve's formula. Assuming that following Dicken's formula is available. This gives flood discharge of 25 years frequency

$$Q = 1000 A^{3/4}$$

Where,

Q = Flood discharge in cusecs

A = Catchment area in sq.miles

$$Q = 1000 \times (0.549)^{3/4}$$

$$= 1000 \times 0.638$$

$$= 638.00 \text{ cusecs}$$

$$= 18.09 \text{ cumecs}$$

Length of Spillway

Head over spillway crest = 0.5 m

For weir discharge per m length, $q = 1.84 (h)^{3/2}$

$$\text{Length of spillway} = \frac{Q}{1.84(h)^{3/2}}$$

$$= \frac{18.09}{1.84 \times (0.5)^{3/2}}$$

$$= 27.82$$

Say 28 m

Design of Surplus Course

Area of flow = $(28+0.5) \times 0.50 = 14.25 \text{ sq.m}$

Bed slope = 1 in 750

$$P = 28 + (2 \times 1.118 \times 0.50) = 29.118 \text{ m}$$

Say 29.12 m



$$R = \frac{14.25}{29.12}$$

$$= 0.4894 \text{ m}$$

$$R^{2/3} = (0.4894)^{2/3} = 0.621$$

$$\text{Velocity} = \frac{1}{n} \times R^{2/3} S^{1/2}$$

$$= \frac{1}{0.025} \times 0.621 \times \frac{1}{(750)^{1/2}}$$

$$= \frac{1}{0.025} \times 0.621 \times \frac{1}{27.38}$$

$$= 0.907 \text{ m/sec}$$

$$\text{Discharge} = 14.25 \times 0.907$$

$$= 12.92 \text{ cumecs as against } 12.66 \text{ cumecs}$$

Hence safe

Depth of foundation

$$\text{Design flood discharge, } Q = 18.09 \text{ cumecs}$$

$$\text{Normal Scour depth, } R = 1.35 \left(\frac{q^2}{f} \right)^{1/3}$$

$$q = \frac{18.09}{28} = 0.646$$

$$\text{Assuming, } f = 1$$

$$R = 1.35 \left(\frac{0.646^2}{1} \right)^{1/3}$$

$$= 1.00 \text{ m}$$

$$\text{Scour depth} = 1.5 R$$

$$= 1.5 \times 1.00$$

$$= 1.5 \text{ m}$$

$$\text{Maximum scour level} = 100.00 - 1.50$$

$$= 98.50$$

$$\text{Height of body wall} = 0.90 \text{ m}$$

$$\text{Thickness of foundation concrete} = 0.15 \text{ m}$$



Foundation level = $99.50 - 0.90 - 0.15$
= 98.45 O.K.

Earthen Bund

Top width = 1.85 m

Side slopes : Taking into consideration the nature of soil and local practice, side slopes of 2:1 are proposed on both sides of the bund.



APPENDIX - V : DESIGN EXAMPLE OF CHECK DAM

DESIGN EXAMPLE OF CHECK DAM

Data

Catchment area = 15.68 sq. km (6.127 sq. miles)

Nature of Catchment = Good

Average annual rainfall = 825 mm

65 percent dependable rainfall = 717 mm

Gauge-Discharge Table

Discharge	Water Level
50	89.98
60	91.59
70	93.21
80	94.83
90	96.45
110	99.69
115	100.50

Yield from Catchment

From Strange's Table

Yield/sq. km for 717 mm rainfall is 26.08 percent of rainfall = 0.187 MCM

Yield from the catchment = 15.68×0.187
= 2.93 MCM

Design Flood

Where a formula applicable to a given situation is available viz. Dicken's or Ryve's formula. Assuming that following Dicken's formula is available

$$Q = 1000 A^{3/4}$$

$$Q = 1000 (6.127)^{3/4}$$

$$= 3894 \text{ cusecs}$$

$$= 110.37 \text{ cumecs}$$

Design of Sharp Crested Weir

$$\text{Discharge, } Q = 1.84 (L - KnH) H^{3/2}$$



Where,

L = Length of weir

K = Coefficient of end contraction (adopted 0.1)

n = Number of end contractions (in this case = 2)

H = Total head over spillway crest

Q = Discharge

Providing a total head (including velocity head of 0.05) = 1.05 m

$$\begin{aligned} 110.37 &= 1.84 (L - 0.1 \times 2 \times 1.05) 1.05^{3/2} \\ &= 1.84 (L - 0.21) \times 1.076 \end{aligned}$$

$$L = 55.95 \text{ m}$$

Say 56 m

$$\begin{aligned} \text{Discharge intensity, } q &= \frac{110.37}{56} \\ &= 1.97 \text{ cumecs} \end{aligned}$$

$$\begin{aligned} \text{Normal Scour depth, } R &= 1.35 \left(\frac{q^2}{f} \right)^{1/3} \\ &= 1.35 \left(\frac{1.97^2}{f} \right)^{1/3} \end{aligned}$$

Assuming, $f = 1$

$R = 2.12 \text{ m}$ below the maximum flood level

Computed flood level at weir site corresponding to the design discharge of 110.37 cumecs is 99.75 m

Keeping the crest level = 99.00 m

$$\begin{aligned} \text{Maximum water level} &= 99.00 + 1.05 \\ &= 100.05 \text{ m} \end{aligned}$$

Thus, there will be a net flood lift of $(100.05 - 99.75)$ i.e. 0.3 m at the weir site

$$\begin{aligned} \text{Depth of downstream cutoff} &= 1.5 R \\ &= 1.5 \times 2.12 \\ &= 3.18 \text{ m} \end{aligned}$$

$$\text{Desired R.L. of cut off} = 100.05 - 3.18 = 96.87 \text{ m}$$

Average bed level of deep channel is 97.30 m

Providing a minimum depth of 1 m for cutoff

$$\begin{aligned} \text{Actual R.L. of cutoff} &= 97.30 - 1.00 \\ &= 96.30 \text{ (against the desired level of 96.87)} \end{aligned}$$



Design of Weir Floor

Design flood = 110.37 cumecs

Length of weir = 56 m

Height of weir above the bed = $99.00 - 97.30$
= 1.7 m

Bottom width of weir = 1.6 m

Total maximum head, $H = 1.7$ m

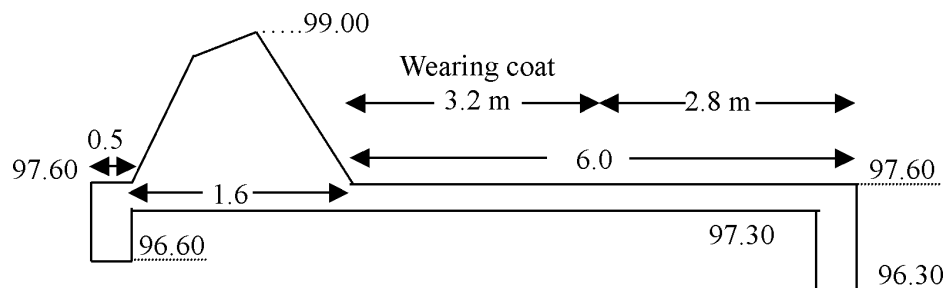
Total creep length required, $L = C \times H$

Adopting $C = 4$

$L = 4 \times 1.7$
= 7.22 m
Say 7.25 m

Length of downstream floor, $L_d = 2.21 C \sqrt{\left(\frac{H}{13}\right)}$
 $= 2.21 \times 4 \sqrt{\left(\frac{1.7}{13}\right)}$
= 3.19 m
Say 3.20 m

Provide a length of 6.0 m and provide wearing coat for 3.20 m.



Bottom level of downstream cutoff = 96.30

Assuming bottom level of U/S cut off = 96.60

Provide floor thickness = 0.3 m

Actual creep length = $1.0 + 0.5 + 1.6 + 3.2 + 2.8 + 1.3 = 10.4$ m against 7.25 m required.
Hence O.k.



Appendix-VI

Village Drinking Water Plans of Kachchh Region





Photo Gallery - Kachchh Region



DADOR SOLAR PUMP



NALIYA DRINKING WATER SCHEME



Appendix-VII

Annexure-I

MODEL SCHEME FOR DRINKING WATER SUPPLY ARRANGEMENT BASED ON RAIN WATER STORAGE POND. (Design population - 500, 1000, 1500)

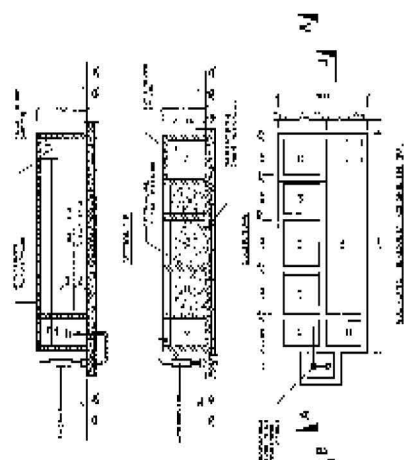
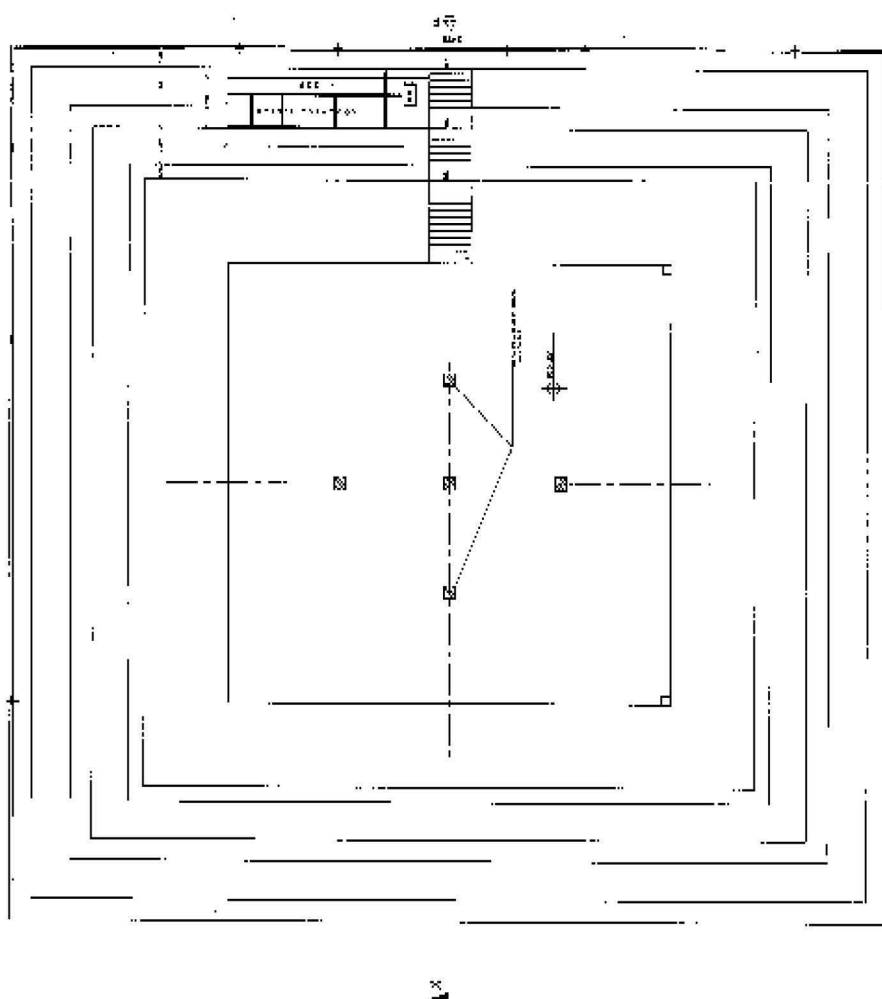
Design Calculations:

A. Pond:						
1.Type of area:	"A" (Annual rain fall ≥ 1600 mm)			"B" (1200 $\leq$ Annual rain fall < 1600)		
2.Design population:	500	1000	1500	500	1000	1500
3.Service level (lpcd)	10	10	10	10	10	10
(For Drinking & cooking only)						
4.Expected annual rain fall (mm)	1600	1600	1600	1200	1200	1200
5.No of non rainy days	270	270	270	270	270	270
6 a.Side slope of the tank (1In)	3	3	3	3	3	3
b. Slant length/vertical	3.16	3.16	3.16	3.16	3.16	3.16
7.Free board (m)	1	1	1	1	1	1
8.Dead storage (m)	0.5	0.5	0.5	0.5	0.5	0.5
(Including sludge accumulation)						
9 a.Berm width (m)	1.2	1.2	1.2	1.2	1.2	1.2
b.Top width of embankment	1.5	1.5	1.5	1.5	1.5	1.5
10 a.Daily water demand (lpd)	5000	10000	15000	5000	10000	15000
10 b.Annual water demand (Cu.m)	1825	3650	5475	1825	3650	5475
11.Top surface area reqd (Sq.m)	1141	2282	3422	1521	3042	4563
12. Net storage reqd (Cu.m)	1350	2700	4050	1350	2700	4050
13. Pond volume reqd (Cu.m)	2835	5670	8505	2835	5670	8505
(Ref. Cl. 6.5 of GOI manual on rain water harvesting and artificial recharge)						
14.Pond depth proposed BGL(m):	2.1	2.1	2.1	1.7	1.7	1.7
15.Mid depth area reqd. (Sq.m)	1350	2700	4050	1668	3335	5003
16.Size of the pond (square shaped), Length of side (m):						
At bottom:	30.7	45.7	57.7	35.9	52.9	65.9
At mid depth	37	52	64	41	58	71
At Ground level	43.3	58.3	70.3	46.1	63.1	76.1
At top of embankment	51.7	66.7	78.7	54.5	71.5	82.1
17.Land reqd. (Sq shaped) (mxm):	60.7	75.7	87.7	63.5	80.5	91.1
(Top width of embankment(m):1.5m + 1.5 m extra bottom of embankment - refer attached drawing)						
B. SSF Unit:						
Gross operating hour (7am-5pm):	10	10	10	10	10	10
Net operating hrs (80% of gross):	8	8	8	8	8	8
No of units proposed:	1	2	3	1	2	3
Plan area required:	6.25	6.25	6.25	6.25	6.25	6.25
Size:						
width (m):	1	1	1	1	1	1
Length (m):	6.35	6.35	6.35	6.35	6.35	6.35

Source : PHED, Govt. of West Bengal

[illegible]

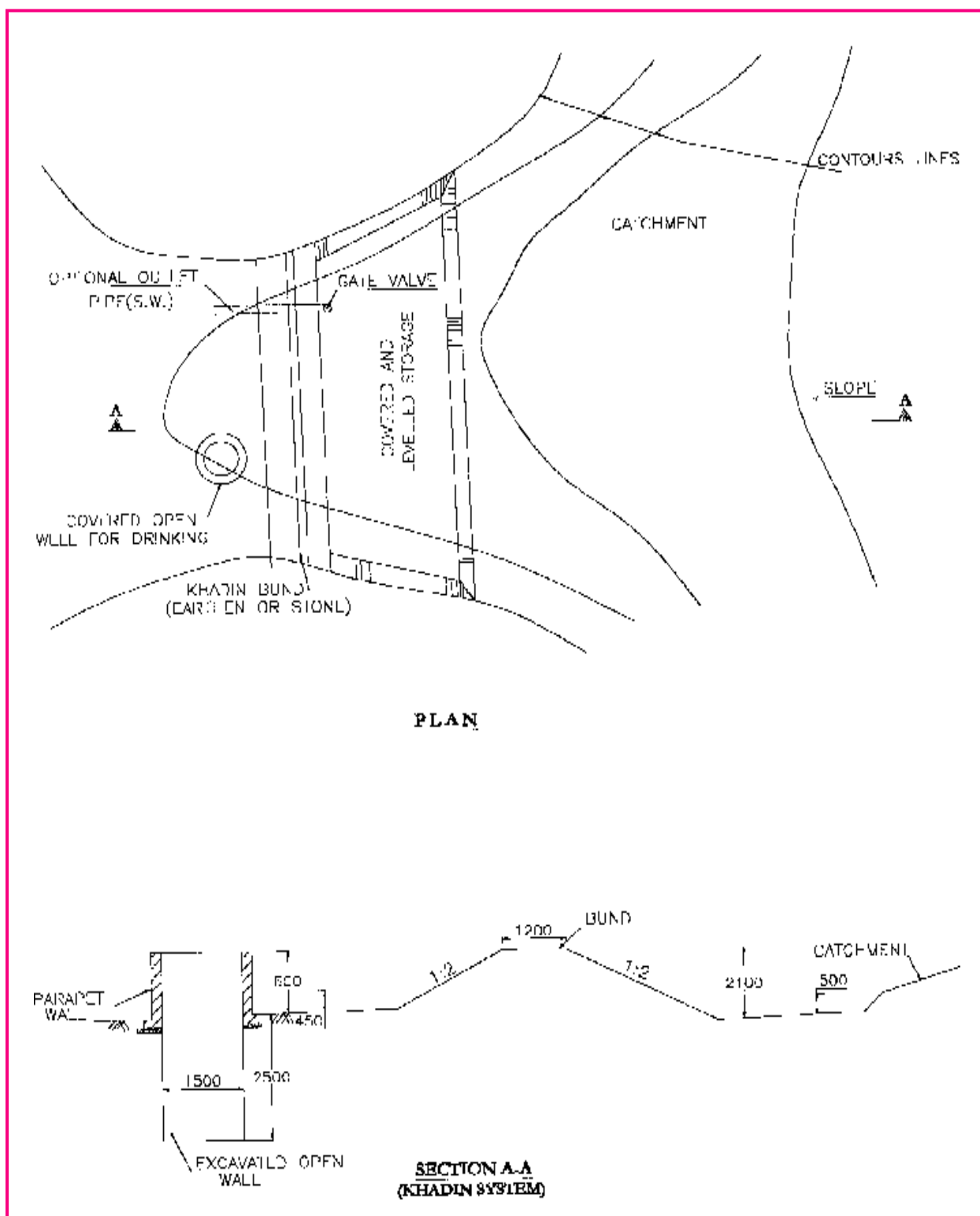
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FIGURE 1 : KHADIN SYSTEM





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Bringing Sustainability to Drinking Water Systems in Rural India



**Government of India
Ministry of Rural Development
Department of Drinking Water Supply
Rajiv Gandhi National Drinking Water Mission**



“Underneath the verandah in front of the room in which the abhatma was born, in the space enclosed by the three wings of the house, is an underground reservoir, 20 feet long, 20 feet wide and 15 feet deep, with a capacity of 20 thousand gallons, for storing rainwater for domestic use. The well water in Porbandar, owing to its vicinity to the sea, is brackish, hard and unfit for cooking. Rainwater was, therefore, collected and stored in the underground reservoir for use the year round. The terrace on the top floor, carefully washed before the first monsoon showers, served as catchment for the water, running down a pipe straight into the tank. heap of lime at the mouth of the pipe served to filter and purify the water”.

In this house five generations of Gandhis lived and prospered.

- Mahatma Gandhi

Vol 1 (The Early Phase) by Shri Pyarelal





रघुवंश प्रसाद सिंह
DR. RAGHUVANSH PRASAD SINGH



ग्रामीण विकास मंत्री
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MINISTER OF RURAL DEVELOPMENT
GOVERNMENT OF INDIA
KRISHI BHAWAN, NEW DELHI-110 001

29th June, 2007

Message

India is endowed with a rich and vast diversity in Natural Resources, “Water” is one of them. Integrated water management is vital for poverty reduction environmental sustenance and sustainable economic development.

Ours is a country with immense regional diversity and geo-hydrological features, cultural preferences and way of life which require diverse solutions as per local context. Thus there is need to look at traditional ways of life and wisdom in water management and sanitation that have sustained over years and try to refine and upgrade the same with new scientific knowledge. Sustainability in systems can be ensured when projects are managed at the grass roots for which demystification of technical knowledge and simplifications of technical know-how is fundamental and key to mass dimension and acceptance by rural Communities.

Unless safe drinking water and rural sanitation are taken up on a war footing, the health of rural citizens will not improve and our children will continue to live in unhealthy, unhygienic environments. Good sanitary conditions are indicators of the development status of a nation, and to achieve the mission of transforming India into a developed nation by 2020, good clean potable water in hygienic rural environments will be most important.

I am glad to note that the Department has prepared a document entitled “Bringing Sustainability to Drinking Water Systems in Rural India” in collaboration with the States and organizations working in this field. I am confident that this document will inspire and guide the users to plan for sustainability interventions and adopt a new approach to wise water management.

I hope the State Ministers of Water Supply will deliberate on these issues at the conference of State Ministers in-charge of Rural Drinking Water Supply and help us all achieve the goal of Reliable Drinking Water System at village level in every Panchayat and habitation.

I wish our combined efforts all success.

(Raghuvansh Prasad Singh)



चन्द्र शेखर साहू
CHANDRA SEKHAR SAHU



ग्रामीण विकास राज्य मंत्री
भारत सरकार
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MINISTER OF STATE FOR RURAL DEVELOPMENT
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NEW DELHI-110 001

M E S S A G E

I am happy that a conference of State Ministers-in charge of Rural Drinking Water and Sanitation has been organized by the Department of Drinking Water Supply, Ministry of Rural Development.

It is common knowledge that fresh water, a finite and fragile resource is increasingly becoming scarce day by day. Ground water is the principal source for rural water supply in many parts of the world catering to the requirements of one third of global population. Excessive withdrawal of ground water, more than recharge has become widespread resulting in appreciable fall in water level. Over extraction of ground water has also affected its quality leading to saline ingress in coastal areas. There are many natural constraints to access fresh water like uneven distribution, temporal and spatial variation in the climatic conditions and variations in geology and topography including soil cover. It is to be noted that some of the most water scarce countries in the world have access to adequate supplies of safe water largely due to effective and sound water management strategies warranting large scale propagation and emulation.

I reiterate that in keeping with mandate the given to the Department for ensuring a time bound coverage of all rural habitations, including quality affected areas with safe drinking water, it is high time to evolve a pragmatic and implementable strategy for sustainable development of rural water supply with a participatory management approach. I am glad to note that the Department has prepared a document entitled "Bringing Sustainability to Drinking Water Systems in Rural India" in collaboration with the states and organizations working in this field. This document will inspire and guide the users to plan for sustainability interventions and adopt a new approach to wise water management.

I wish the Conference all success.

(CHANDRA SEKHAR SAHU)

New Delhi
June, 2007



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FOREWORD

Clean and safe drinking water is a resource which is essential for survival. Access to drinking water is central to good governance as well as to the well-being of people. Providing clean and safe drinking water, therefore, has been recognized as a key element in our development efforts. The Bharat Nirman Programme includes drinking water as one of its six thrust areas which are key to building rural infrastructure in all parts of the country.

But despite these efforts, the goal of clean drinking water 'at all times and for all' has remained elusive. The focus in the past has been to reach the un-reached and to improve quality and per capita availability of potable water in rural areas. While considerable progress has been achieved on this front, there has been a problem of sustainability in the government interventions.

The challenge before us, therefore, is to make our systems sustainable and reliable in terms of quality as well as quantity. All government programmes have continuously and consistently tried to meet this challenge. The efforts, however, have had limited success because of the detrimental impact that development in other sectors has exercised on the groundwater status, availability and quality.

The Accelerated Rural Water Supply Programme (ARWSP) was launched in 1972. Since its inception, the programme has attempted to keep pace with the demands of the times and has achieved considerable success in terms of coverage of the rural population. However, currently, the issue of sustainability has emerged as a central concern as the model, which emphasizes on capital-intensive engineering solutions has certain limitations in terms of enhancing the sustainability of the system.

The department has, therefore, tried to seek solutions to these challenges by emphasizing **a combination of traditional wisdom and best practices in water management with modern technologies and scientific understanding** to bring in sustainability in our interventions for creation of a decentralized water supply network.

A number of dimensions and resources need to be converged for preparing a roadmap to sustainability. The most critical among these are technical know-how, human capital and financial resources. This document is an effort towards presenting a basic framework for the mobilization of these resources and dimensions. Accordingly, the document has been structured into various themes that need to be interwoven for a framework of sustainability in the drinking water sector.

The first segment on '**Mobilising Technological Resources for Sustainability**', takes us on a journey of technological options — from past practices to the modern era. The aim is to offer



today's water managers a range of choices which will enable them to make their own water security plans in an effective manner. Traditional structures such as the tankas and khadins of Rajasthan, baoris (step-wells) of western India, the ooranis, cheruvus and temple tanks of south India, and the bamboo-split pipe harvesting method practised in the north-east still serve as lifeline for local people. The chapter revisits and understands these and various other conservation and collection systems for surface, ground and rain water.

It also examines the existing state-of-art technologies and scientific tools and practices in use across the country – an example could be the use of satellite imaging and data for scientific planning. The section emphasizes on the urgent need to replenish and restore existing surface water bodies and create new ones. It also stresses on the significance of rainwater harvesting for replenishing ground water and enabling water availability at the doorstep through household collection.

The segment that follows — **'Mobilising Human Resources for Sustainability'** — takes a look at the role of various stakeholders: PRIs, CBOs and local communities. It is critical to have a 'people-centric approach' for sustainability in which community leaders, organizations and the people themselves can be involved in planning, execution and management of their water security systems. This approach was adopted as a policy under the Swajaldhara programme, which with its emphasis on management of water supply systems through Village Water and Sanitation Committees, was based on principles of cost sharing by communities and a demand-driven approach.

Any system that is aiming at sustainability requires an assessment of its demand and supply aspects: in fact, demand management is critical for its success. This assessment has to keep in view the likes, dislikes and consumption practices of the community. It has to be matched with water availability in the region. Naturally, this assessment has to be done by the community itself. Thus, a household, community or village can be trained to do water budgeting after identifying their resources and needs and reconciling the two so that the extraction or consumption does not exceed the availability. This availability can only be ensured in the long run if the quantum of replenishment balances the current levels of consumption/extraction. People, therefore, will have to be trained to tailor their needs according to the availability: this, of course, will be put to test during phases of acute 'water stress' where demand management becomes all the more essential.

We need to understand that water is not a commodity to be controlled by market forces, nor a resource that is everlasting and unlimited. It is a gift of nature that needs to be treated with respect and caution. Sustainable use of water calls for self-discipline and an understanding of the resource in this light.

The final segment of this trilogy is **'Mobilising Financial Resources for Sustainability – Convergence and the Role of the State'**: it is important in the current context. Numerous government programmes on soil and water conservation and for augmentation of groundwater are being

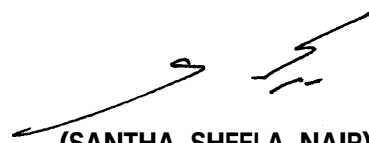


undertaken by various ministries at the Central and state levels. There is a need to converge these efforts at the district, block, village and habitation levels as well to optimize the benefits of the range of technical options and financial outlays in a synergistic manner. The role of the State and planners — as ‘facilitators’ — becomes important in bringing about such convergence. The State also has a central role to play in providing the legislative framework for protection of water bodies, regulating indiscriminate extraction of groundwater and in the arbitration of competing interests for water. Additionally, the State has a facilitating role to create institutional mechanisms for community ownership and management of water supply systems, as well as for monitoring strategies and devising new ways to move ahead on the journey of continued sustainability.

The draft document has been shared with state governments, practitioners in the sector and experts, and their views have been duly incorporated in the document.

The observations of the states have been summarized in the segment entitled **‘Sustainability-Practices and Issues : Views from the States’**. It is important to reiterate here that each state will have to come up with its own individual road map, keeping in view the geo-hydrological features, cultural preferences and lifestyles.

We hope that the journey to sustainability will be easier with this road map, and that this document will provide the genesis for new ideas and creative efforts for achieving our vision.


(SANTHA SHEELA NAIR)

Secretary
Department of Drinking Water Supply
Ministry of Rural Development
Government of India



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We acknowledge the contribution made by participants during the National Workshop on Sustainability held on 16th May, 2007 at New Delhi. The presentations made by various States and Organisations have been appropriately incorporated in this document.

The Department also acknowledges the efforts of our own Officers who have worked tirelessly to put together this document.

Finally, this compilation is a “mosaic” of several experiences and studies from all parts of the country, the known and unknown “Water Warriors” whose support, we acknowledge with humility and respect.