Jan Teun Visscher
IRC

Final Report

Evaluation of Four Slow Sand Filter Plants in Andhra Pradesh

Sponsor :

Netherlands Assisted Projects Office, Hyderabad

National Environmental Engineering Research Institute
Nehru Marg, Nagpur - 440 020

December 1993

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FOREWORD

The Netherlands Government, under its bilateral assistance programme, has been providing since 1979, financial support to the Government of Andhra Pradesh in the implementation of rural water supply schemes. The first phase of the programme, termed as AP-I covering 201 villages has been completed in 1992. The AP-II programme initiated in 1988 covering 288 villages is under implementation. The programmes are coordinated by the Netherlands Assisted Projects Office (NAPO) at Hyderabad.

The periodic review and support missions organised by the Royal Netherlands Embassy (RNE), New Delhi, observed that the slow sand filters built under AP-I are not functioning with maximum efficiency. The January, 1993 mission recommended that detailed investigations be undertaken by experienced Indian consultants in close cooperation with Panchayat Raj Engineering Department (PRED). In pursuance of this recommendation, the NAPO, Hyderabad retained the National Environmental Engineering Research Institute (NEERI), a constituent laboratory of CSIR to carry out a critical evaluation of the functioning of four slow sand filters at A.B. Palem, Darsi, Vinukonda and Pothunuru with a view to suggest recommendations for improvements in construction and operation and maintenance of slow sand filters (SSF).

This report presents a review of SSF design and construction practice followed by PRED, an indepth assessment of the performance of the identified slow sand filters, an appraisal of the operation and maintenance practices, and the knowledge base of the plant and supervisory staff with special reference to SSF. Recommendations have been delineated to bring about improvement in source protection, design, construction, operation and maintenance of slow sand filters.

The Cooperation and assistance rendered by NAPO and PRED engineers and other field staff in the evaluation study is gratefully acknowledged.

(R. PARAMASIVAM)
Coordinator

Nagpur
December, 1993

PROJECT PERSONNEL

Mr. Elyas, S.I.

Mr. Rama Rao, K.G.

Mr. Rammohan Rao, I.

Mr. Ravindar Rao, R.

Ms. Shinde, A.B.

COMPUTER ASSISTANCE

Mr. Krishna Kumar, C.

Mr. Sankaran, V.K.

PROJECT LEADER

Dr. Reddy, R.C.

PROJECT COORDINATOR(S)

Dr. Paramasivam, R.

Dr. Vittal Rao, M.

DIRECTOR

Dr. Khanna, P.

RESOURCE PERSONNEL

NETHERLANDS ASSISTED PROJECTS OFFICE

Er. K. Naram	Adviser (Till Sept. 1993)
Mr. Henk op het Veld	Team Leader
Ms. Rebecca	Secretary

PANCHAYAT RAJ ENGINEERING DEPARTMENT

Er. R. Kondala Rao	Engineer-in-chief
Er. K. Thirupathaiah	Superintending Engineer
Er. K.V. Rangam Setty	Executive Engineer

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1. PREAMBLE

Provision of safe drinking water in adequate quantity is a basic necessity for the well being and socio-economic development of a community. Throughout the developing world, supply of potable water to rural population has been a challenging task. In India, water supply programmes form a part of National Development Plans and are implemented in a phased manner under the Five Year Plans. A number of departments and ministries of the central and state governments have been vested with the responsibility for water supply and sanitation.

With the advent of International Drinking Water Supply and Sanitation Decade (1981-90), the rural water supply programme received a great impetus. In order to further accelerate the pace of coverage, the Government of India launched in 1986, the Technology Mission on drinking water for villages and related water management with the objective of covering all the residual problem villages with safe drinking water by 1990 through cost effective technologies.

2. RURAL WATER SUPPLY IN ANDHRA PRADESH

In the state of Andhra Pradesh, the Panchayat Raj Engineering Department (PRED) is the implementing agency for all rural development schemes such as roads, buildings, and water supply and sanitation. The water supply and sanitation programmes are looked after by a separate Chief Engineer. While at the middle level the Panchayat Raj Engineers deal with all the developmental schemes, separate staff is deployed at the field level for water supply and sanitation programmes. Rural water supply schemes are funded mainly under the Accelerated Rural Water Supply (ARWS) programme and the Minimum Needs Program (MNP) of Govt. of India.

Due to inherent advantages of slow sand filters over conventional rapid sand filters, the PRED, Government of Andhra Pradesh has designed and constructed a number of slow sand filters for rural water supply schemes in the state.

3. THE NETHERLANDS ASSISTED PROJECTS (NAP) IN ANDHRA PRADESH

The Netherlands Government, under its bilateral assistance programme has been providing since 1979, financial support to the Government of Andhra Pradesh in the implementation of rural water supply schemes. The programmes are co-ordinated by The Netherlands Assisted Projects (NAP) office at Hyderabad. The first phase of the programme, termed AP-I and covering 201 villages has since been completed in 1992. The AP-II programme initiated in 1988 and covering 288 villages is under implementation. The AP-I schemes are based on both surface and subsurface sources whereas AP-II schemes utilise only surface waters.

Under AP-I programme, wherever surface (canal) water is used as a source, summer storage tanks are provided to tide over the canal closure period. The stored water is treated in slow sand filters and chlorinated before supply. In AP-II schemes, rapid sand filters or slow sand filters are used depending upon the site specific conditions. Rapid sand filters have been preferred for comprehensive protected water supply schemes with a common surface source serving a cluster of villages.

4. BACKGROUND TO THE PRESENT STUDY

During the half yearly Review and Support Missions organised by the Royal Netherlands Embassy in India, it has been noticed that the slow sand filters built under AP-I, are not functioning with maximum efficiency and output, thereby resulting in less water supply, particularly to the tail end areas. The last Review and Support Mission in January, 1993 was of the strong opinion that, contrary to the experience in India and other parts of the world, the slow sand filters in all the schemes are operated at lower than the recommended design filtration rate of 0.1 m/hr. The average filtration rates (calculated on the basis of actual discharge measurements) were 30-65% of the design value of 0.1 m/hr.

Against this background, the mission recommended that detailed investigations be undertaken by experienced Indian consultants in close cooperation with PRED. Accordingly, the NAP office, Hyderabad retained NEERI, a constituent laboratory of CSIR to carry out a critical evaluation of the functioning of slow sand filters in Andhra Pradesh with a view to suggest recommendations for improvements in construction and O & M of SSF including a review of design criteria followed by PRED.

The schemes identified by the Engineer-in-chief, PRED in consultation with NAP office for the detailed study are as under :

A.B.Palem, Prakasam District, AP-II
Darsi, Prakasam District, AP-I
Vinukonda, Guntur District, AP-I
Pothunuru, West Godavari District, non-NAP (individual scheme)

The Royal Netherlands Embassy (RNE), New Delhi which has been appraised of the NAP-PRED's initiative for a critical evaluation of four slow sand filter installations in Andhra Pradesh, recommended the following terms of reference with a view to improving the performance of slow sand filters so as to obtain maximum output and to design future installations in keeping with the findings and recommendations of the evaluation study.

5. TERMS OF REFERENCE

i) To critically study and review the design and construction practices of selected slow sand filters in Andhra Pradesh.

ii) To study the organic and turbidity loads the filters are subjected to and suggest ameliorative measures when they exceed accepted parameters.

iii) To study and recommend on practices such as adopting declining rate and back-fill and the general operation of the filters with particular reference to

dealing with chokage, timely action to prevent the same and avoiding deep penetration of silt and organic matter etc.

iv) To study the quality of sand and gravel media used and suggest economical alternatives that do not impair efficiency.

v) To study the efficiency of the filters with regard to removal of turbidity, organic matter and micro-organisms.

vi) To study the procedure for removal, cleaning and replacement of media.

vii) To study the disinfection practices and suggest improvements to ensure economy and reliability.

viii) To suggest suitable manual for the care-takers of slow sand filters which will be translated into Telugu after assessing the level of knowledge/ skills of the present operating staff.

6. METHODOLOGY

The study team comprising NEERI Scientists accompanied by PRED Engineers undertook visits to the four slow sand filter plants and collected relevant information as per proforma (Annexure I) and held detailed discussions with the plant and supervisory staff.

Samples of raw (influent to the filter) and filtered water were collected and analysed for relevant physico-chemical and microbiological parameters so as to assess the performance of the filters. Representative samples of filter sand were collected from each plant and subjected to sieve analysis to determine their E.S. and U.C.

The indepth evaluation of the slow sand filter installations addressed to the following :

i) Source water quality and protection

ii) Design and construction aspects of plants

iii) Operation and maintenance problems and modifications/ improvements with special reference to inlet and outlet design and piping

iv) Knowledge base and skill level of O & M and supervisory staff

v) Community awareness and participation in source protection and effective plant operation and maintenance

7. BRIEF DESCRIPTION OF THE SCHEMES EVALUATED

7.1 A.B.Palem: Central Protected Water Supply Scheme (CPWS)- AP II Programme

The CPWS scheme at A.B.Palem has been designed to provide water supply to 14 villages in Prakasam district through surface water from Nagarjuna sagar canal as this area is prone to excessive fluoride levels in ground water sources. The scheme is implemented to serve an ultimate population of 27,390 in 14 villages (including augmentation for 3 villages) with an ultimate water demand of 1.37 mld. The system receives water from Nagarjuna Sagar right canal through the Nuthulapadu Minor, canal at Bobbapalli. From Nuthulapadu Minor raw water is conveyed by gravity to summer storage tank (SST) at A.B.Palem over a distance of 23 km through a 500-350 mm diameter RCC pipe. Part of the flow from this gravity main is diverted to six protected water supply schemes (PWS) to cater to enroute villages. The SST is provided to take care of water requirements during canal closure period (120-150 days) and also to serve as a sedimentation basin. The capacity of the SST is 372 million litres. One

compartment of 142 million litres capacity has already been constructed while two more of 230 million litres capacity are nearing completion.

From SST the raw water is pumped to three slow sand filters of size 35 m x 10 m each, situated at a distance of 350 m. The filtered water is collected in a clear water sump of capacity of 200 m^3. From clear water sump, the treated water is pumped to various OHSRs situated in the respective villages for distribution. The disinfection is carried out by injecting bleaching powder solution into the pumping main. The plant commissioned in July, 1992 is maintained by PRED. The treatment flowsheet is depicted in Fig. 1 and the salient features of the plant are presented in Table 1. Details on design of slow sand filters are given in Annexure II.

7.2 Darsi: Central Protected Water Supply Scheme- AP I Programme

The CPWS Scheme at Sivaraj Nagar, Darsi is one of the largest schemes of its kind designed to serve an ultimate population of 2,43,000 by the year 2012 in 111 villages of Prakasam district. The design capacity of the plant is 12.15 mld with a per capita water supply of 50 l/day. The scheme was completed in 1983 under AP-I programme assisted by NAP.

125 villages in Prakasam district are identified as problem villages with excessive fluoride concentration in ground water sources. To obviate the need for defluoridation, this comprehensive protected water supply scheme has been implemented.

The scheme draws raw water from Nagarjuna Sagar right canal. The canal water is pumped over a distance of 462 m through two parallel 600 mm dia, AC pipes to a summer storage tank of 2538 million litres capacity. The provision of SST is necessary to meet the demand during canal closure period (120-150 days) and it also serves as a sedimentation basin. Raw water from the SST flows by gravity to 7 no. of slow sand filters of size 50 m x 20m each. The treated water from the clear water sump of 500 m^3 capacity after disinfection with bleaching powder solution is distributed by pumping/ gravity to 111 villages through 47 nos. of OHSRs and 62 nos. of GLSRs. The total length of the distribution mains is about 250 Km. The treatment flowsheet is depicted in Fig. 2

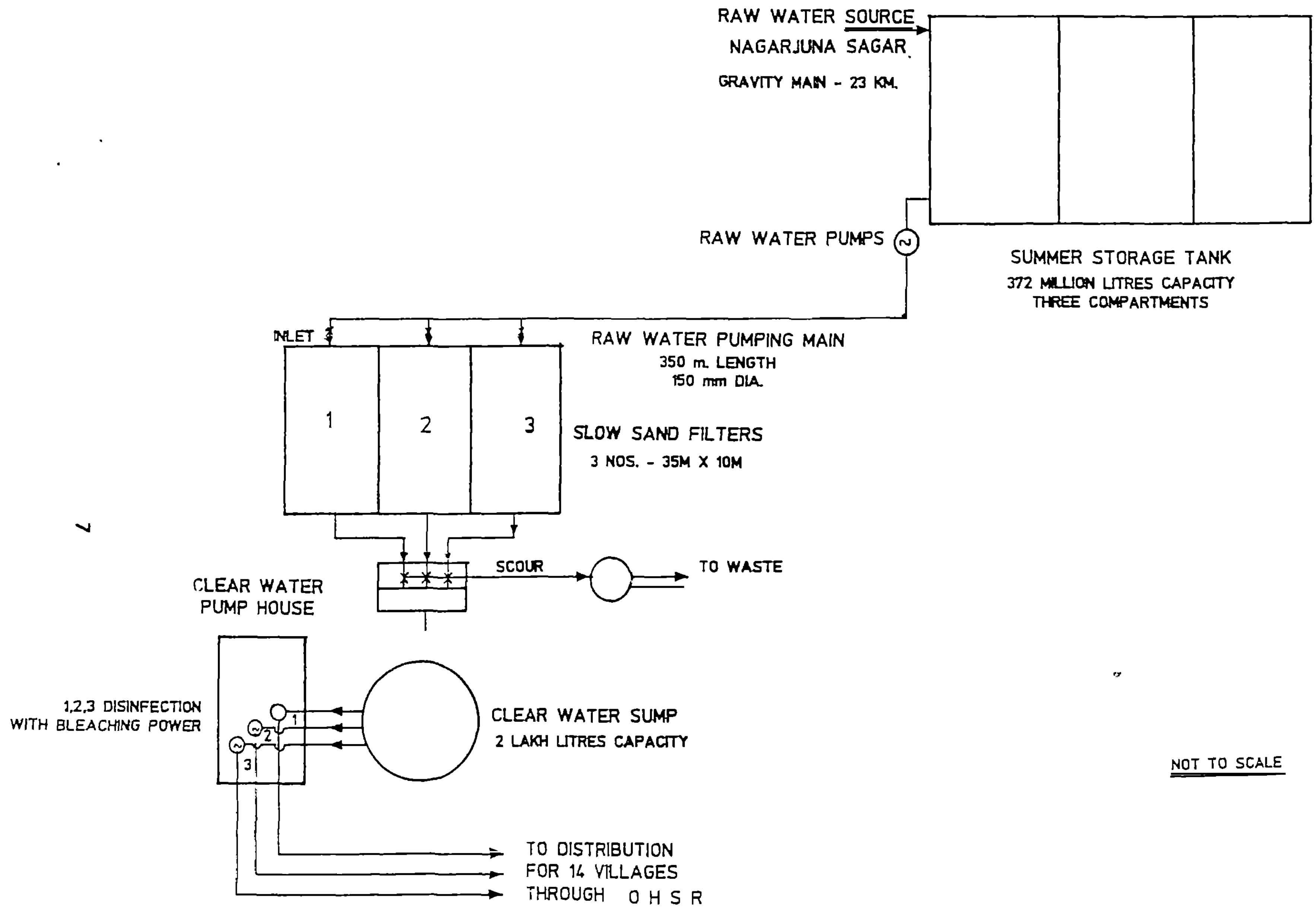

FIG. 1 : CENTRAL PROTECTED WATER SUPPLY SCHEME - A.B.PALEM
PRAKASAM DISTRICT, ANDHRA PRADESH

TABLE 1

SALIENT FEATURES OF SSF PLANT AT A.B. PALEM

General		
Name of the Plant	:	Central Protected Water supply scheme Head works - A.B. Palem For 14 villages.
Location	:	A.B.Palem
Mandal	:	Parchur
District	:	Prakasam
Year of construction	:	1992
Present supply	:	0.4-0.8 mld
Water supply duration	:	Daily 8 hours
O & M Agency	:	Panchayat Raj Engineering Dept. Govt. of Andhra Pradesh
Design Data		
Design period	:	Raw water conveyance and SST - 30 years, SSF - 15 years
Population 1981 census	:	14,817
Design population (2012)	:	27,390
(2002)	:	22,523
Source of raw water	:	N.S.Canal through Nuthulapadu minor canal at Bobbapalli
Per capita water supply	:	50 Lpd
Design capacity (2002)	:	1.126 mld
Technical		
Raw water transmission to summer storage tank	:	Gravity main 500 - 350 mm dia, 23 Km length
Pretreatment	:	Summer storage tank

Contd ...

TABLE 1 (Contd ...)

Summer storage tank	:	Pond type
Capacity for ultimate stage (2012)	:	372 million litres
Raw water conveyance from summer storage tank to SSF	:	Pumping main of 150 mm dia and 350 m length
Slow sand filters		
- No. of filters	:	3 - one stand by
- Size of each filter	:	35 m x 10 m
- Filtration rate	:	0.1 m/hr
- Depth of supernatant	:	1.0 m
- Mode of filter operation	:	Intermittent (designed to operate 16 hours continuously followed by 8 hours declining rate)
Filter Media details		
- Sand depth	:	100 cm
- Effective size	:	0.35 mm
- Uniformity coefficient	:	2.0
- Supporting media	:	Graded gravel 35 cm depth
Method of sand scraping	:	Manual
Filter rate control	:	V-notch at outlet
Disinfection	:	Bleaching powder solution feed
Clear water sump capacity	:	200 m^3 (9 m dia. x 3.2 m depth)
Distribution	:	Through OHSR, public stand posts and house service connections, 3 Pumping mains for three different areas

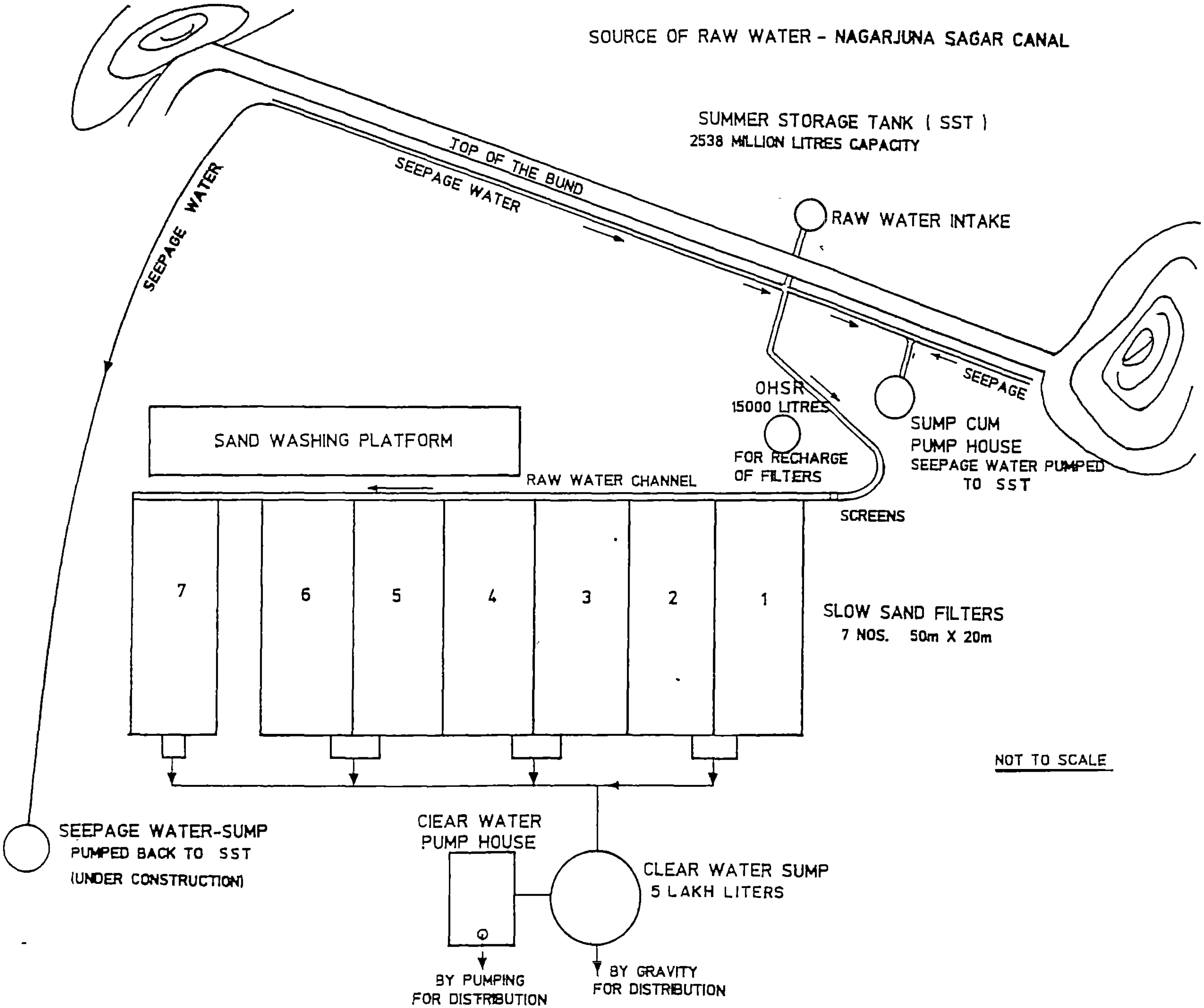

FIG. 2 : CENTRAL PROTECTED WATER SUPPLY SCHEME - DARSI

and the salient features of the plant are presented in Table 2. Details on design of slow sand filters are given in Annexure III.

7.3 Vinukonda: Individual Protected Water Supply Scheme- AP-I Programme

The protected water supply scheme at Vinukonda was commissioned in the year 1984 to cater to a population of 39,674 in the year 1997 with an ultimate water demand of 2.0 mld. The system draws raw water from Singara tank spread over an area of 78 ha. The source, which is an irrigation tank, has its own catchment area and also receives water from Nagarjuna Sagar right canal through Perumalpalli Major. At present, the water from Singara tank is exclusively used for Vinukonda water supply scheme.

The tank water is conveyed by gravity to a raw water sump at the treatment plant over a distance of 1 Km. through a 300 mm of RCC hume pipe. It is then pumped to 3 nos. of slow sand filters of size 30 m x 16 m each through 3 nos. of centrifugal pumps each of 5 HP. The treated water after disinfection is collected in a clear water sump and then pumped to OHSR for distribution through PSPs and individual house service connections. The operation and maintenance of the water supply scheme is with the village Panchayat. The treatment flowsheet is depicted in Fig. 3 and the salient features of the plant are presented in Table 3

7.4 Pothunuru: Individual Protected Water Supply Scheme (non- NAP)

The protected water supply scheme at Pothunuru is a small individual scheme implemented by the PRED. The scheme commissioned in the year 1980 is designed to serve a population of 6236 expected in the year 2001 with a demand 0.28 mld at 45 lpcd. This plant received financial assistance from IRC, Netherlands through NEERI under the SSF Research and Demonstration Project supported by IRC.

The PWS scheme draws water by gravity from Eluru canal of river Godavari through SST of size 200 m x 100 m x 1.35 m. The SST caters to the demand during canal closure period (120-150 days) and also serves as a sedimentation basin. The raw water from SST is pumped to two nos. of SSFs, each of size 10.97 m x 7.92 m. The

TABLE 2

SALIENT FEATURES OF SSF PLANT AT DARSI

General		
Name of the plant	:	Central protected water supply scheme Head works - Darsi for 111 villages
Location	:	Sivaraj Nagar, Darsi
Mandal	:	Darsi
District	:	Prakasam
Year of construction	:	1985
Present supply	:	6-9 mld
Water supply duration	:	3-4 hr through OHSR - 47 Nos. 24 hrs through GLSR- 62 nos
O & M Agency	:	Panchayat Raj Engineering Dept. Govt. of Andhra Pradesh
Design Data		
Population 1981 census	:	1,31,988 (80 villages)
Design period	:	Raw water conveyance and SST - 30 years SSF - 15 years
Design population (2012)	:	2,42,939 (say 2,43,000)
(1996)	:	1,78,183
Source of raw water	:	Nagarjuna Sagar Canal
Per capita water supply	:	50 lpd
Design capacity (1996)	:	8.91 mld
Augmentation/modification if any	:	One additional slow sand filter constructed in 1991
Technical		
Raw water transmission to summer storage tank	:	Pumping main of 462 m.length & 600 mm. dia - 2 parallel mains 75 HP centrifugal pumps - 3 Nos.

Contd ...

TABLE 2 (Contd ...)

Pretreatment	:	Summer storage tank
Summer storage tank	:	Made of Earthen Dam
Capacity	:	2538 million litres
Raw water conveyance from summer storage tank to SSF	:	Through open channel
Slow sand filters		
- No. of filters	:	7
- Size of each filter	:	50 m x 20 m
- Filtration rate	:	0.1 m/hr (max.)
- Depth of supernatant	:	1.2 m
- Mode of filter operation	:	Continuous (designed to operate 16 hours continuously followed by 8 hours declining rate)
Filter media details		
- Sand depth	:	100 cm
- Effective size	:	0.3 mm
- Uniformity coefficient	:	1.75
- Supporting media	:	Graded gravel 2-36 mm size, 32 cm depth
Method of sand scraping	:	Manual
Filter rate control	:	V-notch at outlet
Disinfection	:	Bleaching powder solution feed- at the outlet chamber of SSF
Clear water sump capacity	:	500 m^3 (13 m dia. x 3.75 m depth)
Distribution	:	Through 47 OHSRs & 62 GLSRs- mostly gravity to Pothili &partly by pumping through- public stand posts and house service connections in 111 villages

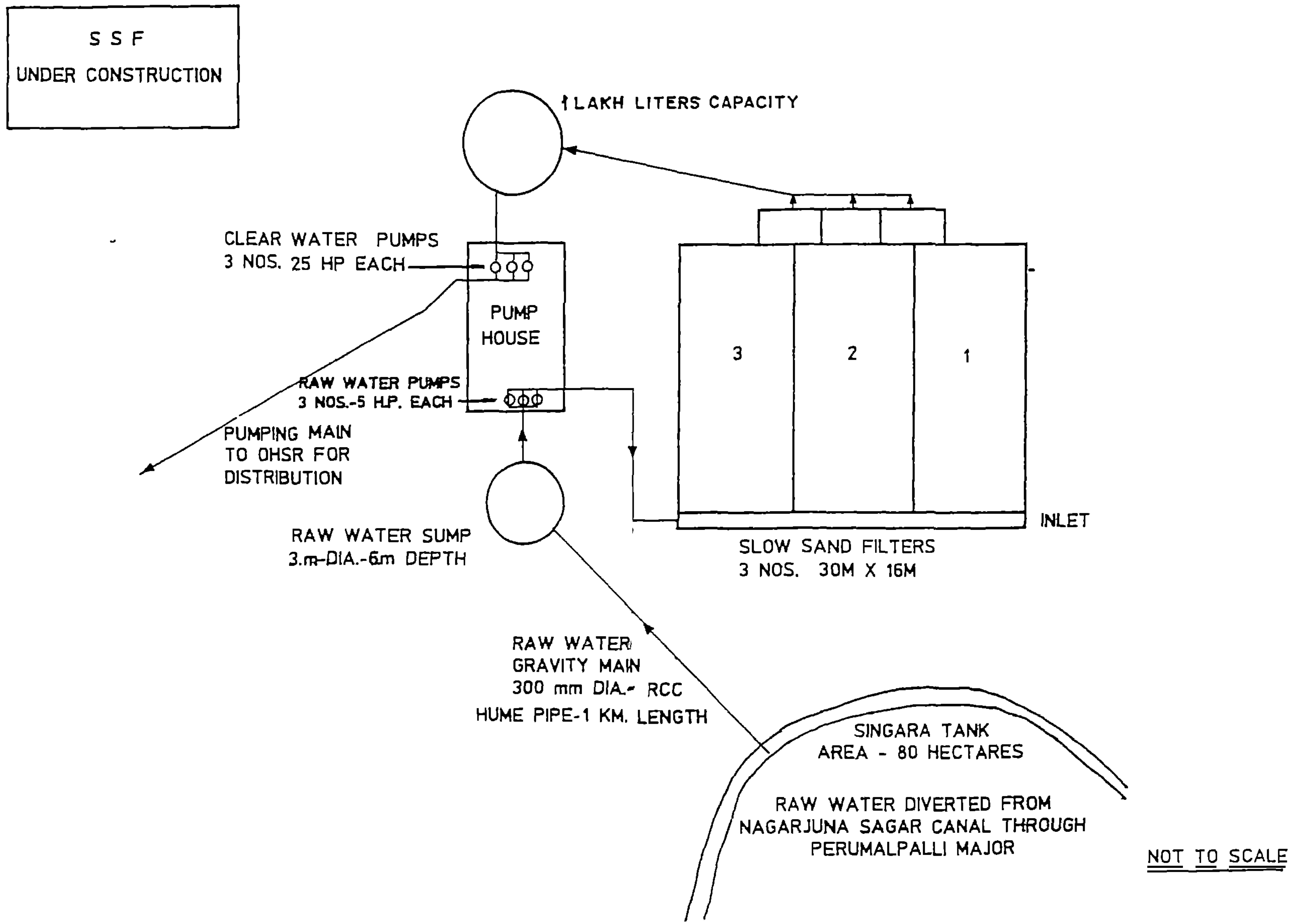

FIG. 3 : PROTECTED WATER SUPPLY SCHEME
VINUKONDA-GUNTUR DISTRICT
ANDHRA PRADESH

TABLE 3

SALIENT FEATURES OF SSF PLANT AT VINUKONDA

General		
Name of the Plant	:	Protected water supply scheme Head works - Vinukonda
Location	:	Vinukonda
Mandal	:	Vinukonda
District	:	Guntur
Year of construction	:	1984
Present supply	:	0.82 mld
Water supply duration	:	1 hr - morning 1 hr - evening
O & M Agency	:	Gram Panchayat, Vinukonda
Design Data		
Population 1991 census	:	34,802
Design period	:	Raw water conveyance and SST- 30 years SSF - 15 years
Design population (2012)	:	48,000
(1997)	:	39,674
Source of raw water	:	Nagarjuna Sagar Canal
Per capita water supply	:	50 lpd
Design capacity (1997)	:	2 mld
Augmentation/modification if any	:	One additional slow sand filter of size 30 m x 16 m is under construction
Technical		
Raw water transmission to summer storage tank	:	Through a Kutcha canal distance of 4 Km

Contd ...

TABLE 3 (Contd ...)

Pretreatment	:	Summer storage tank
Summer storage tank	:	78 ha. - Singara Tank (Irrigation Tank)
Raw water conveyance from summer storage tank to SSF	:	a) Through a closed conduit to raw water sump at treatment plant 300 mm RCC Hume pipe-gravity about 1 Km length b) Raw water sump to SSF- pumping - 3 Nos. 5 HP each centrifugal pumps
Slow sand filters		
- No. of filters	:	3 - one stand by
- Size of each filter	:	30 m x 16 m
- Filtration rate	:	0.1 m/hr
- Depth of supernatant	:	1.0 m
- Mode of filter operation	:	Intermittent (designed to operate 16 hours continuously followed by 8 hours declining rate)
Filter media details		
- Sand depth	:	100 cm
- Effective size	:	0.40 mm
- Uniformity coefficient	.	1.5
- Supporting media	·	Graded gravel 4-20 mm, 35 cm depth
Method of sand scraping	:	Manual
Filter rate control	:	Outlet rate control
Disinfection	:	Bleaching powder solution feed
Clear water sump capacity	:	100 m^3 (5 m dia x 5.0 m depth)
Distribution	:	Through OHSR Public stand posts- 315 Nos. House service connections 541 Nos.

treated water after disinfection (now discontinued) is collected in a clear water sump and then pumped to a 91,000 litres capacity OHSR for distribution through individual house service connections and PSPs. The treatment flowsheet is depicted in Fig. 4 and salient features of the plant are presented in Table 4.

8. EVALUATION FINDINGS

8.1 A.B. Palem

Raw water from Nagarjuna Sagar right canal is drawn through a gravity main to the SST consisting of three compartments. Presently, only one compartment is in use while the other two are under construction. The maximum depth of water in the SST is 3.1 m. Because of the large size of the SST, there is considerable wind induced wave action causing erosion of the tank bunds on either side of the intake well. This increases the turbidity of raw water at the intake, while the water is fairly clear in the rest of SST. Stone pitching/ turfing of the bunds atleast near the intake well is necessary to prevent bund erosion and also for structural safety of the bunds. Also, no provision has been made in the intake well for drawl of water from different depths. While locating the intake in the second SST under construction, the prevailing wind direction during major part of the year should be taken into account and should be so located as to minimise impairment of water quality and drawal of floating weeds/ debris at the intake. It is also desirable to construct a permeable gravel bund/baffle around the existing intake to minimise weed nuisance and also to improve the quality of raw water entering the intake tower.

As only one SST has been constructed as against three required to store raw water for meeting the requirements during canal closure period, the daily filter output is much less than the actual requirement of the community. Due to this reason, the filters have to be operated at a much lower filtration rate than the design value of 0.1 m/hr. In order to overcome this problem, the construction and commissioning of the remaining two SSTs should be expedited.

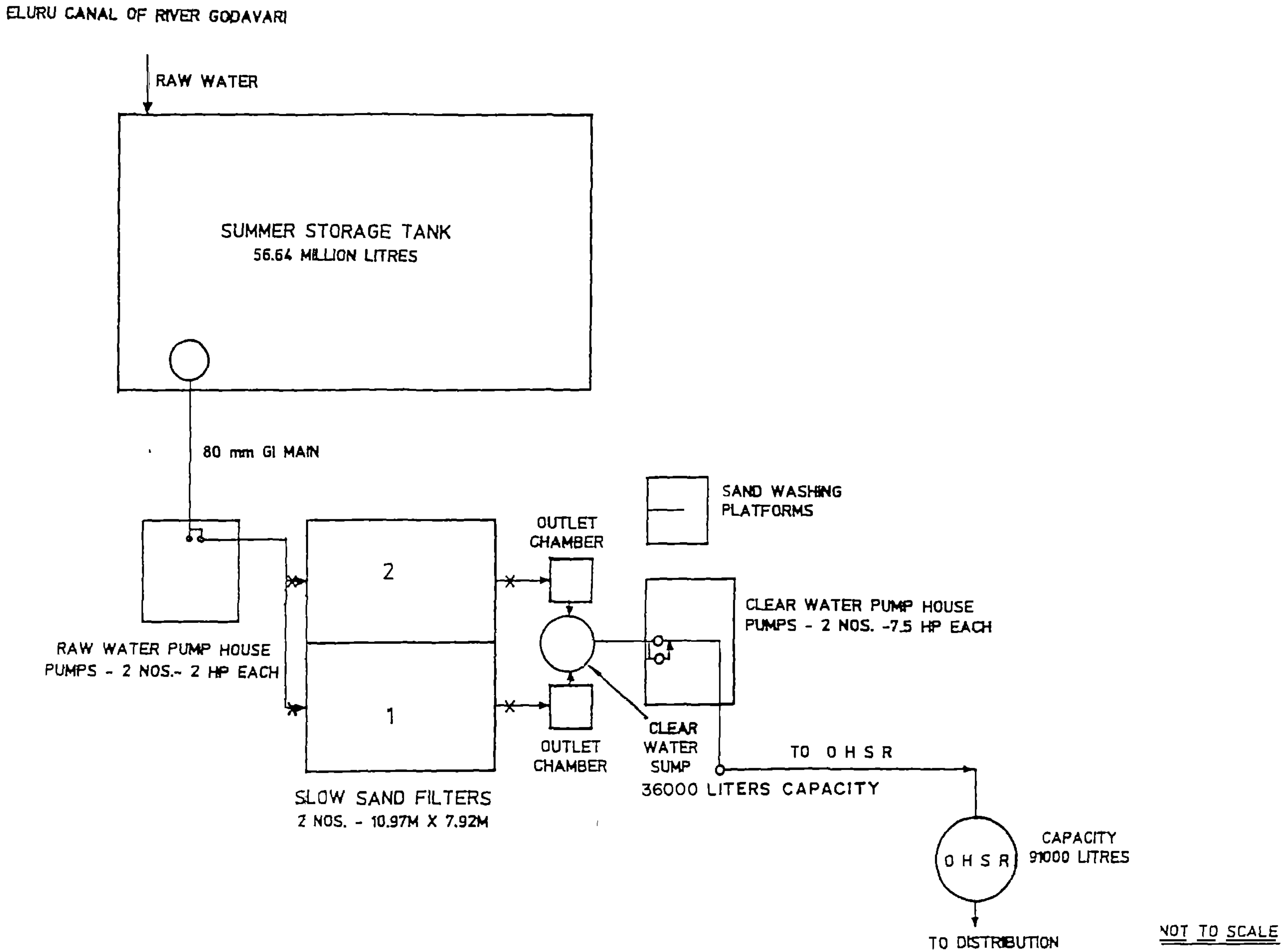

FIG. 4 : PROTECTED WATER SUPPLY SCHEME POTHUNURU.
WEST GODAVARI DISTRICT, ANDHRA PRADESH.

TABLE 4

SALIENT FEATURES OF SSF PLANT AT POTHUNURU

General		
Name of the Plant	:	Protected Water supply scheme - Pothunuru
Location	:	Pothunuru
Mandal	:	Denduluru
District	:	West Godavari
Year of construction	:	1980
Present supply	:	160 m^3-180 m^3
Water supply duration	:	45 minutes - morning 45 minutes - evening
O & M Agency	:	Gram Panchayat, Pothunuru
Design data		
Population 1991 census	:	4,452
Design period	:	30 years
Design population (2001)	:	6,236
Source of raw water	:	Eluru canal of river Godavari
Per capita water supply	:	45 lpd
Design capacity	:	0.28 mld
Technical		
Raw water transmission to summer storage tank	:	Field canal
Pretreatment	:	Summer storage tanks
Summer storage tank capacity	:	56.64 million litres
Intake well with RCC rings	:	Dia.- 1 8 m; Depth - 3.3 m

Contd ...

TABLE 4 (Contd ...)

Raw water conveyance from summer storage tank to SSF	.	By pumping through 2 HP Monoblock pumps - 2 Nos. one standby
Slow sand filters		
- No. of filters	:	2
- Size of each filter	:	10.97 m x 7.92 m
- Filtration rate	:	0.1 m/hr
- Depth of Supernatant	:	1.2 m
- Mode of filter operation	:	Intermittent
Filter media details		
- Sand depth	:	100 cm
- Effective size	:	0.2-0.3 mm
- Uniformity coefficient	:	2.0
- Supporting media	:	Graded gravel 2-20 mm size, 30 cm depth
Method of sand scraping	:	Manual
Filter rate control	:	V-notch at outlet
Disinfection	:	Bleaching powder solution feed
Clear water sump capacity	:	36 m^3 (4.26 m dia. x 2.3 m depth)
Distribution	:	Pumping to OHSR and distribution through public stand posts (30 nos.) and house service connections (248 nos.)

It was observed during the visits that the SST is also being used for other purposes such as bathing and washing, which cause pollution of raw water leading to undesirable growth of algae and weeds. A community awareness and education programme with focus on health hazards and importance of source protection should be initiated so as to prevent access of the people and cattle to the tank. Alternatively, the access should be restricted to the farthest end of the SST from the intake point and this area should be segregated by forming a separate bund inside the SST.

Raw water from SST is drawn by gravity from the intake well to a sump and then pumped to the filters. One diesel pumpset is provided as standby to take care of frequent power failures.

The SSFs have been designed for an intermediate population of 22523 in the year 2002 and for a per capita supply of 50 lpd. Accordingly, the daily average demand works out 1.126 mld. The slow sand filters are designed for a filtration rate of 0.1 m/hr with 16 hours continuous operation followed by 8 hours declining rate filtration. With this operation mode, the filter area required is 536 sq m. However, three filters each of size 35 m x 10 m are provided with a total area of 1050 sq.m. i.e. almost 100% more than the required area. One filter is intended to serve as a standby. This practice of providing 100 % extra area and standby unit(s) is against the recommended norms. Further, the number and size of the filters for the given area are not optimal. Apart from the higher initial cost, the filters are underutilised and due to intermittent operation there is deterioration of filtered water quality (Tables 5 and 6).

The raw water inlets to the filters are submerged. As raw water delivery is by pumping, there is a possibility of back siphonage of filter supernatant during pumps shut down period. To avoid this problem, free fall of raw water at the inlet chamber should be ensured. The inlet weir chambers have not been constructed. Also, no overflow arrangements have been provided for the filters.

It was observed that the filters are being operated intermittently depending on power availability and water requirement. During the first visit, all the filters were in operation and when the raw water pumping is stopped, the filter outlet valves are closed

TABLE 5

PHYSICO-CHEMICAL AND BACTERIOLOGICAL QUALITY OF RAW AND FILTERED WATERS- A.B. PALEM

Date of Sampling : 6-4-93

Parameters	Raw	Filtered
Physico-chemical		
Turbidity (NTU)	3.5	1.5
pH	8.4	8.3
Temperature (^{o}C)	29.0	29.0
Conductivity (Micromhos/cm)	332.0	332.0
Dissolved solids	185.0	187 0
Total alkalinity ($CaCO_3$)	114.0	110.0
P-alkalinity ($CaCO_3$)	2.0	2.0
M-alkalinity ($CaCO_3$)	112.0	108.0
Total hardness ($CaCO_3$)	64.0	62.0
Alkaline hardness ($CaCO_3$)	64.0	62.0
Calcium as Ca	12.0	13.6
Magnesium as Mg	8.3	6.8
Sodium as Na	34.3	33.0
Potassium as K	1.0	1.5
Chlorides as Cl	30.0	30.0
Sulphates as SO_4	13 0	14.0
Chemical oxygen demand	12.0	4.0
Ammonical Nitrogen	N.D	N D
Nitrate as NO_3	2.0	3.0
Phosphate as P	Traces	Traces
Fluoride as F	0.5	0.5
Dissolved oxygen	7.0	2.7
Bacteriological (MPN/100 ml)		
Total coliforms	21.0	Nil
E.coli	7.0	Nil
Faecal streptococci	Nil	Nil

All values are expressed in mg/l except pH

N.D - Not Detectable

TABLE 6

PHYSICO-CHEMICAL AND BACTERIOLOGICAL QUALITY OF RAW AND FILTERED WATERS- A.B. PALEM

Date of Sampling : 6-7-93

Parameters	Raw	Filtered
Physico-chemical		
Turbidity (NTU)	7.0	5.5
pH	8.6	8.1
Temperature (^{o}C)	28.0	28.0
Conductivity (Micromhos/cm)	353.0	342.0
Dissolved solids	198.0	204.0
Total alkalinity ($CaCO_3$)	82.0	76.0
P-alkalinity ($CaCO_3$)	20.0	Nil
M-alkalinity ($CaCO_3$)	62.0	76.0
Total hardness ($CaCO_3$)	22.0	28.0
Alkaline hardness ($CaCO_3$)	22.0	28.0
Calcium as Ca	4.0	8.0
Magnesium as Mg	2.9	2.0
Sodium as Na	53.0	53.0
Potassium as K	1.2	1.5
Chlorides as Cl	38.0	38.0
Sulphates as SO_4	25.0	25 0
Chemical oxygen demand	8.0	4.0
Ammonical Nitrogen	N.D	N D
Nitrate as NO_3	3.7	3.3
Phosphate as P	Traces	Traces
Fluoride as F	0.6	0.6
Dissolved oxygen	7.2	4.8
Bacteriological (MPN/100 ml)		
Total coliforms	Nil	Nil
E.coli	Nil	Nil
Faecal streptococci	4.0	4.0

All values are expressed in mg/l except pH

N.D - Not Detectable

simultaneously. During the second visit filter no.1 was under cleaning. When the raw water pumping was stopped, the filters were allowed to run on declining rate. Thus, there is no consistency in the filter operation mode.

Based on the pumping schedule for three consecutive months, the average duration of pumping worked out to about 8 hours with a total raw water inflow of about 0.68 mld. For this inflow, the rate of filtration works out to be 0.12 m/hr or 0.08 m/hr depending upon whether two or three filters are in operation. Thus, the filters were in operation for about 8 hours a day only and were idle for the remaining period. This mode of intermittent filter operation results in deterioration of filtered water quality due to stagnation of water in the filters for a prolonged period. It was also reported that whenever there is shortage of water, the filters are allowed to run on declining rate after pumping is stopped. The raw water pumping schedule needs to be streamlined so as to make optimal use of the standby diesel pumps.

A detailed study of the filter drawings has revealed that the inlet and outlet arrangements are defective. The V-Notch in the outlet chamber was found to be defective and needs replacement. It was also observed that the outlet rate control valves are not readily accessible resulting in operational problems. The valves need to be provided with extended spindles for easy operation.

It can be observed from the results of physico-chemical and bacteriological analysis, that the raw water had a turbidity of 7 NTU and a COD 12 mg/l (Tables 5 and 6). The microbiological quality was also good. However, the turbidity of treated water was found to be high (5.5 NTU) during the second visit. The bacterial removal efficiency was good during the first visit but was not satisfactory during the second visit.

The sieve analysis of a representative sample of filter sand collected from the filter No.1 indicates that the sand has an E.S. of 0.22 mm and U.C. of 2.37 (Table 7). The depth of sand varied from 0.9 to 1.00 m.These values are within the recommended limits.

TABLE 7

SIEVE ANALYSIS OF FILTER SAND

Source of sample : A.B.Palem- Filter Bed No.1

Sieve No. (ASTM)	Sieve Size (mm)	Wt.Retd. (gms)	% wt. Retained	Cum.%Wt. Retained	% Wt Passing
12	1.68	4.45	0.89	0.89	99.11
14	1.41	5.16	1.03	1.92	98.08
16	1.20	18.14	3.63	5.55	94.45
18	1.00	20.20	4.04	9.59	90.41
20	0.84	34.42	6.88	16.47	83.53
25	0.71	43.25	8.65	25.12	74.88
30	0.59	39.98	7.99	33.11	66.89
35	0.50	51.24	10.24	43.35	56.65
40	0.42	9.48	1.90	45.25	54.75
45	0.35	132.35	26.46	71.71	28.29
50	0.29	49.78	9.95	81.66	18.34
70	0.21	49.92	9.90	91.64	8.36
80	0.18	31.40	6.28	97.92	2.08
Finer than	0.18	10.40	2.08	100.00	0.00

Effective Size	:	0.22 mm
Uniformity Coefficient	:	2.37
Acid Solubility (40 % HCl (V/V))	:	0.62 % W/W
Loss on Ignition	:	0 13 % W/W

It was reported that the filters which were commissioned in July, 1992 have not been cleaned even once. Considerable amount of floating algae was observed in the filters. During the second visit, one of the filters was taken out for cleaning and was out of operation for more than a week. The schmutzdecke has been allowed to dry completely as also the sand bed. This practice of allowing the filter to dry completely is detrimental to the efficient functioning of the filters. It was also reported that, at the time of cleaning only the top dried biological layer is removed without removing the clogged sand layers below.

Provision has been made for disinfection of filtered water with bleaching powder solution. 'Universal' make chlorinators are provided with direct injection of bleaching powder solution into the filtered water delivery main. However, the chlorinators were not in working condition due to the non-functioning of the non- return valves caused by the deposition of a thick coating of lime.

The plant is maintained by the PRED. The knowledge base of the plant supervisory staff and operators on the basics of SSF and their O & M is poor. A programme of organised training for the staff in routine O & M of SSF is essential. There are no laboratory facilities at the treatment plant. Since it is a CPWS scheme serving a population of 27,390, it is desirable to have a laboratory with necessary equipment for routine monitoring and plant control.

Unscheduled operation on intermittent mode for only 6-8 hours, defective inlet and outlet arrangements, defective method of filter cleaning and lack of basic knowledge of SSF technology on the part of both supervisory and O & M staff are the major factors responsible for the unsatisfactory performance of the system. The corrective measures should include rectification of construction defects in the inlet and outlet structures and scientific O & M of the filters by properly trained staff.

8.2 Darsi

This is the largest CPWS scheme implemented under the NAP programme. The SST is well protected against pollution and misuse. Raw water is drawn by gravity

through an intake well provided with valved inlet ports at three levels. At the time of the visit, raw water from the SST was drawn from near the bottom of the intake tower. This is not conducive to drawing the best quality of water. Depending upon the water level In SST, raw water should be drawn from near the surface to minimise the problem of floating debris reaching the filters. The valves at the intake well should also be provided with extended spindles to facilitate their operation from top of the well.

There are two channels, located down stream of the tank bund and parallel to SST to collect seepage water through the SST bund. Major part of this seepage water is collected in a sump and pumped back to the SST. It is seen from the analysis results that the fluoride concentration in the seepage is 2.5-3.2 mg/l which is more than the permissible concentration of 1.5 mg/l. Hence, most of the seepage water is pumped back to SST so that the fluoride level in the raw water after dilution is well within the permissible levels. However, some portion of seepage directly joins the raw water channel to SSF.

The raw water channel leading to the filters was found to be infested with molluscs. Their presence in the filters, however, could not be ascertained. Periodic removal of molluscs physically from the inlet channel is necessary to minimise possible nuisance in O & M of the filters.

The total area of the filters provided is 7000 sq.m with the individual filter area being 1000 sq.m. (50 m x 20 m). The size of individual filter is too large to facilitate efficient O & M, rapid cleaning and resanding. Also the plant is oversized to the extent of 40 %. The filters can produce 16.8 mld of treated water at a filtration rate of 0.1 m/hr, working continuously for 24 hours and 14 7 mld with 16 hours continuous working followed by 8 hours declining rate. The ultimate demand of water for the year 2012 is, however, only 12.15 mld.

The slow sand filters were designed to operate continuously for 16 hours at a filtration rate of 0.1 m/hr followed by 8 hours of declining rate filtration. However, presently the filters are operated continuously for 24 hours. The raw water is drawn to SSF through a common gravity channel with individual inlets to the filters. It has been

noticed that all the inlets are fully opened and submerged. It appears there is uneven distribution of inflow to the filters. There seems to be design and construction deficiencies particularly with respect to the inlet and outlet arrangements. The O & M division of NAP office at Darsi should explore the feasibility of introducing inlet rate control after ascertaining the hydraulic levels.

The inlet bends to the filters are at an angle and submerged because of which scouring of sand bed near the inlet of many filters was noticed. There are no overflow and scour arrangements provided to the filters. Any overflow has to occur only through flooding of the filters. The sill level of V-notch at the outlet is found to be below top of the sand bed.

During the visits all the seven filters were in operation. Outlet valves were fully opened. But the output was comparatively low and was of the order of 40-80 % of the designed capacity. Based on a scrutiny of the log book maintained at the plant for the last three months, the average output of the filters was of the order of 6-11 mld with the rate of filtration varying from 0.04 m/hr to 0.08 m/hr. The supernatant water depth ranged from 1.0-1.2 m. Based on the flow measurements in the raw water inlet channel and output from the filters, it is seen that considerable amount of water is being lost due to seepage from the filters.

It can be observed from the results of analysis that the raw water quality is quite good with a turbidity of 2 NTU and a COD of 8 mg/l (Tables 8 and 9). The filtered water had a turbidity of 1.0 NTU. The bacterial removal efficiency of the filters and reduction in organic matter content (COD) has not been satisfactory.

The filters are reported to be in use for the last 7-8 years but still the depth of sand in the filters is around 80 cm which indicates that the filters have not been cleaned periodically as necessary. Also, resanding is not done even once in any one of the filters. It was reported that during cleaning, only the top slimy layer is removed without scraping the clogged sand layers below. This results in short filter runs/ low filtration rates. The sample of filter sand collected from filter No.5 had an E.S. of 0.20 mm and U.C. of 2.13 (Table 10) which are within the recommended range.

TABLE 8

PHYSICO-CHEMICAL AND BACTERIOLOGICAL QUALITY OF RAW AND FILTERED WATERS- DARSI

Date of Sampling : 7-4-93

Parameters	Raw	Filtered
Physico-chemical		
Turbidity (NTU)	2.0	1.0
pH	8.4	8.0
Temperature (^{o}C)	28.0	28.0
Conductivity (Micromhos/cm)	310.0	321.0
Dissolved solids	144.0	148.0
Total alkalinity ($CaCO_3$)	100.0	102.0
P-alkalinity ($CaCO_3$)	2.0	Nil
M-alkalinity ($CaCO_3$)	98.0	102.0
Total hardness ($CaCO_3$)	84.0	90.0
Alkaline hardness ($CaCO_3$)	84.0	90.0
Calcium as Ca	18.4	21.6
Magnesium as Mg	9.2	8.8
Sodium as Na	24.0	20.0
Potassium as K	1.4	1.5
Chlorides as Cl	25.0	25.0
Sulphates as SO_4	8.0	6.0
Chemical oxygen demand	8.0	8.0
Ammonical Nitrogen	N.D	N.D
Nitrate as NO_3	5.0	2.0
Phosphate as P	Traces	Traces
Fluoride as F	0.5	0.5
Dissolved oxygen	6.8	2.9
Bacteriological (MPN/100 ml)		
Total coliforms	23.0	9.0
E.coli	4.0	Nil
Faecal streptococci	4.0	Nil

All values are expressed in mg/l except pH

N.D - Not Detectable

TABLE 9

PHYSICO-CHEMICAL AND BACTERIOLOGICAL QUALITY OF RAW AND FILTERED WATERS- DARSI

Date of Sampling : 8-7-93

Parameters	Raw	Filtered
Physico-chemical		
Turbidity (NTU)	1.5	0.5
pH	8.4	8.2
Temperature (^{o}C)	28.0	28.0
Conductivity (Micromhos/cm)	390.0	390.0
Dissolved solids	165.0	160.0
Total alkalinity ($CaCO_3$)	74.0	76.0
P-alkalinity ($CaCO_3$)	10.0	Nil
M-alkalinity ($CaCO_3$)	64.0	76.0
Total hardness ($CaCO_3$)	56.0	52.0
Alkaline hardness ($CaCO_3$)	56.0	52.0
Calcium as Ca	11.2	10.4
Magnesium as Mg	6.8	6.3
Sodium as Na	30.5	31.0
Potassium as K	2.5	2.4
Chlorides as Cl	29.0	29.0
Sulphates as SO_4	18.0	18.0
Chemical oxygen demand	8.0	4.0
Ammonical Nitrogen	N.D	N.D
Nitrate as NO_3	0.9	0.8
Phosphate as P	Traces	Traces
Fluoride as F	0.8	0.8
Dissolved oxygen	7.2	4.3
Bacteriological (MPN/100 ml)		
Total coliforms	43.0	4.0
E.coli	21.0	4.0
Faecal streptococci	9.0	4.0

All values are expressed in mg/l except pH

N.D - Not Detectable

TABLE 10

SIEVE ANALYSIS OF FILTER SAND

Source of sample : Darsi - Filter Bed No. 5

Sieve No. (ASTM)	Sieve Size (mm)	Wt.Retd. (gms)	% wt. Retained	Cum.% Wt. Retained	% Wt Passing
14	1.41	3.20	0.64	0.64	99.36
16	1.20	6.86	1.38	2.03	97.97
18	1.00	9.28	1.87	3.90	96.10
20	0.84	18.47	3.72	7.62	92.38
25	0.71	31.02	6.25	13.86	86.14
30	0.59	32.04	6.45	20.32	79.68
35	0.50	43.64	8.79	29.11	70.89
40	0.42	59.69	12.02	41.13	58.87
45	0.35	115.24	23.21	64.34	35.66
50	0.29	57.67	11.62	75.96	24.04
70	0.21	53.30	10.74	86.70	13.30
80	0.18	53.76	10.83	97.53	2.47
100	0.15	7.50	1.51	99.04	0.96
120	0.12	0.37	0.07	99.11	0.89
Finer than	0.12	4.41	0.89	100.00	0.00

Effective Size	:	0.20 mm
Uniformity Coefficient	:	2.13
Acid Solubility (40 % HCl (V/V))	:	1.46 % W/W
Loss on Ignition	:	0.41 % W/W

The filtered water is disinfected at the outlet chamber of each filter using bleaching powder solution. The dosing equipment was working satisfactorily. The residual chlorine concentration in the treated water collected from the tap near the clear water sump was found to be 1.0 mg/l. The feasibility of chlorinating the entire supply at a single point in the clear water sump may be explored to facilitate monitoring and control.

The water testing laboratory at Darsi is well equipped for routine water quality monitoring of rural water supply schemes as well as the SSF plant at Darsi. The laboratory is manned by a qualified chemist.

The plant is maintained by the PRED. The O & M staff, though young and enthusiastic, need training in the basics of SSF and O & M of the plant at Darsi. The plant at Darsi may serve as a centre for training of the O & M staff of all the SSF plants of NAP.

8.3 Vinukonda

The raw water source (Singara tank) receives water from N.S. canal through Perumalpalli major which picks up a lot of pollution enroute over a distance of 4 Km. This was evident from the mere appearance of raw water in the SST. The SST is infested with different types of weeds and the water is highly eutrophic with profuse growth of algae due to pollution from man made activities and agricultural run off. Because of the poor water quality at the SST, the performance of the filters was adversely affected. Conveyance of canal water to the SST through a closed conduit is not being considered by the department due to the high cost involved.

Three SSFs each of 30 m x 16 m in size have already been in use while a fourth unit is under construction to augment the plant capacity. All the three filters were under complete overhauling at the time of the visit. It was reported that the performance of the filters is adversely affected due to the poor raw water quality.

The SSFs are designed to meet the ultimate water demand of 2 mld by the year 1997. Three filters are provided to operate 16 hours continuously at a filtration rate of 0.1 m/hr followed by 8 hours of declining rate filtration. With this operation mode, the filter area required for the ultimate stage would be 1123 sq.m. The three filters each of size 30 x 16 m provide a total area of 1440 sq.m which is sufficient even to meet the ultimate demand. The provision of an additional filter of size 30 x 16 m will then be redundant.

The only available drawing is not clear to study the constructional details of filters. There seems to be deficiencies in design, construction as well as O & M of the plant. The filtered water outlet chambers of the existing units are not covered. However, such a provision is being made for the 4th unit which is nearing completion.

The turbidity and COD of raw water collected from the SST was found to be 20 NTU and 12 mg/l respectively (Table 11). The plant is operated and maintained by the local panchayat with technical assistance from PRED.

At the time of the visit, the water supply to the Panchayat was being met from an infiltration well located at Gundlakamma river bed as well as from the Singara tank without treatment. The yield of the well was reported to be quite adequate to meet the demand. The water quality with respect to physico-chemical parameters is found to be satisfactory (Table 12). This source is even being considered as an alternative to the existing system. In view of this, the need for augmentation of the existing plant capacity by commissioning the 4th filter unit needs justification. Also, overhauling and renovation of the existing filters has to be looked into critically.

Effective measures should be initiated to minimise the pollution of raw water enroute. Necessary steps have to be taken to clear the weeds from the SST. A gravel bund has to be provided around the raw water intake to prevent the aquatic weeds and plants from reaching the intake. With the poor quality of raw water as obtained at present, the filters may not perform efficiently unless some form of pretreatment such as roughing filtration is provided. Serious consideration should also be given to conveying the canal (raw) water through a closed conduit and to restrict the area of

TABLE 11

PHYSICO-CHEMICAL AND BACTERIOLOGICAL QUALITY OF RAW AND FILTERED WATERS- VINUKONDA

Date of Sampling : 8-4-93

Parameters	Raw	Filtered
Physico-chemical		
Turbidity (NTU)	20.0	Filters were not in operation
pH	9.1	
Temperature (^{o}C)	28.0	
Conductivity (Micromhos/cm)	856.0	
Dissolved solids	437.0	
Total alkalinity ($CaCO_3$)	262.0	
P-alkalinity ($CaCO_3$)	12.0	
M-alkalinity ($CaCO_3$)	250.0	
Total hardness ($CaCO_3$)	54.0	
Alkaline hardness ($CaCO_3$)	54.0	
Calcium as Ca	7.2	
Magnesium as Mg	8.7	
Sodium as Na	120.0	
Potassium as K	2.0	
Chlorides as Cl	74.0	
Sulphates as SO_4	2.0	
Chemical oxygen demand	12.0	
Ammonical Nitrogen	N.D	
Nitrate as NO_3	23.0	
Phosphate as P	0.2	
Fluoride as F	1.4	
Dissolved oxygen	2.2	
Bacteriological (MPN/100 ml)		
Total coliforms	7.0	
E.coli	7.0	
Faecal streptococci	4.0	

All values are expressed in mg/l except pH

N.D - Not Detectable

TABLE 12

PHYSICO-CHEMICAL QUALITY OF RAW WATER-GUNDLAKAMMA RIVER BED (VINUKONDA)

Date of Sampling : 8-4-93

Parameters		Raw
Physico-chemical		
Turbidity (NTU)	...	3.5
pH	...	7.8
Temperature (^oC)	...	28.0
Conductivity (Micromhos/cm)	...	1017.0
Dissolved solids	...	515.0
Total alkalinity ($CaCO_3$)	...	350.0
P-alkalinity ($CaCO_3$)	...	Nil
M-alkalinity ($CaCO_3$)	...	350.0
Total hardness ($CaCO_3$)	...	146.0
Alkaline hardness ($CaCO_3$)	...	146.0
Calcium as Ca	...	29.6
Magnesium as Mg	...	17.5
Sodium as Na	...	130.0
Potassium as K	...	4.1
Chlorides as Cl	...	81.0
Sulphates as SO_4	...	27.0
Chemical oxygen demand	...	12.0
Ammonical Nitrogen	...	N.D
Nitrate as NO_3	...	3.0
Phosphate as P	...	Traces
Fluoride as F	...	1.5
Dissolved oxygen	...	2.0

All values are expressed in mg/l except pH

N.D - Not Detectable

SST through appropriate bunding in order to isolate some portion from the rest of the area and to minimise the problem of weeds etc.

The E.S and U.C.of sand used in the filters was found to be 0.19 mm and 2.54 respectively (Table 13), indicating that the sand is in the recommended size range.

The educational background and the skill level of O & M staff are not of a desired standard. They have not been given any formal training on the basics of SSF and routine O & M practice. The same is the case with the supervisory staff also.

8.4 Pothunuru

Presently, the raw water from the SST is drawn through an intake well situated very close to the raw water inlet to the SST. This does not lend itself to bring about maximum improvement in water quality of canal water stored in the SST due to short circuiting. It is suggested that the canal water is admitted to the first of the series of SSTs and drawn to the filters from the last to allow maximum improvement in raw water quality. Further, the intake should be surrounded by a permeable bund/ baffle of sufficient depth to avoid weed nuisance. At the time of visit, the canal was closed for annual maintenance.

The slow sand filters are designed to meet the ultimate water demand of 0.281 mld expected by the year 2001. The filters were to operate for 8 hours continuously followed by declining rate filtration for 16 hours. The filter area required for this mode of operation works out to 187 sq.m. for the ultimate stage at a filtration rate of 0.1 m/hr. But the total filter area provided is only 173.6 sq.m., which is little less than the required area. But this may not affect the filter performance significantly and the filters can be operated at higher filtration rate (say 0.15 m/hr) without adversely affecting the performance in view of the good quality of raw water drawn from the SST.

At present the filters are operated intermittently for 8-16 hours depending on availability of power. When the raw water pumping is stopped, the filter outlet valves

TABLE 13

SIEVE ANALYSIS OF FILTER SAND

Source of sample : Vinukonda - SS Filter

Sieve No. (ASTM)	Sieve Size (mm)	Wt.Retd. (gms)	% wt. Retained	Cum.% Wt. Retained	% Wt Passing
14	1.41	23.23	4.65	4.65	95.35
16	1.20	20.81	4.17	8.82	91.18
18	1.00	19.11	3.83	12.64	87.36
20	0.84	29.36	5.88	18.52	81.48
25	0.71	40.16	8.04	26.56	73.44
30	0.59	38.99	7.81	34.37	65.63
35	0.50	14.04	2.81	37.18	62.82
40	0.42	76.22	15.26	52.44	47.56
45	0.35	61.93	12.40	64.84	35.16
50	0.29	36.47	7.30	72.14	27.86
70	0.21	60.10	12.03	84.17	15.83
80	0.18	46.19	9.25	93.42	6.58
100	0.15	1.70	0.34	93.76	6.24
120	0.12	14.25	2.85	96.61	3.39
Finer than	0.12	16.93	3.39	100.00	0.00

Effective Size	:	0.19 mm
Uniformity Coefficient	:	2.54
Acid Solubility (40 % HCl (V/V))	:	5.4 % W/W
Loss on Ignition	:	0.99 % W/W

are closed simultaneously. This results in stagnation of water in the filters leading to deterioration of filtered water quality when filter operation is resumed.

During the visits, only one filter was in operation and the other was under cleaning. The rate of filtration as measured at the outlet chamber was 0.12 m/hr. The performance of the filter during the first visit was quite satisfactory as shown by the results of analysis of raw and filtered water (Table 14) while during the second visit, the performance was poor (Table 15). This can be attributed to intermittent operation and defective method of filter cleaning.

Discussions with the plant staff revealed that the procedure adopted for filter cleaning was defective. At the end of filter run, the filter is drained off completely and allowed to dry for 5 to 7 days. Then the dried top biological layer "Schmutzdecke" alone is removed without removing the clogged sand layers below. This results in incomplete cleaning of the filter causing high initial head loss and shorter filter runs (4-5 days). The problem is further aggravated due to the overloading of the other filter caused by the long down time for cleaning. It was reported that after commissioning in 1980, resanding was done once in 1991 with new sand. Scraped sand is not washed, dried and stored for reuse. The filter drawings (not available) need to be studied to ascertain if inlet and outlet arrangements as also piping would facilitate effective O & M.

The sand used in the filter with an E.S. 0.23 mm and U.C. 2.43 (Table 16), is optimal to produce reasonably long filter runs consistent with good quality filtrate. Efforts are not being made to reuse the filter sand after washing and drying which can reduce the cost of resanding.

The filtered water was not being chlorinated reportedly due to objections from the villagers due to chlorinous taste. This appears to have been caused due to lack of control on chlorination.

The plant is maintained by village Panchayat with technical guidance from PRED. As in other plants, there is an urgent need for organised training of the supervisory and O & M staff in the basics of SSF and proper O & M of the plant.

TABLE 14

PHYSICO-CHEMICAL AND BACTERIOLOGICAL QUALITY OF RAW AND FILTERED WATERS- POTHUNURU

Date of Sampling : 9-4-93

Parameters	Raw	Filtered
Physico-chemical		
Turbidity (NTU)	3.5	1.5
pH	7.4	7.5
Temperature (^{o}C)	28.0	28.0
Conductivity (Micromhos/cm)	321.0	332.0
Dissolved solids	158.0	161.0
Total alkalinity ($CaCO_3$)	112.0	120.0
P-alkalinity ($CaCO_3$)	Nil	Nil
M-alkalinity ($CaCO_3$)	112.0	120.0
Total hardness ($CaCO_3$)	94.0	96.0
Alkaline hardness ($CaCO_3$)	94.0	96.0
Calcium as Ca	19.2	19.2
Magnesium as Mg	11.2	12.6
Sodium as Na	19.2	18.5
Potassium as K	1.2	1.2
Chlorides as Cl	28.0	27.0
Sulphates as SO_4	Traces	Traces
Chemical oxygen demand	16.0	4.0
Ammonical Nitrogen	N.D	N.D
Nitrate as NO_3	3.0	2.0
Phosphate as P	Traces	Traces
Fluoride as F	0.4	0.4
Dissolved oxygen	3.6	4.1
Bacteriological (MPN/100 ml)		
Total coliforms	93.0	9.0
E.coli	93.0	9.0
Faecal streptococci	9.0	Nil

All values are expressed in mg/l except pH

N.D - Not Detectable

TABLE 15

PHYSICO-CHEMICAL AND BACTERIOLOGICAL QUALITY OF RAW AND FILTERED WATERS- POTHUNURU

Date of Sampling : 9-7-93

Parameters	Raw	Filtered
Physico-chemical		
Turbidity (NTU)	2.0	0.5
pH	7.7	7.4
Temperature (^{o}C)	28.0	28.0
Conductivity (Micromhos/cm)	332.0	332.0
Dissolved solids	166.0	170.0
Total alkalinity ($CaCO_3$)	114.0	116.0
P-alkalinity ($CaCO_3$)	Nil	Nil
M-alkalinity ($CaCO_3$)	114.0	116.0
Total hardness ($CaCO_3$)	86.0	86.0
Alkaline hardness ($CaCO_3$)	86.0	86.0
Calcium as Ca	18.4	18.4
Magnesium as Mg	9.7	9.7
Sodium as Na	10.5	10.5
Potassium as K	1.4	1.7
Chlorides as Cl	30.0	31.0
Sulphates as SO_4	Traces	Traces
Chemical oxygen demand	24.0	12.0
Ammonical Nitrogen	N.D	N.D
Nitrate as NO_3	3.7	4.5
Phosphate as P	Traces	Traces
Fluoride as F	0.4	0.4
Dissolved oxygen	2.5	3.1
Bacteriological (MPN/100 ml)		
Total coliforms	4.6×10^4	2.4×10^4
E.coli	4.3×10^3	4.3×10^2
Faecal streptococci	150	23

All values are expressed in mg/l except pH

N.D - Not Detectable

TABLE 16

SIEVE ANALYSIS OF FILTER SAND

Source of Sample : Pothunuru- Filter Bed No. 1

Sieve No. (ASTM)	Sieve Size (mm)	Wt.Retd. (gms)	% wt. Retained	Cum.% Wt. Retained	% Wt Passing
16	1.20	1.36	0.28	0.28	99.72
18	1.00	17.00	3.50	3.78	96.22
20	0.84	32.39	6.67	10.45	89.55
25	0.71	57.85	11.92	22.37	77.63
30	0.59	61.60	12.69	35.06	64.94
35	0.50	96.71	19.92	54.98	45.02
40	0.42	5.05	1.04	56.02	43.98
45	0.35	91.78	18.90	74.92	25.08
50	0.29	37.51	7.73	82.65	17.35
70	0.21	50.80	10.46	93.11	6.89
Finer than	0.21	33.46	6.89	100.00	0.00

Effective Size : 0.23 mm

Uniformity Coefficient : 2.43

Acid Solubility (40 % HCl (V/V)) : 1.35 % W/W

Loss on Ignition : 0.44 % W/W

8.5 Parchur

Though the Parchur slow sand filtration plant was not within the scope of the present evaluation study, it was visited at the instance of NAP staff. The SST is infested with weed growth and the water is coloured. The only SST also receives surface drainage from the village and is used for all purposes by the village folk and the cattle. There is an urgent need to initiate action for protecting the SST from indiscriminate use by the local people. The access to cattle should be localised. A community education programme should be launched to minimise the pollution of water in the SST.

The weed growth in the SST should be minimised by mechanically removing them from time to time. The existing SST should be partitioned with interconnecting arrangements so as to minimise pollution at the intake point. Out of the four filter units, one was under testing for water tightness. Apparently, the filters are designed for outlet rate control. No detailed drawings were available for study. A sample of filter sand procured and stacked for use in the filters was collected for sieve analysis and other parameters (Table 17). These are found to be within the desired range for SSF. However, a slightly coarser sand with E of about 0.25 mm as against the present 0.19 mm should be preferred.

8.6 Jagirla Madugu

The two circular slow sand filters which treat water drawn from SST are badly maintained. This was evident from the foul smell emanating from the filtered water outlet chamber. Profuse weed growth was observed in the SST. People were found fetching their drinking water from the supply well constructed inside the SST. Reportedly, the filtered water, because of its poor quality, is being used for purposes other than drinking.

The filters need to be thoroughly overhauled by taking out the entire filter media. The possibility of pumping raw water from supply well instead of from SST needs to be explored. The SST should be partitioned and the intake point so located as to minimise manmade pollution and accumulation of weed due to wind action. There is an urgent

TABLE 17

SIEVE ANALYSIS OF FILTER SAND

Source of sample : Parchur - New Sand

Sieve No. (ASTM)	Sieve Size (mm)	Wt.Retd. (gms)	% wt. Retained	Cum.% Wt. Retained	% Wt Passing
16	1.20	21.47	4.34	4.34	95.66
18	1.00	17.49	3.54	7.88	92.12
20	0.84	28.04	5.67	13.55	86.45
25	0.71	37.07	7.50	21.05	78.95
30	0.59	39.91	8.07	29.13	70.87
35	0.50	28.12	5.69	34.81	65.19
40	0.42	63.60	12.87	47.68	52.32
45	0.35	76.81	15.54	63.22	36.78
50	0.29	51.52	10.42	73.64	26.36
70	0.21	56.97	11.52	85.16	14.84
80	0.18	47.71	9.65	94.82	5.18
100	0.15	12.69	2.57	97.38	2.62
Finer than	0.15	12.94	2.62	100.00	0.00

Effective Size	:	0.19 mm
Uniformity Coefficient	:	2.40
Acid Solubility (40 % HCl (V/V))	:	1.20 % W/W
Loss on Ignition	:	0.33 % W/W

need for community awareness and participation programme to bring about an overall improvement in water supply.

9. A CRITIQUE OF THE FINDINGS

Slow sand filtration is an appropriate, simple and economical process to purify surface waters containing turbidity and bacterial contamination. It can provide a single step treatment when raw water turbidity does not exceed 30 NTU except occasionally for a few days. When higher turbidities are encountered, suitable pretreatment should be provided to reduce the turbidity to a desired level. Safety chlorination is necessary.

As far as possible, slow sand filter plants should be so located that the raw water can be gravitated to the filters. Plant layout should be compact and based on modular concept to facilitate future expansion. A good design does not automatically guarantee a good filter plant because much depends on the quality of materials used for construction, the available skills and the quality of technical supervision provided during construction.

A good design should facilitate routine operation and maintenance which is essential for regular supply of good quality potable water. Involving the plant operators right from the construction stage would enable them to get to know their plant. Training can start at this stage itself and should be combined with good supervision to ensure sustainable water supply.

It has emerged from the evaluation studies that many aspects such as source protection; design, construction and also O & M of slow sand filters, warrant improvements. The following is a critical appraisal of the evaluation findings.

9.1 Source Protection

The first step in assuring a safe and acceptable public water supply is to protect the source from pollution so as to minimise the future liability to the health and well being of people and economic burden to the water supply agency. All the four slow

sand filter plants evaluated draw water from irrigation canals through summer storage tanks. The raw water quality indicates moderate organic pollution and bacteriological contamination.

The maintenance of summer storage tanks (SSTs) at A.B.Palem, Vinukonda and Pothunuru is far from satisfactory. The SSTs which serve as raw water sources are also used for other purposes like bathing and washing. These activities pollute the raw water and causing undesirable growth of algae and aquatic weeds, which interfere with the effective functioning of SSF. Hence, a community education and awareness programme highlighting the importance of source protection and need for enhancing the quality of raw water should be initiated. The access of people and cattle should be restricted to the farthest corner of the SST from the intake point. This area should be segregated by forming a bund inside the SST.

Because of the large size of the SST and also due to wind action, there is considerable erosion of the tank bunds in A.B. Palem. This results in an increase in the turbidity of raw water, specially near the intake points. Therefore, it is necessary to provide stone pitching/ turfing of the tank bunds in the vicinity of the intake well to prevent erosion. This will also improve the structural stability of the bunds.

9.2 Intake Location

Profuse growth of aquatic weeds was observed in the SSTs of all the plants evaluated. Often these were found concentrated near the raw water intake points (e.g. A.B. Palem) due to wind action. This nuisance could have been minimised if due consideration had been given at the design stage to the wind direction preventing during major part of the year. In the case of Pothunuru, the intake well in the SST is located in the vicinity of the canal water inlet. This is not conducive to bring about any significant improvement in the quality of canal water due to storage because of possible short circuiting. Hence, the raw water intakes should be located farthest from the canal water inlet to the SST. This will ensure longer detention time of canal water and concomitant improvement in the raw water quality.

It is also desirable to construct a permeable gravel bund/ baffle around the intake to minimise the ingress of weeds. This arrangement would improve the quality of raw water entering the intake tower. As for the SST in Vinukonda, it is necessary to remove the aquatic weeds and plants and to desilt the tank in order to bring about an improvement in raw water quality. The feasibility of conveying raw water to the Singara tank through a closed conduit should also be explored.

9.3 Filter Design

All the four slow sand filter plants are designed for 15 years. However, the area provided for the filter beds is more than what is required except in the case of Pothunuru plant. The filter area provided for the plant in A.B.Palem is 100 % more than the actual requirement and 40 % more in the case of Darsi. Provision of such a large filter area (in the form of standby units) results in under-utilisation of the facility.

9.4 Number and Size of Filter beds

It is observed that some of the important design decisions like the number of filter beds for the required area-and the size of each bed do not conform to sound engineering practices.

The number of beds provided in A.B.Palem and Darsi is less than the recommended optimum as given by the formula $n = 0.5(A^{1/3})$. The area of each bed at A.B.Palem, Darsi and Vinukonda is 350 m^2, 1000 m^2 and 480 m^2 respectively. From practical considerations of cleaning and resanding, the area of the individual bed should be kept around 200 m^2.

The length to breadth ratio of filters in A.B.Palem, Darsi and Vinukonda is 3.5, 2.55 and 1.88 respectively as against the recommended range of 1.3 to 1.5. The economical length (L) and width (B) of a rectangular filter can be determined using the formula.

$L = 2A/(n+1)$

$B = (n+1)L/2n$

Where

A = total area of filter beds in sq.m.

n = no. of filters in the plant

9.5 Filtration Rate

In all the designs reviewed, a design filtration rate of 0.1 m/hr has been adopted to arrive at the area of filters. However, with the exception of Pothunuru, in all the plants extra area ranging from 40-100 % of the actual area required has been provided. With the result, the actual filtration rate when the total area is in use would be less than the design filtration rate. Running the filters at less than 0.1 m/hr should be preferred to intermittent operation or keeping one or more units idle as standby. This would ensure a superior quality of filtrate. Low dissolved oxygen levels in the filtrate at lower filtration rates can be readily corrected by the free fall over the outlet weir. It may also be mentioned that with a high quality of feed water (as in case of Darsi), it is feasible to increase, if necessary, the output through higher filtration rates, with no impairment in filtrate quality.

9.6 Filter Sand

The filter sand used in the four plants with respect to effective size and uniformity coefficient, acid solubility and loss on ignition generally conform to recommended specifications. It is gathered from PRED that there are not many local sources from where stock sand could be readily obtained and that processing stock sand to the desired size specifications remains an expensive task. On the other hand, no attempts are being made by plant authorities to reuse, after washing and drying, filter sand periodically removed at the time of cleaning.

9.7 Mode of Filter Operation

Out of four plants studied, only one plant viz. Darsi receives water by gravity from SST. In the three cases where raw water pumping is resorted to, the filters are operated intermittently, 6-12 hours per day. Occasionally, the filters are allowed to run on declining rate. As per design, the filters are to be operated for 8/16 hours continuously followed by declining rate filtration. However in practice, the filters are operated intermittently resulting in poor bacteriological quality of the filtrate. This is necessitated as the electric power supply in the instant cases is available only for 12-18 hrs. in general and for 6-8 hrs. during summer. In such cases high level storage tanks may be provided before filters to balance intermittent pumping of raw water and facilitate continuous feed to the filters. The storage tank capacity required will depend on the pumping schedule. A float valve will have to be provided on the feeder pipe from the high level storage tank to the filters to maintain constant level in the filters, though water level in the storage tank will be fluctuating. Increasing the depth of supernatant water will often be a costly substitute for high level storage.

9.8 Inlet arrangements

The main function of the inlet chamber is to dissipate the inlet velocity and to distribute the flow to the filters without disturbing the top biological layer or sand around the inlet chamber.

In all the plants, the inlet pipes are overhanging and are also not vertical resulting in scouring of sand bed near the inlet.

Usually the inlet structure has also a provision to drain out the supernatant when the filter needs cleaning. Draining the supernatant through the filter takes considerable time because of the comparatively high resistance of the biological film at the end of the filter run. Provision of removable wooden planks enables adjustment of the inlet weir level when the depth of filter sand is reduced as a result of successive cleanings.

Even though the SSF plant at Darsi is reportedly operated with inlet rate control, there is no provision to measure the inflow to the filters. The inlets are submerged and there is unequal distribution of flow to the filters.

The inlet arrangements in all the four plants are thus defective and need modification/ improvement to achieve the aforementioned objective. The details of a typical inlet chamber is depicted in Fig. 5.

9.9 Outlet arrangements

The outlet arrangements at A.B.Palem including the outlet chamber are located underground. The outlet valve and drain out valve are not readily accessible for routine operation and maintenance. The construction of outlet weir is faulty and requires modification. Ventilation facilities have to be improved.

In Darsi, the outlet valves are located at the ground level and are leaking. There is no proper ventilation of the outlet chambers. From detailed drawings, it is observed that the sill of V-notch is below the top of sand bed.

Detailed construction drawings are not available for Vinukonda and Pothunuru plants. The outlet chamber at Vinukonda is open and no provision for flow measurement has been made. At Pothunuru, the outlet chamber needs to be provided with proper ventilation.

In filters with outlet rate control, the outlet valve should be so located as to facilitate ready access and convenience of operation. As the filtered water is taken out through an outlet weir, the sill of weir should be placed at a level few centimeters above the top of the sand bed to avoid accidental draining of the filter bed and air binding. The outlet chamber must be covered and proper ventilation facilities provided. It should also provide a means to drain the filter to waste and to backfill the filter with clear water after the filter is cleaned. A typical sketch of outlet arrangement is shown in Fig. 6.

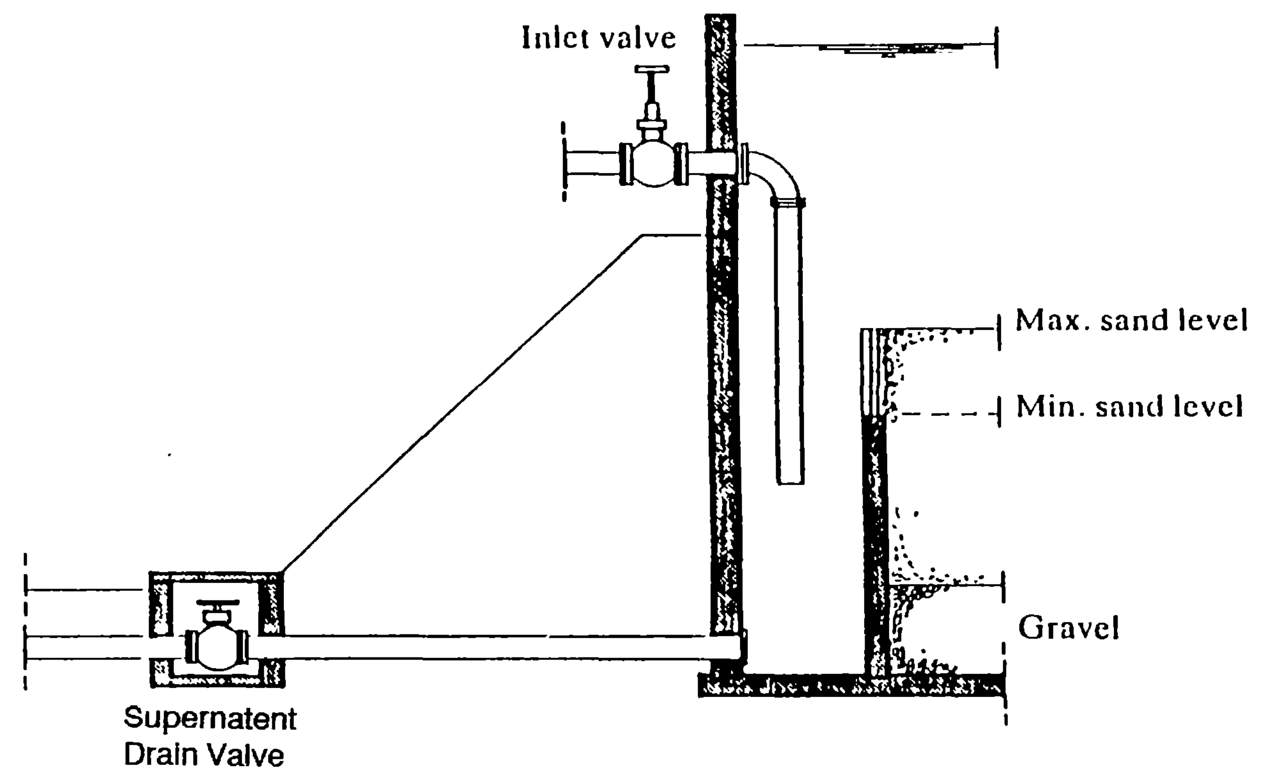

FIG. 5 : TYPICAL INLET ARRANGEMENT FOR SLOW SAND FILTER

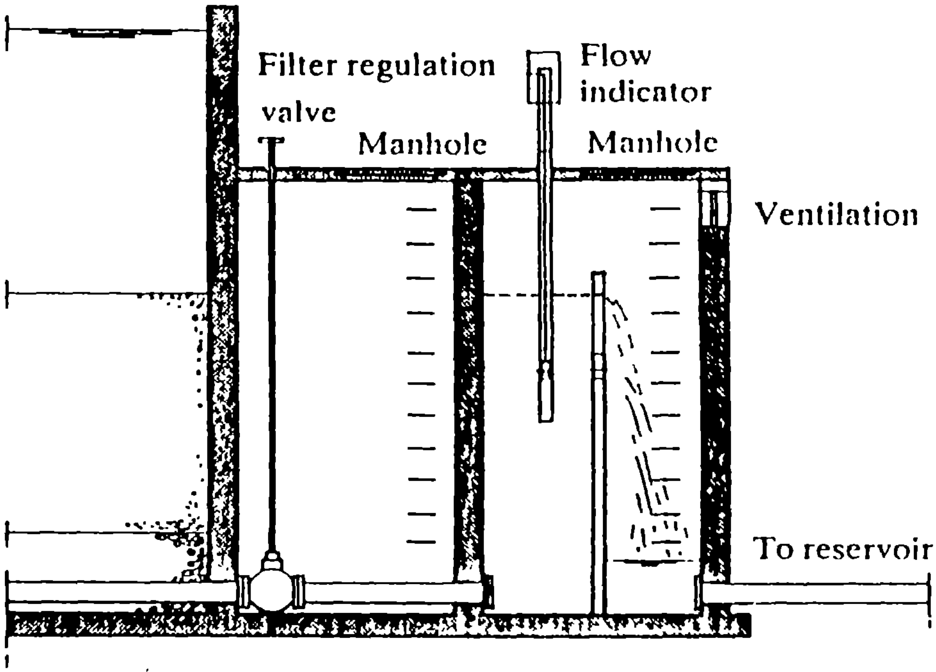

FIG. 6 : TYPICAL OUTLET ARRANGEMENT FOR SLOW SAND FILTER

9.10 Filter Cleaning and Resanding

A striking observation in respect of all the plants is that the method of filter cleaning is not only defective but also detrimental to the effective functioning of the filters. When a filter is to be cleaned, the bed is allowed to dry completely for 5-6 days, after draining the filter. Only the top biological layer, in completely dry condition is removed without removing any sand layer below and the filter restarted. This results in accumulation of organic matter in the filter, high initial head loss, short filter runs with reduced output and poor quality of filtrate.

The frequency of cleaning is arbitrary and not based on the filter head loss or the filtered water quality. There is no record of above operations in any of the plants studied. The filters at Darsi were commissioned in the year 1984-85. It was observed that the sand depth in the filters is around 0.8 m. It was also reported that resanding has not been done even once since the commissioning of the plant.

9.11 Safety Chlorination

In all the schemes studied, filter water is disinfected using bleaching powder solution, either gravity fed or injected into the clear water rising mains under pressure. The chlorination system at A.B. Palem was non-functional as the control valves had become inoperative due to lime deposits from the bleaching powder. In Pothunuru, safety chlorination has been discontinued reportedly due to complaints of chlorinous taste in water from the consumers. In Vinukonda, the filters were under overhauling and hence out of commission. In Darsi, gravity fed B.P. solution system has been installed at the outlet chamber of each one of the filters except filter No.7 and was functional. The filtrate quality in the plants evaluated is not always free from microbiological indicators of faecal contamination and therefore needs disinfection to ensure its hygienic safety and also to leave a residual to take care of possible after contamination in the distribution system. The study has shown that the chlorination systems installed are not consistent in their functionality either for want of regular maintenance or due to system deficiencies. Consumer reluctance to accept chlorinated water can also be attributed to a failure in maintaining optimal concentration of residual

chlorine in the final water and lack of an organised health and hygiene education programme.

9.12 Training

A striking observation of the evaluation study is that the knowledge base among the plant level operators and to a large extent among higher level supervisory staff on the basis of slow sand filtration as a process for purification of polluted surface waters and the daily routine of operation and maintenance of the filters. This was evident from the discussions held with the PRED and local panchayat staff vested with the responsibility of the plant O & M. Particularly, knowledge regarding filter rate control, method of filter cleaning, recommissioning and resanding was very poor among the staff. This has contributed to problems of reduced filter output as also the poor quality of treated water. Hence, there is an urgent need for an organised programme of training for the plant operators preferably at Darsi where good infrastructural facilities are available. A similar training programme is also necessary for the supervisory and higher level staff who are overseeing the routine plant operation and control. As part of the evaluation, a brief awareness programme was organised at Darsi as well as at Eluru (for Pothunuru) by the NEERI team for the benefit of plant staff.

9.13 Community Education and Participation

Most of the plants evaluated, public awareness regarding the importance of the water supply source protection was lacking. There was unrestricted access of people and cattle to the SSTs causing considerable pollution to the stored water. This could be minimised to the large extent to effective community awareness and education programmes. The socio-economic unit of NAP is understood to have taken up such programmes in a number of villages covered under NAP programmes. Such programmes should be initiated on priority basis in those villages/ towns covered by water supply schemes. The implementation of such programmes in Pothunuru would go a long way in convincing the public on the need for chlorination of water supply to ensure safety against water borne diseases.

10. SUMMARY

10.1 General

* The evaluation of the SSF plants installed under the NAP in Andhra Pradesh has brought forth the fact that the 'state of the art' of slow sand filtration practice available then in the country has not been brought to bear upon the engineering design, construction, operation and maintenance of the plants.

10.2 Engineering Aspects

* The location of raw water intakes in the SSTs with respect to canal water entry points is not conducive to bring about optimal improvement in raw water quality and to minimise nuisance due to aquatic vegetation.

* Provision made in the form of standby filter area in the installations evaluated ranges from 40 - 100 % of the actual area required except in the case of Pothunuru plant.

* For the given filter area, the number and size of the units constructed are not economically optimal.

* There have been construction deficiencies with respect to filter inlet and outlet arrangements resulting in operation and maintenance problems. Similarly, filter overflow arrangements are either not provided or are defective.

* The filter rate control mode in the plants evaluated appears complex as it follows neither the traditional outlet rate control nor the inlet rate control.

* With the exception of Pothunuru, all the plants are underutilised and their performance in terms of plant output and filtrate quality is not satisfactory.

10.3 Management Aspects

* The protection from man made pollution of canal water during its conveyance and storage in SSTs has not received adequate attention.

* The procedure followed for filter cleaning is defective and detrimental to the efficient functioning of the filters. This results in short filter runs as the clogged sand layers are not removed at the time of cleaning.

* The safety chlorination using bleaching powder as practised in the plants is not consistent in its functionality and warrants improvement.

* The knowledge base of the plant operators and supervisory staff on slow sand filtration is poor, thereby adversely affecting the performance of filters.

* Plant records with respect to pumping and filter operation schedule, filter cleaning and resanding, raw and filtered water quality, filter output etc. are not maintained.

11. RECOMMEDATIONS

11.1 Engineering Aspects

* Measures aimed at improving the raw water quality in summer storage tanks through proper location of inlets and offtake points, and with due consideration to prevailing wind direction are necessary.

* Permeable gravel bunds around the intakes in the SSTs should be constructed to bring about improvement in the quality of raw water drawn to the filters. Water from SSTs should be drawn through the inlet port near the surface to ensure the best quality of influent to the filters.

* For future installations, design criteria as detailed in Annexure IV are recommended to be followed. There is no need to provide 25 % extra filter area or any standby units.

* As far as practically feasible, the filters should be operated continuously for 24 hours, with recourse to standby power, if necessary. Wherever this is not feasible, the filters should be operated on declining rate mode avoiding intermittent operation.

* Modifications should be effected in the filter inlet and outlet structures and piping as necessary to i) prevent scouring of sand bed at the inlet, ii) facilitate rapid draining of the supernatant prior to filter cleaning, iii) provide ready access to outlet rate control valves, iv) ensure proper ventilation of the outlet chamber and v) facilitate backfilling of filters after cleaning.

* As all the plants (with the exception of Pothunuru) are oversized, it would be desirable to run them at lower filtration rates so as to achieve longer filter runs and better quality of product water.

* In view of its simplicity, operation of filters with inlet rate control is recommended.

* Provision should be made for a reliable means of measuring plant inflow and outflow as also from individual filters to facilitate filter operation and control.

11.2 Management Aspects

* A community awareness and education programme with focus on source protection should be organised by the socio-economic group of NAPO/ NGOs.

* The access of people and cattle, if unavoidable, should be restricted to the farthest corner of the SSTs from the intake point. This area should be isolated by forming a bund inside the SST.

* Identifying an operator from among the local community and involving him right from the construction stage of SSF plant would enable him to get to know the plant in and out. Training can start at this stage itself to ensure effective operation and maintenance.

* A training programme on slow sand filtration aimed at increasing the knowledge base and skill levels of middle level engineers and plant O & M staff should receive high priority. Necessary tools in the form of operator's manual should be developed in local language for the purpose.

* Adequate stocks of spares and replacements for the chlorination systems should be maintained to ensure uninterrupted and reliable disinfection of filtered water.

* A system of regular water quality monitoring of raw water sources and filtered water by qualified chemists so as to provide necessary feed back for plant operation and control should be implemented.

* Records with respect to plant inflow, outflow, water quality, cleaning of filter beds, and resanding should be maintained.

* Adequate opportunities should be provided in the form of group discussions/ brainstorming sessions for the O & M and supervisory staff to exchange information and experience in plant management.

Annexure I

PROFORMA FOR COLLECTION OF ENGINEERING AND TECHNICAL DATA FOR EVALUATION OF SLOW SAND FILTERS

Name of the Plant	:	
Location	:	
Mandal	:	
District	:	
Year of Construction	:	
Design period	:	
Design Capacity	:	
Design Population	:	
Population (1991 census) of the town served by the plant	:	
Treatment Flowsheet (furnish engineering drawings of all the units)	:	
Provision for future expansion	:	
Augmentation/ Modification, if any with details	:	
Per capita water supply (lpd)	:	
Present daily supply (million litres)	:	
Total daily requirement	:	
Water supply duration	:	
O & M Agency	:	
Source of raw water	:	Lake/River/ Canal/ Impounded Reservoir
Data on raw water quality, if available as per enclosed proforma	:	

Raw Water Intake :

- Distance from the treatment works :
- Screens :
  - – Type (removable/ fixed) :
  - – Size of openings (mm) :
  - – Method of cleaning :
- Source(s) of pollution, if any, in the vicinity (within 1 km) of intake :

Raw water pumping :

- Type of pumps :
- Number of pumps :
- Discharge (m^3/sec.) :
- Total head (m) :
- BHP of motor :
- Standby power :
- Hours of raw water pumping :

Raw water rising mains :

- Type :
- Diameter (mm) :
- Length (m) :

Raw water gravity main :

- Carrying capacity :

Raw water flow measurement and control :

Raw water storage tank (million litres) :

- Shape and Size

Type of pre-treatment, if any : Plain Sedimentation/ Storage/ Infiltration Gallery/ Roughing Filtration/ Coagulation & Sedimentation /Any other (please indicate)

Shape, No. and Size of Slow Sand Filters :

Any extra filter bed area/ unit provided :

Design Rate of Filtration (m^3/m^2.hr) :

- Average :
- Maximum :

Filter Operation

- Intermittent/ Continuous :
- Filter rate control
  - Inlet control :
  - Outlet control :

Free Board (m) :

Normal Depth of Water (m) :

Maximum Permissible Headloss (m) :

Normal Filter Length of Run (days) :

Filter Media Details

- Sand
  - Depth (m) :
  - E.S. (mm) :
  - U.C. :
- Supporting Gravel
  - No. of layers :
  - Depth of each layer :
  - Size of each layer :

Type of underdrains with details (Brick/ pipe) :

Method of sand scraping :

Method of sand washing :

Quantity of water required for sand washing :

Percent loss of sand in washing :

Average time required to put the filter back into service after scraping :

Minimum sand depth permitted before resanding :

Frequency of resanding/ Overhauling :

Provision for back filling and draining of supernatant :

Number of manhours required for scraping :

Provision for headloss measurement (with details) :

Filter rate control :

Filter inlet arrangements (Furnish details with drawings) :

Frequency of check on rate of filtration :

Performance data, if available:

- Water quality characteristics (range) :
- Bacteriological quality :

Difficulties, if any, in operation and maintenance :

a) Short runs due to excessive algal growth

b) Production of tastes and odours in the effluent

c) Underloading/ overloading of filters

d) Scraping and cleaning of sand

e) Availability and procurement of sand

f) Any other, specify

Filtered Water Sump :

- Capacity (million litres) :
- Size :
- FSL :

Filtered Water Pump House :

- Location :
- Size :

Disinfection :

- Chlorine gas :
- Bleaching powder :
- Direct feed/ solution feed :
- Method of dosing :
- Average dose (mg/l) :
- Points of application :
- Contact period provided :

Filtered water pumping machinery :

- Type :
- Number of pumps :
- Discharge capacity :
- Total head on pumps :
- BHP of motor :
- Standby power :

Flow measuring device :

Filtered water rising main :

- Type :
- Diameter :
- Length :
- Capacity :

Elevated service reservoir :

- Type :
- Capacity :
- Ground level :
- FSL :

Distribution System

- Type of pipes used :
- Size and length of pipes :
- No. of Public stand posts :
- No. of house connections :

Laboratory Facilities

- Equipment available :
- Parameters analysed :
- Frequency of analysis :

Staff and Personnel Data :
(Designation, Nos, Grade, Qualifications, Years of Service, Special Training, if any)

Financial Aspects

- Capital cost of the treatment plant :
- Annual Expenditure
  - Interest:
  - Depreciation:
  - Chemicals, Power etc.:
  - Maintenance and Repairs:
  - Staff Salary:
- Cost of water treatment (per mld) :
- Water rates :
- Annual revenue from sale of water :

Plant records maintained (with details) :

Power failures with details :

Physico-chemical and Bacteriological Quality of Raw and Filtered Waters

Parameters		Raw	Filtered
Physico-chemical			
. Turbidity (NTU)	:		
. pH	:		
. Temperature (^{o}C)	:		
. Conductivity (mhos/cm)	:		
. Dissolved solids	:		
. Total alkalinity ($CaCO_3$)	:		
. P-alkalinity ($CaCO_3$)	:		
. M-alkalinity ($CaCO_3$)	:		
. Total hardness ($CaCO_3$)	:		
. Alkaline hardness ($CaCO_3$)	:		
. Calcium as Ca	:		
. Magnesium as Mg	:		
. Sodium as Na	:		
. Potassium as K	:		
. Chlorides as Cl	:		
. Sulphates as SO_4	:		
. Chemical oxygen demand	:		
. Ammonical Nitrogen	:		
. Nitrate as NO_3	:		
. Phosphate as P	:		
. Fluoride as F	:		
. Dissolved Oxygen	:		
. Residual chlorine	:		
Bacteriological (MPN/100 ml)			
. Total coliforms	:		
. E.Coli	:		
. Faecal Streptococci	:		

All values are expressed as mg/l except pH

Annexure II

DESIGN OF SLOW SAND FILTERS AT A.B.PALEM IN GROUP-I
(Netherlands Assisted Programme- A.P II)

I.	Design period	:	15 years
II.	Design population		
	– Population as per 1981 Census	:	14,817
	– Projected population as on 1987 at 2 % annual growth	:	16,684
	– Prospective population as on 2002 at 2 % annual growth	:	22,523
	– Ultimate population as on 2012 at 2% annual growth	:	27,390
III.	Design daily demand S.S. Filters are designed for prospective population.		
	– Design population	:	22,523
	– Per capita daily demand	:	50 lpd
	– Daily demand (22,523 x 50)	:	1.126 mld
IV.	Period of Operation (daily production hours at the rate of 0.1 m/hr)	:	16 hours/ day
V.	Source of required raw water	:	Nuthulapadu minor of N.S.Right Canal
VI.	Design of Slow Sand Filter Units		
	– Design daily demand	:	1.126 mld (1,126.15 m^3/day)
	– Design filtration rate	:	0.1 m/hr
	– Filter area required	:	$X = Q / (0.1a + b)$

Where

Q = Design daily demand (m^3/day)

a = No. of daily production hours at normal operation (at rate of Filtration 0.1 m/hr)

b = 0.5 (since daily period of declining rate of filtration amounts to 8 consecutive hours)

∴ X = 1126.15/(0.1 x 16 + 0.5) = 536.262 sq.m

Add 25 % extra area of filtration for losses
(As per A.P. IX Mission Report)

∴ Filter area required = 536.262 x 1.25
= 670 m^2

However, provide 3 Nos. of 35 m x 10 m size units in which
1 No. may be used as stand by

Annexure III

DESIGN OF SLOW SAND FILTERS AT DARSI
(Netherlands Assisted Programme- A.P.- I)

I.	Design period	:	15 years
II.	Design population		
	– Population as per 1971 census	:	1,08,187
	– Population as per 1981 census	:	1,31,988
	– Prospective population as on 1996	:	1,78,183
	– Ultimate population as on 2011	·	2,38,898
III.	Design daily demand		
	– Design population (1996)	:	1,78,183
	– Per capita daily demand	:	50 lpd
	– Daily water demand (1,78,183 x 50)	:	8.91 mld
IV.	Period of operation	:	16 hours/ day
V.	Water source	:	Darsi branch canal of N.S. Canal

Treatment System : Plain sedimentation in summer storage tank followed by slow sand filtration

VI.	Design daily demand	:	8.91 mld (8909.15 m^3/day)
	Design filtration rate	:	0.1 m/hr

Adoption of 16 hours period of operation brings down the operation to two shifts

Filters can be operated for part of the day by adoptiong declining rate of filtration

Filter area required : $X = Q / (0.1a+b)$

Where

X = Filter area in sq. m

Q = Design daily demand in (m^3/day)

a = No. of daily production hours at normal operation at 0.1 m/hr

b = 0.5 (since daily period of declining rate of filtration amounts to 8 consecutive hours)

$X = 8909.15/(0.1 \times 16 + 0.5) = 4242.45$ sq.m

Adopt each unit of size : 50 m x 20 m

No. of filters required taking 25 % extra filter bed area = (4242.45 x 1.25)/1000 = 5.30

Provide 6 Nos. of one row

Total area provided for 6 filters = 6000 m^2

Annexure IV

RECOMMENDED DESIGN CRITERIA FOR SLOW SAND FILTERS FOR RURAL WATER SUPPLY

Parameter		Recommended Value
Design Period	:	10-15 years
Mode of Operation	:	24 hr/day or 16 hours continuous operation followed by 8 hours declining rate
Filtration rate	·	0.1-0.2 m/hr
Depth of filter sand :		
- Initial	:	0.8-1.0 m
- Final before resanding	:	Not less than 0.5 m
Sand specification :		
- Effective size	:	0.15-0.30 mm
- Uniformity coefficient	:	5, preferably below 3
Depth of underdrain including gravel layer	:	0.5 m
Depth of supernatant water	:	1.0 m
Free Board	:	0.2 m
Depth of Filter Box	:	2.7 m
Filter bed area per unit	:	Maximum 200 m^2
No. of filters	:	0.5 ^{3}A, A = Area in sq.m.
Minimum No. of Filters	:	2
L : B	:	1.3-1.5 to 1