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Performance of sub-surface drainage system installed at Appikatla region of Andhra Pradesh

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ABSTRACT : The increase in salinity caused by the rise in water table and lack of drainage is considered as a major environmental problem that is threatening the irrigated agriculture and its sustainability. Estimates of areas under soil salinity and water logging varied from one source to another. The National Commission on Irrigation estimated that 4.84M ha area has been affected by soil salinity and alkalinity in the country. Out of the total geographical area of 274.4 lakh ha in the Andhra Pradesh state, 3.4 and 8.1 lakh ha, are waterlogged and salt-affected, respectively. To test and demonstrate the drainage need for control of soil salinity and water logging in heavy soils, as well as to compare the performance of different drain materials, a study has been initiated by AICRP on management of salt affected soils and use of saline water in agriculture, Bapatla centre at Appikatla, of Krishna Western Delta, where most of the delta area suffers from high water table and soil salinity leading to very low crop productivity. Under the project, an area of 7.5 ha area was selected for the project activities based on pre-drainage investigations and subsurface drainage (SSD) systems were designed and executed during 2002. This research article describes the design parameters for the design and execution of the system and as well the performance under various spacing and drain material used.

KEY WORDS : Sub-surface drainage system, Drainage

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The introduction of irrigation in arid and semi-arid in regions has resulted in development of twin problems of water logging and soil salinization. The increase in salinity caused by the rise in water table and lack of drainage is considered as a major environmental problem that is threatening the irrigated agriculture and its sustainability. Out of about 1474 M ha of cultivated area in the world, approximately 227 M ha has been irrigated by 1989. It is estimated that the land degradation due to secondary soil salinization is of the order of 15 to 30 per cent of the irrigated areas. Globally the annual loss from the 45.4 M ha salt affected lands in irrigated areas has been estimated as US $ 11.4 billion (Ghassami *et al.*, 1995). Estimates of areas under soil salinity and water logging varied from one source to another. The National Commission on Irrigation estimated that 4.84M ha area has been affected by soil salinity and alkalinity in the country. The National Commission of Agriculture put the figure at 6 M ha area, while the Ministry of Agriculture (1984-85) estimated water logging as 8.53 M ha area. Rhoades *et al.* (1988) and Postal (1990) reported that nearly 35-36 per cent (about 14 M ha) of irrigated area in India was salt affected and waterlogged.

Out of the total geographical area of 274.4 lakh ha in the Andhra Pradesh state, 3.4 and 8.1 lakh ha, are waterlogged and salt-affected, respectively (Anonymous, 2002). To reclaim some of these soils sub-surface drainage system were installed in 25 ha area in Andhra Pradesh under different projects at five different locations using stoneware pipe drains and corrugated PVC pipe drains. Corrugated PVC pipe drains were used in two locations (Konanki and Uppugunduru) and stone ware pipe drains were used in three locations (Vuyyuru, Chintalapudi and Yendakuduru). Though the systems performed well in reclamation of saline soils and improve the crop productivity, there is no comparative study of performance of different drains materials used for installation of drains. Srivinivasulu *et al.* (2002) studied the performance of closed and open sub surface drainage systems in an area of 7 and 5 ha, respectively nod Uppugunduru pilot area, Krishna western Delta. Closed drains were laid with corrugated PVC pipes. Different spaced drains were installed in the pilot area. The average discharges for the year 2001-02 from the pipe drains laid at 30, 45 and 60 m spacing.

To test and demonstrate the drainage need for control of soil salinity and water logging in heavy soils, as well as to compare the performance of different drain materials, a study has been initiated by AICRP on management of salt affected soils and use of saline water in agriculture, Bapatla center at Appikatla, of Krishna Western Delta, where most of the delta area suffers from high water table and soil salinity leading to very low crop productivity. Under the project, an area of 7.5 ha area has been selected for the project activities based on per-drainage investigations and SSD systems were designed and executed during 2002. In present present study it was proposed to study the performance of drainage system.

METHODOLOGY

Study area description:

The study area lies under the Krishna Western Delta (KWD) command area. Study area is located geographically between 15^0 58' N latitude and 80^0 28' E longitude. The experimental area is bounded by Guntur-Bapatla road in the West and natural main drain in South-West, the site as main drain along the Southern boundary. The project site has a serious problem of water logging and salinity due to seepage of water from the adjoining irrigated area as it is located at the tail end of the command. Most of the fields in the experimental site are connected to natural drain bit the drain is at field level and causes back flow. The irrigation channels that exist in the site are used as open drains and field to field carrying drain.

The irrigation needs of the area are met from the KWD Canal. Paddy is the major crop in the area. Farmers allow irrigation water to paddy fields weekly once. The ground water is of poor quality and not useful for agriculture. There is no control for irrigation water in the project area as there are no separate irrigation/drainage channels.

The daily magnitudes of 10 years weather data (1992-2002) were used to work out mean values. The mean annual temperature recorded is 28.4^0 C with mean summer temperature of 31.6^0 C and a mean winter temperature of 25.8^0 C. The fourteen years (1989-2002) of rainfall data was analyzed to work out mean monthly and yearly rainfall, at 50 and 75 per cent probability of exceedance and the effective rainfall to assess the irrigation water requirement at different probabilities. It was observed from the data that the daily rainfall was found to be very high in the months of September and October. Weibull's technique was dated to carry out the rainfall probability analysis. Rainfall depth-duration-frequency curve method was adopted to estimate the drainage co-efficient and it was found to be 22.5 mm/day for 5-year return period because of the highest event of rainfall recorded

Table A : Summary of design parameters of the subsurface drainage system

1.	Area covered	7.5ha
2.	Hydraulic conductivity	0,22 m/d
3.	Rainfall	900-1300 mm
4.	Drainage coefficient	2 mm/d
5.	Hydraulic head above the drains	0.4m
6.	Depth of obsercation wells	2.5 m
7.	Depth of watertable(june,2002)	1.35 m
8.	Drain depth	0.85-1.1 m
9.	Depth to impervious layer from drain level	4.8 m
10.	Equivalent depth	2.33 m
11.	Drain spcing	30 m (computed) 60 m (Sensitivity analysis)
12.	Lateral pipeline	Depth:0.5-1.1 m Diameter: 0.1 m Total length: 1640 m
13.	Type of envelope material	Nylon 60 mesh socks gravel packng
14.	Collector pipe line	Depth: 1.2-1.5 m Slope: 0.2% Diameter:0.20 m Total length: 255 m
15.	Inspection chambers	No. of IC: 9 Depth of IC: 1.8-2/1 m Diameter of IC: 0.75m
16.	Main sump	Depth:4.2 m, Dia.:1.5
17.	Battery of piezometers	4 No., 2.5, 5, 7/5, & 10 m

Table 2 : Length and area of influence of each lateral in the study area

Lateral drain	Length of lateral (m)	Influence area (ha)
IC-1	120	0.720
IC-2	150	0.900
IC-3 *	120	0.720
IC-4*	150	0.900
IC-5	120	0.720
IC-6	150	0.675
IC-7 L	120	0.540
IC-7 R	150	0.450
IC-8L*	120	0.360
IC-8R*	150	0.450
IC-9L	120	0.360
IC-9R	150	0.600

*Monitoring network for hydraulic performance of laterals during this period. But for design of SSD system under AICRP-SWS, Bapatla, a drainage co-efficient of 2mm/d was considered. The soil of the study area was loamy textured in the top layers followed by clay loams in deeper layers. The percentage of sand and clay increased with depth.

Drain depth and spacing:

Drain spacing could be computed by several formulae developed from the theories of ground water flow substituting the appropriate soil and other parameters. Broadly speaking the drainage spacing formulae are based on a) steady state flow and homogeneous b) non-steady state flow conditions, a steady-state flow conditions. For the present study as the profile in the experimental site is homogeneous and isotropic, Hooghoudt's equation was used for computing the drain spacing :

$$\mathbf{q} = \frac{\mathbf{4kh^2 + 8kdh}}{\mathbf{L^2}}$$

where,

q = drainage co-efficient or drain discharge rate per unit surface area, m/d

K = hydraulic conductivity of the soil, m/d

D = hydraulic head above the drains, m

H = hydraulic head above the drains, m

L = drain spacing, m.

The auger holes method was used for measuring hydraulic conductivity (k). The detail procedure of measurement of K by the auger hole method as explained by Ritzema (1994) was followed. Adequate care was taken to ensure that the k-measurements were obtained in the same season maintaining the similar auger hole depths as that of the pre-drainage situations. From the conductivity tests, the value of hydraulic conductivity was found to be 0.265 m/d, the maximum head allowed above the drains taken as 0.4 m and a drainage co-efficient of 2 mm/d was selected for installation. The designed drain spacing is 29 m and a spacing of 30 m was considered. Considering the economic view, 60 m drain spacing also was considered for performance study.

Drain materials

Two types of drain materials were used for installation of lateral pipes *i.e.* 100 mm stone-ware pipes and corrugated PVC pipes were used. Gravel/sand and nylon socks type filter of pore size 60 mesh were used as envelope materials for stone-ware and CPVC pipe drains, respectively.

Drainage layout:

The layout of the drainage system of the study area of 7.5 ha is depicted in the Fig. A. A total of 12 lateral drains were installed covering the whole area of which six lateral drains were of corrugated PVC and remaining were of stone ware pipes. For monitoring of the drains 9 manholes (Sumps or ICs) were provided. A collector line of 255 m long was installed for collection of the drained water from the lateral drains. In the study area, out of 7.5 ha, 2.76 ha was drained by 30 m spaced drains and 4.355 ha drained by 60 m spaced drains. In the system a total length of 1640 m length of lateral line was laid at a depth of 0.84-1.1 m with a slope of 0.1% (Table A and B).

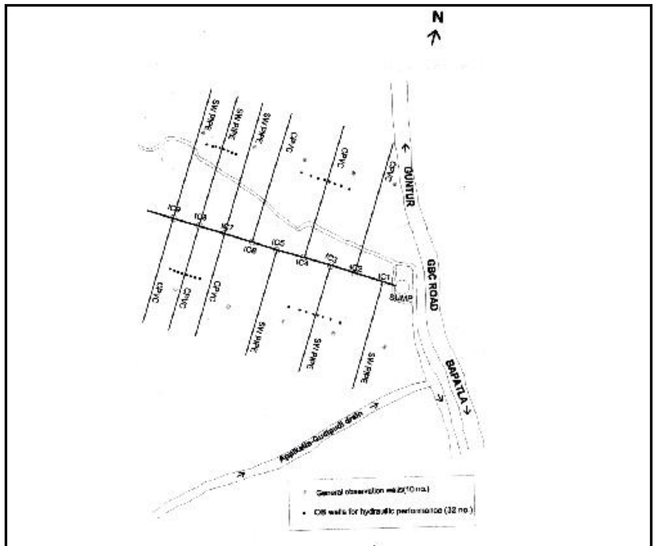

Fig. A : Layout of Subsurface drainage system at Appikatla, Bapatla

Ground water table :

In order to assess the working or the drainage system 32 observation wells were installed and monitored regularly. The depth to ground water table in the observation wells was measured by using a 5 m sounder tape.

Drainage system efficiency:

For evaluating the functioning of the drain (30 m and 60 m) a series of observation wells were installed on either side of the drains at 0.5, $1/4^{th}$,$1/8^{th}$ and1/2 the distance between the drains. The hourly variation of the water table depths in the observation wells was monitored continuously for an event of 5 h pumping. Then the drainage efficiency curves were drawn and compared with the theoretical water table positions between the drains.

Three factor analysis:

For the factorial analysis the combination of drain materials, drain spacing and water table depths were analyzed for studying the performance of discharge from the laterals. For this analysis, MSTAT software is run by entering the water table data of the monitoring period.

RESULTS AND DISCUSSION

The experimental findings obtained from the present study have been discussed in following heads:

Lateral drain discharge rates:

The drain discharge in the study of area was monitored at manholes. The discharge rate of the drain laterals was found to vary from 0.05 to 3.554 mm/d. The discharge at 90 per cent cumulative frequency of non-accidence was 0.743 mm/d which indicated that 90% of the times the drain discharge was below the design discharge rate (2 mm/d) during the observation period. The median value for lateral discharge was 0.015mm/d. The non-zero median value shows that the drains were working more than 50 per cent number of days.

The statistical analysis of discharge from the laterals was performed and presented in the Table 3. The results revealed that the maximum discharge rate from the laterals varied from 0.032 to 3.554 mm/d and the discharge rate was recorded in IC-1. The average drain discharge rate varied from 0.006 to 0.772 mm/d, respectively. Further the value of high discharge should not be considered for designing of any system as they do occur once in while. The non-zero median value indicates that the drains were working more than 50 per cent number of days except in IC-6L and BL and 8R. It could be seen from the Table 1 that the discharge in laterals was found to be high in case of stone ware (SW) pipes, which may be due to the reason that the perforations in SW pipes are at the bottom with more perforated area.

Drain discharge v/s drain spacing:

The drain discharge rates revealed that in 30 m spacing the maximum and minimum discharge rates were 2.201to

Table 1 : Characteristics of drain discharge from the laterals of the study area, mm/d (24th Dec.' 02th Jan.' 03)

Lateral No.	Drain material	Area of influence	Max	Min	Ave.	Median
60 m drain spacing						
IC -1	SW	0.72	3.554	0.59	0.772	0.081
IC - 3	SW	0.72	0.743	0.002	0.154	0.007
IC -5	SW	0.72	0.340	0.002	0.071	0.002
IC - 2	CPVC	0.90	1.093	0.15	0.235	0.019
IC -4	CPVC	0.90	0.408	0.009	0.094	0.019
IC -6	CPVC	0.67	0.725	0.005	0.154	0.011
30 m drain spacing						
IC -7L	CPVC	0.54	0.453	0.003	0.107	0.011
IC – 8L	CPVC	0.36	1.02	0.006	0.208	0.005
IC – 9L	CPVC	0.36	0.023	0.005	0.006	0.005
IC – 7R	SW	0.45	2.201	0.030	0.497	0.036
IC -8R	SW	0.45	1.224	0.000	0.245	0.000
IC -9R	SW	0.60	0.032	0.000	0.014	0.012

Table 2 : Hourly water table variation in 60 m spaced drains with pumping (24th Dec.'02-28th Jan.'03)

Pumping hours	Water table in the observation wells, cm							
	1/2R	1/4R	1/8R	0.5R	0.5L	1/8L	1/4L	1/2
	-30	-15	-7.5	-0.5	0.5	7.5	15	30
IC-3								
BP	42	51	56	60	61	54	49	43
1h	45	54	59	62	64	58	52	46
2h	48	56	61	64	66	61	55	49
3h	51	58	63	66	68	63	57	51
4h	56	61	66	69	70	65	59	54
IC-4								
BP	63	65	66	67	67	66	65	63
1h	66	68	69	70	70	68	67	65
2h	67	70	71	72	72	70	69	66
3h	70	71	72	73	73	71	70	68
4h	71	72	73	74	74	72	71	69

0.005 mm/d and corresponding discharge rates for 60 m spacing were 3.554 and 0.002 mm/d and the average values for 30 m and 60 m spacing were 0.174 and 0.274 mm/d, respectively. The median values for 30 m spacing discharge rates were 0.010 to 0.017 mm/d. The non-zero median value shows that the drains were working more than 50 per cent number of days. The drain discharge rate was high in 60 m spacing when compared to 30 m spacing due to the more influence of area of contributing to the drain pipes.

Drain discharge of collector:

The analysis of discharge from the collector line was carried out. The maximum and minimum discharge rates in the collector were 0.11 and 1.82 mm/d. The average discharge rate was 0.59 mm/d. The median value of discharge rate from collector was 0.23 the non-zero. It could be seen from the Table 3 that the discharge in laterals was found to be high in case of stone ware (SW) pipes, which may be due to the reason that the perforations in SW pipes are at the bottom with more perforated area.

Further scrutiny of results revealed that the maximum discharge rates from collector and laterals were 1.82 and 3.554 mm/d, respectively. The average cent of the times the drain discharge rates from collector and laterals were below 12.73 and 0.743 mm/d, respectively. It would be interesting to know that the average discharge from the collector was double than that of the average discharge from the laterals. The results show that of collector line was contributing more discharge than the laterals due to the perforated stone-ware collector pipeline.

60 m drain spacing:

The drainage system efficiency in term of the water table depth measured in the observation wells installed between the 60 m drains is presented in Table 2. The results showed that the water table depths adjacent to the drain varied from 60 to 64 cm and at half of the distance from the drain varied from 42 to 56 cm, respectively in case of IC-3 (SW Pipe). Where as in case of IC (CPVC) the water table depths adjacent to the drain varied from 67 to 74 cm and at half of the distance from the drain it varied from 63 to 71 cm.

The non-zero median value indicates that more than 50 per cent of the times the water table was below the ground level.

30 m drain spacing:

The results revealed that the water table depths adjacent to the drain IC-8 L (CPVC) varied from 73 to 80 cm and at the half of the distance from the drain it varied from 66 to 73 cm. Where as in case of IC-8 R (SW pipe) varied from 69 to 77cm and at the half of the distance from the drain it varied from 63 to 71 cm. From above results it can be observed that the 30 m drain spacing was more efficient than the 60 m drain spacing. The water table in the general observation wells were recorded both before and after pumping and presented. The results revealed that 30m drain spacing was effective in controlling the water table compared to 60 m drain spacing.

Drain spacing v/s water table:

The depths to water table levels were monitored from the observation well network. The maximum and minimum water tables for 30 m spacing were 80 and 63 cm, respectively and the corresponding values for 60 m spacing were 74 and 42 cm. The median values of water table in 30 m and 60 m spacing were 63.15 and 71 cm, respectively. The water table levels of 30 m and 60 m spacing at 90 per cent cumulative frequency of non-exceedance were 77 and 72 cm, respectively.

Ground water table levels (General observation wells):

The ground water table level was monitored using 10 observation wells and the data were compared with the pre-drainage situations. The maximum and minimum water table

Table 3 : Comparison of ground water table in pre-drainage and post-drainage situations

Location No.	Location	Depth to water table	
		Pre-drainage* (mar'02)	Post-drainage (Mar'03)
L-1	Out side L 1	138	205
L-2	Between L 1 and L 2	138	200
L-3	Between L 2 and L 3	138	213
L-4	Between L 3 and L 4	142	209
L-5	Between L 4 and L 5	145	210
R-1	Out side R 1	146	202
R-2	Between R 1 and R 2	145	195
R-3	Between R 2 and R 3	140	210
R-4	Between R 3 and R 4	143	207
R-5	Between R 4 and R 5	140	203
Average		142	205

Source: AICRP – SWS, Bapatla

depths in pre-drainage were 138 and 146 cm, respectively (Table 3) where as in post-drainage they were 195 and 213 cm, respectively. The average water table depths for pre-drainage and post-drainage were 142 and 205 cm, respectively. The results revealed that the ground water table in the study area has been lowered by 63 cm compared to a pre-drainage situation.

Three factor analysis:

The level of significance for the 3 factors, drain materials, drain spacing and water table depth was calculated by ANOVA test running MSTAT software.

F_1- Drain material: CPVE and SW

F_2- Drain spacing: 60 m and 30 m

F_3- Water table: Before and after pumping.

The analysis of the data revealed that :

– SW pipe is more significant that CPVC pipe drains in lowering the water table.

– 30m drain spacing is more significant than 60 m drain spacing in lowering the water table.

– The water levels before pumping are more significant than pumping water levels.

Soil salinity and reaction:

The analysis of pre and post monsoon sample at different locations have been carried out. The EC_e varied from 2.6 to 23 ds/m in pre drainage and 18.6 to 1.6 ds/m in post drainage with on average value of 8.17 ds/m in pre drainage and 6.25 ds/m in post drainage. The results reveal that decrease in the soils salinity values indicated the leaching of the salts. Which indicate that the drains were effective in reducing the soil salinity. It was observed the EC_e decreased by 5 to 64.2% compared to pre-drainage. The pH of soil varied from 8-6.5 in pre-drainage and 7.68-8.24 with an average value PH of 7.38 in pre-drainage and 7.86 in post-drainage. This shows that slight increase in soil reaction value was found during post during post-drainage. The increase in soil PH_s was negligible.

Change in hydraulic conductivity:

The hydraulic conductivity (k) measurements were determined by inverse auger hole method. These measurements were compared with that of pre-drainage values. The hydraulic conductivity in the pre-drainage ranged from 0.078 to 0.537 m/d with an average value of 0.265 m/d, where as in post-drainage the values ranged from 0.04 to 0.595 m/d, respectively with an average of 0.258 m/d. The results revealed that the hydraulic conductivity decreased by 2% when compared to pre-drainage. This may be due to reduction in salinity and increase in alkalinity proportion in the drained area.

Conclusion :

From the above performance study of SSD the following conclusions could be drawn. The average discharge from the pipe drains spaced at 60 m (0.247 mm/d) was higher than those spaced at 30m (0.179 mm/d). However, at 90% confidence level the 30m spacing drain discharge was at higher rate. The average discharge of perforated collector drain was observed to be 0.59 mm/d as compared to 0.213 mm/d of discharge combine from all the 12 lateral drains. In practice this appears to be disadvantageous, perforated collector line is discharging at a very higher rate requiring application of large quantity of water. The EC_e was reduced in the range of 5 to 64.2% due to installation of drainage system. Due to influence of drainage system, the water table has been lowered by 63 cm when compared to pre-drainage situation. There was no significant and definite trend in respect of change in pH of collected soil samples. It was estimated that a total of 59.79 tones of salts were leached out through the drainage system. On an average the hydraulic conductivity and infiltration rates of the soil at the ORP site were reduced by 2 and 37%, might be due to slight increase in alkalinity.

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