are manufactured in accordance with IS 458: 2003. Plastic footrests in the walls of manholes and sump wells are provided for cleaning and inspection. Under gravity outlet system, a small masonry structure at outlet with rodent guard is provided to safeguard the pipe edge from collapsing and rodent damaging. Recently, light weight manholes, sump and outlet pipes are introduced in place of RCC pipes. For pumped outlet system, a pump house (3x 3 x 2.4 m size) is constructed and a 6 HP diesel pump set for drainage is provided in accordance with IS 11538: 1986.

Costs of PVC pipes, synthetic filters, RCC pipes, pump house and pump set are based on 2016-17 price.

iii) Pipe installation

A fully mechanized method of installation of drain pipes on large scale is recommended. In this method, a self-propelled heavy duty chain trencher or trenchless machine with automatic laser control and other supporting drainage machineries are used for large scale mechanized installation of lateral and collector pipes at the

recommended grade and other structures. Installation costs of drain pipes and structures are based on 2016-17 price and are also compared with semi-mechanized rates under DSR of CPWD .

iv) Supervision of material and installation quality

A proper installed SSD system has an economic life of 30 years or longer. Therefore, total quality control of drainage materials and their installation is ensured in compliance with BIS drainage design specifications and installation standards. Supervision charges @ Rs. 4,000/- per ha are provided.

v) Operation and maintenance (O & M)

For pumped outlet system, pumping hours needed for first year dewatering and reclamation leaching, and second and third year leaching are worked out to be 350, 300 and 250 hours per year, respectively. The corresponding charges for pumping operation are Rs. 600/-, 500/- and 400/- per ha. Subsequently, O&M charges after three years will be met by farmers' drainage society (FDS).

vi) Contingencies

Cost estimate at feasibility stage may vary within 4-8% of actual cost. Therefore, contingencies @ 5% are provided to meet the unforeseen expenses as per the CPWD norms.

vii) Farmers' awareness training

Charges for farmers' awareness training including field visits @ Rs. 750/- per ha are allocated to enhance stakeholders' capacity on improved operation and maintenance of SSD systems.

viii) Monitoring and evaluation (M&E)

It is not necessary to monitor and evaluate all SSD projects. Nonetheless, a representative block in a few drainage projects should be monitored and evaluated by national institute/SAU/ NGO with experience in land drainage. M&E charges @ Rs. 2,000/- per ha are allocated.

COST OF SSD SYSTEMS

A model drainage block each in light, medium and heavy texture soils was considered for estimating drainage materials and their installation cost. Drain spacing is varied from 50 to 100 m in light and medium texture soils (with clay ≤ 30%) and from 20 to 50 m in heavy texture soils (with clay> 30%). Both pumped and gravity outlet conditions were considered. All cost calculations have been done with and without M&E charges to work out the total and per ha costs which are rounded off to rupee five hundred values. The costs of SSD system with and without M&E charges for light and medium, and heavy texture soils for pumped and gravity outlet conditions for drain spacing from 20 to 100 m are presented in Table 4. The recommended drain spacing in medium texture soils with pumped outlet for north-western states is 60-67 m based on field orientation (killa line) whereas the spacing in heavy texture soils including Vertisols with gravity outlet for central and southern states is 30 m. Therefore, corresponding costs for medium texture soils are Rs. 74,000-79,000/- with M&E charges whereas the cost for heavy texture soils is Rs. 111,500/- with M&E charges. The component wise cost and its share in total cost for 67 m spacing and 30 m spacing are provided (Table 5).

SSD costs under light & medium texture soils are applicable to Haryana, Punjab and Delhi, & part of Rajasthan (IGNP), MP & UP whereas system costs under heavy soils (Vertisols)/ coastal soils are applicable to Maharashtra, & parts of Rajasthan, MP, Karnataka, Gujarat, AP, Telangana, T.N, Kerala and other coastal states.

Table 4. Cost of SSD systems in different soil textures, outlets and drain spacing

Soil texture & outlet type	Cost of SSD system (Rs. per ha) for different drain spacings (m)								
	20	30	40	50	60	67	80	90	100
• **Light and Medium Texture Soils** (Clay ≤ 30%)									
Without M&E charges									
Pumped outlet	--	--	--	84,500	77,000	**72,000**	67,500	65,500	60,000
Gravity outlet	--	--	--	74,500	68,000	63,500	59,500	57,500	52,500
With M&E charges									
Pumped outlet	--	--	--	86,500	79,000	**74,000**	69,500	67,500	62,000
Gravity outlet	--	--	--	76,500	70,000	65,500	61,500	59,500	54,500
• **Heavy Texture Soils including Vertisols** (Clay > 30%)									
Without M&E charges									
Pumped outlet	172,500	129,000	105,000	91,000	--	--	--	--	--
Gravity outlet	148,500	109,500	88,000	76,000	--	--	--	--	--
With M&E charges									
Pumped outlet	174,500	131,000	107,000	93,000	--	--	--	--	--
Gravity outlet	150,500	**111,500**	90,000	78,000	--	--	--	--	--

Table 5. Cost of SSD components with gravity/pumped outlet in heavy and medium texture soils

Component of SSD	Cost (₹ ha^{-1}) and share (%) in			
	Heavy soils (30 m)		Medium soils (67 m)	
Preparation of DPR	2,500	(2.2)	2,500	(3.4)
Pipes & fittings	41,989	(37.6)	21,750	(29.2)
Filters	14,776	(13.2)	8,334	(11.2)
Structures and pumpset	3,785	(3.4)	7,142	(9.6)
Installation cost	36,766	(32.9)	22,953	(30.9)
Dewatering & O&M	0	(0.0)	1,500	(2.0)
Supervision charges	4,000	(3.6)	4,000	(5.4)
Contingencies	5,066	(4.5)	3,431	(4.6)
Farmer's training	750	(0.7)	750	(1.0)
M&E	2,000	(1.8)	2,000	(2.7)
Total:	**111,500/-**	(100)	**74,000/-**	(100)

Above SSD cost does not include tree removal, drain cleaning and deepening, approach road and land development, maintenance cost, farmers share and pumping cost for fourth year onwards. This cost includes collector length (25 m per ha) assuming surface drain in vicinity.

Additional charges for drain cleaning and deepening @ 7,500/-per ha, and extension of underground collector pipeline to open drain @ 15,000/- per ha may be provided separately on case to case basis.

WAY FORWARD

Costs of SSD systems vary considerably from north-western states to central and southern states depending on soil texture, drain depth and spacing, and outfall condition. These guidelines and costs may be used as cost norms for funding of large scale SSD projects under various national programmes to speed up reclamation of waterlogged saline soils through project agency or outsourcing in PPP mode in alluvial and heavy soils (Inland and coastal).

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Guidelines and Costs of Sub-Surface Drainage Technology for Large Scale Reclamation of Waterlogged Saline Soils

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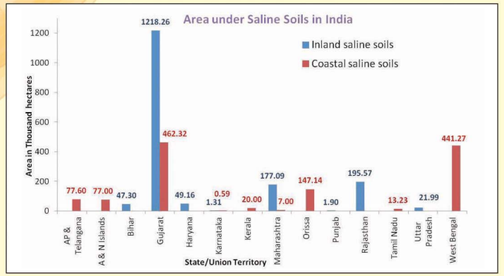
INTRODUCTION

Irrigated agriculture without drainage is not sustainable in arid, semi-arid and sub-humid regions of India and has brought nearly 2.95 million hectares (M ha) area under saline soil due to waterlogging and soil salinization adversely affecting crop productivity in 16 states/UT of the country. Recently, ICAR-CSSRI estimated the national losses of annual crop production and monetary as 5.66 million tonnes and ₹8,000 crores, respectively, due to soil salinity in the country. Waterlogged saline alluvial or heavy soils characterized by shallow water table (<2.0 m) and high concentration of soluble salts (ECe> 4 dS m^{-1}, pHs < 8.2 and ESP<15) are often associated with irrigation commands. These affected soils in inland and coastal areas have been reclaimed through sub-surface drainage (SSD) technology for controlling salinity and enhancing crop productivity and farm income. This technology implemented on large scale in alluvial and heavy soils has enhanced crop intensity, crop yield and farm income by 40-50%, 50-120% and 200-300%, respectively, leading to a B/C ratio of 1.5-3.2 and an internal rate of return of 20-58%. Cost of installing a SSD system varies considerably from alluvial to heavier soils and depends upon water table depth and water quality, soil texture and salinity, drain depth and spacing, drainage material, outlet condition, and pipe laying machinery. Therefore, guidelines and costs of SSD technology are worked out and suggested for funding and implementing large scale drainage projects through state department/project agency as well as through public-private partnership (PPP) mode in order to accelerate the reclamation of waterlogged saline soils.

SCOPE AND COVERAGE

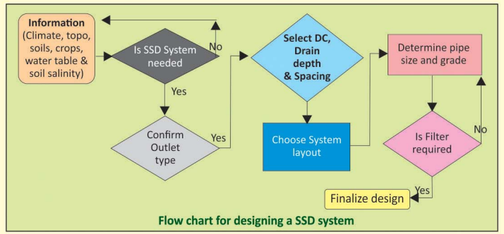
ICAR-CSSRI conducted the researches on manually, semi and fully mechanically installed pilot scale SSD projects since 1980s and standardized the drainage technology for large scale implementation of mechanically installed projects in eight states such as Haryana, Rajasthan, Punjab, Maharashtra, Karnataka, Gujarat, Andhra Pradesh and Telangana. During the last 10 years, implementation of projects has increased exponentially under various national schemes viz. TDET, CADWM, RKVY, etc. These projects were executed through state departments/ project agencies or through a suitable Public-Private Partnership (PPP) model. Total extent of inland and coastal saline soils in India is estimated as 2.95 M ha. This estimate does not segregate waterlogging induced or saline groundwater irrigation associated salinity. State wise distribution of inland and coastal saline soils in India reveals that inland salinity area is 1.71 M ha in 8 states whereas coastal salinity area is 1. 24 M ha in 9 states.

So far, 66,084 ha affected soils in 11 states (26,500 in Karnataka, 16,500 in Rajasthan, 10,584 ha in Haryana, 6,500 in Maharashtra, 3,000 in Punjab, 1,300 in Gujarat, 950 in MP, 500 in AP and Telangana, and 250 ha in other states) have been reclaimed. Therefore, there is a huge scope of implementing SSD technology on large scale for reclamation of waterlogged saline soils.



DRAINAGE DESIGN CRITERIA

A SSD system is designed to control soil salinity and waterlogging in an affected area with unit drainage block ranging from 20 to 60 ha and consists of a underground network of corrugated perforated lateral and perforated/ blind collector drain pipes wrapped with proper synthetic filters are installed at the designed depth and spacing to remove excess salts and water from the affected fields. Drainage water is disposed off under gravity or by pumping into open drains, streams, rivers or evaporation ponds. A flowchart for designing SSD system is as follows:



Flow chart for designing a SSD system

Outlet: Type and location of an outlet is the starting point in planning and designing a SSD system. Pumped or gravity outlet may be chosen as per the outfall condition. Pumped outlet is used in most canal/tubewell irrigation projects due to flat topography whereas gravity outlet is used in most lift irrigation projects.

Drainage coefficient: Drainage coefficient of 1-5 mm per day is sufficient for controlling salinity and waterlogging in different agro-climate conditions (Table 1). Most of the reclamation salt leaching is expected to take place during the S-W monsoon period.

Drain depth: Drain depth influenced by outfall condition, varies between 0.9 and 2.0 m to avoid pipe damage from use of heavy machinery (Table 1). Generally, deep drains allow wider drain spacing. Initially increasing the depth up to 1.4 m can result in cost reduction whereas further increase in depth might increase the installation cost.

Drain spacing: Drain spacing is mainly affected by soil texture (Table 2). Drain spacing of 20 m in heavy textured soils is feasible under a condition when additional cost over 30 m drain spacing is recovered from additional crop yields in the first three years.

Drainage layout: After drain spacing, a drainage layout with mostly composite system with parallel grid or herringbone pattern is prepared considering topography constraints, outfall condition, and man-made structures including canal, road, etc.

Drainage design equation: For irrigated soils under arid and semi-arid monsoon climate, the transient state Glover-Dumm equation has been used for drainage design. However, steady state Hooghoudt equation is practically preferred for designing a system with good performance for all climates.

Pipes size, slope, and filter requirement: Guidelines for slope is controlled by drain pipe size. Filter (envelope) criteria are suggested to avoid sedimentation in pipes (Table 3). However, due to deeper cracks in heavy soils, filter is still suggested to check preferential flow of sediments* to drain pipes.

Table 1. Guidelines for drainage coefficient and drain depth under different conditions

Climatic region	DC Range (mm/day)	Optimum (mm/day)	Outlet	Depth range	Optimal depth (m)
Arid	1-2	1	Gravity	0.9- 1.2	1.0
Semi-arid	1-3	2	Pumped	1.2- 1.8	1.5
Sub-humid	2-5	3			

Table 2. Guidelines for drain spacing under different soil texture groups

Soil texture group	Drain spacing range (m)	Optimal spacing (m)
Light	100-150	100
Medium	50-100	60, 67
Heavy including Vertisols	30-50	30

COST COMPONENTS

Eight major components of SSD systems are discussed below while making cost estimates.

i) Preparation of detailed project report

For preparation of Detailed Project Report (DPR), site surveys and drainage investigations are conducted to collect all the relevant data for designing an efficient SSD system. Data includes project area, size and location, soil type and salinity, topo survey, hydraulic conductivity, drainable pore space, upward seepage and lateral inflow, geology and geo-hydrology. The outputs generated are 1:5,000 scale topographical map with spot levels for preparation of drainage design and layout, information on soil texture, soil salinity, hydraulic conductivity, etc and 1:2,500 scale drainage layout map with laterals and collectors, manholes, sump well/ outlet, and their specifications. The charges for preparation of DPR are worked out and allocated as Rs. 2,500/- per hectare.

Table 3. Guidelines for drain pipe size, slope and filter requirement

Pipe size (mm)	Grade (%)	Clay & SAR	Filter required
80- 100 (lateral)	0.10	< 30%	Yes
100-315 (collector)	0.09-0.05	30-40% and SAR > 8	Yes
		> 40%	No*

ii) Drainage materials

Lateral and collector pipes: Single Wall Corrugated (SWC) pipes of UPVC (Unplasticized poly vinyl chloride) with 80-315 mm outside diameter are widely used. The flexible perforated lateral pipes (80 and 100 mm dia) with coil length up to 150 m are manufactured in accordance with IS 9271:2004. Collector pipes are needed to transport water to the outlet, so non-perforated pipes (SWC/DWC) are preferred. Pipe diameters (100-315mm) depend on the expected flow discharge. These pipes are manufactured in compliance with IS 9271:2004 & 2010 and double wall corrugated (DWC) non-perforated pipes as per IS 16098 Part 2: 2013. However, perforated corrugated collector pipes can be used to prevent floating of pipes during installation under severe waterlogged condition. Moulded pipe fittings (coupler, reducer, end cap, saddle tee, bend, etc) are used for pipe connections. HDPE drain pipes are 20% more expensive than UPVC pipes, so HDPE pipes may be used wherever feasible.

Synthetic filters: Synthetic filters are preferred over gravel envelopes due to low cost and weight and easy installation. Non-woven poly propylene geotextiles (thickness > 2.5 mm and O_{90}> 300 micron) for light and medium texture soils, and non-woven poly propylene/polyester fabrics with needle punched geotextile for heavy texture soils are used for lateral pipes whereas woven nylon socks/sleeves (60 mesh) are used for perforated collector pipes. These filters are tested for thickness and characteristic opening size (O_{90})/ mesh size as per the BIS standards based methodologies before their use. Better quality prewrapped perforated pipes wherever available should preferably be used.

Structures and pump set: Pre-fabricated RCC pipes of 900 mm diameter with 3.75 m length (1.25 m each) for manholes, and 1200 mm diameter pipes with 5.0 m length (4 pieces) for sump well are used in pumped outlet system whereas manholes of 900 mm dia and 2.50 m length are used in gravity outlet system. These NP-3 class RCC pipes


Filter wrapped Lateral Pipes


Collector Pipes