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Drainage well design option for saline zones

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INTRODUCTION

Water and Power Development Authority (WAPDA), based on extensivewater and soils surveys (1954-60), carried out a number of studies to eradicate waterlogging and associated salinity. These studies, keeping in view the development of agriculture and the future need, resulted in the "Salinity Control and Reclamation Projects" concept popularly known as "Scarps". Scarp concept, in addition to others, aimed at two stage development i.e. the first stage covered tubewell drainage in sweet water zones and to use this effluent to alleviate chronic irrigation water shortage; in the second stage the saline ground water zones drainage was undertaken in the saline zones. So far (June 1987) WAPDA has completed 35 such projects covering an area of 9.23 million acres and work on 13 more projects is in hand to provide relief to another 8.32 Ma.

After catering for the drainage needs of most of the usable groundwater area, the drainage facilities are being extended to area having good acquifer but brackish groundwater which is unfit for irrigation even after mixing with available surface water. The saline effluent thus needs to be disposed off either in existing natural water-ways such as rivers or in planned to be disposed off in lagoons in the desert area. Keeping in view the disposal facilities in some areas where existing waterways can accept the effluent or where it can be disposed off in lagoons "tubewell drainage" has been adopted, while in others tile drainage is being used/proposed.

Purpose and Scope

As indicated above some saline groundwater zones are being provided with "tubewell drainage" as it is less cost-intensive as compared to the tiledrainage. The brackish areas so far provided with tubewell drainage include; saline zone SCARP-II and Satiana Pilot Project (Scarp-V) in Punjab and SCARP Khairpur in Sind. The projects lined up for construction include; saline zone SCARP-VI in Punjab and Sanghar, Nawabshah and Mirpur Khas sub projects of the Left Bank Outfall Drain in sind (Fig.1). To resist the corrosive effect of brackish effluent non-corrosive material/protective coatings have been used both for tubewell and pumping equipment. Tubewell design however, remains strictly the one used in SCARPs in non-saline zones i.e. tubewell fitted with vertical turbine pump. The purpose of this paper is to examine technical and economic feasibility of an alternate tubewell design option for brackish zones.

EARLIER DESIGN

The two main saline zone projects planned and implemented as such include; SCARP Khairpur in Sind where 365 tubewells were installed in 1968-69 and SCARP-II (Saline Zone) in Punjab where 189 tubewells wer installed along the drains in 1978-79. Tubewell material and pumping equipment used in these SCARPs was as under:

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SCARP Khairpur

The tubewell housing, reducer and screen were all of fibre glass except in few wells where wire-wound stainless steel screens were used instead of the fibre glass screens. For the selection of pump design, the wells were categorized as 'low salinity' if the effluent was less than 2,000 ppm and 'high salinity' for values greater than 2,000 ppm. For the high salinity pumps the bowls, impellers and spiders were made of zincless bronze, shafts of stainless steel and the discharge column pipes of mild steel electro-phoretically coated with rubber including the matting faces of joint flanges to prevent electrolytic corrosion. The discharge column pipes had flanged joints. PVC suction pipes 12-15 feet long were screwed into the lower intake end of the pump bowl.

SCARP-II (Saline Zone)

In saline zone SCARP-II, tubewells and pumping equipment were not specifically designed to prevent corrosive action presuming that the anticipated salinity of water is not going to be that high. Therefore, mild steel housing and reducer alongwith fibreglass screen/plain pipe were used for tubewells. The vertical turbine pumps had standard impellors with mild steel shafts and discharge column pipes joined with threaded sockets.

Tubewell Performance in Brackish Zones

Performance of wells is guaged from two angles i.e. hydraulic performance and behaviour of tubewell and pump material against corrosion etc. Hydraulic performance though generlly independent of the quality of water yet is indirectly affected by the corrosive action of water on the material used for well screens and the pumping equipment. The performance of tubewell and pumping equipment material in the corrosive waterquality environments and their effect on tubewell working is briefed as under:

SCARP Khairpur

In this project corrosive resistant fibre-glass housing, reducer and screens were used for well construction. For pumping equipment stainless steel shafts, zincless bronze impellor, bowls and spider were used. Discharge column pipes were coated with rubber and joined through flanges to avoid corrosion at screwed joints. In view of using corrosion resistant materials for tubewell and pumping equipment, no effect of water quality on tubewell performance has been reported.

SCARP II (Saline Zone)

After project operation complaints about certain tubewells pumping gravel were received. Also serious reduction in discharges were observed. A special committee was constituted to look into the problem and suggest remedial measures. The problem was studied in selected tubewells including inspection by the T.V. camera and actual inspection of pumping equipment. The observations were:

1. Mild steel reducers used to connect housing with the fibre-glass screens had been eroded from where gravel is being sucked in;

2. Mild steel housing at places had been eaten away by corrosive action of water:

3. Pump impellors, shafts, column pipes had been eroded seriously affecting the efficiency of pumps.

Selected pictures are given in Fig. (2) which depict the condition of pumping equipment. Remedial measures proposed and implemented included:

a) Stainless steel reducers were manufactured and pushed in place to stop the pumping of gravel from the damanged portions.

b) Mild steel shafts were replaced by stainless steel shafts.

c) The discharge column pipes were fitted with flanges for joining instead of threaded sockets. The inner side of column pipes were coated with some innert material.

d) Spiders were replaced with bronze spiders.

DESIGN OPTION

Present Approach

The experience gained in relative performance of the tubewell designs for Khairpur and SCARP-II (S.Z.) has been made use of in designing the tubewells for saline zone of SCARP-VI, where 391 tubewells are planned to be installed along the drains; 72 of 1.5 cfs capacity, 128 of 2 cfs and 191 of 3 cfs capacity. in designing these wells the main stress has been to use material which can resist corrosion. The tubewell housing pipe, reducer, plain pipe and screen are all of fibre-glass. Vertical turbine pump to be used will consist of parts made from the corrosion resistant material such as; shafts of stainless steel, impellor of zincless bronze, discharge column pipes internally coated with innert material and connected through flanges with stainless steel bolts etc. The design adopted is typical of the standard design arrangements used in sweet groundwater zones for irrigation-cum-drainage wells except that corrosion resistant material has been used.

Similaly, in LBOD three schemes namely Nawabshah, Sanghar and Mirpur Khas are planned to provide drainage and scavanger wells as detailed below:

Sub Project	Drainage Wells Capacity (cfs)				Scavanger Wells Capacity (cfs)	
	2	1.5	0.75	0.5	1.5	3.0
Nawabshah	294	92	-	-	94	-
Sanghar	296	-	-	-	699	59
Mirpur Khan	-	331	246	138	-	-

The well design include use of M.S. housing pipe, fibreglass screens, zincless bronze impellor, stainless steel shafts, cost iron pump bowl and column pipes of steel protected by hard rubber or plastic coating.

Alternate Approach

Drainage well's operational requirements are somewhat different from irrigation-cum-drainage tubewells. The capacity of the later is determined by the planned cropping intensity and size of the chak and are sited at water course head to permit conjunctive use of surface and groundwater. Their operation is controlled by the crop water requirement as no alternate arrangement for disposal of excess effluent is provided. Drainage in this case becomes the secondary objective. Contrary to this drainage wells are linked to the surface drainage channels and their effluent being highly brackish is disposed off into the drains. Their operation is controlled strictly by the drainage requirements. Because of the basic difference in objectives and operational requirements, following factors may guide the optimum design arrangements:

(1) For best drainage results tubewells are required to be as evenly distributed as feasible.

(2) Greater the number of wells more uniform lowering will be achieved.

(3) Exceptnear major sources of reacharge the drainable surplus can be assumed to be fairly uniform.

(4) Capacity of the wells is to be determined by aquifer characteristics and also the overall cost effectiveness.

(5) Pumping equipment being exposed to severe corrosive conditions, should have minimum moving parts and permit easy and quick inspection and repair.

Keeping these guidelines in view centrifugal pump fitted tubewells, where feasible, merit consideration as an alternate option to vertical turbine pump wells with the following apparent advantages:

(i) Use of large diameter fibre-glass housing, which is very expensive, can be avoided.

(ii) Centrifugal pumps which have very few moving parts can be used thus reducing wear and tear and also O&M cost.

(iii) In brackish tubewells, frequent inspection of pumps is inevitable. Inspection and repair of C.F. pumps is much easier and quicker.

(iv) In the event of discharge reduction twin bore concept can be adopted without replacing the existing well. This also saves dismantelling of pump house and discharge box etc at the time of replacement.

The planners and disigners have some inhibition in recommending use of centrifugal pump wells for reasons of; (i) priming difficulty; (ii) likely submergence of motors due to sudden fluctuation of sub-soil water level on account of canal closure; and above all (iii) lack of confidence in the operating staff ability to maintain the system and operate it efficiently. However, none of these difficulties are insurmountable and warrant to ignore use of such wells if these are technically feasible and also economical to install and operate.

DESIGN CONSIDERATIONS

Pumps Limitation

Centrifugal pumps operate under the principle of suction and therefore has certain operational limitations i.e.

a) maximum theoratical suction lift is 34 ft.

b) certain minimum positive head at pump inlet is required to avoid cavitation and smooth operation. This requirement is function of pump design and vary with discharge and speed.

Pump manufacturers data can be used to determine the static suction capability of a particular pump and its variation with discharge. Fig.(3) gives the static suction capability and its variation with discharge for three low head centrifugal pump models.

Aquifer Limitations.

Centrifugal pump has operational limitations and to determine its technical feasibility the anticipated working water levels needs to be examined. Assuming the general range of specific capacity of wells in the Indus plain aquifers and allowing 3 feet for pump setting above the water-table and 5 feet to account for future lowering of water-table due to drainage, specific capacity lines have been drawn in Fig. (3) which give the pumping levels i.e. static suction lift below centre line of pump for discharges upto 2 cusec.

Project Operational Requirements.

The first question is what waterable lowering is acceptable. In tile drainage area the tile lines are laid at 6 to 8 feet below natural surface level (NSL) and at mid point the depth to water below NSL would hardly be more than 5 feet. If small lowering is acceptable in tile drainage area without intensive irrigation then lowering of waterable by 5 feet should adequate in tubewell drainage area also. In addition, in saline zones supplemental irrigation supplies through SCARP tubewells are not available, therefore, if the lowering of sub-soil water is limited to bare minimum then some sub-irrigation can be provided from top thin layer of sweet ground water always present due to local seepage. With this assumption and allowing 3 feet for pump setting above existing watertable the minimum lowering catered for is in fact 8 feet below NSL.

Presently the criteria for recommending tubewell's replacement is reduction in specific capacity and discharge by more than 50 percent. Therefore, a provision in design is made to cater for this additional head. As discharge is the primary consideration both in irrigation and drainage wells and that discharge and specific capacity are inter-related (if there are no other mechanical causes) therefore, taking discharge as the controlling criteria following observations can be made from Fig. (3):

1. Pump ETA 80-20 can work at 1.0 cfs capacity at minimum specific capacity of 34 gpm/ft. For higher specific capacity excess discharge to be controlled with sluice valve. Its discharge would reduce to 0.55 cfs gradually if the specific capacity reduces to 14 gpm/ft.

2. Pump ETA 100-26 can work at 1.5 cfs capacity at minimum specific capacity of 37 gpm/ft. For higher specific capacity the excess discharge to be controlled with sluice valve. The discharge would decrease to 0.7 cfs. with decrease in specific capacity to 17 gpm/ft.

It is, therefore, obvious that CF fitted pump wells of capacity upto 1.5 cfs can very easily be designed to operate in the specific capacity range of 34-37 gpm/ft and more with due provision of watertable lowering of about 8 feet below NSL. In 0-3 feet depth to watertable area the pump house can be placed at NSL without any provision for subsequent lowering. In area where depth to watertable is 3 to 5 feet the pump house may be kept 3 feet below the NSL. Neither any sinking of pump house well nor any subsequent lowering of pump setting has been envisaged or required in this design option.

COST EFFECTIVENESS

The decision to choose the design alternative is also affected by the capital and operation and maintenance costs. To enable this caparison to be more realistic the cost analysis given below is limited to. wells upto 1.5 cfs capacity and has been made with respect to SCARP-VI (Rahimyar Khan) however, it would also be applicable to all other areas where centrifugal pump fitted drainage tubewells are technically feasible.

Cost of Drainage Wells SCARP-VI

Design discharge of drainage wells proposed vary from 1.5 to 3.0 cfs and the typical design statistics of each is as given below:

Capacity (cfs)	Depth (ft.)	Housing/dia (ft/inch)	Screen/blind pipe* (ft.)
1.5	220	60/12	160
2.0	260	60/14	200
3.0	365	65/14	300

*20% blind pipe estimated; 10" dia.

The tendered cost for 202 tubewell's installation and effluent disposal arrangements is Rs.50.65 million, for the total designed capacity of 430 cfs. The break up of this cost is as under:

Item	Total Cost (m.Rs.)	Cost/cfs
Tubewells	28.04	65220
D&T	1.1275}	
App. Works	2.2285}	7802
Equipment	5.864	13628
Disposal Work	13.390	31140
	50.65	117790

Comparison of Cost

In SCARP-VI 72 drainage wells of 1.5 cusec capacity are proposed to be installed with vertical turbine pump design arrangements. for quick and simple cost comparison between centrifugal and vertical turbine pump fitted wells of 1.5 cfs capacity and to avoid minor details let assume that except for change in length and diameter of Housing pipe and pumps all other arrangement remain the same, the only difference in design if C.F. pump is used would be:

a) 60 feet housing pipe of 12" diameter to be replaced with 10" diameter pipe, 40 feet long causing a saving in material cost of Rs.11040/- per well (unit cost of 12" and 10" pipe is Rs.327/- and Rs.252/- per foot).

b) Instead of using corrosion resistant vertical turbine pump cost Rs.42000/- let use corrosion resistant C.F. pump of same capacity costing Rs.25000/-, thus resulting in saving of Rs.17000/- per well.

The saving per well affected in cost is thus estimated at Rs.28040/- and if spread over this contract saves about Rs.2 million. This saving is only 4% of the tendered cost and may look insignificant. But if this hypothesis is extended to 715 wells of 1.5 cfs and less to be installed in LBOD the saving is going to be a handsome amount.

Not only that this design option is going to cause enough saving in capital cost, but also considerable convenience and saving is affected in operation and maintenance cost. To quote from a study caried out on Minchinabad Pilot Project(1) the O&M cost for C.F. fitted pump is 1/2 of the turbine pump exclusive of power cost which is assumed to remain the same. As no heavy equipment is required to extract and carry the pump for repair, therefore, repair of C.F. pumps is likely to be attended much quicker thus increasing its utilization percentage.

To optimize the tubewell design 12 test wells with different screen length were installed in SCARP-VI. These wells were then operated at discharges varying from 1 to 5 cfs. The actual drawdowns and specific capacities at 1.5 and 2 cfs for various screen lengths is as given below(2):

Capacity (cfs)	Screen Length (ft.)	Drawndown (ft.)	Sp. Capacity (gpm/ft.)
1.5	100	13	52
	120	12	55
	140	9	75
	160	9	75
2.0	100	17.5	51
	120	16.0	56
	140	12.6	71
	160	12.0	75
	180	10.0	90

For 2 cfs well nearly 160 feet for screen length is being used. The specific capacity of such a well is anticipated at 75 gpm/ft with drawdown of 12 feet. If 8 feet lowering below NSL is acceptable then the total suction lift is 20 feet. Under such circumstances low head centrifugal pump concept can be extended even upto wells of 2 cfs capacity which would result in further saving.

CONCLUSIONS

On the basis of analysis presented in the paper following conclusions can be made:

1. In saline groundwater zones selected for tubewell drainage and where low capacity drainage wells are inevitable, centrifugal pump fitted tubewell design option is likely to result in considerable saving in initial and subsequent operation and maintenance cost.

2. C.F. pump fitted wells upto 1.5 cfs capacity are technically feasible for specific capacity of 34-37 gpm/ft. or more, after allowing 5 feet provision of lowering of regional water level and without provision of lowering the pumpsetting.

3. For drainage wells in disaster areas no pump house well sinking is required for use of C.F. pump fitted wells.

4. Concept of using C.F. pumps can be easily extended to 2 cfs capacity wells where aquifer conditions are favourable.

RECOMMENDATIONS.

If possible, few C.F. pump fitted drainage wells of 1.5 and 2 cfs capacity may be installed in SCARP-VI alongwith vertical turbine fitted pump wells and monitored to test the validity of above conclusions.

REFERENCES

1. Selection of tubewells design for Scarps; Report of Committee by GM(W) Centre vide GM(W) g/80/PXC/6-80/26330-35 dated 22-12-1980.

2. Test tubewell report "Scarp VI-1983" planning and design publication No.31.

Fig. 1

Paper No. 495

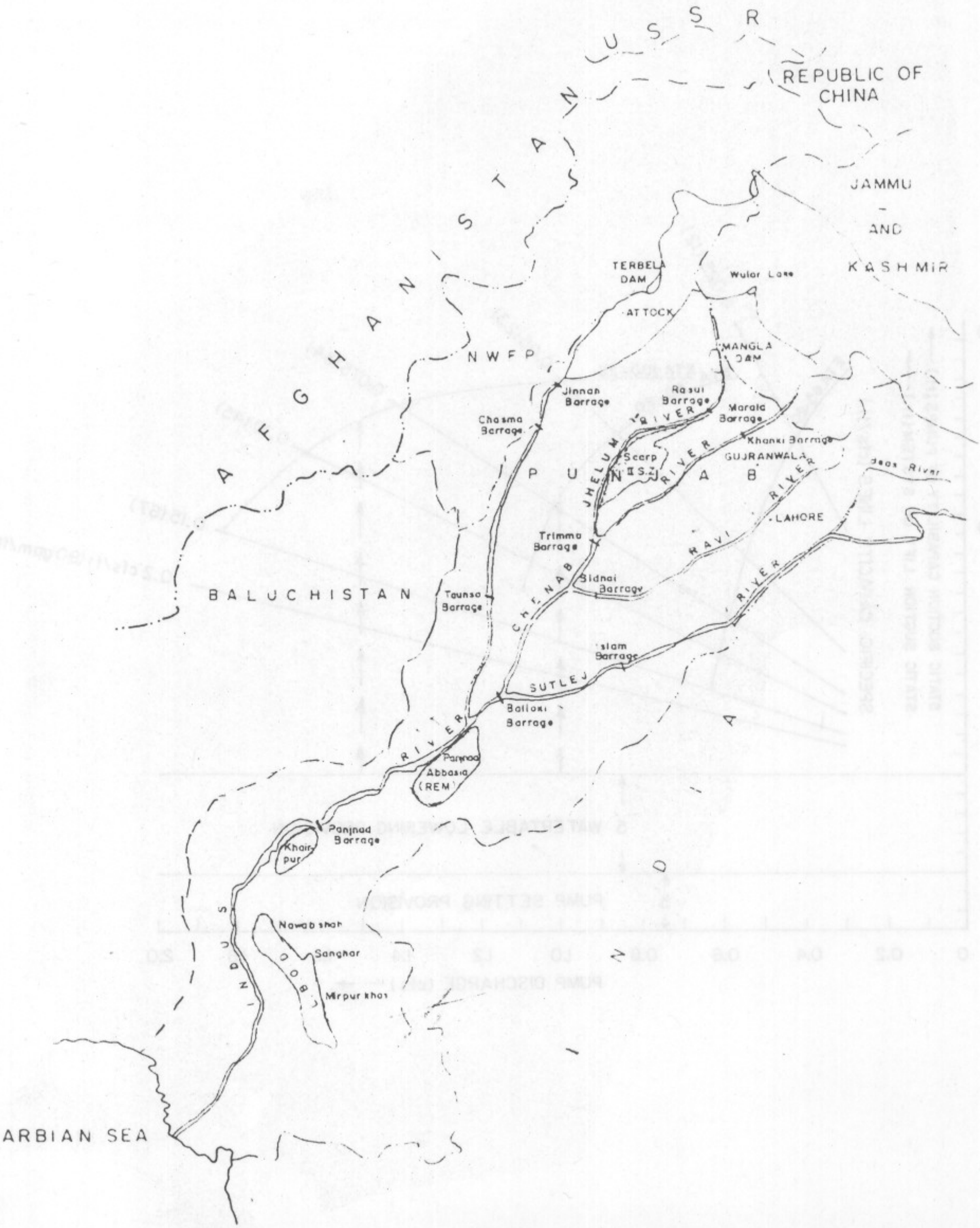
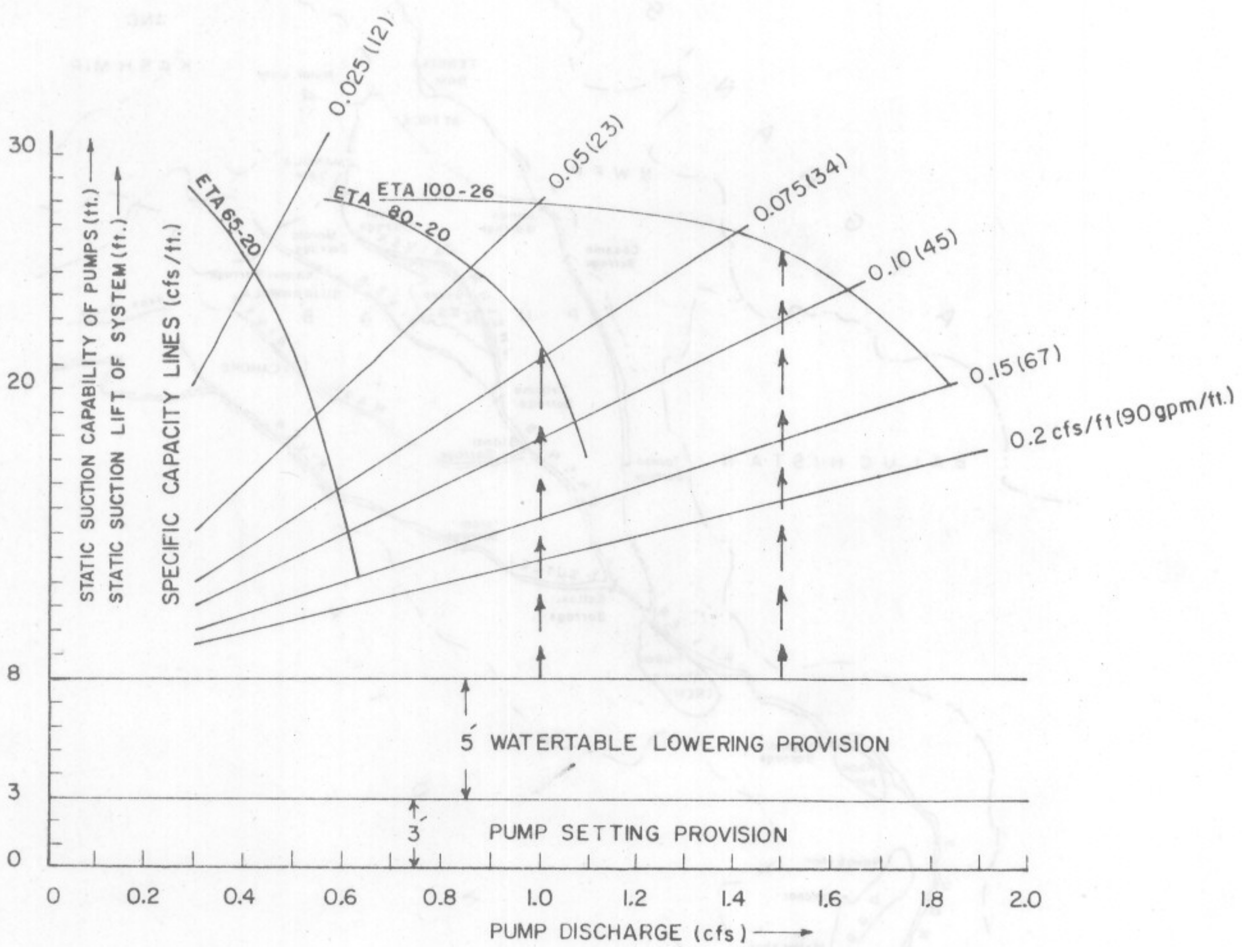
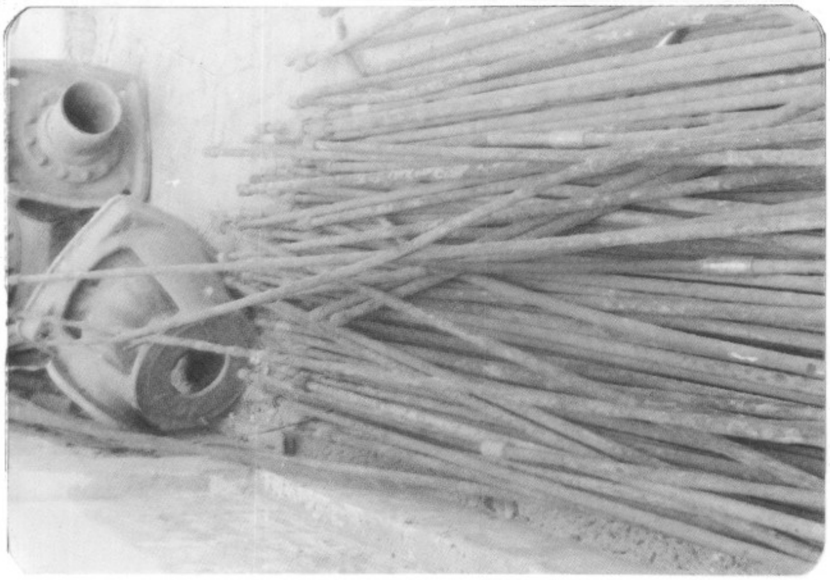
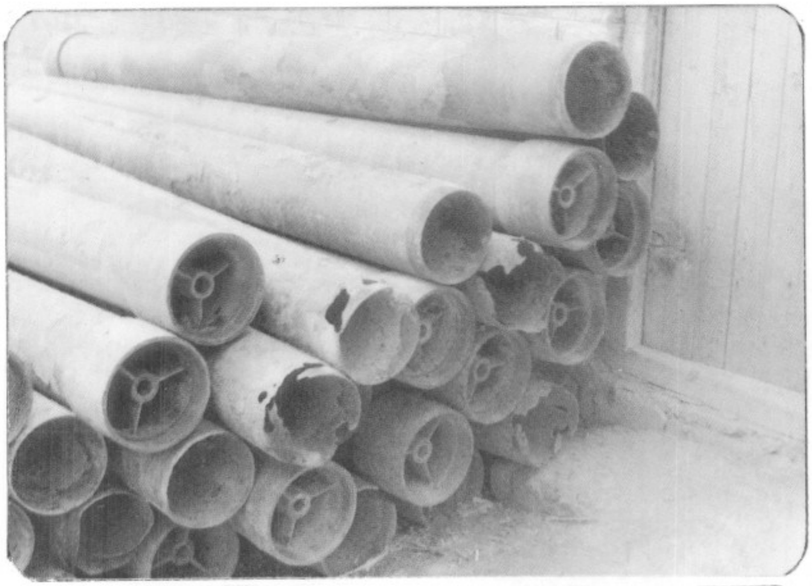


Fig. 3

Paper No. 495







Corroded Coulmn pipes and Shafts
(Saline Zone Scarp II)