Waterlogging and Salinity in the Indus Plain: Comment

by
NAZIR AHMAD*

Mr. Ghulam Mohammad, Senior Research Economist of the Pakistan Institute of Development Economics, by publishing his critical analysis of the Revelle Report in Volume IV, No. 3 of the *Pakistan Development Review* [4] has done a great service to the country. A chance has, thus, been created to examine some of the recommendations for the solution of the problem as put forth by the Panel of scientists from America.

Ghulam Mohammad has summarised the major recommendations of the Revelle Report and then commented upon these, giving alternative suggestions. The main recommendations of the report are to install tubewells in the large agricultural regions of the Indus Plain. This suggestion is to supplement the insufficient diversion of the surface water and at the same time to effect the drainage of the land. Ghulam Mohammad has discussed the results of the quality of groundwater, and has concluded, "that groundwater of the Indus Plain are charged with dangerous limits of bicarbonates and sodium contents and their indiscriminate utilization will make the soils alkaline and impermeable." In his opinion, tubewells should not be installed in areas where concentration of sodium or bicarbonates is very high.

Ghulam Mohammad has further put forth the financial workability of the deep open main drains combined with the open or tile field drains. As for water economy on drained land, the author is in favour of keeping a high level of groundwater to meet with a certain amount of crop requirements from sub-irrigation.

Ghulam Mohammad has cautioned against the indiscriminate use of groundwater on the land. At present, according to the Panel of scientists, the main problem is the insufficiency of water for sustained agriculture and lack of proper utilization of agricultural practices. For finding more water and to effect quick drainage, tubewells are suggested and for improvement

*Dr. Nazir Ahmad is the Principal Research Officer (physics) at the Irrigation Research Institute, Lahore.

of agricultural yield, better management, better seeds, use of fertilizer, pest control, use of insecticide and such other measure, known to increase the yield, are suggested. The Panel has laid great stress on the agricultural aspect of the problem. Very little consideration is given to other means of drainage, on chemistry of soil and water and other hydrological and engineering considerations. Installation of tubewells, mining of accumulated groundwater, disposal ofs aline groundwater, salinity build-up in the aquifer, spacing of tubewells, *etc.*, are the points discussed at length in the report. The points missed are the long term success of this measure with respect to the type and design of tubewells, their life and durability, their working cost and results of mining on water requirements of crops, effect of pumping saline water and its disposal, interaction of the quality of pumped water with the type of soils generally in existence, *etc.*

Tubewells have Uneconomical Durability

This country has had more than fifty years' experience of installing tubewells in fine to medium sand formation of the Indus Plain which contains some small percentages of fines, such as silt and clay. Inspite of trials of many alternatives to develop a long-lasting tubewell, giving high economical yield, the solution has yet baffled success. Chocking of strainers and their incrustation is a major problem. Iron strainers have short lives in the soil and water of this Plain; strainers of inert materials like cadmium, brass and copper were all tried and found to get incrusted. Trials with inert materials like wood, and coir string also did not stop the incrustation. Recent suggestions have been to install large diameter tubewells and use strainers with wide slits. This was tried with iron and brass strainers without much success. In case of SCARP 1, tubewells were installed with all precautions but these have started to misbehave in a short period of four years.

It was suggested that for an economical performance, high discharge capacity tubewell units may be installed. This brought in the use of turbine pumps replacing the centrifugal pumps of 1 to 2 cusecs capacity. The life of components of a turbine pump, however, is lower than a centrifugal pump (*see*, Table I) and components of a turbine pump are difficult to procure.

TABLE I

Item	Estimated useful life
Well and casing	20 years
Pump turbine bowl (about 50 per cent of cost of pump unit)	8 years
Column, *etc.*	16 years
Pump, centrifugal	16 years
Electric motor	25 years
Diesel engine	14 years

Source: [5].

This nullified the advantages of this suggestion. Pumping a high order discharge has some other serious disadvantages of quick incrustation, due to the movement of fine formation. The farmers in West Pakistan have found a solution to the incrustation. The solution is the low cost tubewells and their frequent replacement. A farmer's tubewell, to pump one to two cusecs, hardly costs one or two thousand dollars, so that within the life expectancy of the tubewells (assumed ten years), they not only recover the full capital invested within one or two years, but also make tremendous profits out of agricultural produce due to the large amount of available water. So far, the farmers do not know the advantages of multiple strainer tubewells. If they adopt this device by adding three or four strainers, 100 to 150 feet in length, 50 to 80 feet. apart, they can pump a high order discharge, even upto 3 or 4 cusecs and, at the same time they can prolong the life of the tubewells. Such a technique of multiple strainers has many other advantages not possible with a single strainer, turbine-fitted tubewells. In Table II, pumping from multiple strainer tubewells with respect to power input and discharge is shown. In these tests, the pump capacity was only 2 cusecs and the strainers were very shallow, hardly 50 feet long with 30 feet of blind pipe and were pumping from very fine sand (mean diameter 0.18 mm.). A longer strainer, installed in medium sand, worked by high capacity centrifugal pump, could yield a higher order of discharge.

TABLE II

Strainer	Depression head in feet	Discharge, in cfs/per gallon	Specific yield in		Power in *kwh*
			cfs/foot	gpm/foot	
Niazbeg test					
Single	21.50	0.98/441	0.045	20.2	7.50
Double	15.00	1.48/666	0.100	45.0	9.25
Triple	17.24	1.64/760	0.100	45.0	9.40
Niazbeg					
Single	21.20	1.43/653	0.068	30.6	8.90
Double	18.97	1.73/778	0.091	41.0	9.50
Triple	16.13	1.80/810	0.111	50.0	8.80
Kohali Distributary					
Single	19.60	1.10/495	0.060	27.0	8.20
Double	17.25	1.58/711	0.087	39.1	8.84
Triple	17.48	1.70/765	0.100	45.0	9.05
Lahore Branch					
Single	17.00	1.28/576	0.075	33.8	8.02
Double	15.00	1.72/774	0.112	50.4	9.20

Low Order Storage Coefficient of the Indus Formation

The Revelle Panel based their estimate of mining of groundwater on a high order of storage coefficient. Although extensive boring results were available which clearly showed the existence of clay lenses and existence of silty sand, yet while estimating the yield of groundwater, a storage coefficient for a high yielding sand formation was assumed. It was pointed out [1] to the Panel on the receipt of the first draft report in September 1962 that the storage coefficient assumed at 25 per cent should be reduced by half as within a depth of 100 feet from surface the soil crust and clay lenses constitute about 40 to 50 per cent of the formation, but the Panel scientists used 25 per cent as storage coefficient which gave higher results. The tubewells of SCARP 1 have demonstrated the fallacy of this assumption. The fall in the level of the watertable was found to be too quick when pumping the tubewells to their full capacity.

The Panal has assumed the total infiltration from the Punjab and Bahawalpur area as 20 million acre feet. The total amount of loss of water according to the Panel is 50 per cent of that released at the head. The seepage from canal and links is 35 per cent, the remaining 15 per cent being the evaporation and other losses.

Earlier estimate of Kennedy, Benton and Blench are shown in Table III below:

TABLE III

WATER LOSSES FROM CANAL DISTRIBUTION SYSTEM IN THE PUNJAB

	Kennedy	Benton	Blench	Khunger
Main canals	5	—	5	Seepage only
Branches	15	—	15	—
Sub-total	20	16.4	20	15.5
Distributaries	6	6.1	7	5.4
Water courses	21	20.2	20	6.5
Sub-total	27	26.3	27	11.9
Total	**47**	**42.7**	**47**	**27.4**

The Panel of scientists has attempted a confirmation on the basis of rise of groundwater as a result of infiltration from various sources. Taking the rise of groundwater per year equal to 1.5 feet and assuming a 25 per cent storage coefficient, they have estimated water accumulation in 30 million acres equal to 11.3 MAF ($1.5 \times .25 \times 30 = 11.3$ MAF). Use of a figure of 1.5 feet rise with 25 per cent storage coefficient and without giving attention to the component of sub-soil flow, this figure is a poor proof.

It is proposed to pump 49.5 MAF of groundwater. This will constitute 20 MAF of seepage and 29.5 MAF to be drawn from the reservoir. The quantity of water to be mined is thus:

a) from good quality groundwater zone ... 24.2 MAF

b) from bad quality groundwater zone ... 5.3 MAF

Assuming 15 per cent of this water to be seeping back and assuming 25 per cent to be the storage coefficient, the depth of groundwater to be lowered to yield the required discharge will be:

Good quality groundwater zone $= \frac{24.2}{23} \times \frac{0.85}{0.25} = 3.58$ feet

Bad quality groundwater zone $= \frac{5.30}{7} \times \frac{0.85}{0.25} = 2.58$ feet

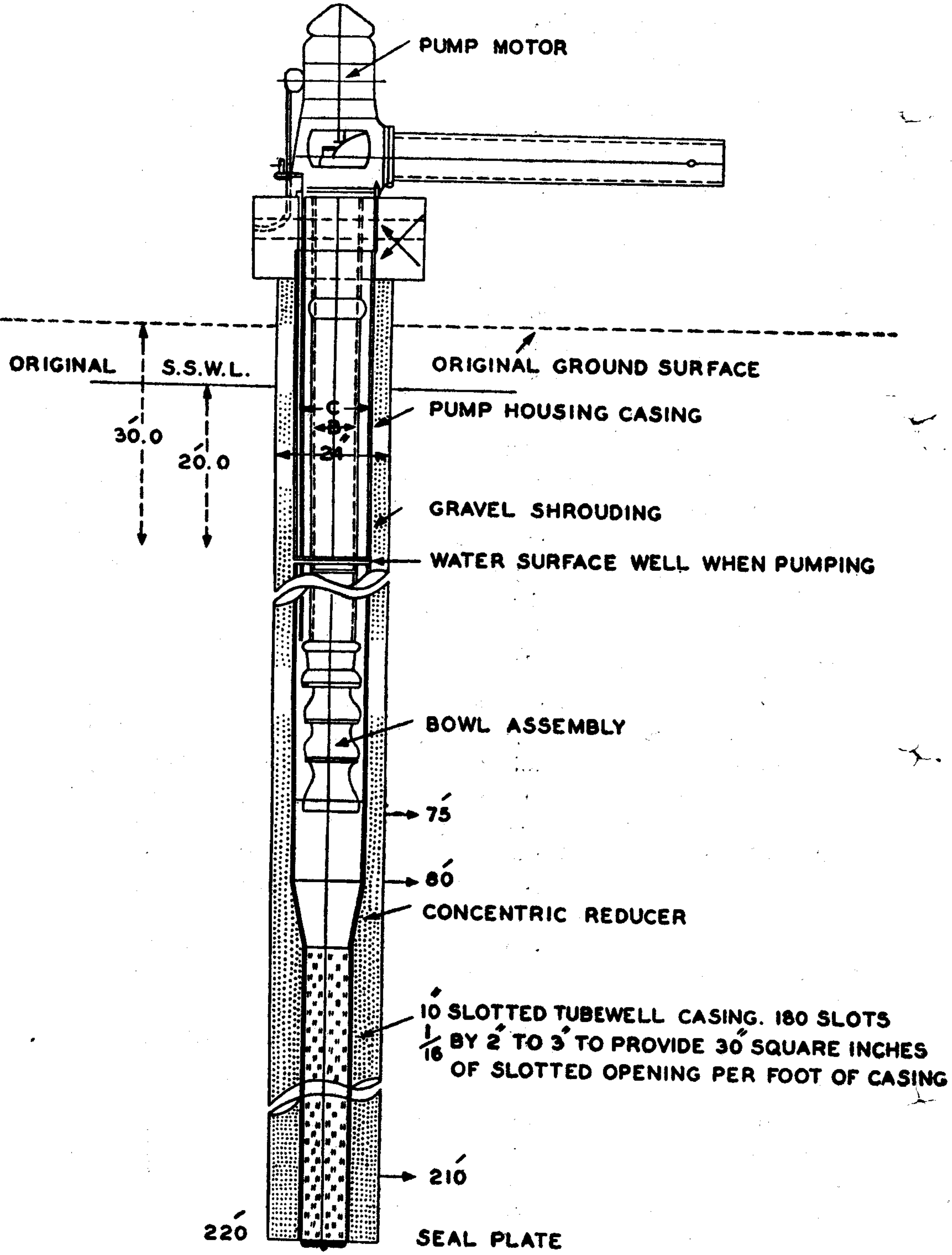
As it is now established that the storage coefficient is about 12 to 14 per cent, the fall of groundwater per year to give the above yield will be doubled, *i.e.*, about 7.0 feet per year in good quality groundwater zone and about 5.0 feet in bad quality groundwater zone.

Defects while Pumping this Order of Water

If this programme of pumping is followed, a fall in the groundwater table of 7 feet per year is expected so that the watertable will be lowered down to 100 feet in 14 years. Let us examine this suggestion for SCARP 1. In this area, tubewells are installed in which the length of housing is 90 feet and the impeller of the turbine pumps are located about 70-75 feet below surface, *i.e.*, about 60-65 feet below average watertable, at the time of the implementation of the scheme. These wells would pump 3 to 3.5 cusecs with an average depression head of 18 to 20 feet (*see*, Fig. 1).

If the mining is to be done as planned with a fall of 7 feet per year, the watertable will be below the impeller after 9 years of the operation. All the 2,000 tubewells of SCARP 1 will become useless if the groundwater is mined as proposed. The 3.0 cusecs discharge was started to be pumped with 20 feet of depression and 40 feet of water cushion. After five or six years, the cushion will be eliminated and water will be pumped by the depression alone. Working of the tubewells may become doubtful. If the conception of free surface opening on the discharge face as put forth by Peterson, Isrealson and Hansen holds [2], then the tubewell of SCARP 1 will stop working when the watertable goes down to 30-40 feet from its present level, *i.e.*, after 4 to 5 years of the pumping to mining capacity. The 2,000 tubewells of SCARP installed to work for 40-50 years shall have to be scrapped much earlier than their assumed life.

If the watertable is to be taken down to 100 feet by tubewell pumping then the length of housing pipe needed is 160 to 170 feet with impellers located at 150 feet and the strainer starting below 170 feet. This design of tubewell is not being followed even in other SCARP areas.


PUMP MOTOR
ORIGINAL
S.S.W.L.
ORIGINAL GROUND SURFACE
PUMP HOUSING CASING
30.0
20.0
GRAVEL SHROUDING
WATER SURFACE WELL WHEN PUMPING
BOWL ASSEMBLY
75
80
CONCENTRIC REDUCER
10" SLOTTED TUBEWELL CASING. 180 SLOTS
1/16 BY 2" TO 3" TO PROVIDE 30" SQUARE INCHES
OF SLOTTED OPENING PER FOOT OF CASING
210
220
SEAL PLATE

Loss of Component of Sub-irrigation if Watertable is Lowered

When Ghulam Mohammad wrote his comments, the data on the amount of sub-irrigation was still preliminary.

Recently detailed studies [3] have been completed on sugarcane and cotton crops. The former can grow in high watertable and the later needs a deep watertable. These studies have shown that a considerable amount of the requirements of a crop is satisfied from the soil moisture if the watertable is high.

Puming Saline Water and its Disposal

The Panel's suggestion to export 3.9 MAF of water with 4000 ppm to lower regions and to make arrangement ultimately to arrange for the disposal of about one MAF of water of 10000 ppm by surface evaporation also needs careful consideration. During three or four summer months from May to August, water is sufficient in rivers to mix 4 MAF (about 5,500 cusecs) of water and cause no harm to ultimate increase of salts but during the remaining 8 months, the river discharges are low and mixing this order of saline water will have serious problems.

Again, to evaporate about one MAF of water we need an exposed surface of about 270 square miles as in this region about 5 cusecs are evaporated from one square mile of the surface. The obvious course appears to be not to touch the saline water and to take such measures as to obtain the requirements without the mining of saline groundwater.

A Suggestion for the Solution of the Problem

The Panel has worked out that 58.8 MAF of water is to be made available at the fields. The present irrigation canal system diverts 48 MAF and makes available 24.3 MAF at the fields. The rest 34.5 MAF is to be pumped from the groundwater storage. This is to be made up of 20 MAF from seepage of canals and 14.5 MAF to be drawn from mining operation.

We know that during the 4 summer months from the beginning of May to the end of August, we have more river water supplies than we can utilize. Suppose we do not pump any groundwater during the 4 summer months. We can arrange our requirements from improved river diversion and further digging of canals. If we spread the pumping uniformly over the full year, then during the four summer months, we have to pump 11.2 MAF of water, During summer we have available water in our rivers. It needs arrangement to divert it on the land and during this period we can do without pumping. If we can succeed in this suggestion then we need only 23.3 MAF from groundwater for the next eight months. The source of this much water can be from seepage of the existing canal (20 MAF) and seepage from the new diversions. We can meet our requirements from the seepage only.

With a storage coefficient of 10 per cent a one foot rise of water in 30 million acres can store 3.0 MAF. During summer, canals run at full supply, temperature is high, and better saturated sub-soil connection exists, so that sufficient seepage is possible. High summer rainfall and high stages of rivers can also be a feeding source. We may take measures to see that as much water infiltrates into the formation as possible. Other measures to feed the aquifer can be :

i) dam water in all drains by providing over-shot gates at proper places,

ii) dam water in all non-perennial canals by providing over-shot gates at proper places and time,

iii) deepen all depressions and make their beds sandy and fill them with water during summer,

iv) construct new canals and keep them full after flood season by providing gates,

v) encourage extensive cultivation of rice,

vi) fill all village ponds, depressions, and lakes with water and adopt measures to keep their bed pervious,

vii) encourage porous shingle beds in places where water can be diverted to fill the formation.

These measures will feed the aquifer during the four summer months.

As soon as the rivers fall we shall start pumping intensively. We shall not only pump all the seepage but also mine the groundwater and take it down if need be to the limit of pumping by centrifugal pumps. The average lowering may even exceed five feet. With the approach of summer, with more water in the rivers, the pumping may stop progressively and completely during the monsoon period to feed the aquifer, so that the mined zone is charged again with water. It is true that with the watertable at 10 or 15 feet more evaporation or evapo-transpiration loss occurs but the stoppage of pumping during summer, feeding from high stage river and heavy monsoon rainfall will all fill the aquifer emptied during dry months.

This system of management of water resources has many advantages. By this system we will

i) mine the groundwater equal to our requirements,

ii) use cheap and durable centrifugal pumps with low lift, *iii*) use shallow multiple strainers to pump 2 to 4 cusecs from each unit of pumping set.

iv) not pump saline groundwater as multiple strainers will be installed to pump the top 70 to 100 feet of the aquifer,

v) replace the stagnant groundwater richly charged with carbonates and bicarbonates as a result of action of root zone by fresh rain water, rich in oxygen and most beneficial to crops,

vi) start fluctuating the groundwater which will rise during summer and will fall by several feet during the remaining eight months, thus creating a system of natural drainage as exists along the flood plains,

vii) not pump saline groundwater, which would introduce the problem of aquifer deterioration, nor have a problem of disposal of highly saline water.

viii) water highly charged with carbonates and bicarbonates will be replaced by rain infiltration, and the problem of conversion of normal soil into alkaline impermeable soils by use of bicarbonate charged water will be remedied.

The financial aspect of these suggestions can further be examined but it is certain that when we have more summer supplies available, we should utilize them by ever-lasting canals, requiring little maintenance as against short lived tubewells with costly maintenance. Integration of the presently constructed storage at Mangla can be so incorporated as to reduce pumping. When we need winter supplies we may install cheap, shallow multiple tubewells. The efforts of the farmers can even be integrated to pump during winter both for drainage and for extra supplies.

These are the suggestions which can be applied in the Punjab and Bahawalpur or where significant pumpable good quality aquifer exists such as along the strip of the Indus in Sind or in Khairpur West or in Larkana-Shikarpur Districts. This suggestion is not workable for Ghulam Mohammad Barrage in general and the lower region of the Sukkur Barrage System adjoining the Ghulam Mohammad Barrage region having high watertable of a very highly saline nature. Here, we have to create good quality aquifer before tubewells can be installed. Tile and open drains are the solution and there is no doubt about the success of this type of drainage in that area.

In the end, it is admitted that Pakistan is much obliged to the American scientists which constituted the Panel for their great service to this country.

They not only thoroughly studied the complicated problem in such a limited period but have suggested a solution. Their study of the problem will remain a source of guidance for generations to those who are to deal with the land and water problems of this country. To the scientists it has given new avenues to explore. Science progresses on new and novel ideas.

REFERENCES

1. Ahmad, Nazir, *A Discussion on Hydrological Estimation of Water Resources as Put Forth in Chapter VI of Kennedy Mission Report.* Special Report No. 255-Ph/ Seep.-53/63. (Lahore: Irrigation Research Institute, 1963).

2. Ahmad, Nazir and Mohammad Akram, *Evapo-transpiration as A Function of Depth to Watertable and Soils.* Special Report No. 291-Ph/Soil. Ph.-7/65 (Lahore: Irrigation Research Institute, 1965).

3. Dean, F. Peterson, O. W. Israelson and V. E. Hansen. *Hydraulics of Wells.* Bulletin 35. (Logan: Utah State University, March 1952).

4. Ghulam Mohammad, "Waterlogging and Salinity in the Indus Plain: A Critical Analysis of Some of the Major Conclusions of the Revelle Report", *Pakistan Development Review,* Vol. IV, No. 3, Autumn 1964.

5. United States Department of Agriculture, Soil Conservation Service, *Irrigation Pumping Plants.* Chapter 8. (Washington, D.C.: United States Department of Agriculture).