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Programme for the Development of Irrigation and Agriculture in West Pakistan: An Analysis of the Public and Private Groundwater Development Programme and the IBRD Draft Report

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1. INTRODUCTION

A study of water and power resources of West Pakistan was undertaken between 1964 and 1967 by arrangement between the International Bank for Reconstruction and Development[1/] as Administrator for the Indus Development Fund, and the Government of Pakistan. The Agricultural problems, including the study of needs of water for agricultural development, were investigated for the Bank between 1964 and 1966 by a group of consultants composed of Sir Alexander Gibb and Partners, London; International Land Development Consultants, N.V., Arnhem, Holland; and Hunting Technical

* The author is a Senior Research Economist at the Pakistan Institute of Development Economics. He is indebted to Dr. Gordon Winston and Mr. Edwin H. Clark, advisors at the Institute; Dr. S.R. Lewis, a former advisor at the Institute; Dr. Nazir Ahmad, Principal Research Officer and Dr. Mushtaq Ahmad, Director, Irrigation Research Institute Lahore; Dr. W.C.F. Bussink and Professor Oddvar Aresvik, Advisors to the West Pakistan Government; ~~Mr. Majid Hasan~~ Khan, Director of Agricultural Engineering, Lyallpur; Mr. Mohiuddin Khan, Deputy Secretary (Development) Irrigation and Power Department, Lahore; and Dr. Frank M. Eaton of the University of California, Riverside, California, for their valuable comments on the earlier drafts of this paper. Responsibility for the views expressed and for any errors is entirely that of the author, however.

The author is grateful to the staff of the Department of Agriculture, particularly to Mr. Mohammad Shafi Gill, Director of Agriculture, Lahore Region, his Deputy Directors of Agriculture, the Extra Assistant Directors of Agriculture, and the Agricultural Assistants, but most particularly the Field Assistants who carried out a number of surveys on private tubewells for the author without any monetary remuneration. But for their help it would not have been possible to produce this paper. Similar thanks are due to Dr. Mohammad Sharif and Mr. Fazal Dad Khan, the Directors of Agriculture, Hyderabad and Peshawar Regions respectively, and to their staff for help in surveys in their regions.

In the Institute, major part of the credit for field work goes to Mr. Mohammad Ghaffar, Research Assistant, who spent a large part of his time in the field and then helped the author in computation work in the Institute. Mr. Amir Mohammad, Research Assistant and Mr. N. H. Nizami, Staff Economist also provided computation help.

1/ The International Bank for Reconstruction and Development will be referred to as the Bank in this paper.

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Services Ltd., London. For the duration of this study the consultants formed the Irrigation and Agricultural Concultants Association (IACA). The finding of the concultants are contained in a Comprehensive Report entitled Programme for the Development of Irrigation and Agriculture in West Pakistan dated May 1966, which was submitted by the Bank to the Government of Pakistan in September 1966. The report of the consultants will be referred to as IACA Report in this paper.

The IACA Report was discussed by a Group of staff members of the Bank and the IACA with the Government of Pakistan in December, 1966, On the basis of these discussions, the IACA Report and information available to the Bank staff itself, the Bank Group has prepared its own report. This report is also titled "Programme for the Development of Irrigation and Agriculture in West Pakistan". A draft of this report was submitted to the Government of Pakistan in March, 1967 and the report was discussed with the Government of Pakistan Officials in April 1967. This report will be referred to the Bank Group Report in this paper.

The Bank Group's Report concentrates on the determination of a feasible Action Programme capable of achieving levels of agricultural production "commensurate with the resources and needs of the economy" within the decade 1965 to 1975. To this end the Bank Group Report evaluates 14 major development projects to be undertaken during the Third Plan and Fourth Plan periods in addition to a number of on-going projects.

The main works under the above projects consist of the following:

i) Construction of Tarbela Dam to provide 8.6 MAF of water by 1975. Out of this 5 MAF will be utilized in 1975 and the whole of 8.6 MAF by 1980. The IACA consider that whole of 8.6 MAF can not be utilized before 1980 because of (a) the need to prevent further deterioration of seriously waterlogged areas (b) insufficient canal capacity to carry the additional water, and (c) difficulty of development of areas where the pumped water requires mixing with fresh surface water or would not be usuable for irrigation.

ii) Installation of 20,000 three to four-cusec capacity public tubewells to cover 10.8 million acres of land in the usuable groundwater areas in 1975.

iii) Installation of 500 "drainage" tubewells in saline groundwater areas to cover 0.5 million acres for control of water-logging (by the year 2000 these will be increased to 15,000 tubewells draining 6.6 million acres).

iv) Increasing the capacity of canals to provide additional river water for 0.9 million acres by 1975 (extended to 16.2 million acres by the year 2000).

v) Construction of Sukh Beas Nallah Drainage Scheme to permit reclamation and to prevent further waterlogging caused by surface run-off in the upper and central parts of the Bari Doab.

vi) Construction of two large outfall drains on both banks of Indus in the Lower Indus Region for the control of waterlogging and salanity. These drains will be constructed mainly in the period after 1975.

In addition to the above public sector programme, IACA and the Bank Group recommend the installation of 21,500 one-cusec capacity new private tubewells by 1970. After 1970, they expect the number of private tubewells to decline sharply in the canal commanded areas with hardly any remaining by 1985 when public tubewells will cover all the useable groundwater areas.

Total cost of the projects recommended by IACA and the Bank Group duringthe Third and Fourth Plan periods will be as under:

		Million rupees
Public Sector		
Tarbela Dam		4,203
Public tubewells 7		3,343
Other Projects		2,794
	Sub-Total	10,340
Private Sector		
Private tubewells		749
Farm drains		13
	Total	11,102

This article analyses the recommendation of IACA and the Bank Group regarding the installation of of public tubewells in the fresh groundwater areas. Other recommendations of the IACA and the Bank Group will be analysed in a second article which will apear in a subsequent issue of this Review.[1/]

The programme of groundwater development recommended by IACA, and supported by the Bank Group, is based on the need to bring groundwater development under public control in order to integrate it with the publicly controlled canal water supplies. The Bank Group, however, adds that it may be necessary to stimulate private investment in new tubewells throughout the Third and Fourth Plan periods as WAPDA is not likely to be able to install all the 20,000 four-cusec capacity public tubewells by 1975. The Bank Group urges the Government of Pakistan to continuously observe the relative performance of public and private development of groundwater resources. It recommends changes in emphysis in public and private groundwater development from time to time as relative advantages emerge more clearly.

This paper analyses the relative advantages of public and private tubewells on the basis of data collected by the author and available from other sources. Section II of this paper summarizes the main findings, recommendations and the programme formulated by the IACA and the Bank Group. It also lists the basic assumptions on which these conclusions and recommendations are based. In Section III, the public tubewell development programme recommended by IACA and the Bank Group is compared with the private tubewell programme recommended in this paper.

1/ The second article will deal specifically with (i) measures to utilize the whole of 8.6 MAF of Tarbela Dam water from 1975 onward instead of 1980 (ii) increasing the capacity of canals to bring in additional river water in major part of the 10.6 million acres of the saline groundwater areas and (iv) provision of deep open main and branch drains combined with covered field drains instead of "drainage tubewells" in the saline groundwater areas.

II. FINDINGS AND RECOMMENDATIONS OF IACA AND THE BANK GROUP

A. Present conditions

1. Irrigation Area.

The irrigation system of the Indus Plain presently has a gross area of about 38 million acres of which 33.5 million acres is culturable commanded area (CCA) and 25 million acres is actually irrigated. Most of the culturable waste (land lying within the CCA but unirrigated) is in the Lower Indus Region [10, p.126]. The IACA and the Bank Group estimate that by fully developing the available surface and ground water, 29.4 million acres of CCA can be brought under irrigation at a cropping intensity of about 150 per cent. (Table I).

2. Surface Water Applications

After full implementation of the Indus Water Treaty in the early 1970's the river water supply entering West Pakistan will be about to 142 MAF a year [10, p.117] of which about 79 MAF a year is presently diverted into canals. Out of this 58 MAF reaches the water courses [10, p.131]. This is equivalent to 2.3 acre feet per acre for the 25 million acres presently irrigated by canal water or about 2 acre feet per acre for 28.4 million cropped acres.

3. Groundwater

The Indus Plains are composed of deep alluvial deposits which form an extensive groundwater aquifer covering a gross areas of about 40 million acres. Before the start of canal irrigation, the groundwater table was well below the surface and the aquifer was in a state of hydraulic equilibrium. The Bank Group estimate [10 p.119] that rechange to the aquifer from rivers and rainfall which probably amounted to about 10 MAF a year mainly in the north was balanced by outflow in various forms. When large scale irrigation was introduced, percolation to the aquifer was greatly increased in the irrigated areas and today the rechange is three or four-fold that of the natural state with the result that water table has risen to within 10 feet of the surface over almost half of the canal commanded land.

In about one-sixth of the irrigated areas the groundwater table is estimated to have risen to within five feet of the surface causing problems of waterlogging and soil salinity in some two million acres

TABLE - 1

Groundwater Quallty of the Culterable Canal Communded Area of the Indus Plain

Region (1)	Groundwater with total salt content of Less then 1000 ppm (2)	1000 - 3000 ppm (3)	Above 3000 ppm (4)	Total (5)
	............million acres...........			
Vale of Peshawar	.6	.1	nil	.7
Punjab and Bahawalpur	11.8	4.0	3.9	19.7
Lower Indus Basin	1.8	.5	6.7	9.0
Total	14.2	4.6	10.6	29.4
	18.8			

Source:- /5, p.5_7.

TABLE - II

Area to be Developed under the IACA

Development (1)	By 1965 (2)	By 1975 (3)	By 1985 (4)	By 2000 (5)
	...........million acres..........			
Usuable groundwater area				
By public tubewells	1.3	10.8	18.7	18.8
Saline groundwater areas				
By public tubewells	nil	0.5	4.3	6.6
By horizontal drainage tiles	nil	0.3	1.1	1.5
Total groundwater	1.3	11.6	24.1	26.9
Area to be developed by canal enlargement.	NIL	0.9	5.9	16.2

Source: /1, p.98_7 .

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in these areas / 10, p.119_7.

Despite the problem of water-logging and salinity this large reserveir of groundwater is potentially very valuable. The physical characteristics of the Indus Basin aquifer are generally favourable to tubewells development except in part of the Lower Indus Region. The quality of groundwater is however, variable as may be seen from Map 1. It is estimated that about one half of the CCA has "fresh" groundwater (less than 1000 ppm Total Dissolved Solids), and another 15 per cent has "marginal" groundwater (1000 to 3000 ppm TDS). The IACA and the Bank Group believe that the "fresh" water can be applied directly to crops and the "marginal" water can be applied to crops after being mixe with canal water. It is stated that groundwaters having 1000 to 2000 ppm can be mixed in the ratio of 1:1 and these having 2000 to 3000 ppm are to be mixed in the ratio 2½:1 /‾1, p.68 and 10, p.123_7. Therefore they propose full tubewell development of both areas. In the remaining 36 per cent of the CCA the groundwaters are too saline for use for irrigation. "Drainage tubewells" are proposed for 6.6 million acres of this area for the control of water table (Table II).

4. Public Tubewells:

In order to provide additional water for irrigation and to reclaim the waterlogged and saline soils, a number of salinity Control and Reclamation Projects (SCARPs) have been taken in hand by the WAPDA. Construction of first of these projects (SCARP I) began in 1959 and a total of 1980 tubewells were completed by 1962 /‾10, p.229_7. Contracts were let out between 1963 and 1966 for 4000 additional tubewells in SCARP II, SCARP III and SCARP IV in the northern zone and the Khairpur project in the Southern zone. By January, 1967, 2400 of the tubewells had been installed though only 700 of these were reported pumping water.1/ All the public tubewells pumped about 2.7 MAF water in 1965 /‾10, p.131_7.

5. Private Tubewells:

Installation of private tubewells by the farmers of West Pakistan has been in progress since early 1950's. Approximately

1/ Figures from Harza Engineering Company International supplied by Dr. W.C.F. Bussink, Senior Economic Advisor, Planning and Development Department, West Pakistan, Lahore.

32,000 tubewells had been installed by 1965 /̅10, p.153_7, of which 25,000 came during the Second Plan period representing private investment of about Rs.200 million /̅10, p.237_7. The Bank Group considers this progress remarkable in view of the fact that it took place without much public support and encouragement. The private tubewells pumped about 6.3 MAP in 1965 /̅10, p.138_7.

B. Development Programme

1. Public Tubewells

The IACA has proposed the installation of 8,138 tubewells in the following on-going projects /̅10, p.230_7:

SCARP II	2,830 Tubewells
SCARP III	1,470 "
SCARP IV	3,270 "
Shairpur	568 "
Total:-	8,138

In addition an "Action Program" involving 12 new public tubewell pojects with 11,403 tubewells is proposed for execution during the Third and Fourth Plan periods /̅10, p.210_7. The details of these tubewells are:

	Total	Average per Tubewell
Installed Capacity	36,980 cusecs	3.24 cusecs
Commanded area	5.76 million acres	500 acres
Annual Pumpage	12.58 MAF	1,100 AF

About half of these tubewells will be located in areas having a water table at less than 10 feet depth.

Total cost of the 19,541 tubewells under the on-going projects and the Action Programme is estimated as Rs.3,343 million (Table III). The rate of installation in given in table IV.

TABLE - III

COST OF PUBLIC TUBEWELL PROGRAMME RECOMMENDED BY IACA AND THE BANK GROUP

	Third Plan	Fourth Plan	Total
	----------million rupees----------		
Tubewells	1,064	1,445	2,509
Electrification	403	431	834
	1,467	1,876	3,343

Source: Tubewells: (10, pp.389 and 390)
Electrification: (1, p.163).

TABLE IV

Private and Public Tubewells in Operation According to IACA and the Bank Group

(1)	1965 (2)	1970 (3)	1975 (4)	1980 (5)	1985 (6)	2000 (7)
	....	....	....	number	....	....
Public Tubewells						
Usuable groundwater areas	2,900	9,600	20,200	32,200	34,300	35,000
Saline groundwater areas	nil	nil	500	4,500	9,800	15,000
Private Tubewells						
Canal commanded areas	29,000	46,500	38,000	3,000	nil	nil
Outside areas	5,000	9,000	14,000	20,000	25,000	25,000
Total private tubewells	34,000	55,500	52,000	23,000	25,000	25,000

Source: 1965,1970,1975 [10, p.248].
1980,1985,2000, public tubewells [10, p.272].
1980,1985,2000 private tubewells [10, p.155].

TABLE V

Rate of Groundwater Development

(1)	1965 (2)	1970 (3)	1975 (4)	1985 (5)	2000 (6)
	......	......	MAF	......	......
Canal Commonded Areas					
Public tubewells	2.7	10.0	22.0	36.5	44.0
Private tubewells	5.3	8.0	7.0	3.5	nil
Persian wheel	1.7	1.0	1.0	nil	nil
Outside Areas					
Private tubewells	1.0	1.8	1.8	2.8	5.0

Source: 1965,1975,1985 and 2000 [10, p.138].
1970 [10, p.248].

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2. Private Tubewells:

Under the proposed programme, the number of private tubewells will increase until 1970 and will then begin to decline (Table IV).

Table VI gives the estimates of private tubewell installation if there were no public development.

The Bank Group appears concerned about the elimination of private tubewells, and states that under the IACA programme for 1975 "about 70 per cent of the projected additional and feasible private well installations-amounting to about 44,000 wells-would not take place because of the competition of the public sector in the development of usuable groundwater. This would mean that in monetary terms some Rs.400 million of private investment would have to be substituted by scarce public funds at initial outlays substantially higher than those required for the installation of private pumping capacity" [10, p.241]. The Bank Group further points out that "the rate of growth of private wells in operation implicit is the IACA projections in less than half the rate experienced during the later part of the second Five-Year Plan ... Given proper incentives, institutional credit facilities, and a policy conducive to private development as enviseged in the Third Five Year Plan, a substantially higher rate of private installations may be achievable" [10, p.241].

Using the IACA projections, the Bank Group estimates that private tubewells (along with existing private persian wheels) will still provide about one MAF more than the public programme by 1970 (Table V).

TABLE VI.

Growth of Private Tubewell Installations "Without" and "With" Public Tubewell Development, Estimates by IACA

Zone	"Without" Public Tubewell Development				"With" Public Tubewell Development				Reduction due to Public Tubewell Development		
	1965	1970	1975	1980	1965	1970	1975	1980	1965/1970	1965-1975	1965-1980
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Canal Cammanded Area	29,000	58,000	82,500	97,500	29,000	46,500	38,500	3,000	11,500	44,000	94,500
Outside areas	5,000	9,000	14,000	20,000	5,000	9,000	14,000	20,000	nil	nil	nil
Total :-	34,000	67,900	96,500	117,500	34,000	55,500	52,500	23,000	11,500	44,500	94,500

Source: [10, p.240].

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3. Rationale of Public Over Private Tubewell Development

IACA have recommended public tubewell development over private tubewell development for the following reasons:

1) "Public tubewell projects offer higher rates of return on investment combined with much faster growth in production than can be achieved with private tubewell development" [5, p.49].

2) "The technical difficulties of drainage, reclamation and soil salinity are all likely to be overcome by a public system. Public control is also desirable to safeguard the quality of irrigation water in mixing zones, by ensuring that the correct mixing ratios are used" [5, p.49].

3) "The integrated use of surface and groundwater under full public control [is] fundamental to the efficient long-term development of water resources" (5, p.49).

4) "From the social point of view, public tubewells should ensure a fairer distribution of water and protect the position of small farmers" [5, p.49].

5) Eventual public control thereby is also likely to be the only feasible solution to the latent problems of groundwater rights which are likely to become extremely serious if the installation of private tubewells is continued to the stage when it results in excessive local lowering of the watertable [5, p.49].

The Bank Group does not agree with the main conclusion of the IACA that the public tubewells offer higher rate of return on investment as compared to private tubewells. However, it agrees with most other conclusions of the IACA and adds the following:

1) "It may not be possible to achieve the same degree of uniform coverage of contiguous areas with the private wells as is possible with public wells. This could result in less effective watertable control as well as lower rate of groundwater abstraction" [10, pp.246-47].

2) "It would be prudent to regard about one quarter of land area in useable groundwater zones as potentially best suited for private tubewell activity but at the same tim making allowance for restrained extension of such activity into tenant operated large farms and, by cooperative agreement, into some of the smaller tenant and owner-operated farms" [10, p.149]. This statement is based on data collected by IACA and Tipton and Kalmbach which purport to indicate that farmsize land tenure and finance rapidly become constraints to private tubewell installations. "They show that the initial rapid installation of private tubewells occurred on larger and wealthier farms and this lead is not automatically being followed on the small farms", and as a result the rate of installation has declined "sharply" since 1963 [10, p.156]. "In particular, Tipton and Kalmbach find that the commanded areas and utilization rates of private tubewells decreases as the density of wells increases" and that "in the Bari Doab ... the area commanded [by private tubewells] would not exceed about 60 per cent of the culturable area". [10, pp.156-157].

4. Basic Assumptions by IACA

The IACA have made the following basic assumptions in their analysis (all underlining is by the author):

i) "Foreign exchange availability should not be regarded as a separate constraint so long as the total agricultural development remains within the limits of total availability of finance" since a retardation of agricultural growth would effect general economic growth and because of the predominant role of the agriculture sector as a foreign exchange earner [1, p.88].

ii) Total availability of "development finance" will not be a constraint on agricultural development [1, p.89].

iii) "Absorptive capacity" or "implementation capacity" will be decisive for the rate of progress of agriculture [1, p.89].

All calculations of public tubewell projects are based on "adequate water delta intensities" whereas it is assumed that "groundwater development will take place over time under private enterprise and ... as a result under-irrigation will persist until 1975" [1, p.150]. The yields in private tubewell areas are reduced "appropriate to the degree of under irrigation" [1, p.150]

III. Comments on IACA and the Bank Group Report and and Alternative Programme for Development in Irrigation and Agriculture in West Pakistan

In this Section, we give our detailed comments on various recommendation of IACA and the assumptions on which these recommendations are based. The programme of public groundwater development proposed by IACA and supported by the Bank Group is compared with an alternate programme of private groundwater development.

It may be pointed out at the outset that, contrary to IACA's assumptions mentioned in the previous section, foreign exchange and total development funds are and will continue to remain upto 1975 a real constraint in Pakistan. According to the Third Five Year Plan there will be a deficit in foreign exchange earnings of Rs.4,185 million in 1970 and Rs.4,000 million 1975 [30, p.24]. The Bank Group recognizes this when it states that "the substantial increase in financial requirements for the Third and in particular the Fourth Plan periods water development is likely to strain the resources available to the public sector and finance may act increasingly as a constraint on the rate at which public development might take place" [10, p.251].

The alternate programme of private development of groundwater resources presented in this paper is based on the following findings which will be substantiated in the sections which follow:

i. Private tubewells can and would be installed more rapidly than public tubewells and would cover a larger area than the proposed public tubewell.

ii. Therefore private tubewells will lead to more rapid and ultimately greater increase in agricultural production.

iii. Private tubewells require less foreign exchange, less public rupee funds, and less total investment for installation and electrification than public tubewells for the same quantity of water delivered to the fields.

iv. Water pumped from private tubewells is used more efficiently than that from public tubewells and there is less wastage from the former.

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v. As a result of the above, rate of return and the benefit cost ratio on private tubewells is higher than that on public tubewells.

vi. Private tubewells will provide better water table control than public tubewells.

vii. Constraints of farm size, land tenure and finance are not likely to affect the rate of private tubewell development.

1. <u>Rate of Installation of Public and Private Tubewells.</u>

For a country like Pakistan speed in the installation of tubewells is of particular importance for rapidly increasing agricultural production. As pointed out in the previous section, the number of private tubewells increased 800 per cent in 5 years [18 and 15]. These tubewells supplied 2.3 times as much water as public tubewells during 1965.

The IACA states that "the choice between public and private development has been largely a case of analysing the most beneficial use of limited installation capacity for public and private tubewells. We particularly wished to avoid the situation where the overall installation capacity of the two sectors was curtailed by the imposition of public programme on private development" [1, p.151].

The author wishes to point out that:

1. For all practical purposes, there is no capacity for public tubewell installation in West Pakistan. This is because there is a very limited number of power-driven rigs in West Pakistan and these are not being fully and effectively utilized for lack of support tools and equipment, support transport and shortage of trained rig operators and supervisors. Kenneth Brown, Diaector of well drilling of Roscoe Moss company, Los Angles, recomends that "additional miecharical rigs should not be acquired until a remedy has been found for the shortage of trained crews and supervisors to man rigs already on had" [12, pp.43-44].

Public tubewells can be installed only by importing foreign contractors and materials. This has been pointed out by the Bank Group when it states that "task of installing wells has been and can in future be carried out by foreign contractors" /10, p.235/.

ii. The rate of installation of public tubewells is quite low even with foreign contractors. The period from the start of field investigations to the start of project work is estimated to take two and half years or more /10, p.145/. and drilling at least an additional three years. /10, p.146/.

iii. Project completion is further constrained by the rate of electrification. The Bank Group estimate that the electrification of public wells and completion of appurteuant works would be expected to take upto a year after the wells are installed /10, p.146/. This is substantiated by experience during 1965/66 when only 140 wells were electrified although more than 1000 were drilled /10, p.147/.

iv. A further constraint may be provided by the failure to train the large number of personnel required to operate the public programme efficiently (10, p.147)

These delays and constraints do not apply to private tubewells. They are not hindered by problems of obtaining foreign loans, preparation of tenders for foreign contractors and electrification. Farmers train themselves and learn from the expreience of others. The rapidity with which private tubewells can be installed is being continuelly demonstrated. The Third Plan provided for installation of 40,000 private tubewells between 1965 and 1970 /30, p.294/. The phasing of installations was assumed as 6,000 in the first year rising to 10,000 in the last year of the Plan. A survey (Appendix Table A-1) indicates

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however that actual installation exceeded the target by forty percent during the first year. On this basis we can estimate that even with no government encouragement the number of tubewell installed may well reach about 60,000 instead of the 40,000 target.

Another example of how rapidly private tubewells can be installed is provide by data from Madras state in India [33] where over 100,000 tubewells and pumping sets were installed in 4 years (See Appendix D-1).

Year	Tubewells and pumping sets installed in Madras Stat
1961/62	23,400
1962/63	26,100
1963/64	24,500
1964/65	31,900
	105,900

It appears as if a major reason for the rapid installation rate in Madras was the extensive rural electrification carried out in that sate (Appendix Table D-2).

One of the factors limiting the rate of installation of private tubewells is the availability of lining pipe. The Department of Agriculture provides some lining pipe at cost (for approxamately 25% of the wells.) Otherwise the farmer has to purchase it on the market at a premium of 60% to 150%[1]

This situation should improve this year since the Department of Agriculture has authorisation to import additional

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1/ Enquiries by author at different times of the year showed the price of lining pipe in the market as Rs.16 to Rs.25 per foot compared to the 10 per foot by the Department of Agriculture.

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pipe which should be adequate for about 11,000 wells[1/].
Thus there should be enough inexpensive lining pipe for a total of 13,000 wells including the number installed by the Department of Agriculture.

Domestic drilling capacity is large (capable of installing 10,000 to 20,000 tubewells a year.) and since it has a low capital companent can expand rapidly [18, p.12]. IACA was aware of this when it stated that "At the moment the production capacity for motors, both diesel and electric, is in excess of projected demand and there does not seem to be any lack of drilling teams not withstanding the rather inefficient methods employed. The problem facing the private tubewell industry is not under capacity but over capacity resulting from too great expectation". [1, p.189].

1/ The Department of Agriculture has been allocated Rs.10 million for the import of lining pipe. Each tubewell needs lining pipe costing about Rs.600 to Rs.900 per well Rs.10 million should be adequate for 11,000 wells.

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2. Comparative Cost of Installation of Tubewells

i) Public Tubewells

I.A.C.A estimated the cost of installation of a public tubewell of 4 cusec capacity as Rs 90.000 (excluding electrification, custom duties and taxes and interest during the period of construction /‾5, p.39_7. The Bank Group increased this by about 30 per cent to Rs 117,000 /‾10, p. 213_7.

The electrification cost is estimated to be about Rs 42,000 /‾9, p.14_7. Interest charges during construction are estimated as Rs 28,000 if drilling and electrification of tubewells is carried out as planned by I.A.C.A and the Bank Group. /‾Table VII Column (3)_7. The total installation cost of a public tubewell as it begins operation is Rs 187,000 out of which Rs 95,000 is in foreign exchange[1/]. If electrification of tubewell is carried out simultaneously with the drilling operations, the total cost is reduced to Rs 173,000 with the foreign exchange component of Rs 90,000 (Table VII).

ii) Private Tubewells

The cost of a private tubewell is much less Rs 7,000 for an electric (not including electrification) and Rs. 9,000 for diesel tubewell of one-cusec capacity /‾5, p. 37_7. Installation takes about a monthwhen the tubewell begins to pump water so interest charges during construction are negligible. The foreign exchange component is estimated at Rs 1,400 for an electric and Rs 1,800 for a diesel tubewell /‾5, p. 37_7. The cost of electrification of a private electric tubewell is estimated at Rs 13,000 /‾9, p. 54_7.

1/ Total foreign exchange required for 11,403 tubewells is estimated by the Bank Group as Rs 917 million /‾10, p. 214_7. The foreign exchange required for one tubewell thus comes to Rs 80,400. Interest on this during the period of construction raises the cost to Rs 94,500 (See Table VII). The foreign exchange component of electrification cost is estimated as 61 per cent, /‾9, p. 14_7. This is equal to Rs 25,600 per well. The balance of Rs 54,800 is for tubewell installation.

According to IACA the life of public tubewells is 20 years and that of private tubewells is 10 years [5, p. 43]. In order to make the investment costs comparable, we have to add the present value of replacement cost of a private tubewell at the end of 10 years. At 8 per cent rate of discount that is equal to Rs 3,240 for an electric tubewell and Rs 4,170 for a diesel tubewell. Total investment cost of a private tubewell for a period of 20 years is, therefore, 10,240 for an electric well and Rs 11,170 for a diesel well. The present value of foreign exchange component of the cost of an electric tubewell comes to Rs 650 per well whereas that for a diesel tubewell it comes to Rs 830 per well.

TABLE XII

Cost of a Public Tubewell, Estimate by IACA And the Bank Group (with interest added by the author):

	Table Cost		Foreign Exchange component	
	IACA	Bank Group	IACA	Bank Group
(1)	(2)	(3)	(4)	(5)
	-----thousand rupees-----			
Cost exchange interest				
Cost of the tubewell	90.0 (a)	117.0 (b)	45.9	54.8
Cost of electrification	41.9 (c)	41.9 (c)	25.6	25.6
Total :	131.9	158.9	71.5	80.4 (d)
Interest during construction (e)				
On tubewell cost for 2½/(1½) (f) years at 8 percent	18.0 (10.8)	23.4 (14.0)	9.0 (5.5)	11.0 (6.6)
On electrificiation cost for 1½ years at 8 per cent	5.0	5.0	3.1	3.1
Total cost inclusive of interest	154.9 (147.7)	187.3 (177.9)	83.6 (80.1)	94.5 (90.1)

Notes: (a) Estimates by IACA from [5, p. 39].

-- continued on next page ---

Continued from overleaf

(b) IACA's estimate of cost increased by 30 per cent by Bank Group [10, p. 213].

(c) From [9, p. 14].

(d) Calculated from [10, p. 210 and 214]. The foreign exchange component of electrification cost is estimated as 61 per cent [9, p. 14]. This is equal to ₨ 25,600 per well. The balance of ₨ 54,800 is for the tubewell.

(e) IACA and the Bank Group calculate the interest at 6 per cent for 2 years. We consider that 6 per cent rate of interest is low as a measure of operating cost in Pakistan and have used an interest rate of 8 per cent for all calculations in this paper. The period of construction for tubewell is 3 years but tubewell does not pump water for another year till electrification work is completed. We have, therefore, calculated the interest for 3 years on the average cost and for one year on the total cost of tubewell. For electrification cost we have calculated the interest for 3 years on average cost or for 1½ years on total cost.

(f) Figures within parenthesis will apply if electrification is completed along with drilling within 3 years. In this case inter-est is calculated for 3 years on the average cost or for 1½ years on total cost for both the tubewell and the electrification cost.

(iii) <u>Comparative cost of Public and Private Tubewells</u>

A one-cusec private tubewell covers about 100 acres /̅18, p.36, 5, p.30_7. A 4-cusec public tubewell covers about 500 acres.1/ Therefore one 4-cusec public tubewell has been assumed to be equivalent to 5 one-cusec private tubewells (with the addition of the present value of the cost of replacing these wells after 10 years). Comparative costs on this basis are given in Appendix B, and summarized in Table VIII (columns 2,5,8). The cost of a public tubewell is about 60 per cent higher than that of private electric tubewell and more than twice that of a private diesel tubewell.

Putting shadow prices on the scarce resources of foreign exchange and public rupee funds shows private tubewells to have an even greater comparative advantage. Such calculations are given in Table VIII. For instance assuming that foreign exchange is under valued by 50% and public rupee funds by a third, public tubewell are 90 percent more expensive than private electric and 300% more expensive as private diesel tubewells for an equivalent

/ rupee funds is eliminated and that on foreign exchange is reduced to 150 per cent, the public

capacity (Table VIII, columns 4,7,10). Even when the shadow price on public/tubewell are still 70 per cent more expensive than private electric and 200% more expensive as diesel (Table VIII, columns 3,6,9).

If the public sector rupee funds (which are a real constraint on overall economic development in the country) are considered, the public tubewells are 2½ times as expensive as private electric tubewells. No public sector funds are involved in the diesel tubewells.

1/ According to IACA and the Bank Group 11,40C tubewells will cover 5.76 million acres /̅10, p.210_7. Each tubewell will thus cover 500 acres.

TABLE- VIII

Cost of Installation of one-cusec capacity Public and Private Tubewell with different-Shadow Prices for Foreign Exchange and Public Sector Rupee Funds.

	Public Tubewells			Private Electric Replaced after 10 years			Private Diesel Replaced after 10 years		
	Official rate	Shadow price I	Shadow price II	Official Rate	Shadow price I	Shadow price II	Official rate	Shadow price I	Shadow price II
1	2	3	4	5	6	7	8	9	10
				thousand rupees					
Total economic cost	37.5	47.0	65.6	23.3	27.3	34.0	13.2	14.5	15.8
Total public sector cost	37.5	47.0	65.6	13.1	17.1	23.8	nil	nil	nil
Public sector rupee cost	18.6	18.6	27.8	5.1	5.1	7.8	nil	nil	nil
Total foreign exchange cost	18.9	28.4	37.8	10.0	15.0	20.0	2.6	3.9	5.2

Note: Shadow price I assume 100 per cent price for private fund, 100 per cent for public rupee funds and 150 per cent for foreign exchange funds.
Shadow price II menas 100 per cent price for private funds, 150 per cent price for public rupee funds and 200 per cent for foreign exchange.

Source: Appendix B, Table B-1 to B-4.

8. Rate of Utilization and Use of Water on Public and Private Tubewells

IACA has assumed a rate of utilization of 40 per cent for public tubewells and 27.4 per cent (2400 hours a year) for the private tubewells (5,p. 40). Thus public tubewells are assumed to supply more water per acre than private tubewells. Does this mean that the public wells are more efficient? The Bank Group has considered this question and states that "while the private tubewells may be pumped at a lower rate than public wells, this would generally reflect a pumping pattern directly related to farmer's actual water requirements rather than to generalized requirements used to establish pumping patterns for large areas. It may therefore lead to more efficient use of groundwater pumped" (10, p. 246).

This is substantiated by a 1965 survey by the author in 17 Punjab villages which showed that 10 to 90 per cent of the farmers in these villages purchased water from private tubewell owners at critical periods of crop growth. The quantity of water purchased varied from 15 per cent to 60 per cent of the water available from canal irrigation (Appendix A-3 and Table IX). Thus when water can be used efficiently, the farmer will use it.

The water course studies by IACA suggest that unreliablity of water supplies rather than the absolute quantity of water made available was, in many cases, the main deterent to increased agricultural production /̄10, p.319̲/. This is where private tubewells have a great advantage over the public tubewells. They provide water when the farmers need it. The Bank Group states that "An ideal system of water allocation is one based on demands which are varied through the season in accordance with the crop water requirements of the farmers. IACA concluded however that such a system could not be achieved in the foreseeable future" /̄10, p. 305̲/.

The "ideal system" of water allocation cannot be achieved as effectively with public tubewells, as with private tubewells, because "farmer's control over at least part of the groundwater exploitation would tend to make them more independent of the rigidities associated with the installation of public tubewell fields as well the water distribution, project planning and maintenance under absolute public control over all water resources" /̄10, p. 224̲/.

Data from the presently operating public tubewell project indicate that there is serious waste and generally inefficient use of the water. This can be explained by the facts that:

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Table IX

Purchase of Tubewell Water by Farmers in The Multan, Sahiwal and Gujranwala Districts

Season	District (1)	Percentage of farmers who purchased water (2)	Purchased water as a percentage of canal water (3)
Rabi 1964/65	Multan	68	25
	Sahiwal	58	24
	Gujranwala	9	15
	Average	48	22
Kharif 1965	Multan	92	63
	Sahiwal	62	38
	Gujranwala	17	34
	Average	60	42
Rabi 1965/66	Multan	90	42
	Sahiwal	58	60
	Gujranwala	33	20
		64	45

Source: /Appendix Table A.3/

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i) Since on the average a public tubewell supplies water to an area 5 time larger than thatsupplied by a private tubewell, and carries a greater discharge there is inevitably more loss from the longer channels with greater wetted area[1/].

ii) The existing water courses are too small to carry the water supplied by a public tubewell. Their capacity is about one to two cusecs whereas with a public tubewell they are expected to carry from 2.6 to 5.2 cusecs.

iii) Since the farmers do not pay for the volume of water pumped from a public tubewell they have no incentive to enlarge and repair the watercourses or to otherwise prevent waste. This could be prevented by introducing volumetrie sale of water, but the cost is likely to be prohibitive.

iv) The pumping schedules of public tubewells result in water availability being unsensitive to actual crop requirements. Some of the time there is too much water which is allowed to run to waste, at other times there may be too little. At this time the farmers may have to pay illegal gratification to see that they do get there share of tubewell water.[2/]

According to US-AID field officials the "water losses may reach over 50 per cent for lands that are situated a half mile from the water course"[3/] [34, p. 1]. It might be argued that many of these losses can be avoided by strengthening the watercourses at a relatively small real cost to the nation. However, only 3 watercourses out of 2000 in SCARP I have been onlarged and strengthened during the last 5 years at cost Rs. 12,000 a piece, and still no provision has been made for their maintenance. The local officials believe that

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1/ The assumption that seepage from a water course is twice a shigh when the water supply is coming from four-cusec well as when it is coming from five evenly spaced one-cusec wells in partially supported by empirical data as well as by rough theoretical analyses. Making the normal assumption that seepage is proportional to the wetted area time pumping time, the Manning, Chezy, and Darcy-Weishack formula for open channel flow indicate that the total seepage from a four-cusec well should be 3 to 5 times that from five one-cusec wells with calculation biases generally infavour of the larger tubewells. Since the larger wells pump twice as much water over time, losses as a per cent of water pumped should be 1.5 to 2.5 times as high for the larger wells.

2/ The Bank Group states that it has "received enough information, unofficially and informally, to be convinced that farmers pay extra premium for assured supplies of irrigation water and that failure to make such payment can result in being cut off from supplies at critical times during a cropping season. Under the circumstances the Bank Group feels it necessary to point out that failure to curtail these activities would have serious impact on the rate at which the development of water resources would be translated into physical products which Pakistan needs so urgently [10, p. 361].

3/ Estimates(not shown in this paper) by the author based on the total water delivered in SCARP I and water requirements of crops including those for leaching purposes indicate that about 35 per cent of the water pumped by SCARP I tubewells is lost in the water courses.

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within a few years, the strengthened watercourses will breach and revert to their original conditions. If the farmers will not maintain these watercourses in public areas, the government will be forced to do so itself. This, however, will require a staff of engineers and trained supervisors quite beyond what is likely to be available[1/].

Assuming that the loss of water is reduced from the existing level of about 35 per cent to about 25 per cent, that 200 acre feet of water will be pumped from a private tubewell and 1170 acre feet from a public tubewell (as estimated by the IACA /_5, p. 43_/) the water delivered to the fields will be about 180-acre feet from a one-cusec private tubewell and about 880 acre feet from a four cusec public [illegible].

According to studies by Kennedy, Benton and Blench, former Chief Engineers of the Punjab, as quoted by Dr. Nazir Ahmad /_26, p. 374_/ losses on ordinary water-courses (covering about 500 acres) are about 20 per cent of the water delivered at the head of watercourses. If it is assumed thatwatercourses with public tubewells will lose no more than ordinary watercourses, then the water delivered to the fields will be about 940 acre feet from public tubewells against 180 acre-feet delivered by a private tubewell.

1/ Total length of canals, branches and distributories on the lower Jhelum, Lower Chenab, and Lower Bari Doab canals is 5995 miles /_44, p. 62 -63/._ The number of water course on these canal is 11, 719 /_32, pp: 10,24,50_/. Each watercourse is about 2 miles long. The total length of watercourses is thus about 21,800 miles which is nearly 4 times the length of canals, branches and distributories of these canals.
Therefore, the staff in the Government Department dealing with irrigation will have to be considerably increased in order to handle this job. There would be no objection to this if adequate number of trained engineers were available in the country and if public tubewells were the only solution for groundwater development. However, West Pakistan is short of trained engineers in all fields requiring engineering services. Total requirements of engineers for all fields are estimated as 7,000 for execution of the various programmes included in the Third Five Year Plan. But only 3,^ new graduates are expected to come out of engineering colleges. The IACA development programme alone will need about 1,000 engineers for planning and construction and 300 for supervision and operation of tubewell projects (10, p, 35). If water courses are also to be managed by the Government as the experience in SCARP I suggests, a much larger number of trained engineers will have to be put in the SCARP areas. Pakistan'sProgress in other development fields requiring engineering services will therefore be serverely affected.

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4. Cost of Water Pumped and Delivered to the Fields

The IACA estimated the cost of water pumped as Rs.17 per acre foot from a public tubewell, Rs.16 per acre foot from a private electric tubewell and Rs. 24 per acre foot from a diesel tubewell (See Appendix Table C-1). They state that "cost of an acre foot of water pumped is roughly the same for a private electric and for a public tubewell of four-cusec capacity which is the average capacity proposed for fresh groundwater zones. The higher capital and operation and main-tenance costs of public tubewells in fresh groundwater zones are therefore offset by their lower electric power costs, higher utilization rates, greater hydraulic efficiency and longer life" [5), p.18], /but has not taken this into account in calculating the cost of pumping water [10, p.245]. We have made this adjustment. We have also used a shadow price for foreign exchange and for the public sector rupee funds in order to calculate the social cost of pumping water from public and private tubewells. The Power Consultants to the Bank had estimated the cost of electricity to be Rs.0.11 per Kwh for public and Rs.0.13 Kwh for private tubewells. The higher cost for private tubewells is caused by the larger number of connections required for smaller capacity wells and the fact that connections are made individually rather than as a part of a large contract [5, p.40]. The IACA reduced the cost of power for public tubewells from Rs.0.11 to Rs.0.09 per Kwh because of load shedding for 2 hours a day on 75 per cent of the wells in usuable groundwater areas. For private tubewells, it is state that "load shedding is not feasible" [1, p.150]

Actually, there has been large scale load shedding of private tubewells with power being shut off for 4 to 8 hours a day [38, curve 4, sheet 2]. In fact load shedding of private tubewells increased to about 12-16 hours a day during 1965/66 and 1966/67. Since the feasibility of load shedding of private tubewells has been demonstrated daily for two years, we have assumed the economic cost of electricity for private tubewells to be equal to Rs. 0.11 per Kwh, and that for public tubewells to be equal at Rs.0.09 per Kwh.

/ The Bank Group, has revised upward the capital cost of installation of tubewells by 30 per cent [10, p.213]

Assuming that load shedding will not be resorted to for private tubewells, and to test the sensitivity our analysis, we have made on alternative calculation using a price of Rs.0.13 per Kwh for private tubewells while keeping Rs.0.09 per Kwh for public tubewells.

Using these power costs and the shadow price for foreign exchange and public rupee funds, we have recalculated the total cost per acre foot of water from public and private tubewells in Appendix Table C-2 and summarized it in Table X. Cost of pumping water comes to Rs.21 per acre foot from public tubewells compared to Rs.16 per acre from private electric and Rs.23 per acre foot from private diesel tubewells when official prices, which include duties and taxes on diesel oil and a subsidy on electricity, are used. However when a shadow price of 200 per cent for foreign exchange and of 150 per cent for public sector rupee funds is used, and when taxes and duties on diesel oil are eliminated, and electricity is charged at full price the cost of pumping water comes to Rs.29 per acre foot from public tubewells compared to Rs.23 per acre foot from a private electric tubewell and Rs.21 per acre foot from a private diesel tubewell.

The difference in the cost of water delivered to the fields is even greater. Using the figures of 900 acre feet and 180 acre feet delivered to the field by public and private tubewells respectively, and still using the same shadow prices, the cost of water delivered to the fields from public tubewells is 35 to 65 per cent higher than that from private tubewells (Table X).

Cont'd ....

TABLE X

Cost of pumping water from public and Private Tubewells using different shadow prices for capital

(1)	Public Tubewells 4 - cusec (a) (2)	(b) (3)	Private Electric 1-cusec (c) (4)	Private Diesel one-cusec (c) (5)
	....		Rupees per acre foot	....
Cost of water pumped:				
Using official prices	21 (f)	20 (f)	16 (g)	23 (j)
Using shadow prices(I) (d)	23 (f)	22 (f)	20 (h)	18 (k)
Using shadow prices(II) (e)	29 (f)	27 (f)	23 (i)	21 (l)
Cost of water delivered to the field				
Using offocial prices	28 (f)	25 (f)	18 (g)	25 (j)
Using shadow prices(I) (d)	31 (f)	28 (f)	23 (h)	20 (k)
Using shadow prices(II) (e)	38 (f)	35 (f)	26 (i)	23 (l)

Source: / Appendix Table C-2 /.

Notes:
a) Column (2) assumes 25 per cent loss in public tubewell water courses.

b) Column (3) assumes 20 per cent loss in public tubewell water courses which is the same as loss on existing water courses (without tubewells) serving an equal area.

c) Columns (3) and (4) assume 10 per cent loss in water courses as the area covered by a private tubewell is only 100 acres against 500 acres covered by a public tubewell.

d) Shadow price I means 100 per cent value for private capital 100 per cent for public rupee funds and 150 per cent for foreign exchange.

e) Shadow price II indicates 100 per cent value for private capital 150 per cent for public rupee funds and 200 per cent for foreign exchange.

f) Electric power at Rs.0.09 per Kwh.

g) Electric power at Rs.0.08 per Kwh.

h) Electric power at Rs.0.11 per Kwh.

i) Electric power at Rs.0.13 per Kwh.

j) Diesel oil at market price.

k) Diesel oil after removing taxes and duties but valuing forrign exchange component of the cost at 150 per cent of official price.

l) Diesel oil after removing taxes and duties but valuing foreign exchange component of the cost at 200 per cent of official price.

There is a high divergence between private and social cost for the two types of private tubewells. For diesel tubewells, the private annual operation and maintenance (O & M) cost, are Rs. 3,300 whereas the social O & M costs (eliminating the high taxes and valueing the foreign exchange at 150% of the official rate) are only Rs.2,240. For private electric tubewell, the private costs are Rs.2,300 while the social cost (using Rs.0.11 per Kwh) are Rs.3,070.

The present value of capital plus O & M cost for the two types of tubewells are as follows; (assuming an interest of 8 per cent)

	Private cost to the farmer	Social Cost Period of Analysis		
	10 years life	10 years	20 years	30 years
Diesel tubewell Rs.	31,400	23,900	37,500	41,800
Electric tubewell"	22,800	28,300	41,400	47,500

Thus the farmers have an incentive to install electric tubewells, over diesel tubewells. However, diesel tubewells can be made equivalently attractive by providing a subsidy. The following table shows the extent of subsidy required assuming the existing costs, a 10 years investment horizon, and under different assumptions about the private discount rate:

	Farmer's Assumed Implicit Discount Rate			
	15%	20%	25%	30%
Present Worth-Diesel Tubewell	27,000	24,400	22,400	20,800
Present Worth-Electric Tubewell	19,700	17,900	16,400	15,300
Difference	7,300	6,500	6,000	5,500

Since the farmers's implicit discount rate in Pakistan appears to be quite high a subsidy in the above range would probably make diesel tubewells as attractive as electric tubewells, and would increase the overall rate of installation. As the rapidity of installation is of paramount importance, the Government may like to (i) concentrate on providing connections for private tubewells in fresh groundwater areas as soon as electricity become available from the Mangla Dam, and (ii) give a subsidy on installation of diesel tubewells in areas where electricity is not made available. The subsidy will be recovered by the Government from tubewell farmers in a few years in the form of duties and taxes on the diesel oil. We have assumed in this paper that electricity will be made available for at least one third of the tubewells in fresh groundwater areas by 1975 under the village electrification programme and that a subsidy of Rs.3,000 per diesel well will be provided for farmers having holdings of less than 25 acres.

The Government may consider the advantages of combining the general rural electrification programme with private tubewell electrification. This will provide additional benefits which have not been included in the above analyses. The Government may therefore like to provide electrification for more than one-third of tubewells assumed in this paper.

5. Benefit of Public and Private Tubewells

Three criteria have been employed by IACA and the Bank Group for evaluation of public and private tubewells. These are [10, p.220]:

i) Internal rate of return;

ii) Benefit cost ratios at eight per cent interest;

iii) Net present worth of incremental production at eight per cent interest

The benefits of tubewell projects were estimated by IACA on the basis of projections of agricultural growht "with" public tubewell development as compared to "without" such development. In the "without" case, separate estimates were made for (a) continued private tubewell development, and (b) no further water development [10, p.218]. Table XI shows the results of their calculations.

In making their calculations, the IACA did not distinguish between the two sources of increased irrigation supplies --

additional groundwater and additional surface water - and attributed the total increased production to the investment in public tubewells. (10, p.219). Another assumption made by IACA was that additional water will give the same increase in production whether it is used to incfease the irrigation depth where underwatering presently prevails or to expand irrigated acreage. When additional water becomes available, IACA assumed an almost <u>instantaneous</u> increase in yield equivalent to the degree of underwatering corrected, (.e.g. if the additional water was sufficient to raise the irrigation level from 80 per cent to full delta, this would result in an automatic and instant increase of 20 per cent in agricultural output [10, p.72]). These calculations assume a linear production function for water which is contrary to all experience. More reasonably, the Bank Group estimates that raising the irrigation level from 80 per cent to full delta, will increase the yield 10 per cent [10, p.69]. Furthermore, IACA have adopted apparently biased estimates of intensities for public and private tubewell development areas. Two such examples are:

i) SCARP IV area: The intensities in that part proposed for public development are assumed to increase from 96 per cent in 1965 [5, p.25], to 133 per cent in 1975 [5, p.68]. In that part where private tubewells are being installed at such as rapid rate that the West Pakistan Government has decided to defer public development, intensities are assumed to <u>decrease</u> from 96 per caht to 90 per cent during the same period [5, p.25,68].

ii) Dipalpur below BS Links Intensities under public development are expected to increase by 46 per cent in 5 year, but for the nearby area served by Pakpattan above SM link where privatetubewell growth is presently occurring rapidly, intensities are assumed to increase by only 3 per cent in 10 years with continued private development.

These projections should be contrasted with data which shows that the intensity in the SCARP I area has increased from 78 per cent in 1959/60 [20, Table 9] to 107 per cent in 1965/66 [24, p.5]; while that in private tubewell areas it has increased from 99 per cent upto 131 per cent in the Multan Sahiwal area and from 115 per cent to 146 per cent in the Gujranwala district. [18, p.26]. IACA admit to the possible over estimation of production in public tubewell areas when they state "Since the projections of intensities...are independent from yield projections, it may happen in some cases that the combined affects from the two lead to large and in fact less likely, increase in total production over a short period (2A, p.10). They did not however adjust their results "for this possible over stement of potentionalities" [2A, p.10].

The Bank Group has made the following adjustments in IACA's calculations: [10, p.220]:-

i) division of benefits between the incremental surface water supplies and the tubewell water in project areas.

ii) independent projections of yields and incremental production for "with" and "without" conditions.

iii) upward revision of cost estimates;

iv) treatment of potential savings to private sector as an addition to benefits rather than a deduction in project costs.

Table XI summarize the results of IACA and Bank Group estimates of internal rate of return, the benefit cost ratio and the net worth of incremental production at eight per cent interest for the various proposed projects. [10, p.221].

Rates of return and benefit/cost ratios computed by the Bank Group are substantially below those computed by IACA for public development, and above for private development. In all instance where the IACA shows public development preferable, the Bank Group's calculations indicate the opposite on the basis of these criteria.

Except for three project areas, the Bank Group has, however, shown lower present net worth of incremental production under private tubewell development than under public development. No details of this are shown in the Bank Group Report. We are therefore unable to comment on this. However, as private tubewells are likely to be more rapidly installed than public tubewells and as they lead to higher intensities of cropping and in more productive use of water pumped, we may expect a greater increase in agricultural production with private than with public tubewells.

Table XIA

Internal Rate of Return, Public and Private Tubewell Development, Estimates by IACA and the Bank Group.

Project	Public Development IACA	Public Development Bank Group		Private Development IACA	Private Development Bank Group
1	2	3(a)	4(b)	5	6
			per cent		
Shorkot Kamalia	50	20	16	35	88
Dipalpur above B.S. Link	50	22	11	42	52
Dipalpur Below B.S. Link	47	31	11	44	49
Ravi Syphon-Dipalpur	48	27	17	46	48
Shujabad	60	28	18	80	74
Fordwah-Sadiqia	59	28	22	32	84
Bahawal-Qaim	33	31	25	65	74
Panjnad Abbasia	47	21	28	28	86
Rohri North	35	15	15	19	76
Rohri South	45	21	18	n.a.	45
Begari Sind	33	13	12	more than 100	21
Sukkur Right Bank	29	15	13	more than 100	76

Notes: a) Including potential private savings

b) Excluding potential private savings

Source: [10, p.221]

Table XI - B

Benefit-cost Ratio at 8 per cent, public and private tubewell Development, Estimates by IACA and the Bank Group

Project	Public Development			Private Development	
	IACS	Bank (a	Group (b	IACA	Bank Group
1	2	3	4	5	6
Shorkot Kamalia	5.4	2.1	1.6	3.3	2.0
Dipalpur Above B.S.Link	8.1	1.8	1.2	5.5	2.1
Dipalpur Below B.S.Link	11.4	15.1	1.2	7.5	2.5
Ravi Syphon-Dipalpur	4.2	4.0	1.7	5.0	2.9
Shujabad.1	4.1	3.6	1.7	5.4	2.4
Fordwah-Sadiqia	6.9	3.4	2.3	2.7	2.3
Bahawal-Qaim	4.3	3.4	3.3	4.5	2.1
Panjnad Abbasia	5.1	2.2	1.8	1.6	2.3
Rohri North	3.7	1.7	1.5	3.3	2.0
Rohri South	4.1	2.1	1.7	2.5	2.7
Begari Sind	3.4	1.5	1.3	8.2	1.3
Sukkur Right Bank	3.0	1.8	1.5	7.7	1.8

Notes: a) Including potential private savings

b) Excluding potential private savings

Source: [10, p.221]

TABLE XI-C

Net Worth of Net Product Value at 8 per cent Public and Private Development, Estimates by IACA and the Bank Group

	Public Development		Private Development	
	IACA	Bank Group	IACA	Bank Group
1	2	3	4	5
	Million rupees			
Shorkot	701	159	87	95
Dipalpur Above B.S. Link	645	150	349	150
Dipalpur Below B.S. Link	982	192	818	192
Ravi Syphon-Dipalpur	808	301	352	301
Shujabad	593	259	198	178
Fordwah-Sadiqia	681	302	49	87
Bahawal-Qaim	519	431	99	117
Panjnad Abbasia	1251	596	114	288
Rohri North	721	329	90	162
Rohri South	840	342	196	118
Begari Sind	424	180	139	41
Sukkur Right Bank	309	178	153	52

Source [10, p.221]

The advantages of private over public tubewell development are well summarised by Nobe (27), "Experience in other developing countries has shown... that spontaneous action by the more progressive farmers in adopting new technologies can produce a chain reaction leading to truly spectacular agricultural development...Implications of private tubewells for agricultural development are much broader than merely providing an increase in the irrigation water supply. For these farmers who have made the investment it shows a strong potential in subsequent investment in other inputs that involve risks...With private tubewells now spread throughout those parts of the Indus Plain underlain with fresh groundwater, their demonstration effect is wide spread. In conctrast the SCARP programme affects limited continguous areas and it would take a number of years to cover all the fresh groundwater areas. Realization of output targets in the Third Plan will depend on active farmer participation in Government programme rather than passive acceptance of them" [27, pp. 16-17].

·. Total Cost of Private Tubewells

Private tubewells could be installed in 14.2 million .cres of canal commanded areas with fresh groundwater (Table 1). ut of this about 2.6 million acres are covered by on-going SCARP rojects[1/]. Using the estimate of one private tubewell per 100 .cres /‾18, p. 36, 5, p. 30_7, a total of 116,000 private tube- ells will be needed to cover the remaining area of which 29,000 ad already been installed by the farmers by the end of 1965 10, p.238).

The Bank Group estimates that 9,000 additional tubewells ill be installed by 1975 in areas not commanded by canals. We stimate that an additional 30,000 tubewells will be required for eplacement purposes[2/]. Thus the total number of tubewells new nd replacement, over the next 10 years comes to 126,000, Table XII). In order to make cost estimates comparable with ublic tubewells, we have included the discounted cost of replace- ents for all private tubewells installed through the Fourth Five ear Plan. These estimates are shown in Table XIII. The total ost of all private tubewells comes to about Rs 1,900 million on he assumption that one third of the tubewells will be electric. ut of Rs 1,900 million, about Rs 500 million will be required

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/ 0.7 million acres in SCARP I, 1.1 million acres in SCARP II, 0.7 million acres in SCARP III, and 0.1 acres in Khairpur Project.

/ Our estimate of replacement of 30,000 tubewells is different from that of IACA and the Bank Group's estimate of 47,000 /‾10, p. 252_7. We have assumed that tubewells installed in 1955/56 will be replaced in 1965/66, those installed in 1959/60 will be replaced in 1969/70, and those installed in 1964/64 will be replaced in 1975/75. On the other hand IACA and the Bank Group have assumed that one tenth of tubewell at the end of any year will be replaced during the next year. Thus IACA and the Bank Group assume that 34,000 tubewells (one tenth of 34,000 tubewells at the end of 1964/65) will be replaced during 1965/66 /‾10, p. 252_7. Most of the 34,000 ubewells were installed within the last 5 years and do not need replacement in 1965/66. Actually only 300 tubewells i which were installed during 1955/56 need replacement in 1965/66.

in the public sector, Rs 350 million for electrification of 32,000 tubewells and Rs 140 million for subsidy on 43,000 tubewells to be installed by farmers having holdings of less than 25 acres. Total foreign exchange required will be Rs 520 million against Rs 1560 million required for public tubewell.

TABLE XI

Total Number of Private Tubewells to be Installed in Fresh, Groundwater Areas in West Pakistan

Year (1)	Total number at the end of the year (2)	Number installed during the year (3)	Re-placements during the year (4)	Total number of new and replacements during the yr. (5)
	number in thousand			
1955/56	1.6	.3		
1956/57	1.9	.3		
1957/58	2.2	.3		
1958/59	3.3	1.1		
1959/60	4.6	1.3		
Total First Plan		3.3		
1960/61	8.0	3.4		
1961/62	13.0	5.0		
1962/63	18.5	5.5		
1963/64	25.0	6.5		
1964/65	31.6	6.6		
Total Second Plan		27.0		
1965/66	40	8.5	.3	8.8
1966/67	50	10	.3	10.3
1967/68	62	12	.3	12.3
1968/69	76	14	1.1	15.1
1969/70	92	16	1.3	17.3
Total Third Plan		60.5	3.3	63.8
1970/71	105	13	3.4	16.4
1971/72	115	10	5.0	15.0
1972/73	122	7	5.5	12.5
1973/74	126	4	6.5	10.5
1974/75	128	2	6.6	8.6
Total Fourth Plan		36	27.0	63.0
Grand total Third and Fourth Plan periods		96.5	30.7	126.8
/Plan Tubewells to be replaced in the Fifth/period			63.8	
Tubewells to be replaced in the Sixth Plan Period			63.0	
Grand total Fifth and Sixth Plan periods			126.8	

BASHIR/

T A B L E XIII

Estimate Cost of Private Tubewells in West Pakistan, 1965 to 1975

(With Replacements upto 1985)

(1)	Number (2)	Cost per well (3)	Total cost (4)	Cost in the public Sector (5)	Foreign exchange component (6)
		Thousand Rs.	.. Million rupees......		
A. New Tubewells					
1. Canal Commanded Areas					
Electric	29	7	203	-	41
Diesel	58	9	522	-	104
Total:	87		725		
2. Outside areas					
Electric	3	7	21	-	4
Diesel	6	9	54	-	11
Total:	9		75		
B. Replacements					
Electric	10	7	70	-	14
Diesel	20	9	180	-	36
Total:	30		250		
C. Electrification of new tubewells	32	11	352	352	215
D. Subsidy on the Installation of new tubewells					
On 50% of tubewells installed by small farmers	48	3	nil	144	-
Total:	126		1402	496	425
Third Plan worthof cost of tubewells to be replaced during the Fifth Plan Period			-	-	14
Electric	21	3.2	67	-	35
Diesel	42	4.2	176		
Fourth Plan worth of tubewells to be replaced during the Sixth Plan period.					
Electric	21	3.2	67		14
Diesel	42	4.2	176		35
Grand Total			18[illegible]	496	523

IRAF*

7. Water table control

The Bank Group considers that private tubewells would result in "less effective water table control" /̲10, p. 247_7 whereas IACA believe that "eventual public control is likely to be the only feasible solution to the latent problems of groundwater rights which are likely to become extremely serious if the installation of private tubewells is continued to the stage when it results in excessive local lowering of water table" /̲5, p. 49_7.

It is interesting, though somewhat puzzling, to see that they are worried about private tubewells lowering the water table too little in some areas and too much in others.

Actually, private tubewells control the groundwater quite well. Water table measurements have been made in the seriously waterlogged area of Gujranwala and Sheikhupura districts proposed for development under the SCARP IV programme. Tipton and Kalmbach's report for this project indicates that in 1960, the depth of the watertable was less than 10 feet in about three-fourth of the area (42). Since 1960, about 6,000 private tubewells have been installed in this area (Appendix Table A-1). In May 1966, we found that in about 80% of the area, the watertable had declined by an average of 2.8 feet during the last 3 years. In about 15% of the area, it had been stabilized. Only in about 5% of the area, had it continued to rise.1/

Since private tubewells would be distributed more widely over the fresh groundwater areas than the public tubewells they can be expected to provide better overall watertable control. The proposed public tubewells projects will provide control in only limited areas.

1/ Watertable was measured in May, 1966 in 1022 villages proposed for SCARP IV in the Gujranwala and Sheikhupura districts and the farmers were asked to indicate the depth 3 years earlier. According to their replies, water table had declined by an average of 2.8 feet during the last 3 years in 801 villages, it had been stabilized in 152 villages and was reported to be still rising in 69 villages.

With private development, by 1975 an estimated 28.4 MAF will be pumped each year against recharge of 26 MAF in the fresh groundwater areas 2/. Assuming the specific yield to be 0.14 as estimated by WASID of WAPDA /_11_/, there would be a net decline in watertable of 1.2 feet a year in this area. As most of the tubewells would be installed by early 1970s (Table XII) the water table can be expected to drop by 3 to 6 feet by 1975.

With the proposed "Action Programme" total pumping of water in [illegible] areas by public and private wells in 1975 is estimated as 30 MAF (Table V). Out of this 22 MAF will be pumped by public tubewells in 10.8 million acres of useable groundwater areas which contain about 9 million acres of fresh ground areas /_5, pp. 64-65 and 69-70_/. These area will have effective water-table control. The remaining fresh groundwater area of 5.2 million acres will have a total pumping of 8 MAF (Table V) against an estimated recharge of 9.4 MAF a year, leaving net shortfall of 1.4 MAF. Again assuming the specific yield of 0.14, this will result in the watertable rising by 1.9 feet a year. Part of this may be offset by surface evaporation with a resultant increase in soil salinity.

IACA's concern with "latent" problem of groundwater rights seems somewhat premature regardless of which development takes place. Even if it should arise, it is not necessarily a strong reason for public development. The lowering of the watertable will in itself, provide a check against further lowering since the cost of pumping increases with increasing depth. If further constraints are needed,/or a tax placed on the volume of water pumped.

/ the price of electricity or fuel oil could be raised.

2/ The 116,000 tubewells in 11.6 million acres will pump about 23.2 MAF (2 acre feet per acre) whereas the public tubewells in the existing SCARPs (I, II and III) fresh groundwater areas (2.6 million acres) will pump about 5.2 MAF of water (2 acre feet per acre). Total pumping in the fresh groundwater acres would thus reach 28.4 MAF against an estimated recharge of 26 MAF in fresh groundwater acres /_1, p. 57_/. The IACA give the total estimated recharge to the "useable" groundwater area of 18.8 million acres as 34 MAF in 1975. This has been split up into recharge into the "fresh" and "mixing" zones in proportion to the area of each. Recharge in the fresh groundwater area will thus be 34 x 14.2/18.8 = 26 MAF.

With public supplies, however, since the marginal cost of water is zero to the farmer, it would not be so easy to reduce his wastage and consumption of water. In any case, there is no justifion for proposing an expensive public programme for some "latent" problem which can be solved at less cost by many other means when the problem actually arises.

8. "Constraints" on Private Tubewell Development

Based on findings of IACA and Tipton and Kalmbach the Bank Group consider that farm size, land tenure and finance will rapidly become constraints to private tubewell development. The Bank Group says that Tipton and Kalmbach "show that the intial rapid installation of private tubewells occurred on larger and wealthier farms and this lead is not automatically being followed on small farms" and as a result the rate of installation has "declined sharply" since 1963 [10, p. 163].

(i) Size of Holding

The author carried out a survey on the size of holding of single and joint tubewell farmers during November-December 1965 in the districts of Multan, Sahiwal, Gujranwala and Lahore, which had 20,041 tubewells out of a total of 31,600 tubewells recorded in West Pakistan in August/September 1965. These tubewells were owned by 33,242 farmers. The results of this survey are given in Appendix Table A-2 and are summarized in Table XIV and XV. Seventy per cent were owned by single farmers and the remaining were installed jointly by 18,998 farmers.

Only 17 per cent of single tubewells were installed by farmers having holding of less than 25 acres and 53 per cent were installed by farmers having holdings of 50 acres and above. For joint tubewells, the position was just the revers.e Nearly 62 per cent of the farmers owing joint tubewells had holdings of less than 25 acres of which 32 per cent had holdings of less than 12½ acres.

While the larger and wealthair farmers were installing more tubewells initially, this situation is changing. In the November-December 1965 surveys on the size of holding of single

Table - XIV

Size of Holding of Single and Joint Tubewell Farmers

Farmers having	Below 12½ acres	12½ acres to 25 acres	25 acres to 50 acres	50 acres and above	All farmers
	--total number of farmers having--				
Single Tubewells	860	1572	4206	7606	14244
Joint Tubewells	6013	5766	5198	2021	18998
All Farmers	6873	7338	9404	9627	33242
	------ percentage of farmers ------				
Single farmers	6.1	11.0	27.5	28.9	100.0
Joint farmers	31.6	30.4	27.4	10.6	100.0
All Farmers	20.7	22.1	28.3	28.9	100.0

Source: Survey by PIDE and Director of Agriculture, Lahore / See Appendix Table A-2 /.

TABLE - XV

Number of Farmers Having Joint Tubewells and Number of Joint Tubewells in Different Size of Holdings

	Size of holding of Joint Tubewells farmers				
	Less than 12½ acres	12½ to 25 acres	25 acres to 50 acres	50 acres and above	All Joint Tubewells farmers
Number of farmers	6,013	5,766	5,195	2,021	18,021
Number of tubewells	1,247	1,690	1,932	928	5,797
Number of farmers Joining together to have one tubewell	4.8	3.4	2.7	2.2	3.3

Source: Survey by PIDE and Director of Agriculture, Lahore / See Appendix Table A-2 /.

TABLE - XVI

Change in the size of Holding of Farmers Installing Single and Joint Tubewells between 1957 and 1965

3-Year Period	Size of holding of farmers: Below 12½ acres	12½ to 25 acres	25 to 50 acres	50 acres and above	Total	Size of holding of farmers: Below 12½ acres	12½ to 25 acres	25 to 50 acres	50 acres and above	Total
1	2	3	4	5	6	7	8	9	10	11
	Number of single tubewell farmers					Percentage of single farmers				
1957 to 1959	42	74	232	622	975	4.3	7.6	23.8	64.3	100.00
1960 to 1962	263	474	1334	2774	4845	5.4	9.8	27.5	57.3	100.00
1963 to 1965	491	930	2428	3732	7581	6.5	12.3	32.0	49.2	100.00
Total 1957 to 1965	796	1478	3994	7133	13401	5.9	11.0	29.8	53.3	100.00
	Number of joint Tubewell farmers					Percentage of joint farmers				
1957 to 1959	255	202	276	141	904	31.5	22.3	30.5	15.6	100.00
1960 to 1962	1741	1757	1138	708	5944	29.3	29.6	29.2	11.9	100.00
1963 to 1965	3838	3527	3114	1043	11522	33.3	30.6	27.6	9.1	100.00
Total 1957 to 1965	5864	5486	5128	1892	13370	31.9	29.6	27.9	10.3	100.00
	Number of single and joint tubewell farmers					Percentage of single and joint farmers				
1957 to 1959	327	276	508	768	1879	17.4	14.7	27.0	40.9	100.00
1960 to 1962	2004	2231	3072	3482	10789	18.6	20.7	28.5	32.2	100.00
1963 to 1965	4329	4457	5542	4775	19103	22.7	23.3	29.0	25.0	100.00
Total 1957 to 1965	6660	6964	9122	9025	31771	21.0	21.9	28.7	28.4	100.00

Source: Survey by PIDE and Director of Agriculture, Lahore [See Appendix Table A-2].

and joint tubewell farmers, we noted the year of installation of each tubewell. The results for the 9 years period, 1957 to 1965 are given in Appendix Table A-3 and are summarized in Table XVI and XVII. Several interesting facts emerge from a study of Table XVI.

i) During the period 1957 to 1959, the number of farmers installing joint tubewells was slightly less than those installing single tubewells. During the middle period, 1960 to 1962, the number of farmers installing joint tubewells exceeded the number of farmers installing single tubewells by about 23 per cent. During the period 1963 to 1965, the number of farmers installing joint tubewells exceeded the number of farmers installing single tubewells by over 50 per cent. Thus we may reasonably expect the number of farmers installing joint tubewells to greatly exceed those installing single tubewells in the coming years in continuation of this trend.

ii) Farmers having holdings of 50 acres and above, installed 64 per cent of all single tubewells during the first period of 3 years 1957 to 1959. Their share was reduced to 40 per cent in the last 3 years, 1963 to 1965. On the other hand farmers having holdings of less than 25 acres installed only 12 per cent of all single tubewells during the first 3 year period. Their share increased to 19 per cent in the last 3 year period.

iii) Most of the joint tubewells are installed by farmers having holdings of less than 25 acres. The share of these farmers in all joint tubewells was 54%, 59% and 64% during the three periods. We may expect this trend to continue and in future most of the joint tubewells will be installed by farmers having holdings of less than 25 acres.

These facts demonstrate Tipton and Kalmbach's claim regarding constraint of the size of holding to be invalid.

Similarly the claim of Tipton and Kalmbach that the number of tubewells installed has "sharply" fallen since 1963 is not borne out by facts (Tables XVII and XVIII). The number of installation declined some what in 1965 but picked up rapidly after the war with India and the total number of tubewells installed in West Pakistan during 1965/66 greatly exceeded the number installed during any previous year.

TABLE - XVII

Number of Single and Joint Tubewells Installed in the Multan, Saliwal, Lahore and Gujranwala Districts, 1957 to 1965

Year	Single tubewells	Joint tubewells	Total tubewells
(1)	(2)	(3)	(4)
1957	186	49	235
1958	359	96	455
1959	430	144	574
1960	1152	412	1564
1961	1440	558	1998
1962	2253	864	3117
1963	2666	1170	3836
1964	2736	1259	3995
1965	2179	1114	3293 (a)

Note (a) The survey was done in November and December. Figures do not represent full year data in many parts of the districts.

Source: Survey by PIDE and Director of Agriculture, Lahore / See Appendix Table A-2 /.

TABLE XVIII

Total Number of Electric and Diesel Tubewells in West Pakistan in 1964, 1965 and 1965

	August/ September 1964	August/ September 1965	August/ September 1966	Increase during the year	
				1965 over 1964	1966 over 1965
1	2	3	4	5	6
			-- Number --		
Electric Tubewells	6,600	9,800	12,900	3,200	3,100
Diesel Tubewells	18,400	21,800	27,200	3,400	5,400
Total Tubewells	25,000	31,600	40,100	6,600	8,500

Source: Survey by PIDE and Directors of Agriculture, Lahore, Hyderabad and Peshawar / See Appendex Table A-1 /.

(ii) Finance

The Bank Group quotes Tipton and Malmbach as stating that finance will rapidly become a constraint on private tubewell development. Historically, this has not been the case 1/. Of the tubewells included in our 1964 survey [18] 82% had been financed from the farmer's own resources or non-institutional credit (i.e. from family and friends). Increased activity by the Agricultural Development Bank of Pakistan (ADBP) raised the proportion of tubewells financed by institutional sources in 1965/66 upto about 23 per cent 2/. However, as stated by the Bank Group "it is reasonable to presume that improved credit facilities must be provided if ownership of private tubewells is to spread to the smaller size farmers" [10, p. 150]. We agree with their suggestion "that the Pakistan authorities implement policies conducive to rapid private tubewell development as a matter of urgency. The improvement of existing institutional supports, in particular credit facilities, technical advice and council for cooperative ownership and utilization should be given high priority. Financial resources required for such support would be small if compared to the savings to the public resources on the scale indicated" [10, pp. 243-44].

1/ A survey by the staff of the Pakistan Institute of Development Economics, on the sources of finance of private tubewells, in major tubewell districts of the Punjab is under way at the time of writing of this paper (July 1967). The results of this survey will be reported in a subsequent issue of this Review. However, in our preliminary field work for this survey during April 1967 we found no evidence that finance was acting as a constraint on tubewell installation. We found that small farmers were making great efforts for saving money for tubewell installation.

2/ The ADBP issued loans for 2100 tubewells during the year 1965/66 [29]. Gross number of tubewells installed during 1965/66 is estimated as 9,000 which consists of 8,500 net additions (Appendix Table A-1), 200 replacements in the Gujrat district due to SCARP II and an estimated 300 replacements of old tubewells which were installed in 1955/56.

9. Other Issues Raided by IACA.

i) Reclamation of Saline Soils and Quality of Water in Mixing Zones

The IACA state that "technical difficulties of drainage, reclamation and soil salinity are likely to be overcome by a public system" and that "public control is desirable to safeguard the quality of irrigation water in mixing zones by ensuring that correct mixing ratios will be used" /̅5,p. 49_7.

The questions of the reclamation of saline soils and development of saline groundwater areas will be covered in another paper to be published in a latter issue of this Review. In the present article we are concerned only with the most efficient development of the 14.2 million acres with fresh groundwater. The IACA's argument is unrelated to this issue.

ii) Integration of Groundwater with Surface Water.

The IACA states that "integrated use of surface and groundwater under full public control /̅is_7 fundamental to the efficient long-term development of water resources" /̅5, p. 49_7, and the Bank Group lists the following types of integrated development they have in mind /̅10, p. 179-180_7:

i) Reallocating surface water from fresh groundwater areas. "Only about half of the CCA proposed for development is underlaid by fresh groundwater which can be applied directly to the crops, but surface water supplies could be improved throughout the remainder of the CCA by transfer from fresh groundwater areas..... In such cases rabi surface supplies could be released and reallocated to other areas" /̅10, pp. 179-180_7.

ii) Mixing "marginal" groundwater with fresh surface water so that it can be used for irrigation.

iii) Smooting out the tubewell power load on the electricity system. "Integration of tubewell pumping and surface water deliveries is necessary in order to rationalize the pattern of demand for tubewell pumping which would represent a substantial part of total system power and energy demand in West Pakistan" /̅10, p. 180_7.

Regarding the first point, if it is found to be efficient to reallocate surface water away from fresh groundwater areas, this can be done as easily with private development as with public[1/]. If the supply of surface water is decreased, the farmers will automatically increase their use of groundwater. They use tubewell water when necessary to supplement the surface water supplies. No better integration of the two is possible.

The second point, as mentioned above, is outside the issue being dealt with in this article.

The third point has been taken care of in the economic analysis by reducing the cost per KWH for public tubewells to take account of load shedding (i.e. shutting down tubewells during certain peak load hours to rationalize the pattern of demand)[2/]. These calculations show that even taking this factor into account, private tubewells are more economic

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1/ Some form of compensation for _rabi_ water transferred may be provided to the farmers in fresh groundwater areas. It may be provided as a lumpsum of say Rs 50 per acre (Rs 5000 for each 100 acres) which will be about half of the cost of a diesel tubewell. Or it may be provided in the form of subsidized electric power by covering the fresh groundwater areas first with electricity under the rural electrification programme.

2/ See discussion on pages 22-23.

IV. SUMMARY AND CONCLUSIONS

A programme for development of irrigation and agriculture in West Pakistan has been proposed by the International Bank for Reconstruction and Development based on extensive field studies three foreign consulting firms during 1964 to 1966.

The Bank Group recommends the installation of 20,000 three to four cusec capacity public tubewells covering 10.8 million acres of "fresh" and "mixing zone" groundwater areas at a cost of Rs.3,343 million out of which Rs.1,562 million will be in foreign exchange. Approximately 1,000 of these wells have already been installed in 1965/66 and 140 are in operation. In addition 400 public wells were installed during the Second Plan period.

Simultaneously the farmers of West Pakistan have been rapidly installing, with very little assistance from the Government, private tubewells in fresh groundwater areas. They installed 27,000 tubewells during the Second Plan period and 8,500 during the first year of the Third Plan. In contrast to the public tubewells all tubewells installed during 1965/66 are already in operation.

The Bank Group estimated the cost of a four-cusec public tubewell as Rs.117,000 plus Rs.42,000 for electrification. Adding interest during the period of construction (Rs.28,000 at 8 percent) raises the total investment cost of Rs.187.000.

The costs of a one-cusec private tubewell is Rs.9,000 for a diesel well and Rs.7,000 for an electric well plus Rs.13,000 for its electrification. A four-cusec public tubewell delivers about five times as much water to the fields as a one-cusec private well. Allowing for replacement of the end of 10 years, and taking market prices, the cost per cusec capacity for a public tubewell is 60 per cent higher than that of a private electric tubewell and more than twice that of private diesel tubewell. When a shadow price is put on foreign exchange and public rupee funds, public tubewells become 60 to 90 percent more expensive as private electric and three to four times as expensive as private diesel tubewells for the same capacity of water delivered to the fields.

The private tubewells are operated according to the actual water requirements of crops, while the public tubewells are worked according to generalized requirements used to establish pumping patterns for large areas. With private wells, therefore, the water is used more efficiently and there is less wastage in both the water courses and the fields.

Using market prices and including taxes and subsidies, the cost of water delivered to the fields comes to Rs.27 per acre-foot from public tubewells, Rs.18 per acre foot from private electric tubewells and Rs.25 per acre foot from private diesel tubewells. However, applying reasonable shadow prices to foreign exchange and public rupee funds and eliminating taxes and subsidies, the cost of water delivered to the fields comes to Rs.38 per acre-foot from public tubewells, Rs.26 per acre foot from private electric tubewells and Rs.23 per acre-foot from private diesel tubewells, if drilling and electrification is carried out as planned by the Bank Group. However, if electrification of public tubewells is carried out simaltaneously with drilling operations, and if losses from watercourses are assumed to be no more than those from canal watercourses covering an equal area, the cost of water delivered to the fields is reduced from Rs.38 to Rs.35 per acre-foot from public tubewells against Rs.26 and Rs.23 per acre foot from private electric and private diesel tubewells respectively.

Installation, operation, and maintenance costs are all lower for electric tubewells than for diesel tubewells. The rate of installation, therefore, is generally higher in areas where electricity is made available although 68% of existing private tubewells are diesel powered. Subsidizing the cost of diesel tubewells should increase their rate of installation and agricultural production in areas not provided with electricity.

This subsidy will be recovered in a few years from duty and taxes realized on diesel oil.

The internal rate of return and benefit cost ratios are higher for private tubewells than for public tubewells. With private tubewells now spread throughout the fresh groundwater areas of the Indus Plain, their demonstration effect is widespread. In contrast, public tubewells are concentrated in limited contiguous areas and will require many years to cover the whole of fresh groundwater areas. Total agricultural production therefore, should increase more rapidly and reach a higher level with a private than with a public programme.

The private tubewells provide effective watertable control even in areas most severly affected by water-logging. In 3 years they have already lowered the watertable by an average of about 3 feet over 80 per cent of the area proposed for development by SCRAP IV in the Gujranwala and Sheikhupura districts, and could be expected to lower the water table over the whole of the Indus Plain fresh groundwater area by 3 to 6 feet by the end of the Fourth Plan period. With the public programme, the watertable will be lowered in only the two-thirds of the fresh groundwater areas actually covered by the public wells, and will rise in the remaining one-third.

Size of land holdings, finances, and "absorbtive capacity" are not acting as a constraint on the installation of private tubewells. The smaller farmers are now follwing the lead given by larger and wealthier farmers in the earlier years. When there is a constraint on finances, they become partners in the installation of "joint" tubewells. Whereas in the period 1957-59, the number of farmers installing joint tubewells was less than the number of farmers installing single tubewells, it exceeded the number installing single tubewells by over 50 per cent during the period 1963 to 1965. Most of the joint tubewells are installed by farmers having holding of less than 25 acres. The share of these farmers in all joint tube-wells was 54 per cent during 1957 to 1959, and 64 per cent during 1963 to 1965. Both these trends towards more joint tubewells and ownership by smaller owners can be expected to continue and can be accelerated by the provision of improved credit facilities.

The rate of tubewell installation continues to increase; the 8,500 installed during 1965/66 greatly exceeded the number installed in any previous year and was about 40 per cent higher than the target of 6,000 private wells in the first year of Third Five Plan. By extropolation, we may expect some 60,000 private tubewells to be installed during the Third Plan period (against 40,000 proposed in the Plan itself) if there is no interference by public tubewells. Installing another 36,000 during the Fourth Plan period will provide complete coverage for the 11.6 million acres of f esh groundwater arease in West Pakistan.

The total cost of the private tubewells required to cover the 11.6 million acres would be about Rs.1,400 million (including electrification) on the assumption that two-third will be diesel and one third electric powered. In order to make cost estimates comparable with public tubewells, the discounted cost of replacements for all private tubewells installed through the Fourth Plan period is to included. On this basis the total cost comes to Rs.1900 million. Of this, about Rs.500 million will be in the public sector, and about Rs.520 million in foreign exchange (compared to Rs.1560 million required for public tubewells for an equal area). Thus the Government of Pakistan appears to have two clear options open. It can follow the recommendations of the IBRD and spend Rs.3,340 million of scarce public funds and Rs.1,560 million of scarce foreign on <u>public</u> tubewell program; or, it can save itself 85 per cent of the public funds and 67 per cent of the foreign exchange by allowing the farmers themselves to mobilize their own resources to cover the same area more rapidly and more efficiently with <u>private</u> tubewells which will result in a greater total increase in agricultural production at significantly less total cost.

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APPENDIX TABLE A-1

Number of Private Tubewells in Different Districts of West Pakistan 1964, 1965 and 1966

S.No.	District	1964 Count Total	1964 Count Electric	1964 Count Diesel	Gross increase in 1963/64	1965 Count Total	1965 Count Electric	1965 Count Diesel	Net increase in 1964/65	1966 Count Total	1966 Count Electric	1966 Count Diesel	Net Increase in 1965/66
1.	Multan	5148	624	4524	1345	6325	835	5490	1177	8000	1343	6657	1675
2.	Montgomery	4055	1175	2880	1049	5159	2011	3148	1104	6897	2117	4780	1738
3.	Gujranwala (a)	4234	1270	2964	1170	5112	1826	3286	878	5950	2274	3676	838
4.	Sialkot	2458	434	2024	503	3036	579	2457	578	3462	842	2620	426
5.	Lahore	1607	856	751	504	2156	1305	851	549	3009	2121	888	853
6.	Jhang	1540	448	1092	304	1804	651	1153	264	2539	889	1650	735
7.	Lyallpur (b)	1063	291	772	301	1534	441	1093	471	1901	597	1304	367
8.	Rahimyar Khan	443	9	434	117	553	22	531	110	1050	102	948	497
9.	Sheikhupura (c)	460	117	343	125	725	198	527	265	957	275	682	232
10.	Muzaffargarh	443	-	443	142	487	5	482	44	872	12	860	385
11.	Gujrat	719	229	420	274	976	474	502	257	760	432	328	(-) 216
12.	Bhawalpur	398	26	372	122	492	54	438	94	755	179	576	263
13.	Sargodha	352	181	171	109	491	236	255	139	557	287	270	66
14.	Mianwali	228	107	121	60	371	166	205	143	492	261	231	121
15.	Dera GhaziKhan	220	-	220	40	285	-	285	65	420	3	417	135
16.	Bhawalnagar	273	3	270	87	343	4	339	70	368	33	335	25
	Total for 16 districts	23641	5840	17801	6312	29849	8807	21042	6208	37989	11767	26222	8140
	Estimated total (d) for otherdistts, 7	1359	760	599	188	1751	993	758	392	2111	1133	978	360
	Estimated total for West Pakistan:	25000	6600	18400	6500	31600	9800	21800	6600	40100	12900	27200	8500
	Net increase over the previous year:					6600	3200	3400		8500	3100	5400	

Notes: a) Excludes Hafizabad tehsil which falls in SCARP I area but includes Ferozwala tehsil of Sheikhupura district.
b) Excludes Jaranwala tehsil which falls in SCARP I area and is included in the Sheikhupura district.
c) Includes Nankana Sahib and Sheikhupura tehsils of Sheikhupura district, Hafizabad tehsil of Gujranwala District and Jaranwala tehsil of Lyallpur district.
d) Based on actual number in Peshawar, D.I. Khan, Bannu, Khoat, Hazara, Rawalpindi, Cambelpur, Jhelum, Hyderabad, [illegible] Dadu, Sanghar, Tharparkar, Quetta, Chagai, and Loralai Districts and estimated number in other districts.

Source: Survey by PIDE and the Directors of Agriculture Lahore Hyderabad and Peshawar.

APPENDIX TABLE - A-2

SIZE OF HOLDING OF JOINT TUBEWELLS IN MULTAN SAHIWAL, GUJRANWALA AND LAHORE DISTRICTS

DISTRICT	No. of Joint Tube-wells	No. of Part-ners	0-4.9		5.0-7.4		7.5-12.4		12.5-24.9		25.0-49.9		50.0-99.9		100-149.9		150 & above	
			No. of Joint Tube-wells	No. of Part-ners	No. of Joint Tube-wells	No. of Part-ners	No. of Joint Tube-wells	No. of Part-ners	No. of Joint Tube-wells	No. of Part-ners	No. of Joint Tube-wells	No. of Part-ners	No. of Joint Tube-wells	No. of Part-ners	No. of Joint Tube-wells	No. of part-ners	No. of Joint Tube-wells	No. of Part-ners
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
1. Multan	2079	7324	36	290	93	527	238	1119	530	2201	737	2175	357	836	61	123	26	51
2. Sahiwal	1888	6452	33	248	102	585	270	1300	548	1885	635	1758	245	558	48	100	11	18
3. Gujranwala	1497	4075	61	359	81	340	247	843	515	1359	64	963	115	191	12	18	2	2
4. Lahore	337	1149	17	75	27	114	49	213	97	321	96	302	35	88	9	21	7	15
5. Total for 4 districts	5801	18990	147	972	303	1566	804	3475	1690	5766	1932	5198	752	1673	130	262	46	86
6. Average number of Partners per tubewells.	3.3			6.5		5.2		4.3		3.4		2.7		2.2		1.9		1.9
				1254			:6013							928	2021			
					4.8									2.2				

Source: Survey by PIDE and Director of Agriculture, Lahore.

Appendix B.

TABLE B-1.

ECONOMIC COST OF INSTALLATION OF 4-CUSEC PUBLIC TUBEWELL AND ONE CUSEC PRIVATE TUBEWELL

	Public 4-cusec Capacity	Cost for one-cusec Capacity		
		Public (a)	Private Electric	Private Diesel
	(b)		(e)	(f)
1. Cost of Tubewell	117,000	23,400	10,200	13.200
2. Cost of electric transmission and distribution.	(c) 41,900	8,400	(g) 13,100	nil
3. Interest during period of construction	(d) 28,400	5,700	nil	nil
T o t a l :	187,300	37,500	23,300	13,200

Notes: a) One four-cusec public tubewell considered equal to 5 one-cusec private tubewells.

b) IACA'S estimate of Rs.90,000 per well increased by 30 per cent by the Bank Group [10, p.213].

c) [9,p.14].

d) Interest at 8 per cent added by the author for 3 years on tubewell cost and for three years on electrification cost.

e) Present worth of replacement cost at the end of 10 years (Rs.3,200) added to IACA's estimate of Rs.7,000 for a private electric tubewell.

f) Present worth of replacement at the end of 10 years (Rs.4,200) added to IACA's estimate of Rs.9,000 for a private diesel tubewell.

g) [9, p.54].

TABLE - B-2.

PUBLIC SECTOR CAPITAL COST FOR PUBLIC AND PRIVATE TUBEWELLS

	Public 4-cusec tubewell	Cost for one-cusec Capacity		
		Public (a)	Private Electric	Private Diesel
1. Cost of tubewells	117,000	23,400	nil	nil
2. Cost of electric transmission & distribution	41,900	8,400	13,100	nil
3. Interest during period of construction	28,400	5,700	nil	nil
T o t a l:	187,300	37,500	13,100	nil

(See notes under Table B-1).

TABLE A-3

PURCHASE OF TUBEWELL WATER BY NON-TUBEWELL FARMERS IN MULTAN, SAHIWAL AND GUJRANWALA DISTRICTS

DISTRICT	Number of		Number of Non-tubewell farmers						Tubewell irrigation as a percentage of canal irrigations
	Villages studied	Tubewells studied	Total	Those who purchased water	Percentage of those who purchased water	Area some by non-tubewell farmers	Canal Irrigation	Tubewells irrigation	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Rabi 1964/65									
Multan	5	11	129	88	68	1544	7838	1932	25
Sahiwal	5	23	194	112	58	2094	10474	2467	24
Gujranwala	7	23	112	10	9	976	4142	624	15
	17	57	435	210	48	4614	22454	5023	22
Kharif 1965									
Multan	5	11	129	118	92	1453	5684	3593	63
Sahiwal	5	23	194	121	62	2107	10483	3994	38
Gujranwala	7	23	112	20	17	1030	9291	3290	34
	17	57	435	259	60	4590	25458	10877	42
Rabi 1965/66									
Multan	5	16	142	128	90	1393	6444	2688	42
Sahiwal	5	27	184	106	58	2133	6210	3701	60
Gujranwala	6	23	88	29	33	427	2826	559	20
	16	66	414	263	64	3953	15480	6948	45

Source: Survey by PIDE.

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TABLE B-3.

PUBLIC SECTOR RUPEE COST FOR PUBLIC AND PRIVATE TUBEWELLS

	Public 4-cusec tubewell	Cost for one-cusec Capacity (a) Public	Private Electric	Private Diesel
1. Cost of tubewell	62,200	12,400	nil	nil
2. Cost of electric transmission distribution	16,300	3,300	5,100	nil
3. Interest during period of construction	14,300	2,900	nil	nil
Total:	92,800	18,600	5,100	nil

(See Notes under Table B-1).

TABLE B-4.

TOTAL FOREIGN EXCHANGE COST FOR PUBLIC AND PRIVATE TUBEWELLS

	Public 4-cusec tubewells	Cost for one-cused capacity (a) Public	Private Electric	Private Diesel
1. Cost of tubewells	54,800 (h)	11,000 (j)	2,000 (j)	2,600 (k)
2. Cost of electric transmission and distribution	25,600 (h)	5,100 (i)	8,000	nil
3. Interest during period of construction	14,100	2,800	nil	nil
Total:-	94,500	18,900	10,000	2,600

Note: a) See notes (a) to (g) under Table B-1.

h) Total foreign exchange cost for one tubewell (Rs.80,400) calculated from [10, p.214]. Foreign exchange cost for electrification (Rs.25,600) calculation at 61 percent of total cost as shown in [9, p.14]. The remaining foreign cost (Rs.54,800) shown for tubewell construction.

i) Foreign exchange cost for electrification taken as 61 per cent of total cost as shown in [9, p.54].

j) Present worth of replacement cost at the end 10 years (Rs.600) added to IACA's estimate of Rs.1400 for private electric tubewell.

k) Present worth of replacement cost at the end of 10 years (Rs.800) added to IACA's estimate of Rs.1800 for diesel tubewell.

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19th July, 1967.

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TABLE - C-1

IACA'S ESTIMATES OF COST OF PUMPING WATER FROM PUBLIC AND PRIVATE TUBEWELLS

COST ITEM	Unit	Public tubewell 4-cusec capacity	Private Tubewell 1-Cusec electric	Private Tubewell 1-Cusec electric
Tubewell life	Years	20	10	10
Capital Cost	Rupees	90,000	7,000	9,000
Annual Cost				
Depreciation	Rs/Year	4,500	700	900
Interest at 8 percent.		3,600	280	360
Operation and Mintanence		3,000	500	1,000
Power (economic Cost)		8,630	1,800	2,560
Total annual Cost.		19,730	3,280	4,820
Annual Pumpage	AF/Year	1,170	200	200
Cost of Pumped Water.	Rs/AF	16.9	16.4	24.1

Source:- [5, Table 5.9, p. 43].

APPENDIX TABLE C-2

Cost of Pumping Water from Public and Private Tubewells Using Different Shadow Prices for Capital Cost

	Unit	Public tubewell 4-cusec capacity: Official Price	Public tubewell 4-cusec capacity: Shadow Price I	Public tubewell 4-cusec capacity: Shadow Price II	Private electric tubewell of once-cusec capacity: Official price	Private electric tubewell of once-cusec capacity: Shadow Price I	Private electric tubewell of once-cusec capacity: Shadow Price II	Private diesel tubewell of one-cusec capacity: Official Price	Private diesel tubewell of one-cusec capacity: Shadow Price I	Private diesel tubewell of one-cusec capacity: Shadow Price II
Life	Years	20	20	20	10	10	10	10	10	10
Capital Cost (with electri-ication)	Rupees	140,000 (131,000)	173,000 (162,000)	243,000 (227,000)	7,000	7,700	8,400	9,000	9,900	10,800
Annual Cost	Rs. Per Year	7000 ([illegible])	8650 (8100)	12150 (11350)						
Depreceation	"	5600 (5240)	6920 (6450)	9720 (9080)	700	770	840	990	990	1,080
Interest at 8 Percent	"				280	510	340	360	400	430
Operation & Maintanace	"	3,000	3,000	3,000	400	400	400	800	500	500
Power (economic cost)	"	8,650	8,630	8,630	1,900	2,600	3,090 (b)	2,500	1,750 (c)	2,100 (d)
Total annual cost:-		24230 (23420)	27,200 (26,210)	33,500 32 060	3,200	4,080	4,670	6,580	3,640	4,110
Water Pumped	acre feet)	1,170	1,170	1,170	200	200	200	200	200	200
Water delivered to the fields		880 (940)	880 (940)	880 (940)	180	180	180	180	180	180
Cost per acre foot of Water pumped	Rs.	20.7 (20.0)	23.2 (22.4)	28.6 (27.4)	16.4	20.4	23.4	22.8	18.2	20.6
Water delivered to the fields	"	27.5 (24.9)	30.9 (29.9)	38.1 (35.2)	18.2	22.7	25.9	25.3	20.2	22.8

NOTE:

(a) Electricity cost at Rs. 0.11 per Kwh.

(b) Electricity cost at Rs. 0.13 per Kwh.

(c) Elimirating taxes and duties and taxes and valuing foreign exchange companant of diesel oil at 150 per cont. of Official price

(d) Fliminating takes and duties and taxes and valuing foreign exchange corponent of diesel oil at 200 per cent of the official price.

NOTE:- Figures within parenthesis apply if drilling and electrification of public tubewells is carried out simaltaneously and if public tubewell watercourses lose no more water than canal watercourses covering an equal area.

APPENDIX TABLE - D-1.

Number of Tubewells Installed in Madras State, India 1961/62 to 1963/64

	1961/62	1962/63	1963/64	1964/65	Total
Financial grant (in Lakh Rs.)	8	22	17	64	111
Physical targets (number)	751	1,078	957	3,639	6,425
Total pumps installed during the year.	23,400	26,100	24,500	31,900	105,900
Percentage of government help to total installed pumps.	3	4	4	11	6

Source: [33, p. 215].

APPENDIX TABLE D-2.

Number of wells and Rank of Districts in Number of Wells and Number of Villages Electrified in the Madras State in India

District	Number of Pumps sets in 1963-64	Rank in the Number of Wells in 1963/64	Rank in the Number of Villages electrified IN 1961 - 1962
Coimbatore	42,600	1	1
North Arcot	35,200	2	2
Salem	26,400	3	5
Chingleput	21,100	4	3
South Arcot	19,900	5	8
Madurai	16,500	6	4
Tirunelveli	10,800	7	6
Tiruchirappalli	10,200	8	10
Ramanathapuram	9,100	9	7
Thanjavur	600	10	9
Kanyakumari	(a)	11	11
Nilgiris	(a)	12	12
	192,400		

NOTE:- (a) Less than 50

Source: [32, pp. 216-217].