5. Other Relevant Data

Background

Balochistan is the largest province of Pakistan and covers an area of about 347, 190 km^2; however, in terms of population it is the smallest, with a density of 12 persons per km^2. It has abundant natural resources and wildlife and excels in its variety and subtlety of culture, tradition, climate, vegetation, geology, geography and resources.

The population of Balochistan was 4.3 million according to the 1981 census. Presently, the population is estimated at around 6.5 million. Out of this 6.5 million people, about 84 percent live in rural areas. Culturally, the province by and large tribal. Traditional tribal customs and practices are still followed, resulting in an exceedingly complex system of land tenancy, water rights and income sharing. Disputes over land and water rights are common. The province is reckoned to be comparatively less developed and the sole reason is scarcity and paucity of water. The groundwater development program as the scheme of the project covers six main basins in Balochistan. They are located in 6 districts, namely Zialat, Mastung, Khran, Kalat, Panjgur and Trubat. The area of these six districts totals about 103,200 km^2 which forms 29.7 percent of Balochistan as shown below.

Table 5-1 Balochistan District Area

Division		District		Project
Name	Area (km^2)	Name	Area (km^2)	Area No.
Quetta	64,310	Quetta	2,653	
		Pishin	11,112	
		Chngi	50,545	
Zhob	46,200	Zhob	27,129	
		Loralai	19,071	
Sibi	27,055	Sibi	6,082	
		Ziarat	3,203	①
		Kohlu	15,122	
		Dera Bugti	2,648	
Nasirabad	16,946	Jaffarabad	2,445	
		Tambo	3,387	
		Kachhi	11,114	
Kalat	138,034	Kalat	8,437	②
		Mastung	4,081	③
		Khuzdar	64,892	
		Kharan	48,051	④
		Lasbela	12,574	
Makran	54,646	Panjgur	16,891	⑤
		Turbat	22,539	⑥
		Gwader	15,216	

Source: Groundwater Resources of Balochistan Province, Pakistan, 1993, WAPDA

5.1 Natural Environment

The natural environment of the Balochistan and project sites are as follows.

5.1.1 Geography

Alluvial areas form 67.0 percent of the total area of Pakistan. In Balochistan, the alluvial area forms 54.8 percent of total area. Balochistan itself accounts for 43.6 percent of Pakistan's land area . Hard rock areas are widely distributed in Balochistan, much the same as the Northwest Frontier Province (NWFP). The project area covers 33.6 percent of Balochistan (or 14.6 percent of Pakistan), but the hard rock areas form 66.1 percent of the project area.

The altitude of the project sites are around 200 m in the southern districts, and up to 2,500 m maximum in the northern districts, such as in Ziarat.

Most of the developed land in Balochistan has been appropriated for farm land. The arable land area is 1,850 km^2, which accounts for only 0.53 percent of Balochistan. The cultivated land area is 167 km^2 and forms only 9.0 percent of the arable land. This cultivated land covers only 0.09 percent of the alluvial areas. The alluvial and hard rock areas in Balochistan are tabulated below.

Table 5-2 Geographic Summary in Balochistan

Hydrogeological Basins	District	Total Area (km^2)	Alluvial Area (km^2)	Hard Rock Area (km^2)	Height Above the Sea Level (M)
Nuri River	Ziarat	21,829	6,680	15,149	1,000 ~ 3,500
Pishin Lora	Mastung	16,928	7,873	9,055	1,740 ~ 3,600
Mula River	Kalat	4,188	980	3,208	1,710 ~ 2,990
Hingol River	Kharan	34,190	10,100	24,090	100 ~ 2,940
Rakhshan River	Panjgur	12,410	5,860	6,550	900 ~ 1,600
Dasht River	Turbat	27,100	8,100	19,000	200 ~ 1,100
Project Area Total		116,645	39,593	77,052	
Balochistan Total		347,190	190,400	156,790	
Pakistan Total		796,100	533,300	262,800	

Source: Groundwater Resources of Balochistan Province, Pakistan 1993, WAPDA

5.1.2 Meteorology

The precipitation over a larger part of the province is about 100 mm per year. On the basis of isohyetal contours, three district regions can be identified as below and in Table 5-3.

Table 5-3 Isohyetal Contours in mm (1960-85)

Region	Rainfall
Quetta - Zhob	over 200 mm
Turbat - Khara - Sibi	100 mm to 200 mm
Chagai	under 100 mm

Source: Groundwater Resources of Balochistan Province, Pakistan, 1993, WAPDA

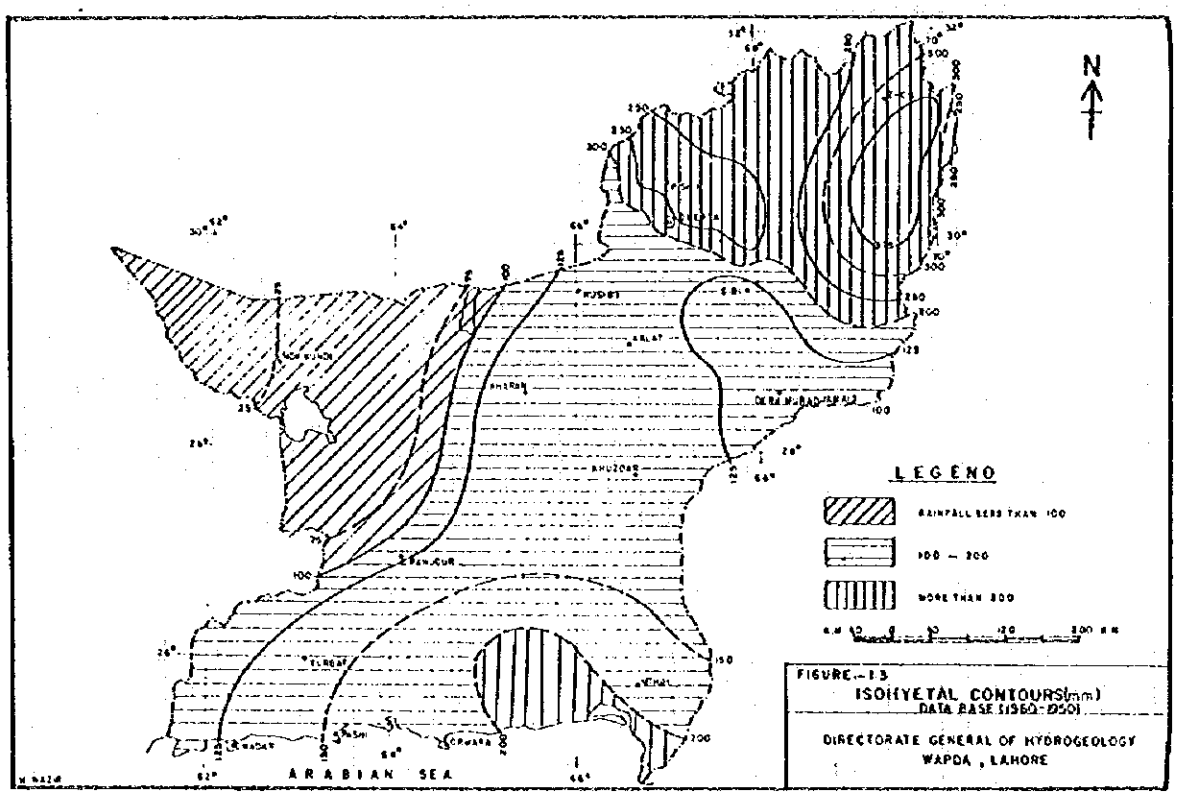


Figure 5-1 Isohyetal Contours in mm (1960-85)

Source: Groundwater Resources of Balochistan Province, Pakistan, 1993, WAPDA

The rainfall is irregular and scanty with wide seasonal variations in annual rainfall are a common feature of desert regions. Generally, the plains and lower highlands receive rainfall during the summer monsoons, during July through August. The upper highlands get their rain in the winter, during February to March, from the storms advancing from the Persian Plateau.

It may be noted that the isohyetal contours drawn from the of 1910 to 1950 show higher ranges of rainfall compared to the records of 1960 to 1985 in the three regions. This may perhaps be indicative of a secular change in the weather pattern of the region as a whole.

The Balochistan is an arid/semi-arid region. Extreme variations have been observed in the temperatures recorded at the Quetta and Sibi observatories. Winter temperatures may dip as low as -12° C at Quetta. The summer temperatures may rise as high as 51° C at Sibi (which happens to be the hottest place in Pakistan).

Table 5-4 Temperature and Precipitation in Normal Annual and Seasonal (1984-89)

Hydrogeological Basins	Temperature (° C)		Rainfall (mm)		
	Max. (Month)	Min. (Month)	Winter Nov ~ May	Summer Jun ~ Oct	Annual
Nari River	48.2 (7)	1.3 (2)	215	107	322
Pishin Lora	39.7 (7)	-0.9 (2)	211	17	228
Mula River	41.3 (7)	-1.1 (2)	154	41	195
Hingol River	43.0 (7)	0.6 (2)	95	97	192
Rakhshan River	43.3 (6)	-3.8 (1)	85	42	127
Dasht River	42.6 (6)	5.3 (1)	120	25	145

Source: Groundwater Resources of Balochistan Province, Pakistan, 1993, WAPDA

5.1.3 Topography and Geology

Balochistan has a wide variety of landforms ranging from highlands skirting the mountains, from plateaus to plains and deserts. A topographical phenomenon known as a playa is also present in two locations: the Human-e-Mashkhel Basin and the Human-e-Lora Basin. A playa is a shallow central basin of a desert plain in which water is gathered after rain and is then evaporated.

Consequential to the geodynamic evolution of Balochistan the stratigraphy of the province is quite complex and entails great lateral variations in contemporaneous sedimentation. The rocks exposed range from the Permo-Carboniferous to the Recent age and are largely of sedimentary origin. Rocks of igneous

origin predominate in parts of the Zhob region in the north and in the Lasbela region in the south. The sedimentary sequence is composed of calcareous and arenaceous rocks. Deposits of aeolian origin are confined to surface accumulation of the Sub-Recent to the Recent age, represented by the dunes and sandy tracts of the deserts.

The tectonics of Balochistan are distinctively characterized by an exceptionally well-developed and exposed example of interaction of major fault systems in a regime of convergence where one type of fault terminates against another. The Chaman Transform fault zone meridioally traversing the entire province intersects with the central Zhob and the Makran convergence zones. These fault systems are of direct relevance to hydrogeological control on groundwater reservoir. In this context, the following twenty six important faults have been identified and shown below.

A. Chaman Transform Zone Main Fault (Kharan, Panjgur and Turbat)

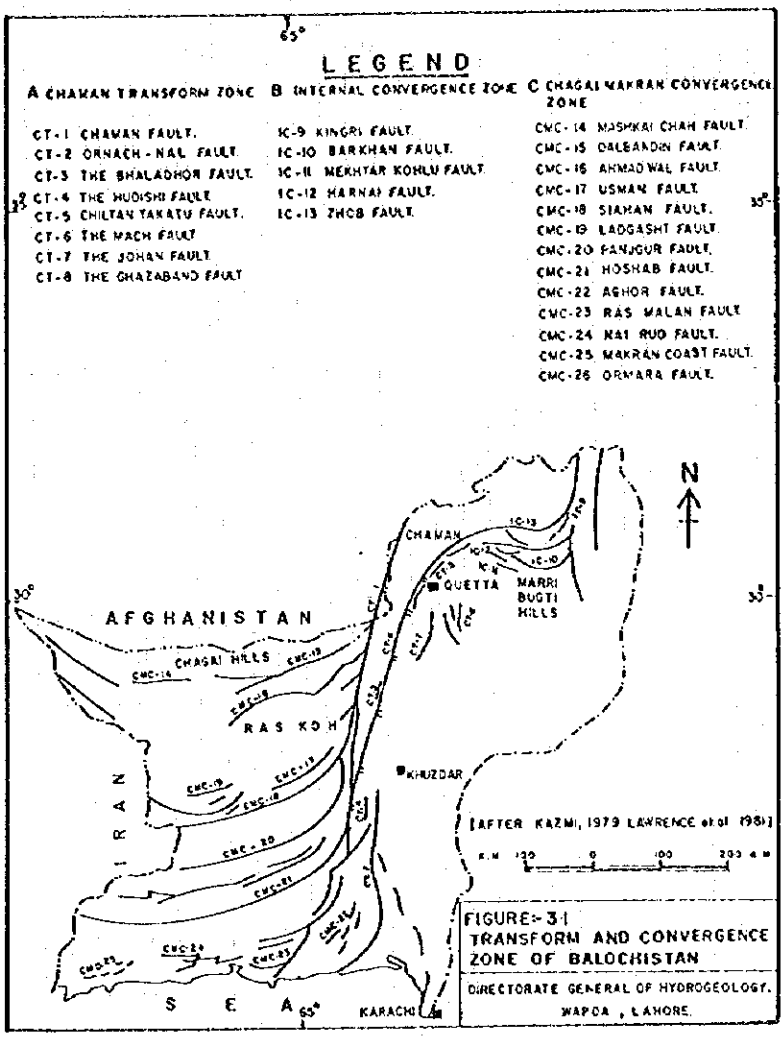
   Chamam, Ornach-Nal, Bhalla Dhor, Hidushi, Chiltan-Takatu, Mach, Johan and Ghazaband.

B. Internal Convergence Zone Main Fault (Ziarat)

   Barkhan, Mekhtar-Kohlu, Harnai, Zhob.

C. Chagai-Makran Convergence Zone Main Fault (Karat, Mastung)

   Mashki Chah, Dalbandin, Ahmadwal, Usman, Siahan, Ladgasht, Panjgur, Hoshab, Aghol, Ras Malan, Nai Rud, West Makran, Ormara.



Source: Groundwater Resources of Balochistan Province, Pakistan, 1993, WAPDA

Figure 5-2 Transform and Convergence Zones of Balochistan

Hydrogeology can be defined as the study of groundwater occurrence, behavior and quality in the framework of geological setting including stratigraphy and tectonics. In hard rocks, faults, fractures and fissures are of special importance and control formation of aquifer. In unconsolidated deposits it is the Quaternary sequence which influences the groundwater resources.

5.1.4 Groundwater

The water sources available for use in Balochistan consist of surface water and groundwater. Surface water is defined as rivers, flood streams, lakes and marshes. Surface water source is utilized in the form of divert and flood irrigation in the rainy season. However, all surface water sources in Balochistan are nonsustainable and are insufficient sources due to the limited precipitation and high evaporation in Balochistan.

The only potential source for sustainable water is groundwater. The groundwater sources are defined as wells and springs. The well structures have to be connected to adequate aquifers. When unconfined groundwater is available for use, usually it is tapped using dug-wells and/or the traditional Karez. If this groundwater is not useable due to the reasons of quantity and/or quality, the remaining target is confined groundwater.

According to the team's field survey, surface water, such as rivers, delay-action dams and spring water are useable water sources in Ziarat. In other districts, still well constructions such as dug-wells and tubewells are requested. Currently, the groundwater investigation of fissured aquifers had been executed since a few years back under the management of the Government of Balochistan and WAPDA. The potential of the fissured aquifers are very high, but they are distributed only in limited areas in Balochistan. The storage capacity and potential of groundwater with the team's observation and presumption is shown as below in Table 5-.

Table 5-5 The storage and potential of groundwater

(x1,000m^3 /d)

Hydrogeological Basins	District	Stage	Developed	Development Potential
Nari River	Ziarat	685.0	293.2	220.6
Pishin Lora	Mastung	1,289.8	354.8	322.5
Mula River	Kalat	377.0	63.6	118.7
Hingol River	Kharan	1,945.2	362.2	623.3
Rakhshan River	Panjgur	240.0	12.3	113.7
Dasht River	Turbat	893.2	191.0	275.1

Source: Groundwater Resources of Balochistan Province, Pakistan, 1993, WAPDA

Finally, the drawdown of the static water level was observed at around three meters per year in Quetta, which has records of its monitoring wells. They were sounded at 30 m to 40 m recently. Thus, groundwater management regarding such issues as water rights, saving water and water recharge should be promoted immediately by the government authorities.

5.2 Irrigation and Water Supply Development

The Agriculture Department of the Ministry of Agriculture is responsible for the promotion and management of the development of agricultural engineering, especially the Irrigation and Power Department (I&PD), which is responsible for the construction of the water sources as well as the facilities for pumping and irrigation.

On the other hand, the Public Health Engineering Department (PHED) is responsible for water works in Balochistan. They construct the water supply facilities which extend from the water sources up to the distribution lines financed from the budget of the Government of Balochistan or the user's finances.

5.2.1 Agricultural Statistics

The following tables show the land forms for agriculture use, the sources for irrigated agriculture land and seasonal crop production. The highest irrigated ratio is 52.9 percent in the Mastung District, and the lowest one is 8.3 percent in the Kharn District.

Table 5-6 The Land Form for Agriculture Use

(x1,000ha)

District	① Cultivated Area	② Cropped Area	③ Non-Cultivated Area	TOTAL ① + ③
Ziarat	12.1	3.5	53.9	66.0
Mastung	59.5	30.3	389.6	449.1
Kalat	67.1	34.1	439.4	506.5
Kharan	63.0	22.4	3,530.4	3,593.4
Panjgur	28.6	16.4	644.6	673.2
Turbat	48.1	41.1	506.3	554.4
TOTAL	278.4	147.8	5,564.2	5,842.6
Balochistan	1,674.2	837.3	16,928.1	18,602.3

Source: Agricultural Statistics of Balochistan, 1993-94, Agriculture Department

Table 5-7 Water Sources for Irrigated Agriculture Land

(x1,000ha)

District	Cultivated Area	Irrigated Area	Non-Irrigated Area	Irrigation Ratio (%)	Water Source			
					Canal	Dug-well	Tubewell	Karez
Ziarat	12.1	3.7	8.4	30.6	0	0	3.3	0.4
Mastung	59.5	31.5	28.0	52.9	0	0.5	29.0	2.0
Kalat	67.1	23.0	44.1	34.3	0	0.4	20.1	2.5
Kharan	63.0	5.2	57.8	8.3	0	0.4	0.9	3.9
Panjgur	28.6	*12.7*	*15.9*	*44.4*	*0*	*0.9*	*2.5*	*1.0*
Turbat	48.1	*20.2*	*27.9*	*42.0*	*0*	*1.5*	*18.3*	*1.8*
TOTAL	278.4	96.3	182.1	34.6	0.0	3.7	74.1	11.6
Balochistan	1674.2	801.3	872.9	47.9	493.7	14.2	197.8	95.6

Source: Agricultural Statistics of Balochistan, 1993-94, Agriculture

Note: numbers in italics indicate that they are based on no data and are estimated based on other district's data.

Table 5-8 Seasonal Crop Production

(x1,000t)

District	Kharif	Rabi	Total
Ziarat	45.2	0.1	45.3
Mastung	174.5	110.0	284.5
Kalat	179.5	71.6	251.1
Kharan	50.3	27.6	77.9
Panjgur	149.2	15.1	164.3
Turbat	433.7	130.4	564.1
TOTAL	1,032.4	354.8	1,387.2
Balochistan	3,062.1	1,705.1	4,767.2

Source: Agricultural Statistics of Balochistan, 1993-94, Agriculture

5.2.2 Water Supply Program

The water works in Quetta are managed responsibly under the Water and Sewage Authority (WASA). The other rural areas are controlled by PHED in Balochistan. Currently, PHED is planning to make a development program called the "Balochistan Rural Water Supply and Sanitation Project (BRWSSP)", as shown below in Table 5-9.

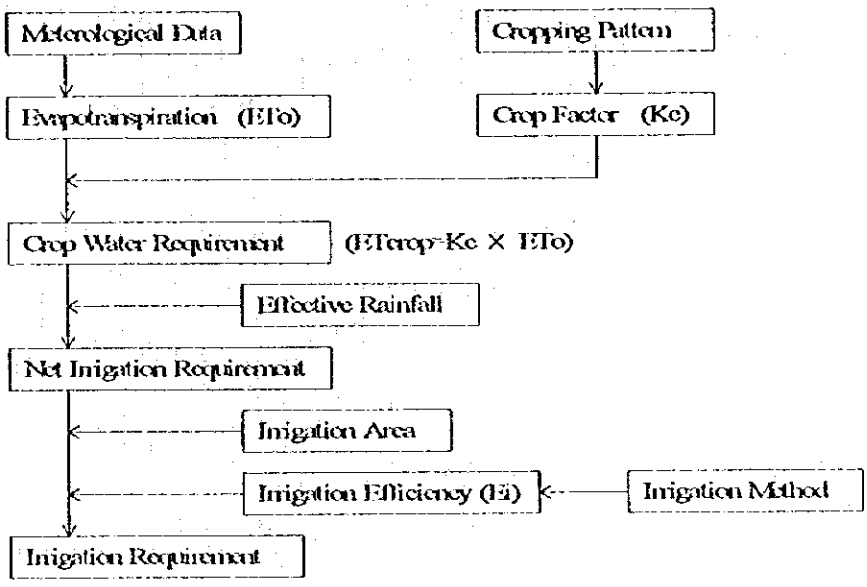
Table 5-9 Water Supply Program, Present and Future

District	1991			2002		
	Population	Projected Population	Water Volume m^3/d	Population	Projected Population	Water Volume m^3/d
Ziarat	45,000	31,500	3,620	75,000	67,500	7,900
Mastung	182,000	127,400	14,650	286,000	257,400	30,120
Kalat	288,000	201,600	23,180	446,000	401,400	46,960
Khuzdar	151,000	105,700	12,160	233,000	221,000	25,860
Panjgur	221,000	154,700	17,790	342,000	307,800	36,010
Turbat	521,000	364,700	41,940	838,000	754,200	88,240
TOTAL	1,408,000	985,600	113,340	2,220,000	2,009,300	235,090

Source: This data were estimated by the team using data from the PHED and the P&DD.

5.2.3 Trial Estimation for Irrigation Water

The irrigation water demands were estimated by the flow-chart shown below in Figure 3-1. The evapotranspiration ratio was quoted from the "Balochistan Minor Irrigation and Development Project-Phase 2, Preparation Studies Perennial Irrigation Schemes (BMIADP)" conducted by the I&PD. In this report, the evapotranspilation ratio was calculated by the Blaney-Criddle Method. This method is very commonly used in Balochistan and is based on temperature, wind velocity and the number of daylight hours. Finally, the irrigation requirements are estimated that the net irrigation requirement divided by irrigation efficiency.



Source: FAO Irrigation and Drainage Paper 24 "Crop Water Requirements" Rome, 1977

Figure 5-3 Estimation Flowchart for Irrigation Water

The planting program is based on the BMIADP report, "Agricultural Statistics in Balochistan, 1993-94" and on important opinions from the Ministry if Agriculture. The crop water requirement was estimated by the month-wise evapotranspiration times the crop factor which is shown as below in Table 3-5.

Table 5-10 Crop Water Requirement

(mm/day)

Month / District	1	2	3	4	5	6	7	8	9	10	11	12
Ziarat	0.1	0.1	2.0	3.9	6.4	7.6	7.0	6.3	5.1	3.8	2.3	0.1
Mastung	0.7	1.6	3.6	5.3	3.8	2.5	2.5	2.3	0.8	0.6	1.0	0.8
Kalat	0.8	1.7	3.1	4.7	3.6	2.6	2.6	2.3	0.9	0.8	1.2	0.9
Khuzn	2.1	4.5	6.2	6.8	2.8	3.2	3.4	3.0	2.9	1.3	1.5	2.1
Panjgur	0.4	4.8	6.7	8.5	9.4	9.8	9.2	8.5	7.5	0.5	0.4	0.4
TOTAL	0.9	4.5	6.5	7.2	8.5	8.8	7.4	7.1	6.8	1.0	0.8	1.1

Source: This data were estimated by the team

Notes: underlined month is maximum ET crop in year.

The effective rainfall should be considered in order to estimate the net irrigation requirement. But in Balochistan, there is little precipitation from April to July--which is most important season to supply the irrigation water to the crops. Thus in this estimation, the effective rainfall is the uncounted factor. The irrigation methods in Balochistan are shown as below in Figure 5-4.

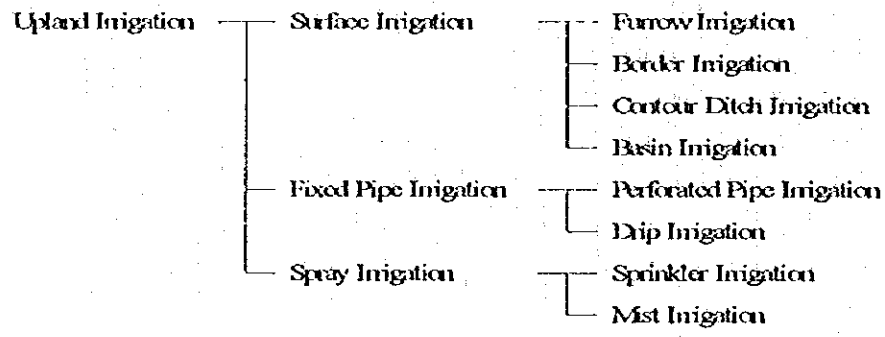


Figure 5-4 Irrigation Methods

In this estimation, the basin and drip irrigation methods are adopted because of following reasons:

A. The border and furrow irrigation methods consume a great deal of water. Thus, they are not suitable irrigation systems for Balochistan.

B. The basin irrigation is widely distributed and common in Balochistan. It consumes a large amount of water, and thus its use will be reduced in future.

C. The sprinkler irrigation system is extremely costly, and thus it is not a utilized method.

D. The perforated pipe irrigation is not so costly but it is difficult to control the water. For saving water resources, the drip irrigation method is most suitable.

Thus the irrigation efficiency rate adopted is 0.7 which is average of the irrigation efficiency from the basin and drip irrigation methods. The water demand for irrigation in future is calculated by the method below.

$$Q = \frac{10 \times ETcrop \times 86,400\ A}{3.6 \times Ei \times 1,000}$$

Q:	Water Demand for Irrigation (m^3/day)
ETcrop:	Crop Water Requirement (mm/day)
Ei:	Irrigation Efficiency
Ti:	Irrigation Time (12 hours)
A:	Irrigation Area (ha)

5.3 Rig Inventory

The following tables are edited by the data from the inventory of the governmental agencies in Balochistan.

Table 5-11 Government Agency Rig Inventory

Type \ Agency		WAPDA	BDA	I&PD	PHED	TOTAL	
Japanese	Rotary	4	5	1	7	17	17
	Percussion	0	0	0	0	0	
Others	Rotary	8	④	6	0	14+④	16+⑥
	Percussion	1+②	0	0	1	2+②	
TOTAL	Rotary	12	5+④	7	7	31 + ④	
	Percussion	1+②	0	0	1	2 + ②	
	Total	13+②	5+④	7	8	33 + ⑥	

Notice: markers means the number of unoperational rigs.

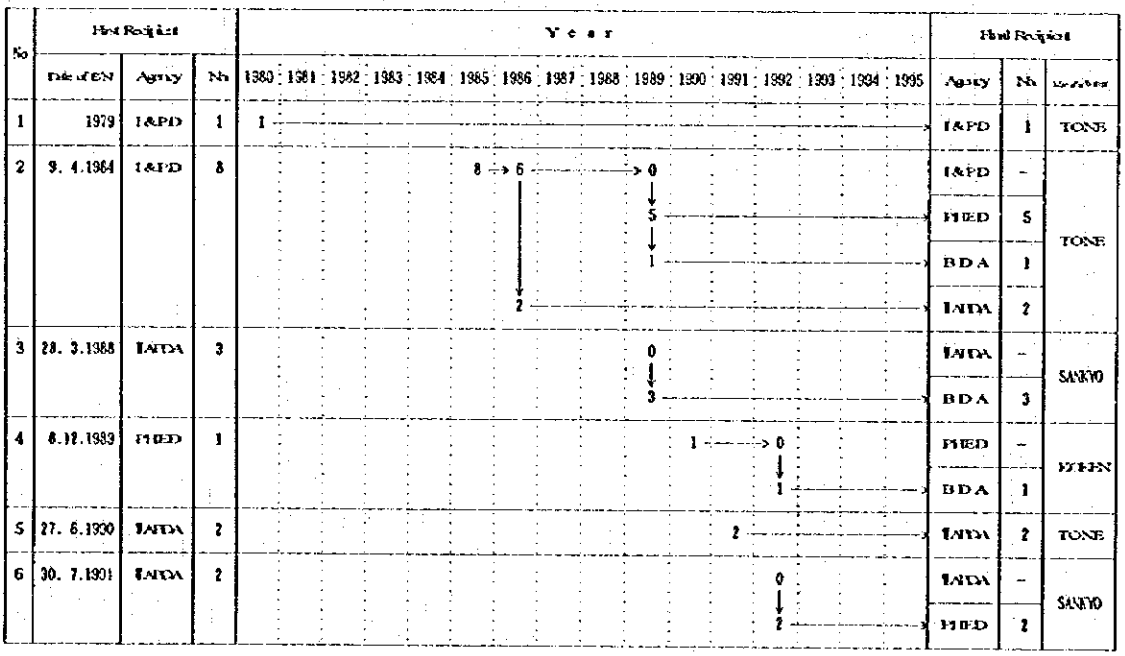
Table 5-12 Working Rig Inventory

Product	Agency	Years In Service																								Total Number	Average Service Life
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	..	..	..	33	
Japan	WAPDA					2						2																	4	8.0
	BDA						1	3				1																	5	7.6
	I&PD																1												1	16.0
	PHED				2							5																	7	9.0
	Total				2	2	1	3				8					1												17	8.8
Others	WAPDA																			2		4		⑤1				2	② 9	23.4
	BDA																					①							④	21.0
	I&PD																	6											6	17.0
	PHED																	1											1	17.0
	Total																	7		2		⑥4		⑤1				2	⑥ 16	20.9

Notice: markers means the number of unoperational rigs.

The 17 Japanese manufactured rigs are younger than 16 years-old, and are still in working condition at present. On the other hand, other 16 rigs are all older than 17 years. Out of these 16 rigs, 13 rigs are already more than 20 years-old, and 6 rigs of these 13 rigs are nonworking condition. In this connection, 10 of these 16 workable rigs of non-Japanese manufactured rigs will be reduced within 5 years.

However, the P&DD controlled the other government agencies concerned with the groundwater development programs. According to the explanation from the P&DD, the Government of Balochistan had enhanced the fleet of each government agency's engineering to make a balance between them. Because of this balancing effort, the P&DD shifted some of the Japanese rigs to other agencies, causing some rig's to be shorter than would otherwise be the case.



Notice: the I&PD and PHED were divided split from the I&PD on July 1989.

Figure 5-5 Circumstances of Drilling Rigs Provided Under the Past Japanese Grant

5.4 Groundwater Development

The following tables were edited with data from the government agencies in Balochistan.

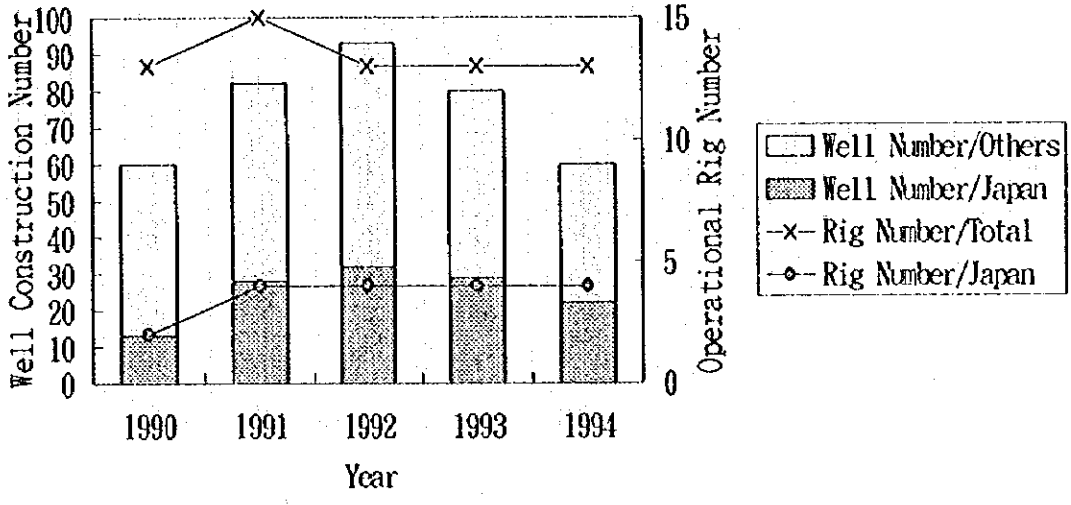


Figure 5-6 Yearly Rig and Tubewell Installation, WAPDA

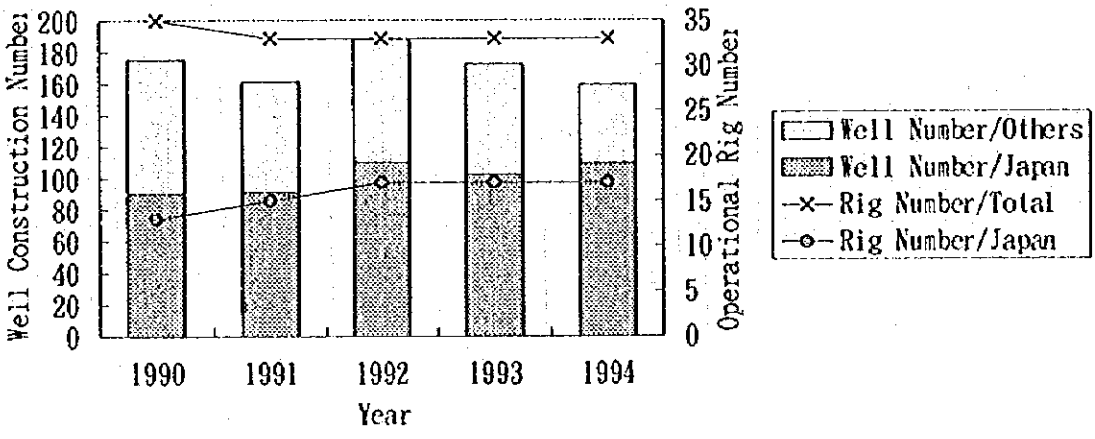


Figure 5-7 Yearly Rig and Tubewell Installation, Government Agencies

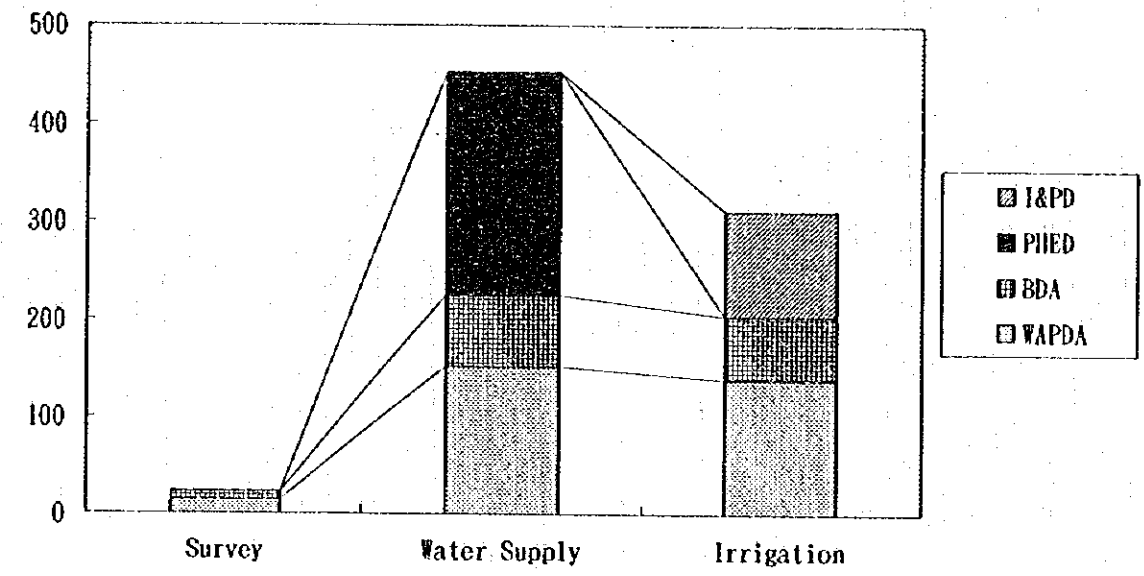


Figure 5-8 Tubewell Installation, Government Agencies by Program (last 5 years)

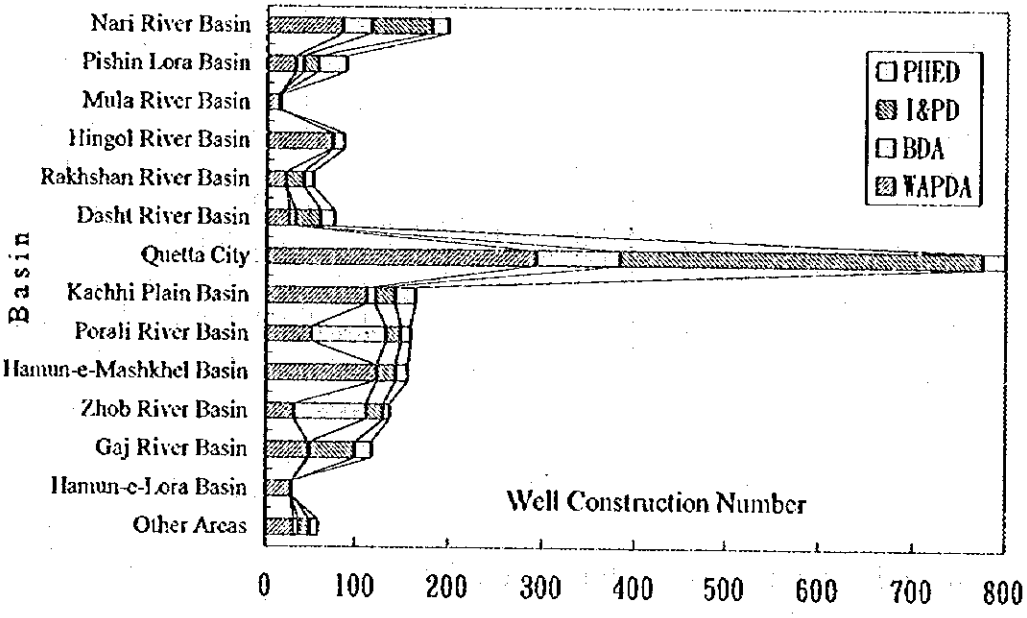


Figure 5-9 Tubewell Installations, Government Agencies by District (1973-92)

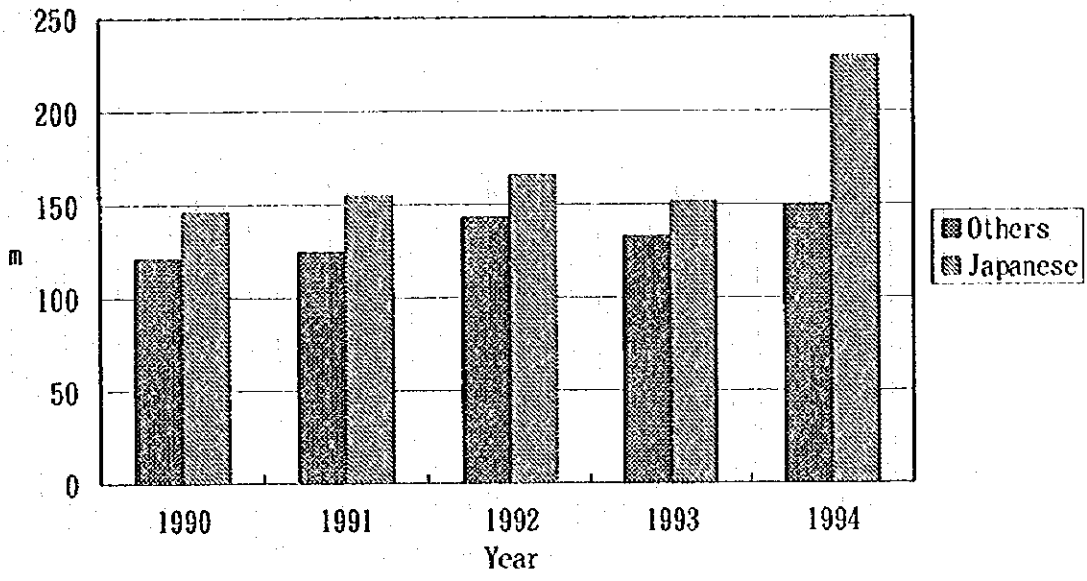


Figure 5-10 Rig Manufactures' Average Meterage, WAPDA (last 5 years)

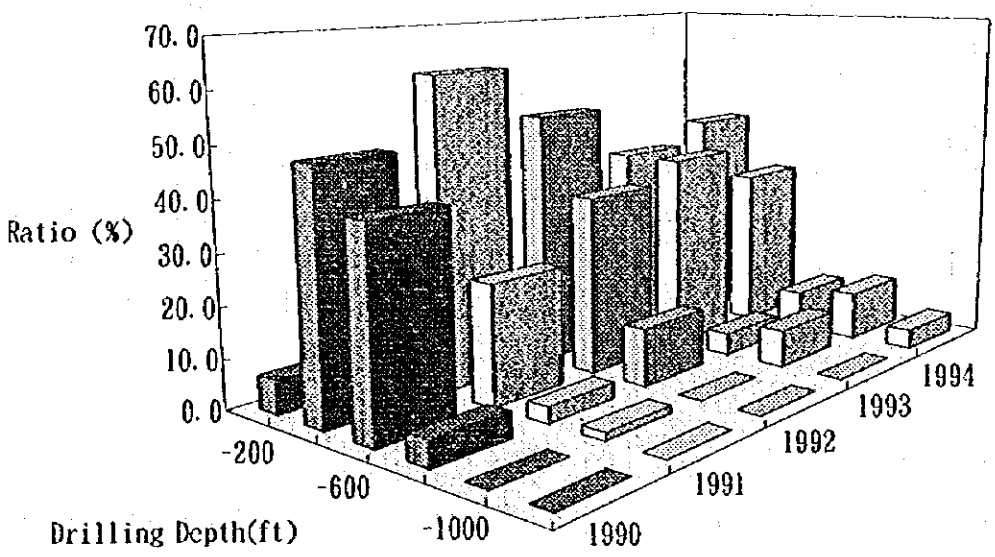


Figure 5-11 Metered Tubewell Installations, WAPDA (last 5 years)

The conclusion to be gained from the above analysis are as follows:

1. The working rigs in Balochistan had been counted the stability numbers last a few years. But the number tubewell installation was smaller than the previous year last 2 years. The reasons are as follows:

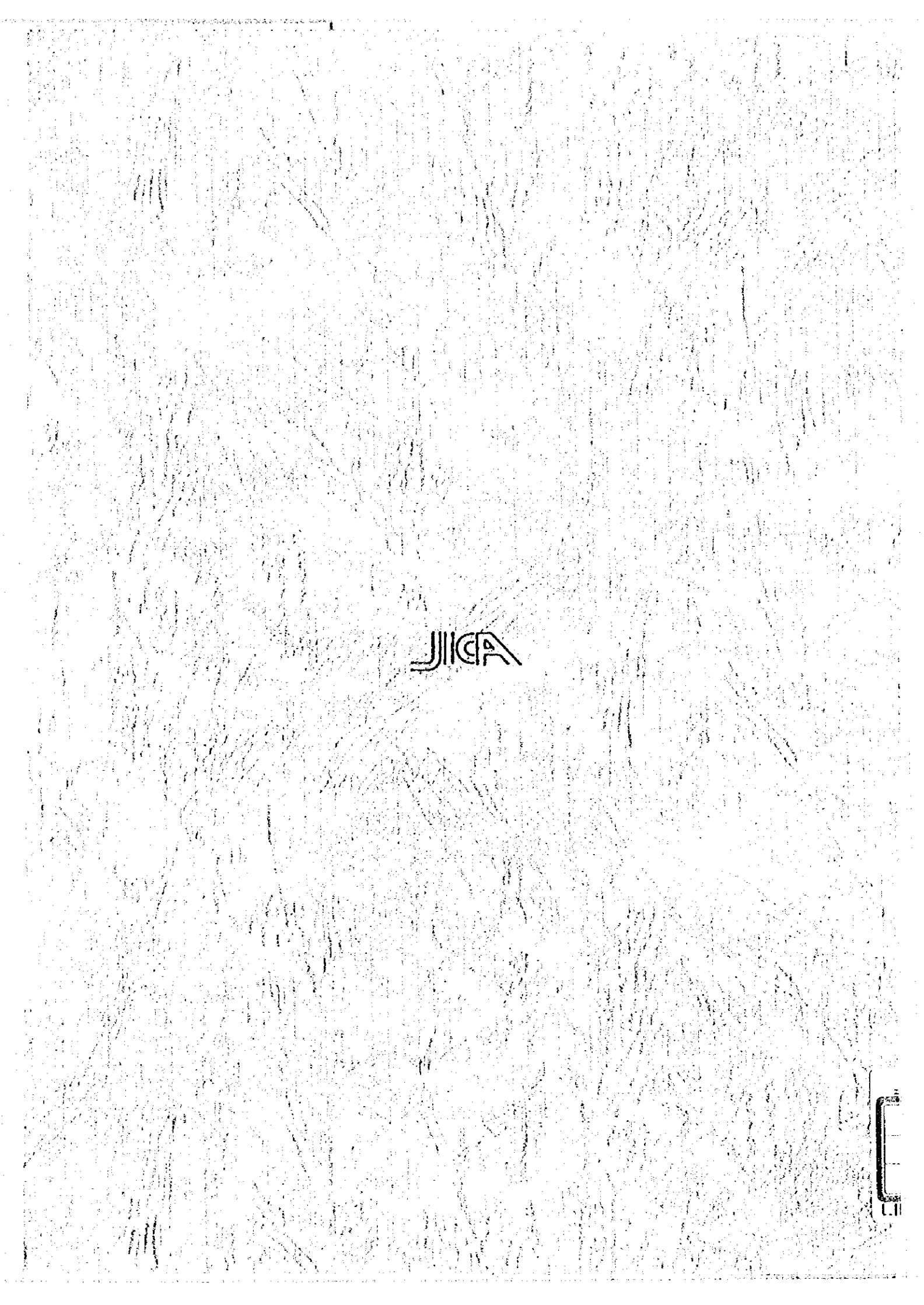
   a) The structure of installed tubewells by the Japanese rigs had become more deeper. Thus the construction schedule had also become longer.

   b) The performance of other manufacture rigs had been described year by year. Thus the construction schedule had also become longer.

2. The ratio of the purpose for irrigation and domestic use is 40% vs. 60% of the last 5 years results.

3. The project sites are in areas where the groundwater development has been delayed since beginning of the program in Balochistan.

4. The average tubewell depth are 180m or less last 22 years, but since 3 years back the tubewell structure installed by Japanese rigs are 240m or more last 3 years.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