10. It may be noted that intention of the framers of the Treaty (by dividing the rivers) was the need to limit the capacity of India (being upper riparian) to manipulate, at will, the waters of Western Rivers. This is evident from the following excerpts from the proposal of the World Bank dated 5th February, 1954:-

i. It is desirable, so far as practicable, ***to avoid control by India*** *over waters on which Pakistan will be dependent and to enable each country to control the works supplying the water allocated to it and determine in its own interests the apportionment of waters within its own territories.*

ii. The Chenab river rises in India, and before it enters Kashmir, provides a substantial flow that could be diverted for use by India. Assurance by India that the flow of this river ***will not be disturbed****, is essential.*

11. Both India and Pakistan have created a post of Commissioner for Indus Waters in accordance with the Treaty. Together, the two Commissioners constitute Permanent Indus Commission (the Commission), whose function is to establish and maintain cooperative arrangements for implementation of the Treaty and to promote cooperation between the Parties for development of waters of the rivers. The Commission is also required to make every effort to settle promptly any question arising between the Parties in accordance with the provisions of the Treaty. The Commission serves as a regular channel of communication on all the matters relating to implementation of the Treaty. To achieve these goals, besides correspondence, the Commission meets regularly (at least once a year) and conducts Tours of Inspection of the Rivers/River Works in both the countries. Details of meetings and Tours of Inspection by the Commission are presented in Table 5.

Table 5

FUNCTIONS OF COMMISSION

➢	The two Commissioners appointed by each Government form the Permanent Indus Commission	
➢	Each Commissioner is representative of his Government and serves as the regular channel of communication	
➢	General Tours of Inspection	103
➢	Special Tours of Inspection	
➢	Meetings	96
➢	Settlement of Differences & Disputes	

MAJOR ISSUES WITH INDIA

12. Since its signing in 1960, the Indus Waters Treaty has stood the test of time. It has worked well even during the times of high political and military tensions between the two countries. No major obstacle has so far been created in the implementation of the Treaty by either side. Following major issues have cropped up between the two countries since 1960:-

Issues Resolved

i. Irrigated Cropped Area as on Effective Date

ii. Salal Plant on river Chenab

Issues Under Resolution

iii. Baglihar Hydroelectric Plant on river Chenab

iv. Wullar Barrage and Storage Project/Tulbul Navigation Project on river Jhelum

v. Kishenganga Storage cum Hydroelectric Project on river Neelum

13. Brief description of the above issues is given hereunder:

i. Irrigated Cropped Area as on Effective Date

The provisions of Article III (2) of the Indus Waters Treaty 1960 allow India certain restricted Agricultural Uses from the waters of Western Rivers, as set out in Annexure C to the Treaty. Under Paragraph 4 of Annexure C, India may withdraw, in addition to the existing uses as on Effective Date, i.e. 1-4-1960, waters from Western Rivers for irrigating new areas to the extent of 70,000 acres from The Indus, 400,000 acres from The Jhelum and 231,000 acres from The Chenab. However, until India can release waters from the conservation storage, the new areas developed from supplies of The Jhelum and The Chenab are not to exceed 150,000 acres and 75,000 acres respectively. So far, India has not developed any conservation storage for Agricultural Use.

In accordance with Paragraph 10 of Annexure C to the Treaty, India was obliged to furnish to Pakistan a statement showing Irrigated Cropped Area as on Effective Date not later than 31st March, 1960. India supplied on said date the total Irrigated Cropped Area to the tune of 694,567 acres, which was later revised to 692,477 acres. After examining the details provided by India, Pakistan Commissioner objected to the authenticity of the area and sought certain clarifications. The matter remained under correspondence for a long period. Ultimately, the issue was taken up in the meeting of the Commission. After detailed deliberations from both sides, India, in the 55th meeting of the Commission in 1982, furnished a statement reducing the Irrigated Cropped Area to 642,477 acres. It was agreed that this statement will be taken as the statement that has been furnished by India under the provision of Paragraph 10 of Annexure C to the Treaty. Thus, Pakistan succeeded in getting the Irrigated Cropped Area as on Effective Date reduced by 50,000 acres.

ii. Salal Hydroelectric Plant on river Chenab

The design of Salal Hydroelectric Plant received from India in 1974 was not found conforming to the criteria laid down in the Treaty in the following respects:-

(i) Works proposed appeared to be capable of artificially raising the water level in the reservoir beyond the full reservoir level in contravention of Paragraph 8(a) of Annexure 'D' to the Treaty.

(ii) A gated spillway had been provided in the design, although the site permitted the provision of ungated spillway, in contravention of Paragraph 8(e) of Annexure 'D' to the Treaty.

(iii) Outlets had been provided below the Dead Storage Level which are not necessary in terms of Paragraph 8(d) of Annexure 'D' to the Treaty.

(iv) The intakes for the turbines are proposed to be located at a level lower than required in contravention of Paragraph 8(f) of Annexure 'D'.

Indian Commissioner disagreed with the Pakistan Commissioner's views and despite protracted correspondence and discussions at the meetings of the Permanent Indus Commission (comprising Indian and Pakistan Commissioners for Indus Waters) the differences could not be resolved. In December 1974, the Indian Commissioner expressed his inability to proceed further in the matter under the provisions of the Treaty as Government of India wished to take up the matter directly with the Government of Pakistan.

Subsequently, at the invitation of the Indian Foreign Secretary, the matter was discussed between the delegations of the two countries headed by the two Foreign Secretaries in May 1975 at New Delhi. This led to the supply of substantial additional information regarding the Project by India and subsequently holding of four meetings between the two Commissioners. However, no headway towards resolution could be made and on 19th July, 1976, PCIW invoked proceedings for appointment of a Neutral Expert.

On the receipt of Pakistan Commissioner's letter, the Indian Foreign Secretary suggested that the two Governments should make another attempt to resolve the matter through bilateral discussions. As a consequence, two meetings at the level of Foreign Secretaries were held during October 1976, one at New Delhi and the other at Islamabad. At the New Delhi meeting the Indian Foreign Secretary ultimately offered the closing of all the six low level outlets after one year of the operation of the Project and to reduce the height of the Spillway gates from 40 feet to 30 feet. The Indian delegation maintained that this was their final offer and they could not improve upon it. At the Islamabad meeting, the Indian delegation did not agree to any further reduction in the height of the gates.

The negotiations between the two Governments were resumed in April 1978, and the agreement was signed at New Delhi on 14th April 1978. Important features are given hereunder:-

(i) The height of the spillway gates should not exceed 30 feet.

(ii) All the 6 low level outlets should be plugged within one year of the completion / operation of the Project.

(iii) Intakes for the turbines may be located as proposed in the present design.

(iv) Pakistan may agree to the diversion programme as proposed by India.

iii. Baglihar Hydroelectric Plant on river Chenab

India supplied information about the Plant in May, 1992 under the relevant provision of the Treaty. The Plant is located on river Chenab about 147 Kilometers upstream of Marala Headworks. The design of the Plant supplied by India envisages construction of 317 meter long and 144.5 meter high concrete gravity dam with Gross Storage of 0.32 Million Acre Feet (MAF) and Live Storage of 0.03 Million Acre Feet. In Stage-I of the Project, three units of 150 Megawatt (MW) each would be utilizing 15475 Cusecs of water. Three similar units have been proposed in Stage-II. The orifice type gated spillway is provided in the middle of the dam with Crest Level at elevation of 808 meter.

Pakistan raised objection on the design of the orifice type gated spillway, excessive pondage/operating pool behind the dam and higher water seal at the intake of the power tunnel. India did not agree to the objections raised by Pakistan and maintained that design was in conformity with the Treaty provisions. A study made on the effects of Indian design revealed that the low level gates will provide India a manipulatable capacity of about 164,000 Acre Feet of Storage behind the dam. If maloperated for stoppage, it may reduce/stop supplies of river Chenab reaching Marala for about 26-28 days during winter months. This may harm our uses from Marala-Ravi (MR), Bombanwal-Ravi-Badian-Depalpur (BRBD) link canal and upper Chenab Canal (UCC).

After having discussed Pakistan's objections on the design of the Plant in various meetings of the Commission, Pakistan Commissioner for Indus Waters (PCIW) recorded failure of the Commission in resolving the questions framed by Pakistan in February, 2003. This was followed by a notice to India on 8th May, 2003 about Pakistan's intention to proceed with the resolution through a Neutral Expert under the Treaty. Since the two Governments were unable to appoint the Neutral Expert as per request by PCIW of 20th June, 2003, the World Bank was requested on 15th January, 2005 to appoint a Neutral Expert.

World Bank appointed Mr. Raymond Lafitte from Switzerland as a Neutral Expert on 10 May, 2005, who called both the Parties for first meeting on 9-10 June, 2005 for determining the procedure to be adopted by him.

iv. Wullar Barrage and Storage Project /Tulbul Navigation Project on river Jhelum

The construction of Wullar Barrage was started by India on river Jhelum in 1985 under the garb of Tulbul Navigation Project without informing Pakistan. A strong protest was lodged by Pakistan and India was asked to stop the work and supply information as per Treaty provisions. India supplied information in March, 1986. The project envisages construction of a barrage at the outfall of natural Wullar Lake on the Jhelum Main. Wullar Barrage would be 439 feet in length having a gated weir and under sluices, and a 40 feet wide navigation lock. It would have a maximum discharge capacity of 50,000 cusecs. Thus, it might be possible to store about 0.30 Million Acre Feet of water in the Lake behind the Wullar Barrage. If India is allowed to go by the project, the Wullar Lake, being a natural lake, would become a man-made reservoir/storage. Further, the Wullar Barrage would enable India to have a control on the waters of river Jhelum. The Commission made efforts to resolve the issue but did not succeed. Then, on the request of India, the matter was taken up by the two Governments. India agreed to stop the construction and bilateral talks started in 1987, which are inconclusive so far.

The Indian posture of bringing about improvement in the navigability between Srinagar and Baramula for transportation of fruits hardly justifies the construction of Wullar Barrage, because already a very good road link exists between Srinagar and Baramula. Moreover, the terrain is also not hilly but almost plain. India's actual design appears to augment storage in the Wullar Lake for use during the lean period for her downstream hydroelectric projects.

Todate, 11 rounds of talks have been held at level of Secretaries of the two Governments. Last round of talks on the issue of Wullar Barrage was held on 28-29 June, 2005 as a part of composite dialogue with India on all outstanding issues, in which both the Parties agreed that the discussions would continue at the next round of the dialogue process with a view to finding a solution to the issue consistent with the provisions of the Treaty.

v. Kishenganga Hydroelectric cum Storage Project on River Neelum

This is a Storage Work of 0.14 MAF capacity for which information/data was supplied to Pakistan in June, 1994 under Annexure-E to the Treaty. India is allowed to construct storage work of 0.75 Million Acre Feet on the tributaries of river Jhelum. The Kishenganga Project envisages construction of concrete gravity dam on river Neelum near Kanzalwan with gated spillway and low level outlets. Flows of Kishenganga river are to be diverted into the Wullar Lake through 28 KM tunnel after generating 330 MW of power. The Power House is located near Bunkot.

Pakistan raised objections on the Indian project as under:

(i) It contravenes the provisions of Paragraph 10 of Annexure E to the Treaty.

(ii) Diversion of flow of one tributary (Kishanganga) to another tributary (Bunar-Madmati Nullah) of river Jhelum is not provided for in Annexure E to the Treaty.

(iii) It does not conform to design criteria (a), (c), (e), (f) and (g), mentioned in Paragraph 11 of Annexure E to the Treaty.

The diversion of flows from one Tributary to another Tributary (river Neelum to Madhumati Nallah of river Jhelum) as proposed by India is not allowed under the Treaty. In addition, this is likely to harm our power potential and Agricultural Uses in the Neelum Valley and would have a direct bearing on the socio-economic life and ecological aspects in the area downstream Kanzalwan. Pakistan has also started work on a hydroelectric plant (named as Neelum-Jhelum Hydroelectric Project) at Nauseri in 1989 by utilizing the waters of river Neelum to generate 969 MW power. The Indian project, if constructed as per their proposed design, will result into 21% reduction in the average annual inflows of river at Neelum-Jhelum Dam site and 9.25% reduction in the power generation potential of the Neelum-Jhelum Hydroelectric Project.

India started construction of Kishenganga Project in year 2002-2003 and work on Head Race Tunnel (HRT), Power House and temporary diversion is being carried out. The present status of works at Kishenganga HEP as reported by India is as under :

(i) Gurez Valley Works

Diversion tunnel work presently held up due to climatic reasons. The activities that interfere with the flow of water (construction activities related to dam and power intake) are yet to be taken up.

(ii) Bandipura Works

Excavation for underground works (Power House Complex and adjoining reaches) is in progress. The enabling works related to Head Race Tunnel are also going on. Some additional underground excavation has been carried out.

The Commission has had four exclusive meetings on the issue so far. India has, however, not changed its stated position that their project is designed as per Treaty provisions. PCIW has given the intention to invoke Article IX(1) and supplied questions arisen between the Parties. Deliberations on these questions are continuing in the meetings of the Commission being held from time to time. The outcome of these deliberations would decide future course of action by Pakistan. ■

PAKISTAN'S WATER RESOURCES DEVELOPMENT AND THE GLOBAL PERSPECTIVE

By

Engr. M. Mushtaq Ch.* and Dr. Allah Bakhsh Sufi**

ABSTRACT

Pakistan's economy is dependent on irrigated agriculture. About 80% of agriculture is irrigated. It contributes 30% of GDP. Agriculture provides 55% job opportunities. This sector provides 60% of country's exports. The development of agriculture will prosper and up-lift 70% of the total population that is annually growing by 3%. The total area of Pakistan is 197.7 MA (79.6 Mha). Out of which about 103.2 MA (41.77 Mha) comprises of rugged mountains, narrow valleys and foot hills, the remaining area of 93.5 MA (37.83 Mha) consists about 54.6 MA (22.1 Mha) is currently cultivated. Remaining 22.5 MA (9.1 Mha) is lying barren lacking water for irrigation. The total surface water availability is 154.5 MAF. Population density is the highest in the canal irrigated areas in the north east of Indus Plains. The increasing population and the associated social, technical and economic activities all depend, directly or indirectly, on the exploitation of water as a resource.

The total surface water availability is 154.5 MAF. Presently water diverted at canal heads is 106 MAF. In Vision 2025 Programme WAPDA has identified to build water sector and hydropower projects such as: i) Water Sector Projects (Gomal Zam, Mirani, Raised Mangla, Satpara, Kurram Tangi Dams and Greater Thal, Kachhi and Rainee Canals) and ii) Hydropower Projects (Jinnah Barrage, Allai Khwar, Khan Khwar, Duber Khwar, Golen Gole, Neelum Jhelum and Low Head Hydropower Project). Besides the above some more projects are under various stages of planning i.e; (i) Basha Diamer Dam Project – Feasibility Detailed Design & Tenders, (ii) Akhori Dam Project – Feasibility, (iii) Sehwan Barrage – Feasibility, (iv) Chashma Right Bank Canal Lift Scheme Feasibility & Design, (v) Bunji Hydropower Project – Pre-feasibility, (vi) Dasu Hydropower Project – Pre-feasibility and Skardu Dam – Pre-feasibility. While, keeping in view the planning and development activities regarding water sector and hydropower projects, the country will be able to sustain future demands of water and power.

In the paper, it is concluded that water has emerged as a very critical & abused natural source. The sedimentation of existing reservoir is enhancing with time, thereby reducing the water availability. Further it is the need of the time to develop water storages – at least two mega reservoirs on main Indus immediately to meet irrigation requirements alongwith, domestic, industry and environment. It is also recommended to move towards sustainable groundwater management through improved irrigation & cultural practices and rainwater harvesting by involving stakeholders in water governance.

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INTRODUCTION

Pakistan's economy is dependent on irrigated agriculture. About 80% of agriculture is irrigated. It contributes 30% of GDP. Agriculture provides 55% job opportunities. This sector provides 60% of country's exports. The development of agriculture will prosper and up-lift of 70% of the total population that is annually growing by 3%.

Pakistan has arid to semi-arid climatic conditions. The availability of assured quantity of good quality of irrigation water is the major factor for the development of agriculture sector. Therefore, it is a dire need to use the available Water Resources in the most effective way and to develop new water resources to meet the growing demands of agriculture (food & fibre), industry and domestics.

The total area of Pakistan is 197.7 MA (79.6 Mha). Out of which about 103.2 MA (41.77 Mha) comprises of rugged mountains, narrow valleys and foot hills, the remaining area of 93.5 MA (37.83 Mha) consists about 54.6 MA (22.1 Mha) is currently cultivated. Remaining 22.5 MA (9.1 Mha) is lying barren lacking water for irrigation.

The River Indus Valleys and its tributaries, called "Indus River Basin" constitute the heart land of Pakistan. It includes the mountain basins of the north and the west, the Indus Plains, the Kachhi Plain, Desert areas of Sindh and the Rann of Kach. Population density is the highest in the canal irrigation areas in the north east of Indus Plains. The increasing population and the associated social, technical and economic activities all depend, directly or indirectly, on the exploitation of water as a resource.

GLOBAL WATER RESOURCES PERSPECTIVE

The water scarcity has been given attention at highest level i.e. World Commission on Water (WCW) which emphasizes to hold World Water Day on 22nd March of every year. World Water Forum also gives high priorities to water conservation and management to cope with water scarcity element as water demand is outstripping available sources of water. The availability of water on earth is in the shape of only 2.5% fresh water, 75% locked in glaciers, 24% contained underground and 1% available on surface. The unmanaged water resources support only 500 m out of 6000 m people of the world. Globally 493 BCM are evaporation losses from sea, 62 BCM evaporation losses from land and 104 BCM is precipitation (rain not evenly distributed).

The average run off is 20% in Amazon Basin, 30% in Congro River Basin of continent Africa, No rains in Acama Desert (Chile) since 1571, Asia has 60% global population with 36% world run off and South Africa has 6% global population with 26% world run off. The average water usage is 70% agriculture (90% in developing countries), 22% for industry and 8% for household on the globe. During the last century uses have been increased many fold i.e. Industrial 20 times, household 24 times and agriculture 4 times.

The water resources development history indicates that Ancient Egyptians built large canals to use Niles' water, Roman engineers transported water in Rome from a very distant source and Chinese engineers in Beijing currently planning to transfer water from 1300 KM to cope the water demands. For harnessing water there are 800,000 dams/reservoirs

(45,000 large) having gross storage capacity of 12 B^2CM and high Aswan Dam/reservoir has 170 BCM with average annual flow of 59 BCM and Egypt drought period : 1988 – 1977 (10 years) ; however irrigation requirements were fully met by the Aswan Carry Over Dam. Similarly, the storage capacity of Colorado River (USA) is 49 BCM having average annual flow 16 CM whereas, in Pakistan situation is otherwise.

EXISTING WATER RESOURCES OF PAKISTAN

Pakistan possesses one of the world largest contiguous irrigation system known as Indus Basin Irrigation System. This system mainly comprises the Indus main river and its five major tributaries. After Indus Basin Treaty with India in 1960, Pakistan was allotted the flows of three western rivers namely Indus, Jhelum and Chenab. The flows in these rivers are quite variable. About 84% flows occur in Kharif (Summer) season. The great variability of water flow has urged to develop and manage irrigation system in such a way so that assured and regular water supply for agriculture can be made available.

The system is comprised of two large reservoirs Mangla and Tarbela Dam, 23 barrages, 12 inter-river link canals and 48 perennial and non-perennial canal commands. The total length of main irrigation canals including distribution system is 60,000 km. The whole canal system serves about 90000 watercourses with approx length of 1 Million km. The location of existing water storage sites of Pakistan and gives the salient of the existing water reservoirs. In addition this there are about 5-dozen small dams built, operated and maintained by the provincial small dams organizations. These dams supply water in the local areas both for irrigation and drinking.

With the completion of Indus Basin Project, including three online storages, Indus Basin Irrigated System (IBIS) has now a significant locality for integration of river supplies. As a consequence, the canal head diversions in IBIS attained a peak of 133 MAF (107.73 BCM) in post Tarbela period as compared to 67 MAF (83 BCM) at the time of independence. At the time of independence the population was 32 million and per capital water availability was about 6000 m^3. It has reduced to nearly 1150 m^3 per person in 2005 with further reduction, a sever shortage shall be felt (Figure-1). The average flow below Kotri since 1976-77 to 2003-2004 is 35.2 MAF per annum (Figure-2).

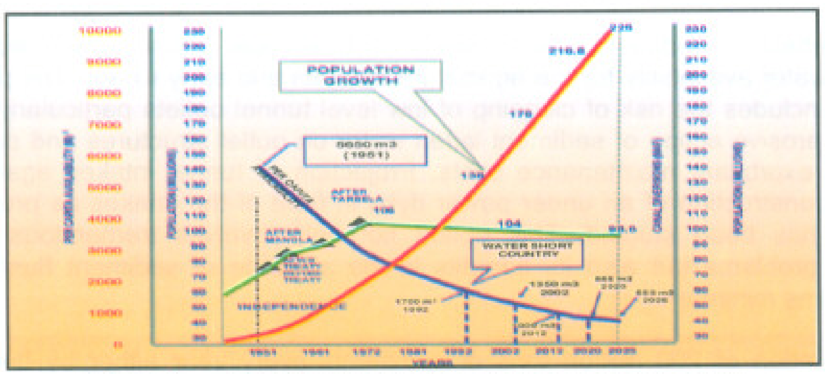

Figure-1 - Canal Water Diversion Vs Population Growth

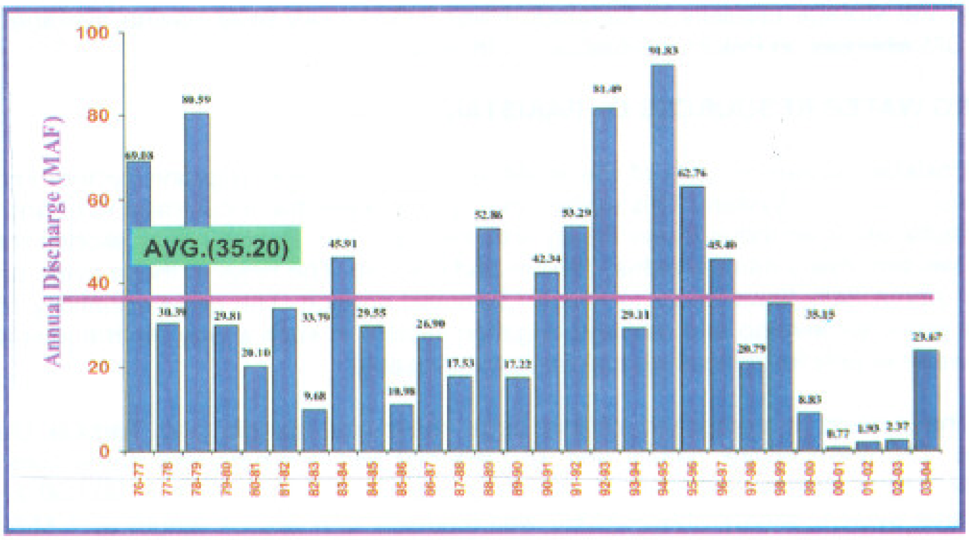

Figure-2 – **Escape Below Kotri (Hydrological Year from April to March)**

SEDIMENTATION OF EXISTING RESERVOIRS

The Indus is one of the four largest sediment carrying rivers in the World. The sedimentation rate in Tarbela reservoir is 200 Mt or 11 MAF per year. According to 2002 hydrographic survey, gross storage capacity of the reservoir has reduced from 11.62 MAF to 8.586 MAF 26.11% in 28 years. Live storage capacity of the reservoir had reduced from 9.679 MAF to 7.778 MAF 19.64%. The delta is advancing towards the dam and at present its pivot point at elevation 1369 is at about 9 miles upstream of the Main Dam.

The effect of sedimentation is loss of live storage which in turn would result in reduction in water availability for the agriculture for Rabi and early Kharif. The physical effect of sediment includes the risk of clogging of low level tunnel outlets particularly in a seismic activity. The erosive action of sediment laden water on outlet structures and power turbines will result in exorbitant maintenance costs. Projection of tunnel intakes against sediment clogging by construction of an under power dyke in front of the intakes as proposed by the Consultants has been studied. This option not only involves tremendous stability and construction problems but also its benefits in the absence of sediment flushing from the reservoir seems minimal.

Evacuation of 200 million tons of sediments every year either by flushing/sluicing through low level high capacity outlets from the right or left bank was proposed by the consultants. This proposal carries a large number of grey areas which need to be prudently addressed before taking it to a feasibility stage. WAPDA considers this an unprecedented option, the sample of which does not exist else where in the World. Moreover, this option would in no time adversely affect the downstream hydropower projects of Ghazi Barotha and Chashma aggrade the river bed and effect the entire irrigation system. The dredging option in case of Tarbela reservoir is not only prohibitive in cost but also is without any precedence and completely impractical. Any dredging proposal to be effective must provide for removal and disposal of 550,000 tons of sediments every day. Realistically, the target is unattainable even if hundred of dredgers and ancillary equipment are deployed over the reservoir stretch of 100 square miles to work round the clock.

A preliminary estimate dredging of yearly deposits of 110,000 AF (135.8 million cubic meters) sediments that about Rs 27 billion at Rs. 200/m^3 would be required annually. Actions plan recommended by the consultants MILLION/s, TAMS/H.R. Wallingford are at pre-feasibility stage and WAPDA has strong reservations against their implementations.

The construction of a big storage project by the year 2010 can only offset the water shortages in the country.

Mangla Dam Project: Gross storage capacity of the reservoir has reduced from 5.88 MAF to 4.76 MAF with average annual sediment load of 34000 AF the reservoir is loosing its capacity at a rate of .6% annually. Live storage capacity of the reservoir has reduced from 5.34 to 4.56 MAF. The major delta is advancing towards the dam and at present its pivot point is at 5 miles upstream of the Main Dam. The depths of sediment deposited at the pivot point and in front of intake structures are 149 ft. and 59 ft. respectively.

WATER CONSERVATION

Water use efficiency both in irrigation and water supply sectors in Pakistan is very low. Total future requirements of Pakistan are going to be substantially greater than total potential supply. Therefore water conservation is critical to meet the needs. This will require concerted efforts in watershed management to reduce upgradation of upper catchments so that sediment is minimized. Irrigation being the largest user of water, great efforts are required in the sector. Irrigation requirement for the year 2013 would be of the order of 250 Bm^3. Lining of canals, distributaries and watercourses to minimize the seepage & conveyance losses. Leveling of farms, use of modern method of irrigation for optimal use of water, crop substitution & judicious use of delta are some of the methods which need to be adopted in the earnest. Groundwater extractions are of the order of 48 MAF & there is limited scope of additional exploitation. No doubt the precious water conserved by lining etc. would benefit the tail enders & add to the productivity of the given command but it cannot be transferred to another command area. Water so conserved also cannot be carried out from one season to another. Therefore, in addition to conservation of this precious natural resource, we must store all the available water for its optimal use.

WATER DEMAND

Pakistan's population currently at 141 million is projected to increase to 173 million is 2010-11 & 221 million in 2025. The %age of urban population will increase from the current 35% to 42% in 2010 & 52% in 2025. The total cultivated area in Pakistan increased from 36.31 MA in 1947 to 56.22 MA in 2000, while irrigated area enhanced from 20.75 MA to

44.68 MA cereal production increased from 5.2 million tons to 28.5 million tons during the same period. The area cereal crops increased by about 20%; the maximum rise was in case of rice which increased by about 318%; & area under sugarcane increased by 544%. There is comparatively much higher increase in the land areas for rice & sugarcane which are high delta crops. Thus, both increase in area & increase in yields have contributed to higher production. Under future scenarios also, additional land & higher cropping intensities both requiring more water would be necessary.

Since the stored water is already insufficient even to meet the needs of the existing cropped area & there is going to be a gradual reduction in stored water because of siltation of the reservoirs, the water availability for agriculture will reduce during the next 2-3 decades. Increasing irrigation intensity of the existing cropped land, requires additional water to be available which will have to be achieved through a combination of improved watershed management, improved efficiency & water availability of critical times of the year. This would require additional expansion/ strengthening of existing irrigation infrastructure.

The net irrigation water requirement for crops in Pakistan was around 77.4 MAF for the year 2000-01. The water requirement for the period 2010-2021 will be 89 MAF for the year 2024 which disregards the contribution from rainfall. The non-irrigation water demands include rural, urban & industrial. Since, a component of the non-irrigation water returns to the river system, the net non-irrigation water demand is the non-irrigation water requirement has been estimated for the 2000 as 3.6 MAF, year 2010 as 7 MAF & year 2025 as 12 MAF.

WAPDA'S VISION 2025 PROJECTS

After completion of Tarbela Dam Project since 1976, the development of water storages has been at stand still. Although Ranking study of Hydropower Projects on river Indus & its tributaries was carried out in early eighties & Detailed Engineering Design & Tender Documents of Kalabagh Dam Project were prepared in mid eighties yet no project came up for implementation. Storage capacity of on-line reservoirs is reducing due to siltation. The present storage capacity is only 11% of total surface flows.

The installed hydropower is only 12% of the total identified potential. In nineties private thermal power projects were inducted in the generation system. Although this eliminated the load shedding but disturbed the hydel thermal ratio from 65:35 to reverse. Fossil fuel being imported the electricity became expensive. The Independent Power Producers (IPPs) which supplied about less than one third of the total power supply of WAPDA had to be paid more than half the revenue of WAPDA. The drought, failure of monsoon, which started in 1999 continued for more than three years. Severe water shortages were experienced in the irrigation system. Realizing the situation WAPDA prepared a 25 years programme of development of water and power resources of Pakistan which was presented to the Federal Cabinet on August 30, 2000. A part of this to be implemented on fast track was approved by the Chief Executive of Pakistan in Jan 2001.

The objectives are; (i) to meet the agricultural & urban demand of the growing population, (ii) increase productivity by bringing more area under cultivation, (iii) to make up the storage lost due to sedimentation, (iv) mitigate the effects of drought, (v) inject cheap hydropower in the system to keep the cost of electricity within affordable limits, (vi) support economy and poverty alleviation in backward areas, and (vii) encourage private investment.

The following projects are being executed under the Vision 2025 Programme. WAPDA is building the following projects under the Vision 2025:

Water Sector Projects	Hydropower Projects
Gomal Zam Dam	Jinnah Barrage
Mirani Dam	Allai Khwar
Raised Mangla Dam	Khan Khwar
Satpara Dam	Duber Khwar
Kurram Tangi Dam	Golen Gole
Greater Thal Canal	Neelum Jhelum
Kachhi Canal	Low Head Hydropower Project
Rainee Canal	

The following projects are under various phases of study:

- Basha Diamer Dam Project – Feasibility Detailed Design & Tenders
- Akhori Dam Project – Feasibility
- Sehwan Barrage – Feasibility
- Chashma Right Bank Canal Lift Scheme Feasibility & Design
- Bunji Hydropower Project – Pre-feasibility
- Dasu Hydropower Project – Pre-feasibility
- Skardu Dam – Pre-feasibility

A No. of small hydel projects on various tributaries are under study. In addition to this other projects shall be taken up in phases II & III.

WATER AVAILABILITY

a) U/S Approach: Annual average surface water flows measured at rim stations is as follows:

Indus at Kalabagh	91.26 MAF
Jhelum at Mangla	23.28 MAF
Chenab at Marala	27.13 MAF
Total at rim stations	141.67 MAF
NWFP Diversions above rim station	5.000 MAF
Eastern River Run Off within Pakistan	3.80 MAF
Total Surface Water available	154.50 MAF
Present utilization	106.00 MAF
Available for future use	48.50 MAF
Subtracting 10 MAF for river losses upto Kotri, The net available for future development	38.5 MAF

b) D/S Approach: Post Tarbela average flow downstream of Kotri Barrage (the data given by Director Regulation I&P, GOSindh Karachi) is presented. On annual average 35.2 MAF flows d/s of Kotri into sea when is available for future development. As per water accord study should be carried out to work out the water requirement to check sea intrusion. Subtracting the most conservation requirement i.e. 10 MAF is available for future development.

FUTURE DEVELOPMENT OF WATER RESOURCES

There is no storage site on River Chenab in Pakistan. After raising of Mangla Dam, no more site for water storage is available in River Jhelum. After silting up of raised Mangla, off channel storage site of Rohtas Dam can be considered. Enough water is available as discussed above in river Indus for storage. The sizeable (about 6 MAF) storage sites on river are Kalabagh D/S of Tarbela, Basha U/s Tarbela & Skardu. There are other sites such as Bunji, Dasu, Pattan, Thakot etc. where run off the river hydropower projects can be built but the storage is less than 1 MAF. On tributaries of river Indus there are sites with very little storage but considerable head can be created by tunnels. Three sites Khan Khwar, Duber Khwar, & Alai Khwar are under construction. Off channel storage sites have been investigated. The preferred site which has storage of about 6 MAF & has comparatively less environmental effects, Akhori dam site which is under feasibility study.

Salient features of Kalabagh Dam, Basha Diamer Dam & Skardu Dam Projects are given in table-1 and these dams are shown in Figure-3. A few technical issues of the large storages are indicated in Table-2. Kalabagh Dam Project is located 210 km downstream of Tarbela Dam on the river Indus. The Project envisages construction of 260 ft. high rock & earth fill dam with its maximum retention. In the event of the highest probable flood, the two spillways can dispose of flood of over 2 million cusecs. On the left bank is powerhouse which will be connected to 12 conduits each 36 ft dia with ultimate generation capacity of 3600 MW. The project design is complete & ready for execution.

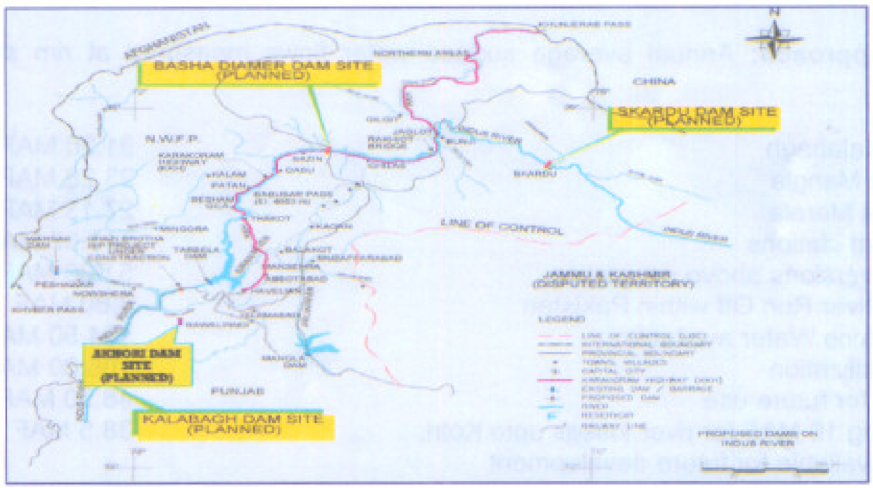

Figure-3 – Location Plan of Dams

Table-1: Perspective Large Storage Projects

Name of project	Live storage (MAF)	Installed capacity (MW)	Status
Kalabagh Dam	6.10	3,600	Detailed design & tender documents completed in 1987
Basha Dam	7.34	4,500	Feasibility study completed in August 2004
Akhori Dam	6	600	Feasibility study in progress
Skardu Dam	Under study		Under appraisal

Table-2: Technical Issues of the Large Storages

	Kalabagh	Basha-Diamer	Akhori	Skardu/ Katzarah
Water availability (MAF)	**90**	**50**	**14**	**27**
	Least	More	Less	Maximum
Power dispersal	Nearest	Very difficult	Nearest	Most difficult
Constructability	Easy	Difficult	Easy	Very difficult
Start of construction	2005	2008	Uncertain	Uncertain
Water availability for irrigation	Early	Late	Early	Very late
Seismicity	Less	More	Less	More
Environmental: Persons displaced Roads affected Land Sub-mergence (acres)	 12,0000 Minor 110,200	 24,000 KKH upgrad 320 km Relocation 140 km Agri. Land 1600	 49300 97 KM Fateh Jang Road 59,200	 160000 40 km 90,000

Basha Dam Project is located 314 km upstream of Tarbela Dam on the river Indus. The Project comprises RCC dam about 908 ft. high, a reservoir with gross & live storage capacity of 9.09 MAF & 7.34 MAF respectively. The two powerhouses one on each bank of the Indus will have ultimate generation of about 4500 MW. The feasibility studies by the consultants are presently underway. Skardu Dam Project is located 10 miles downstream of confluence of Shigar river with Indus near Skardu town. The proposed rock-earthfill dam will have height of about 755 ft & create a reservoir with gross & live storage capacity of 15.4 MAF & 10.6 MAF of the project have been started by WAPDA.

CONCLUSIONS AND WAY FORWARD

Based on the aforementioned facts and discussion a few inferences and recommendations are drawn as follows:

- Water has emerged as a very critical & abused natural source
- Waste & over exploitation, population & depletion of fresh water pose serious threats to mankind.
- Recognize that water has social & economic value, it costs to deliver water and women's role in water management

- Move towards sustainable groundwater management through improve irrigation & cultural practices and rain water harvesting
- Promote use of waste water for agriculture (treated) and biological approaches for rehabilitation of saline lands
- Involve stakeholders in water governance
- Develop water storages – at least two mega reservoirs on main Indus immediately to meet irrigation requirements alongwith, domestic, industry and environment.
- Sedimentation of existing reservoir is enhancing with time, thereby reducing the water availability.
- Studies to confirm the necessity & quantum of water to check seawater intrusion should be carried out early.
- Country is likely to face serious water, food & power shortages after 2010.
- If cheap hydropower is not added to the system the electricity would become more expensive.

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REDUCING THE IMPACT OF UNPLANNED URBANIZATION ON A RIPARIAN ECOSYSTEM : A CASE STUDY ON DESIGNING A PLAN FOR SUSTAINABLE UTILIZATION OF FLOOD PLAINS ON RIVER RAVI

By

Dr. Amin U. Khan*

Abstract

This work emphasizes that utilization of floodplain must be preceded by a study that shows the extent of the floodplain with the primary objective to management and maintaining the integrity of riparian areas for their multiple values. One such design is presented here where the riparian land is used for designing a municipal waste water treatment plant in order to provide a reward feedback to river Ravi. Since the space is becoming expensive for setting up of a treatment plant, this high risk piece of land instead of being used for land filling and housing schemes should be used for designing multipurpose environmentally sustainable projects. The treatment plant is designed to mimic the functional properties of riparian corridor floodplains. This design is based on integrated series of interconnected basins including a sedimentation basin, infiltration basin and a created wetland. This system would promote ground water recharge and passively remove pollutants through a combination of filtering, settling and biological treatment mechanisms and providing an attractive recreation and learning environment for the community at large. Additionally, benefits of such treatment will allow a direct recycling of water and nutrients for beneficial use; the sewage becomes a valuable natural resource that is not simply disposed of untreated.

Introduction

The term riparian is derived from the latin word riparius, meaning stream bank. Riparian definitions are not static; they reflect not only the dynamic physical and biological environment studied by scientists but also the administrative and political demands encountered by managers when implementing riparian management and protection strategies. Riparian areas are three dimensional ecotones of interaction that include terrestrial and aquatic ecosystems that extend down into the ground water, up above the canopy, outward across the flood plain, laterally into terrestrial ecosystem and along the watercourse (Fig. 1). Riparian rights exist where a property owner's land or interests touch a watercourse or body, such as a river or lake. Riparian rights are based on the principle that upstream uses of the water resource should not impair the rights of downstream property owners to use that same resource. Hence, they are normally used to settle issues of water supply, allocation and pollution.

Riparian areas, situated in the interfaces between terrestrial and aquatic ecosystems are located along banks of water bodies. The extent of transitions between the terrestrial and

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aquatic interfaces that delineate the riparian areas are generally site specific. In the case study on the Lahore – Ravi relationship (Khan, 2004), it appears that unplanned urbanization has degraded a vast active flood plain area bordering the main channel, whereas in the past it runs through some of the most fertile soils to be found any where in the world. The study indicates that pressure of ill planned urbanization is such that, it threatens to reduce or even completely destroy the rivers capacity as a life support system. The pace at which blind forces of urbanization are destroying the life support capacity of this river it would soon take the city to the point of no return (Fig. 2, 3).

This is the reason why I have focused here on this endangered high risk piece of land along the river that has to be protected from urbanization. These riparian areas, by carefully designing sustainable solutions, could act as a buffer for the city in case of any major disaster and thus make this city's expansion ecologically and economically more sustainable. One of the objective of this paper is to develop an approach that strives to merge basic and applied science, and to appreciate that how major processes transcend all levels of organization. This approach would permit us to understand better the scale of and challenges associated with seeking solutions to these problems.

Urgency for conserving and managing the fragile riparian system.

Flood damages are the result of poor landuse and environmental planning, and they can be avoided with proper flood plain management practices.

The basic objective of regulating landuse on the floodplain is to reduce the risk of future flood damages. floodplain regulation is generally a responsibility of local govt. Subject to state guidelines. Control can also be exercised by the federal govt. Under the requirement of the national flood insurance program. Many countries have adopted regulations that restricts or prohibit certain types of construction or activities in the flood plain. As the floodways is filled in and built upon, the flow path is restricted. This causes an increase in the flood elevation making the problem ever more severe. It is important to understand that the 100years flood is a statistical value, it can occur twice in a row, several time in a century , or not at all in a period longer than 100years.That is why larger data basis is needed to get more accurate values. At the moment there is no plan for conserving productive and protective lands from unplanned development. Lack of public pressure to preserve and develop riparian areas for recreation, wildlife habitats, and aesthetic values resulted in rapid degradation of riparian ecosystem. Consequently, in the absence of any regulations that restrict or prohibit certain types of construction or activities in the floodplain, the municipalities, waste disposal agencies, agriculturalists, graziers are exploiting the natural resources on public land without responsibility for landownership.

Designing a multipurpose environmentally sustainable project.

Since the space is becoming expensive this high risk piece of land instead of being used for land filling and housing scheme should be used for such compatible low cost projects. For this purpose the area between the sewage channel (outfall) and the active river channel was measured. A block of 1000m x 500m was proposed for developing a hypothetical model for the primary treatment of the sewage in this high risk riparian land. A high quality polished effluent can be obtained by the natural processes that occur as the effluent flows over the land surface and percolates through the soil. The principle is similar to the old subsurface disposal system as it is based on the septic tank and leaching field (Fig. 4). It is designed to mimic the functional properties of riparian corridor floodplain. Design integrated a series of basin including a sedimentation basin, an infiltration basin, a created treatment wetland plant. A schematic design of land treatment system is shown in Fig. 5. Waste water flow through a series of ponds. In each pond the supernatant is allowed to flow over where as the sludge and solid waste is trapped. There is a set of ponds which are operative at one time and when they have enough load of sludge settled than the flow should be cut off and other set should become operative. The first basins act predominantly as settling tanks to store settled and floating solids whereas the second basin acts predominantly as leaching field to distribute the effluent so that it can percolate through the soil. Some of the sludge decomposes under anaerobic conditions, but eventually the undecomposed solids accumulate and the sludge level rises. It should be dredged clean on routine basis. The effluent from the sludge basins flows into an absorption and leaching field which distributes the liquid uniformly over a sizable area. From the leaching field, the effluent percolates downward to the water table. As it flows through the soil voids, microorganisms and other pollutants are removed from the effluent, this provides necessary primary treatment step, and act as sludge storage tank. These two basins provide necessary primary treatment steps and not only act as sludge storage tanks but also as evaporation and infiltration basins. Factors such as average rainfall, wind speed, solar radiation temperature and soil texture in this area are such that it will favour evaporation into the air and infiltration into the ground. Retention time in these ponds will reduce the suspended solids, reduce the biochemical oxygen demand, these two basins remove most of the solid waste before it can be applied to the third basin. Runoff discharged from the leaching basins is directed into a wet pond which further consists of a series of stepped channels supporting a variety of vegetation, including hydrophytes, marshland, grasses, shrubs and trees, having different flood and drought tolerances. Some hydrophytes have the ability to reduce the BOD of the effluent up to 57% and COD up to 28% in 7 days, and accumulate N and P in plant tissue 0.24g/ 100g and 0.12g/100g per day as compared to control (Mian, 2003).

Unfortunately, in this country the legal and regulatory requirements related to riparian resources is mainly concerned with water ownership and use rights, whereas regulations guiding the management and use of the land itself are totally ignored. There is an urgent need for a more holistic form of management for riparian areas by developing an appropriate and timely land-use strategy to sustain the integrity of these fragile ecosystems. A design based on filtration, absorption and biological decomposition on a flood plain plays a role in the purification of the wastewater before its released into the river, this would provide a reward feedback to the river and reduce the risk of ecological backlash. Benefits of treatment plant also include the sewage that is not simply disposed of but is utilized as a natural resource. Sludge management program can create jobs by setting up drying and palletizing plant that converts the sludge into marketable fertilizers; the palletizing facility will find no shortage of raw material for conversion. This hypothetical model can be repeated in this riparian tract at each of the six sites where the sewage channel presently is dumping the raw sewage into the river.

Conserving these areas is only possible if there is an interaction among social, economic and political forces of land stewardship with the technical aspects of riparian resources management and use, and is fostered by locally led initiatives. The lack of this interaction also lies partly with our institutions of higher learning, which have failed to promote and establish mechanisms or structures to administer these interdisciplinary fields of study. Here one can get help from a new interfaced field of ecological engineering. This field is characterized by the virtues of preventive medicine, critical thinking, and problem solving on a landscape scale, and can help towards promotion of such initiatives and thus development of a sustainable society.

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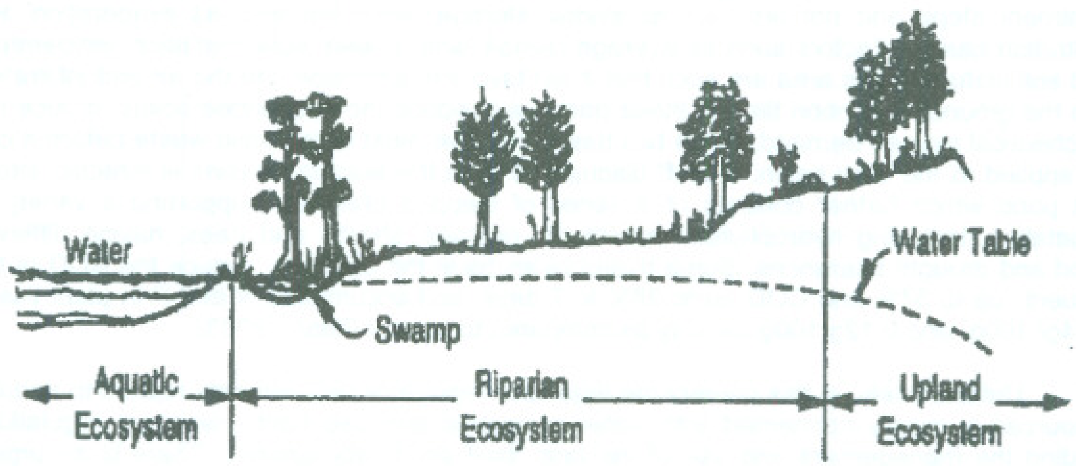

Fig. 1. The three dimensional interaction of the riparian ecosystem.

Fig. 2. The high risk piece of land between the sewage channel (outfall) and the active channel of river Ravi proposed for the treatment plant. This photograph was taken in June 2004.

Fig. 3. The high risk piece of land between the sewage channel (outfall) and the active channel of river Ravi proposed for the treatment plant. This photograph was taken in March 2005; it is showing the rapid pace of encroachment.

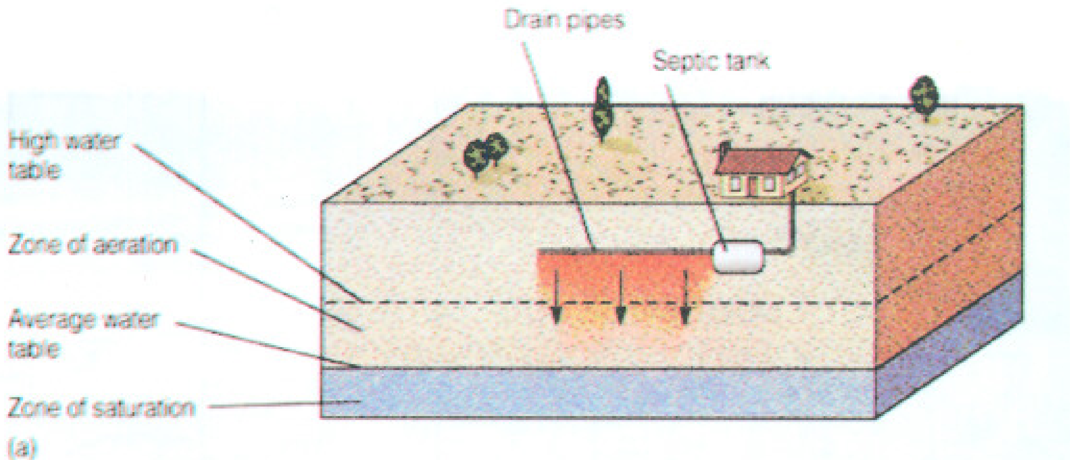

Fig. 4. The principle of the old subsurface disposal system based on the septic tank and leaching field used for the hypothetical model to be designed for the floodplain

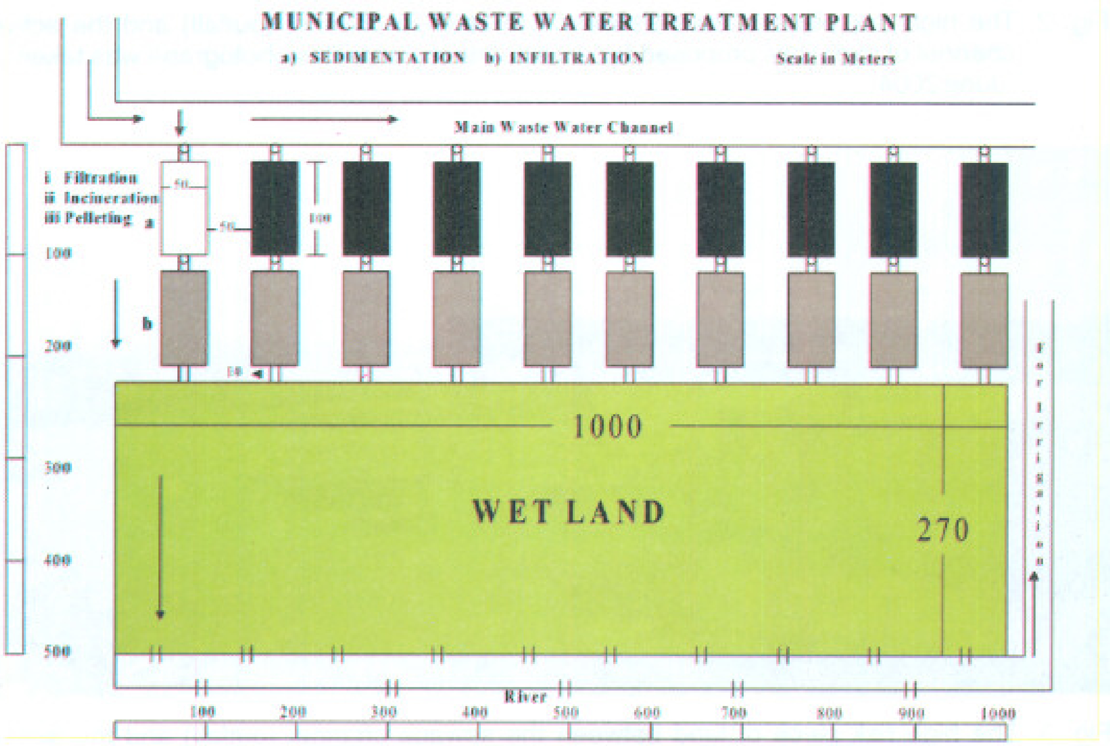

Fig. 5. Hypothetical design based on integrated basin system for the primary treatment of the raw sewage, it mimics the natural processes and compatible with the high risk riparian flood plain.

GROUNDWATER USE IN PAKISTAN : OPPORTUNITIES AND LIMITATIONS

By

Dr. Muhammad Nawaz Bhutta*

ABSTRACT

Groundwater potential in the Indus Basin is mainly due to recharge from irrigation system, rivers and rainfall. Its quality and quantity varies spatially and temporally. However, the potential is linked with the surface water supplies.

Irrigated agriculture is the major user of groundwater. Annual recharge to groundwater in the basin is estimated as 68 MAF. But 50 percent of the area has marginal to hazardous groundwater quality. Existing annual groundwater pumpage is estimated as 45 MAF (55 BCM). More than 13 MAF mainly of groundwater is lost as non-beneficial ET losses. Groundwater contributes 35 percent of total agricultural water requirements in the country. Annual cropping intensities have increased from 70% to 150% due to groundwater use. Increase in crop yield due to groundwater use has been observed 150-200 percent. Total investment on private tubewells has been made more than Rs.25.0 billion.

In the areas where farmers are depending more on groundwater, mining of groundwater has been observed. Population pressure, inadequate supply of canal water and development of cheap local tubewell technology have encouraged farmers to invest in the groundwater development. Deterioration of groundwater has also been observed due to excessive exploitation. The available information about the private tubewells is insufficient for different areas. Although during the past decade the growth of tubewells was tremendous but was not reflected accordingly in the statistics. Monitoring of groundwater quality is not done systematically and adequately. It is very difficult to manage a resource for which adequate information is not available.

The present scenario of groundwater use is not sustainable and therefore certain measures are needed to be taken. It is recommended to have a systematic monitoring of groundwater. For the sustainable use of groundwater, it is recommended to manage the demand of water i.e. grow more crops with less water. To achieve high productivity of water low delta crops should be encouraged. A study on groundwater exploitation in riverine areas should be done. Recharge to aquifer has to be increased by artificial measures from summer river flows and rainfall harvesting. Link between research and development should be strengthened.

1. INTRODUCTION

Groundwater is of the fundamental importance to meet the rapidly expanding urban, industrial and agricultural water requirements in semi-arid and arid areas. Groundwater is

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recognized as a vital natural resource that is playing a key role in poverty alleviation in Pakistan. The use of the groundwater permits the farmers to exercise greater control over the available water use and results in timely application of water for crops. Although groundwater is used in wide area of Pakistan but the scope of this paper is limited to Indus Basin only.

2. OPPORTUNITIES

The importance of groundwater and its role in the economy and protecting food security are discussed in the following paragraphs.

2.1 Importance of Groundwater

Population served with groundwater for drinking water supply varies from 15 percent in Australia to 75 percent in Europe. In Pakistan also major part of population is dependent on groundwater for drinking water supply.

Country productive area is being irrigated with surface water through canals. As the food and fibre requirements are increasing with the increase of population this water is not sufficient to meet the irrigation demands. Therefore groundwater is being exploited through different means and is utilized to augment the irrigation supplies. Estimated agricultural use from groundwater is 35 percent and from surface water is 65 percent. The area irrigated by different sources is given in Table 1.

Table 1. Area irrigated by different sources (Mha)

Year	Total	Canals	Tubewell	Wells	Canal + Tubewells	Canal + Wells	Others
1980-81	14.84	8.14	1.83	0.21	3.95	0.10	0.61
1983-84	15.46	7.95	1.95	0.18	4.58	0.08	0.72
1986-87	16.31	7.96	2.2	0.18	5.16	0.07	0.74
1989-90	16.89	7.74	2.57	0.16	5.72	0.08	0.62
1992-93	17.33	7.91	2.67	0.18	6.23	0.10	0.24
1995-96	17.58	7.6	2.89	0.18	6.58	0.11	0.22
1999-2000	18.09	7.56	3.10	0.18	6.99	0.09	0.17
Diff. between 1999-00 and 1980-81		-0.58	+1.27	-0.03	+3.04	-0.01	-0.44

Source: Govt. of Pakistan 2000-01 Agricultural Statistics of Pakistan.

Table 1 indicates that area irrigated by tubewells is 17% (3.10 Mha) of total and tubewells + canal is 38% (6.99 Mha) of total. Last row of the table also shows the increasing importance of tubewell irrigation. It is very evident that the groundwater has become very important component of irrigation in the country.

2.2 Groundwater Economy

A total of 215 BCM of groundwater is used in South Asia from 21 million pumps. In Pakistan more than 0.6 million private pumps have been installed (Figure 1). These are pumping 55 BCM (45 MAF) of water annually for irrigation. In addition more pumpage is done for domestic and industrial use. Electric tubewells are 0.15 million and 0.45 million tubewells are of diesel. Total investment on private tubewells is more than Rs.25 billion. Contribution of groundwater to national economy is US$ 1.3 billion annually.

The density of private tubewells in Punjab is given in Figure 2. It increased from one tubewell per 1000 ha in 1965 to 32 tubewells per 1000 ha in 2002.

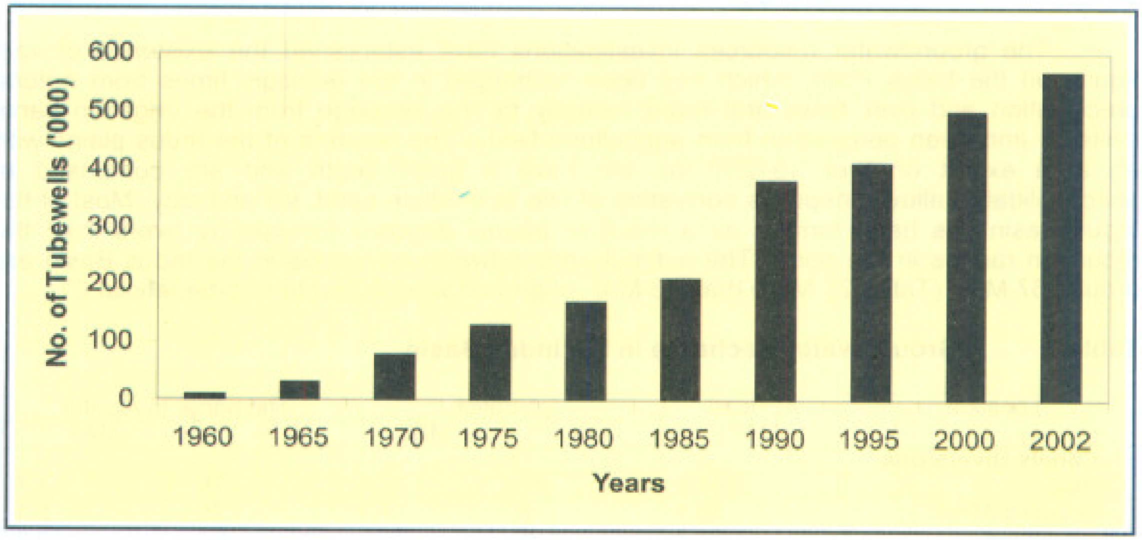

Figure 1. Development of Private Tubewells in Pakistan

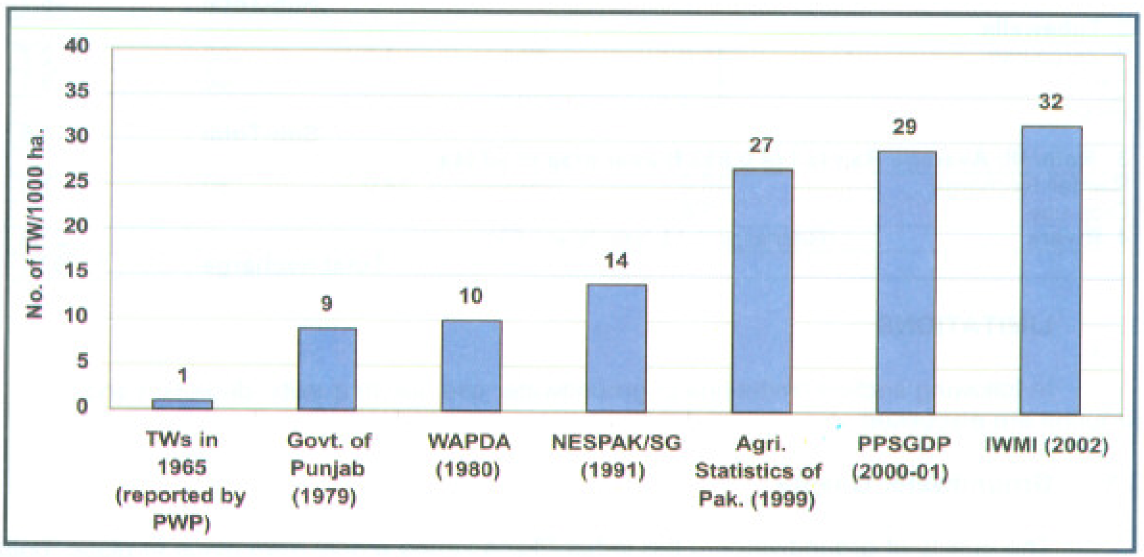

Figure 2. Density of Private Tubewells in Punjab

2.3 Protecting Food Security

Livelihood of 2.5 million families in Pakistan depends upon groundwater use. Due to groundwater use in the irrigated areas the cropping intensities have increased from 70% to 150%. The yields have increased 150–200 percent. Local rural economy has been strengthened.

2.4 Groundwater Recharge

The groundwater resources investigations have established the existence of vast aquifer in the Indus Plain, which has been recharged in the geologic times from natural precipitation and river flows and more recently by the seepage from the irrigation canal systems and deep percolation from agricultural fields. The aquifers of the Indus plains with an area extent of over 194250 sq. km have a great depth and are composed of unconsolidated alluvial deposits consisting of fine to medium sand, silt and clay. Most of the Indus Basin has been formed as a result of alluvial deposits brought by rivers from the mountain ranges in the north. The estimate groundwater recharges in the Indus Basin are around 67 MAF (Table 2). More than 13 MAF of groundwater is lost to non-beneficial ET.

Table 2. Groundwater Recharge in the Indus Basin

Location	At Head (MAF)	Infiltration		Recharge to Aquifer	
		%	MAF	%	MAF
1. Canals Diversions					
Canals	104.0	15	15.6	75	11.7
Distributary/Minor	88.4	8	7.1	75	5.3
Watercourse	81.3	25	20.3	60	12.2
Fields	61.0	30	18.3	90	16.5
Crops	42.7				
				Sub-Total	45.7
2. Tubewells					
Watercourse	45.0	10	4.5	60	2.7
Fields	40.5	25	10.1	90	9.1
Crops	30.4				
				Sub-Total	11.8
3. Rainfall: Average Rainfall of 0.656 ft over area of 43 Ma.					
Rainfall Recharge	28.0	50	14.0	50	7.0
Crop-use	7.0				
4. Rivers	(Recharge 4.11-baseflow 1.53)				2.58
				Total Recharge	67.1

3. LIMITATIONS

In following section limitations of groundwater use due to quality, depletion and pollution are discussed.

3.1 Groundwater Quality

The quality of groundwater in the Indus Plains varies widely from place to place, both vertically and horizontally from completely fresh to extremely saline, depending on its origin, the sources of recharge and the pattern of groundwater movement in the aquifer. Generally groundwater is fresh in strips along the rivers because of seepage of fresh water and deteriorates towards centers and southwest of each doab. Groundwater quality in the Indus Basin upto 125 feet depth is given in Figure 3. It indicates that 34% of Indus Plain is underlain by useable groundwater (Ahmed, 1995). The quality of groundwater varies widely, ranging from less than 1,000 ppm TDS to more than 3,000 ppm.

The mineralization of groundwater generally increases away from the rivers. In the central parts of the doabs in the Punjab, pockets of highly mineralized groundwater have been developed which contain 4,000 to 20,000 ppm of dissolved solids. In Haro Basin of Potohar Plateau, the salt contents of groundwater range from 200 to 800 ppm and increase towards the eastern and western parts. In Dera Ghazi Khan large areas contain water of good quality, but this water is commonly overlain, by waters of poor quality at shallow depths (Technical Report No.30) Punjab Private Sector Groundwater Development Project (PPSGDP).

The general pattern of groundwater quality distribution in Sindh is less than 1500 ppm adjacent to the river with increasing salinity away from the river. The native groundwater of the Lower Indus Plain is highly saline being of marine origin. Some of the most saline groundwater of the region is found in the delta where the samples with salinities as high as twice of seawater have been found (Hunting and MacDonald, 1966).

The salinity of groundwater of NWFP has different origins. The quality of shallow groundwater in the valleys, which is largely derived from infiltration of rainfall and seepage from canals and fields, is generally good (less than 1500 ppm of dissolved salts). However, in Bannu Basin, the chemical contents of the upper horizon range from 350 to 3000 ppm.

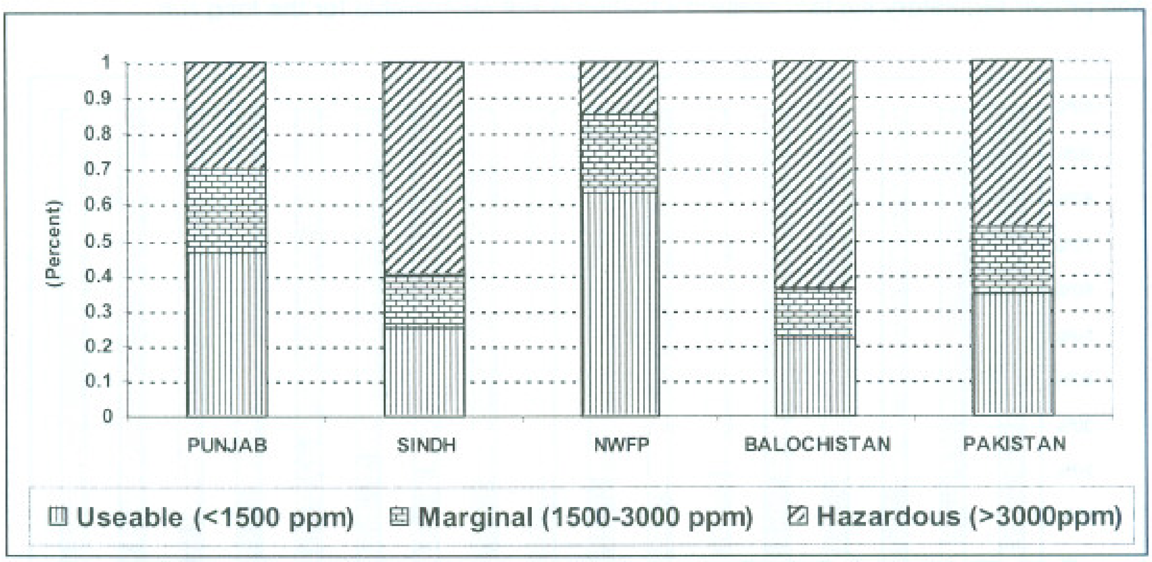

Figure 3. Groundwater Quality in Indus Basin Irrigated Area

The quality of groundwater in Indus Basin irrigated areas in Balochistan is hazardous. However, in the northern region of Blochistan, comprising Zhob, Pishin and Lora, the quality of groundwater is generally good. In the western and southwestern parts quality of groundwater is saline to highly saline at all depths. Sometimes, salinity of groundwater exceeds more than 3000 ppm such as in Nokkundi, Dalbandin, Saindak areas, Kachhi plain, Nushki plain and coastal area. The quality of water in the northern part of the plain is rated as good. Due to excessive pumpage of groundwater, horizontal and vertical movement of highly saline aquifer has been observed. It will restrict the present un-planned pumpage of groundwater in the Indus Basin.

3.2 Mining of Groundwater

Canal command wise data of watertable depth were analyzed to study watertable trends from 1985 to 2002. Ground mining and lowering of watertable was observed in all the canal commands of Indus Basin during 2000. Dropping watertable in Rechna Doab (area between Ravi and Chenab Rivers) is shown in Figure 4. It could be partially due to drought period for the last few years. However, the increased number of private tubewells have also played significant role. It has been reported that due to lowering of watertable, pumping with ordinary centrifugal pump has become impossible. Therefore 5 percent small farmers in Punjab and 15 percent in Balochistan have already been deprived of from groundwater use because they can not afford to pump from deeper layers.

3.3 Groundwater Quality Deterioration

More dependence of agriculture upon groundwater has caused deterioration of groundwater quality. Areas having saline groundwater have been spreading the Doabs. Figure 5 indicates groundwater quality deterioration in Punjab Province. Figure 6 shows changes in groundwater quality in Sindh Province. Without existence of enough information and proper regulatory system present situation is not sustainable for the long run.

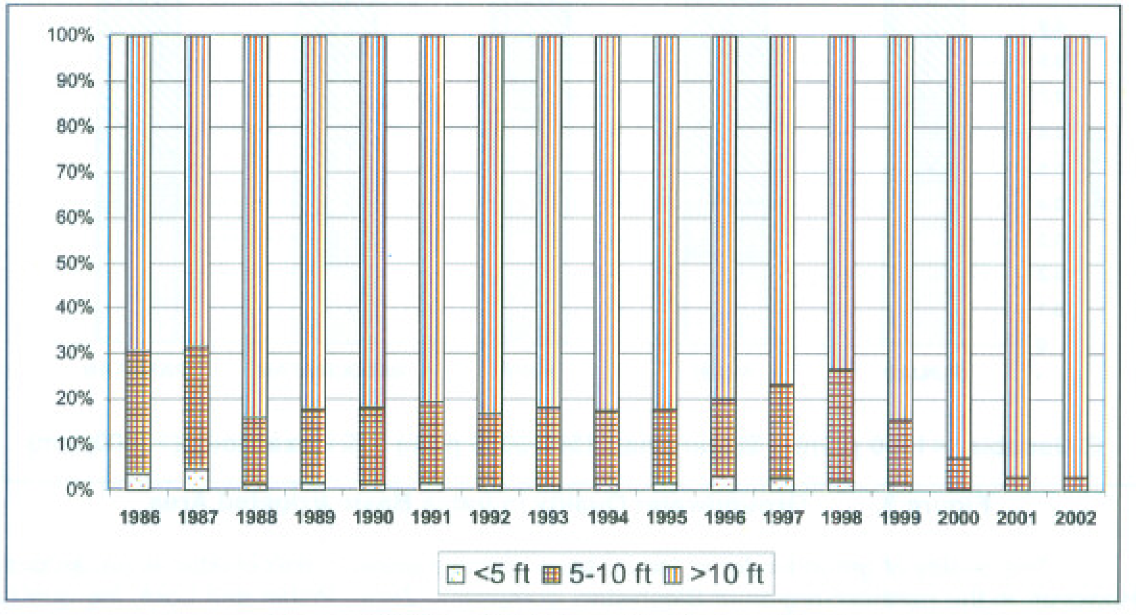

Figure 4. Watertable Drop in Rechna Doab

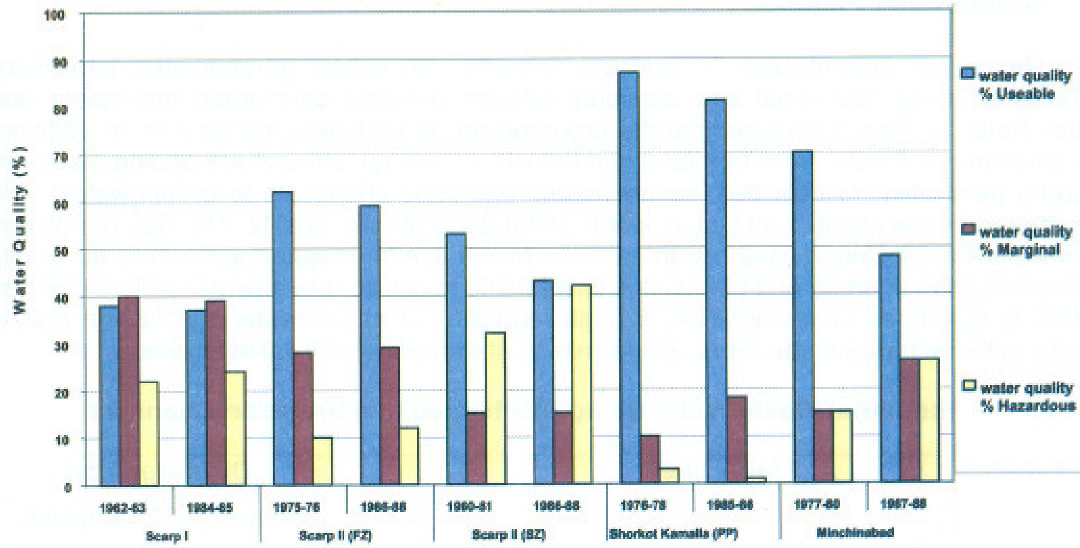

Figure 5. Changes in Groundwater Quality in Punjab

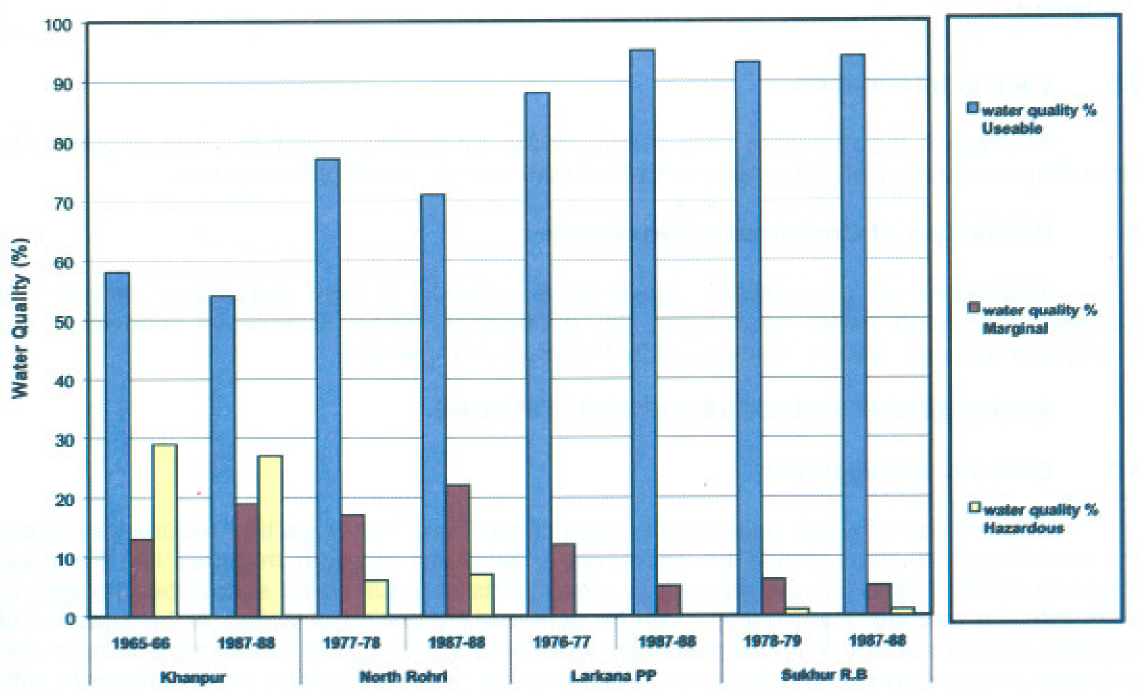

Figure 6. Changes in Groundwater Quality in Sindh

3.4 Groundwater Pollution

Mining of groundwater is causing intrusion of saline groundwater into fresh groundwater areas. Municipal and industrial effluent is being discharged into rivers and canals (Table 3). Part of it recharges the groundwater and pollutes the aquifer. In addition, deep percolation of water from farmland and industrial drainage effluent are adding dissolved fertilizers, pesticides, insecticides, heavy metals and toxic chemicals to groundwater. This will further increase pollution of groundwater and deteriorate the quality. The use of polluted groundwater for drinking causes health hazards and its use for irrigated agriculture adversely affects production of crops and plants. It is essential to minimize groundwater pollution and to improve its quality as far as possible through regulation of groundwater abstraction and or increasing the recharge in the areas where mining of groundwater is taking place.

Table 3. Industrial Waste Water Being Discharged into Irrigation Channels

Main Cities	Discharge (cfs)	
	Municipal	Industrial
Lahore, Kasur, Khanewal, Multan	3403	142
Faisalabad, Hafizabad, Gujranwala, Sheikhupura, Jhang	328	270
Mandi Baha-ud-Din, Gujrat, Sargodha	131	44
Balawalpur, Dera Ghazi Khan, Muzaffargarh, Sukkur, Rahimyar Khan, Hyderabad	286	83

3.5 Lack of Information

At present the available data about private tubewells is sketchy. It is important to have proper inventory of all the tubewells for future management of the system.

3.6 Challenges of Groundwater Goverance

Challenges of groundwater governance include: (i) high population density; (ii) relatively low fresh water availability; (iii) exceedingly large number of tubewells; (iv) widespread poverty; and (v) inadequate institutional arrangement.

4. MANAGEMENT AND DEVELOPMENT OPTIONS

4.1 Demand Management

Efficient use of water resources is need of the time. The crops that require less water for unit food production should be encouraged. Similarly irrigation methods like Panchoo Irrigation System used for rice growing in Lower parts of Indus Basin should be changed to more efficient method. Particularly it can be achieved by pricing of water. At tail reaches of irrigation canals surface water supplies are not being ensured due to mismanagement and changed physical conditions. As a result farmers are more depending on groundwater with paying less attention to quality. Equitable distribution of surface water supplies can reduce demand of groundwater.

4.2 Recharging the Aquifer

As discussed in the previous section the mining of groundwater has been started in all the canal commands. There is an urgent need of recharging the aquifer. It can be done by the following options:

(i) Recharge by river flood flows;
(ii) Rain water harvesting; and
(iii) Use of surface drains for recharge and storage.

Almost every year during monsoon months there are surplus supplies than diversion and storage. Study for use of this water for recharging the aquifer should be conducted.

Saline barren lands are main source of runoff generation during heavy rains. Efforts should be made to utilize these lands for recharging the aquifer from rainfall.

Surface drains carry useable quality of water through many areas which have deep watertable. These drains can be utilized as recharge source in such areas. Chimneys of highly permeable materials can be developed in the bed of drains.

4.3 Groundwater Development in Riverine Areas

The culturable command areas in the riverine areas of Indus Basin cover over 2 million hectares. These areas lie 5 to 10 km on either side of the Indus and its tributaries (Sutlej, Ravi, Chenab and Jehlum). The groundwater salinity/sodicity in riverine areas is very low and groundwater is highly suitable for irrigated agriculture. The groundwater abstraction in these areas is mainly through private tubewells. A large number of unplanned small capacity private tubewells have been installed in these areas and there is still a vast scope for further exploitation of groundwater; provided private tubewells are installed and operated according to a well-planned strategy.

The groundwater in these areas is continuously recharged through seepage from riverbeds and during annual flooding of these areas. The rate of recharge in these areas is much higher during summer months (June–September) when the river flows are high. The recharge rate during winter months is low. Tubewells in these areas should mainly be operated during Rabi Season (October–March). The pumping of groundwater during Rabi will lower the groundwater table and will create suction gradient. Therefore following summer and particularly during monsoon season, the ground water reservoir will rapidly replete due to high rate of recharge. However, it must be ensured through proper planning that annual groundwater discharge does not exceed annual groundwater recharge. The possibility of pumping access groundwater from the riverine areas into adjacent irrigation system should be looked into. A feasibility study of exploitation of groundwater in these areas should be carried out without further delay.

4.4 Groundwater Governance

Pricing of water will be a powerful tool for demand management. Groundwater regulation authority should be established in each province.

5. RECOMMENDATIONS

Following recommendations are made for the sustainable use of groundwater in the Indus Basin:

(i) Inventory of private tubewells should be done for all canal commands.

(ii) The areas where groundwater is being mined should be sufficiently recharged from surface supplies.

(iii) Rainfall harvesting in barren areas may be introduced to recharge the aquifer.

(iv) Equity of water distribution of surface irrigation should be strictly implemented.

(v) Canals having higher water allowances with good groundwater quality should be studied and better options may be adopted.

(vi) A regulatory framework for groundwater use should be introduced.

(vii) Intensive attention should be directed towards water demand management.

(viii) Proper monitoring system for groundwater should be continued.

(ix) Link between research and development should be strengthened.

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DEVELOPMENT OF SUB-SURFACE DRAINAGE DATA BASE SYSTEM FOR USE IN WATERLOGGING AND SALINITY MANAGEMENTS ISSUES

By

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ABSTRACT

A simple user-friendly menu-driven database management system pertinent to the Impact of **S**ubsurface Drainage Systems on **L**and **a**nd **W**ater Conditions (ISLaW) has been developed for use in waterlogging & salinity management issues of drainage areas. This database has been developed by integrating four software viz; Microsoft Excel, MS Word, Acrobat and MS Access. The information in the form of tables & figures with respect to various drainage projects has been presented in MS Word files. The major data sets of various subsurface drainage projects included in the ISLaW database are: i) technical aspects, ii) groundwater & soil salinity aspects, iii) socio-technical aspects, iv) agro-economic aspects, and v) operation & maintenance aspects. The various ISLaW files can be accessed just by clicking at the Menu buttons of the database system. This database not only gives feedback on the functioning of different subsurface drainage projects with respect to above mentioned various aspects, but also serves as a resource document for these data for future studies at other drainage projects. The developed database system is useful for planners, designers and Farmers' Organisations for improved operation of existing as well as development of future drainage projects.

1. INTRODUCTION

Pakistan is fortunate to have been endowed with large rivers fed from lofty mountains with abundant water resource. Accumulatively, it has created World's largest man-made canal irrigation system, nearly a century old. This system provides irrigation facilities to 36 million acres which correspond to about 46% of the total cultivable area (WAPDA, 2004). As such, the country has a history of successful irrigation. Since, irrigation is the mirror image of drainage, therefore, due to inadequate drainage facilities the irrigated lands of Pakistan have suffered from the problem of waterlogging & salinity for the last half century. To mitigate the impact of waterlogging & salinity, since 1960's numerous drainage projects were undertaken by the Government of Pakistan. WAPDA's role in the field of arresting waterlogging & salinity aimed at the life-saving action for Pakistan's agriculture which remains backbone of the national economy. As such during the past 46 years, WAPDA has planned & executed 64 Salinity Control and Reclamation Projects (SCARPs) at a total cost of Rs.37.8 billion, to cover an area of 18.32 million acres of the affected land (WAPDA, 2004). Nevertheless, the performance of these projects has been reported to be below expectations mainly because of deficiencies in policy & institutional matters, inadequate O&M of completed drainage facilities and initiating too many new projects at one time. To overcome these shortcomings and to reappraise the existing situation, National Drainage Programme (NDP) was conceived.

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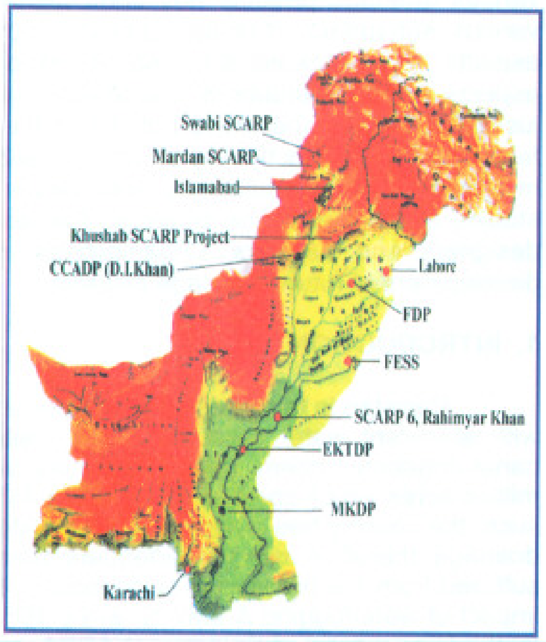
Although, the performance of these projects has been reported to be below expectations, no systematic effort has been made to analyse those projects in terms of *evaluation*. Considering the huge investments incurred and the associated benefits of these projects, it is of great significance to evaluate the performance of those systems; and to develop a database management system to suggest improvements for existing as well as future drainage projects so as to protect them against failures. Hence, a study titled *"Database Management System of Subsurface Drainage Projects"* was conducted by IWASRI under NDP (Azhar et al., 2004). Under this study, four drainage projects namely; Mardan SCARP Project (MSP), Fourth Drainage Project, Faisalabad (FDP), Chashma Command Area Development Project (CCADP) and Mirpurkhas Tile Drainage Project (MKDP) were investigated in terms of performance evaluation and to develop a database management system of these projects.

2. THE SUBSURFACE DRAINAGE PROJECTS IN PAKISTAN

In order to alleviate the twin menace of waterlogging & salinity, to-date eight drainage projects have been installed in various provinces of Pakistan (Figure 1). As stated earlier, for this study only four project sites namely; MSP (*NWFP*), FDP (*Punjab*), CCADP (*NWFP*) and MKDP (*Sindh*) have been selected. These project sites have been selected based on their wide range of geohydrological, climatic and socio-economic conditions. In addition, these sites cover a range of old as well as most recently installed pipe drainage systems in different provinces of Pakistan. Hence, this range of selection would facilitate to investigate drainage projects that were designed using old & new technology (Azhar et al., 2004).



FDP Fourth Drainage Project, Faisalabad
FESS Fordwah Easter Sadiqia South Project
EKTDP East Khairpur Tile Drainage Project
MKDP Mirpurkhas Tile Drainage Project
CCADP Chashma Command Area Dev. Project

Figure 1 Location Map of Drainage Projects in Pakistan

3. DATA COLLECTION & ANALYSIS

As stated earlier, a research study was conducted by IWASRI under NDP. This study focused on the performance of existing subsurface drainage systems with respect to the design expectations; and to develop a database management system to help in developing guidelines for improved planning, design, implementation and O&M of the existing as well as future drainage projects in Pakistan. In this connection, it was conceived that much could be learnt from the analysis of the data of existing drainage projects in the country. Hence, a considerable wealth of data not comprehensively used and/or analyzed in the past was mainly intended to be collected, interpreted and presented under this study. The information used for this study were collected for three stages i.e. *before*, *during* and *post* construction of the drainage projects. The data were collected from various sources such as: WAPDA, Provincial Irrigation & Power Departments, Agriculture Departments, socio-technical surveys, farmers' interviews & field measurements by IWASRI staff etc. Since, examination of drainage accomplishments & prospects is constrained by the availability of reliable data, the collected data were first screened for their integrity and then used for desired analysis. This data provided the basis for development of database management system pertinent to the ***I***mpact of ***S***ubsurface Drainage Systems on ***L***and ***a***nd ***W***ater Conditions (ISLaW) of drainage areas as described in Section 4.

All the relevant details of project features of selected projects have been collected such as canal irrigation system, layout, geohydrological conditions, installed drainage units etc. The data for pre & post-project conditions on groundwater table & quality, soil salinity, cropping pattern & production, agricultural practices, drainage coefficient, effluent water quality and percentage of drainage effluent used for irrigation etc have also been collected. The collected data were processed and analysed in various ways to find the levels of various project impact indicators like improved watertable control, soil salinity conditions, and groundwater quality conditions. Historical trends i.e. year-wise variations during the pre & post-project periods were also analyzed. The level of farmers' satisfaction has been established based on their interviews. The collected data have been processed to develop guidelines for planning, design, construction and O&M of the future subsurface drainage systems in Pakistan. The adverse impacts of drainage systems have also been investigated. The ISLaW database therefore not only gives feedback/information on the functioning of different subsurface drainage projects with respect to above mentioned various aspects, but also serves as a resource document for these data for future studies at other drainage projects. Although, some of the data might have previously been analyzed & presented in other documents, conclusions may differ as we have given our own interpretation to the data supplied.

4. SUBSURFACE DRAINAGE DATABASE MANAGEMENT SYSTEM

As stated earlier, ISLaW is the database management system pertinent to *"Impact of Subsurface Drainage Systems on Land & Water Conditions"*. It has been developed by integrating four software namely; Microsoft Excel, MS Word, Acrobat and MS Access. The data information in the form of tables & figures with respect to various subsurface drainage projects has been presented in MS Word files. Various ISLaW files can be accessed through MS Access interfaces as described below:

4.1 How To Use ISLaW Database System

To use this database, one can enter into ISLAW_DATABASE folder and click on ISLaW database execution file. The Main Menu (first screen) will appear as shown in Figure 2. Pressing NEXT will display the second screen as shown in Figure 3. Pressing Menu buttons at this screen (Figure 3) will lead the user to the desired information. For example, pressing '*Help*' will lead to the information on how to move around in the ISLaW database for various types of data items. This information is in MS Word files. Pressing "*Study Brief*" button will lead to the briefing of the study described in Sections 1&3. Pressing "*Database System*" button will lead the user to the next screen as displayed in Figure 4.

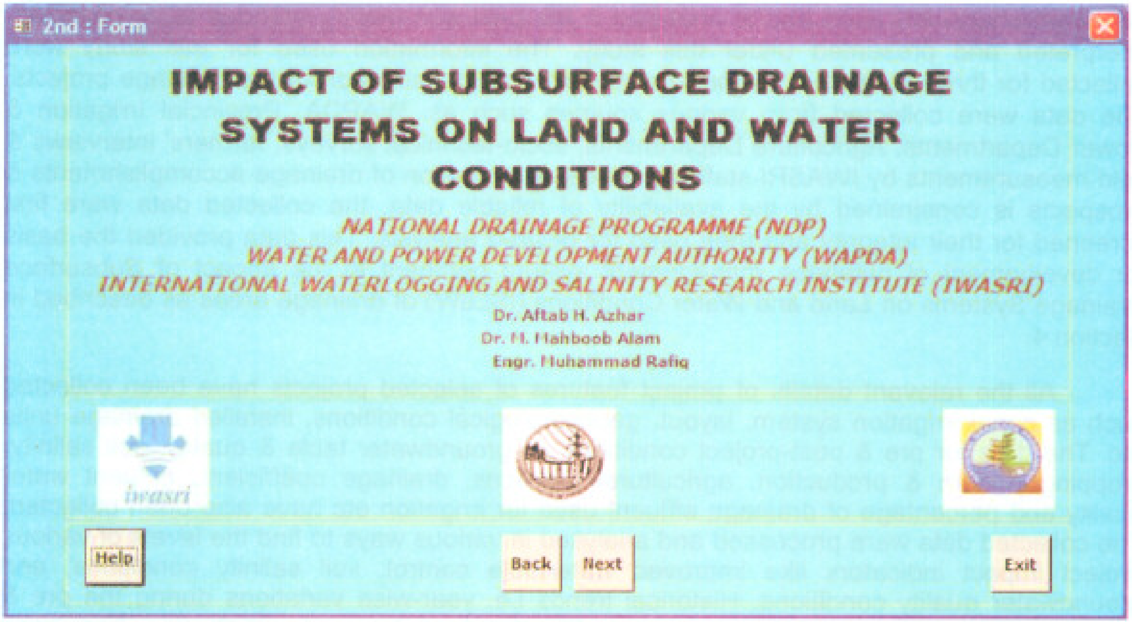


Figure 2 Main Menu of ISLaW Database System

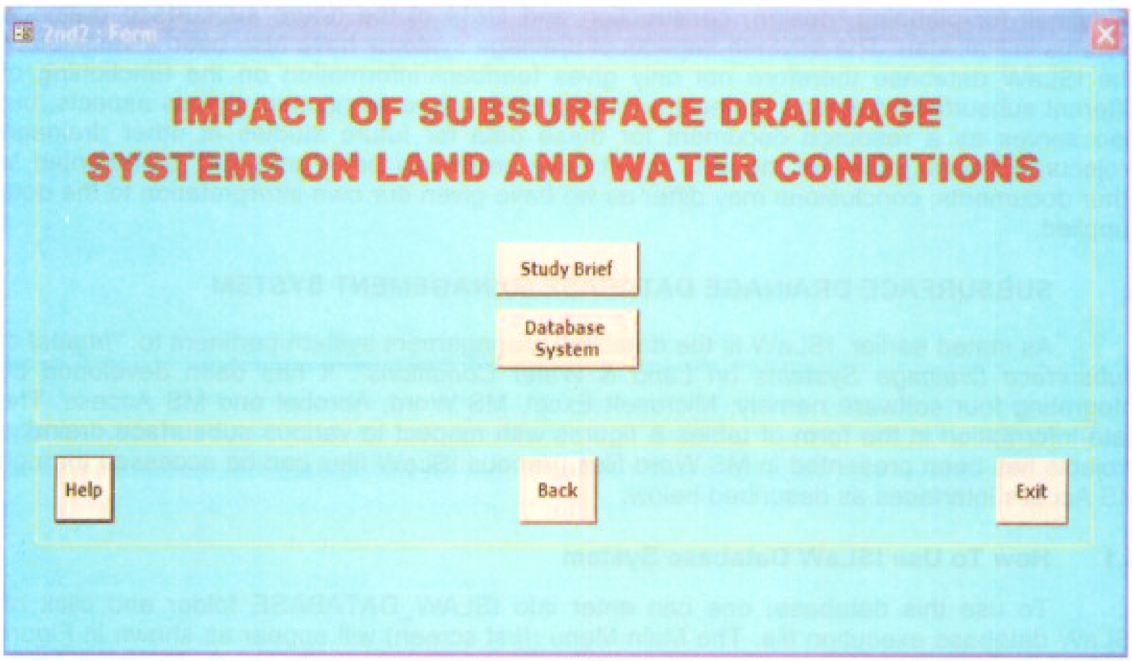


Figure 3 First Sub-Menu of ISLaW Database System

This screen will allow the user to enter into the main database system. The major data sets of various drainage projects contained in the ISLaW have been categorised as follows:

1. Technical Aspects
2. Groundwater & Soil Salinity Aspects
3. Socio-technical Aspects
4. Agro-economic Aspects
5. Operational Aspects

Entering button on left side of each aspect (Figure 4) will allow moving around the data with respect to that aspect. For example, pressing button on left side of *"Technical Aspects"* will open another sub-menu as shown in Figure 5. Pressing *"Details"* button of this screen will allow entering into technical aspects of various drainage projects contained in the ISLaW database system.

Similarly, the *"Groundwater & Soil Salinity Aspects"* button in Figure 4 will allow moving around the data with respect to that aspect. Pressing *"Details"* button of that screen will allow entering into the relevant features of that aspect. For example, as shown in Table-1 and Figures 6 through 9.

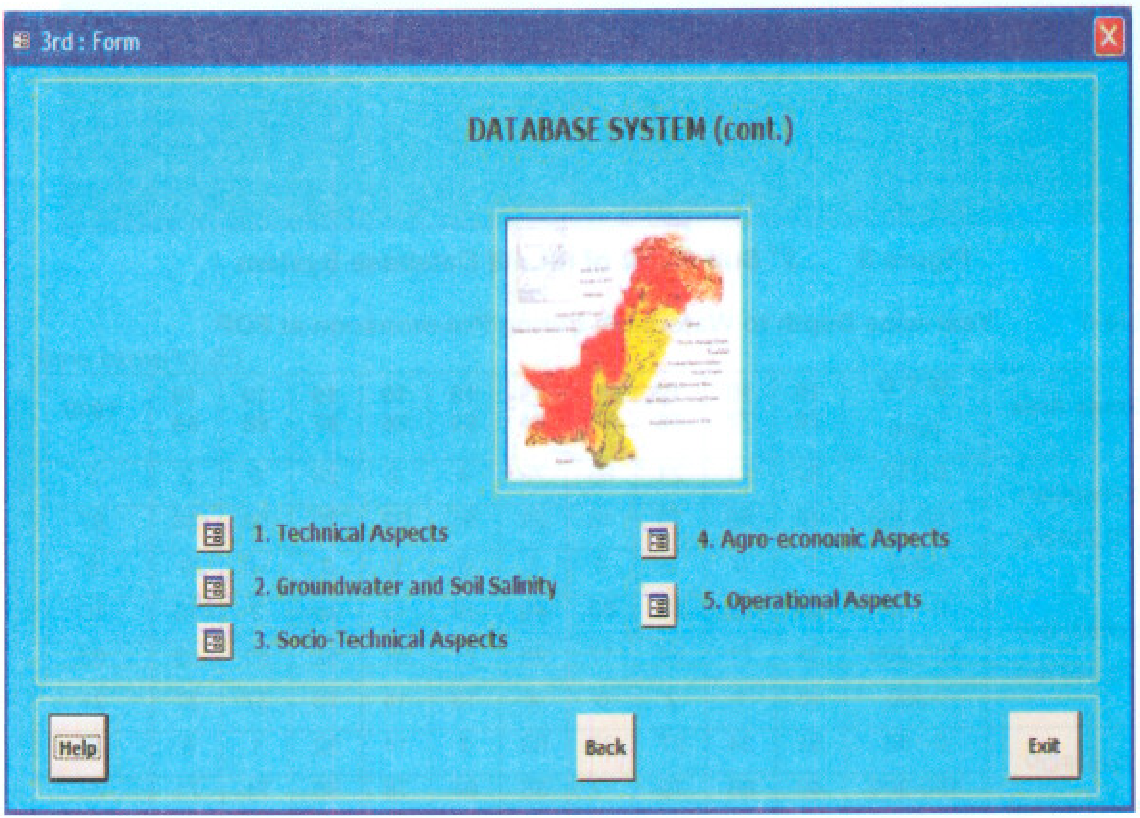


Figure 4 Second Sub-Menu of ISLaW Database System

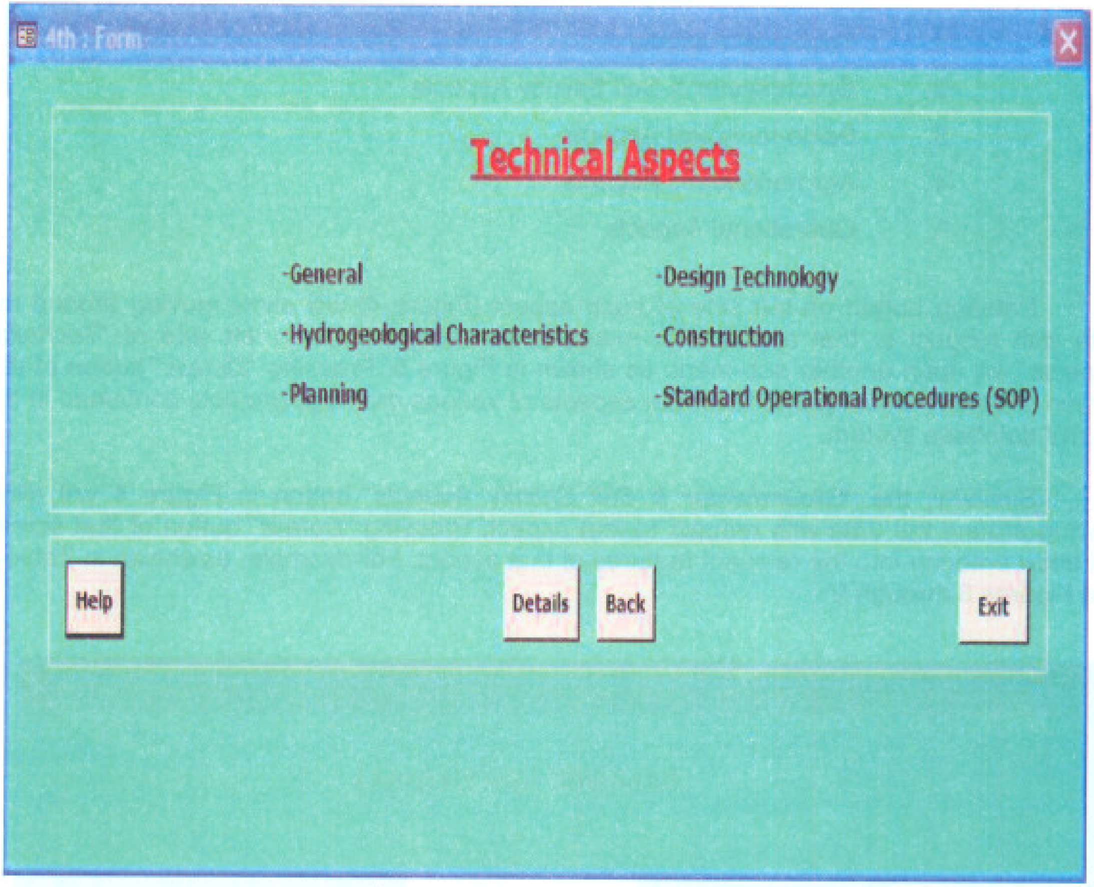


Figure 5 3rd Sub-Menu of ISLaW Database System

Table-1 Year-wise Depth to Watertable during Pre-monsoon at FDP

(% of gross area)

Gross Area	W.T D (cm)	1976	1977	1978	1983	1984	1985	1986	1987	1988	1989	1990
Schedule-I (70,294 ha)	0-150	52	41	21	85	79	4	2	28	0	2	5
	150-300	46	59	79	15	21	91	89	70	82	88	87
	>300	2	0	0	0	1	6	9	2	18	9	8
Schedule-II (73,046 ha)	0-150	51	29	35	83	48	10	19	35	2	10	10
	150-300	34	71	64	17	48	77	67	52	61	53	63
	>300	15	1	2	0	4	13	14	13	37	37	27
Total FDP (1,43,340 ha)	0-150	51	34	27	83	63	7	11	32	1	6	8
	150-300	40	66	72	17	35	84	78	60	71	71	75
	>300	9	0	1	0	2	9	12	8	28	23	18

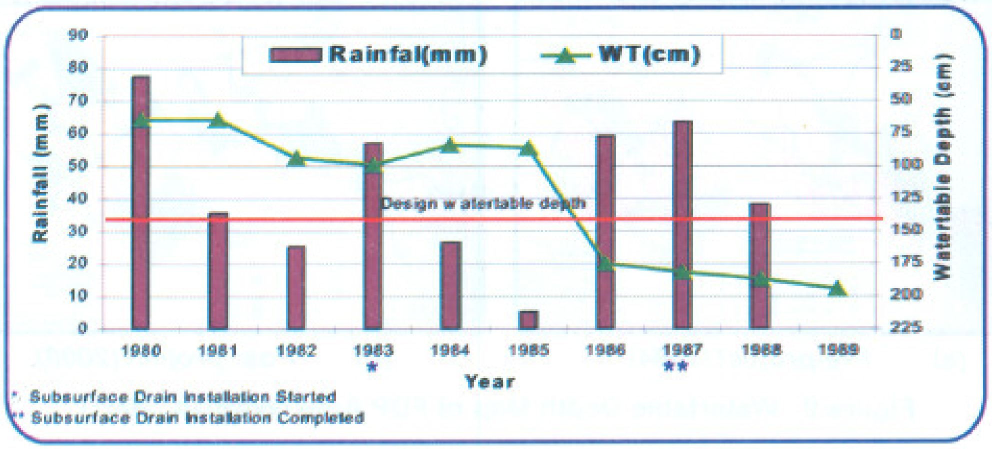


Figure 6 Average Watertable Depth & Rainfall in MSP Contract-I Area

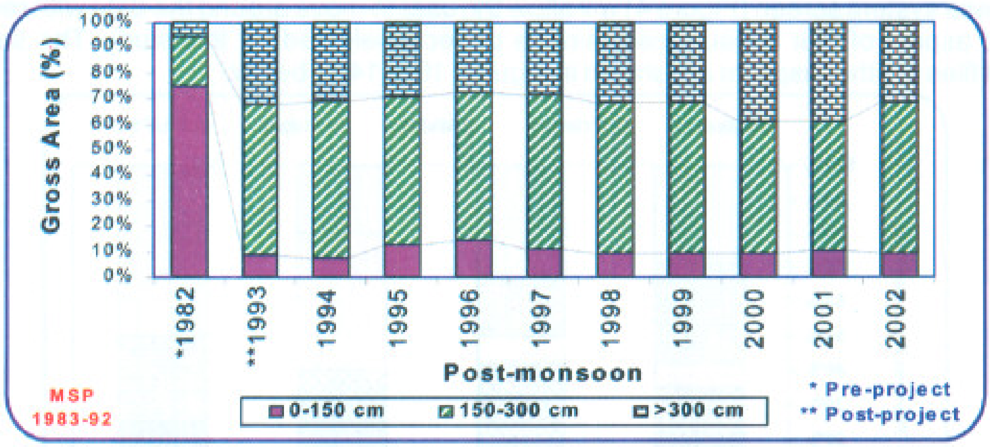


Figure 7 Percentage of Area under Various WT Depths at MSP

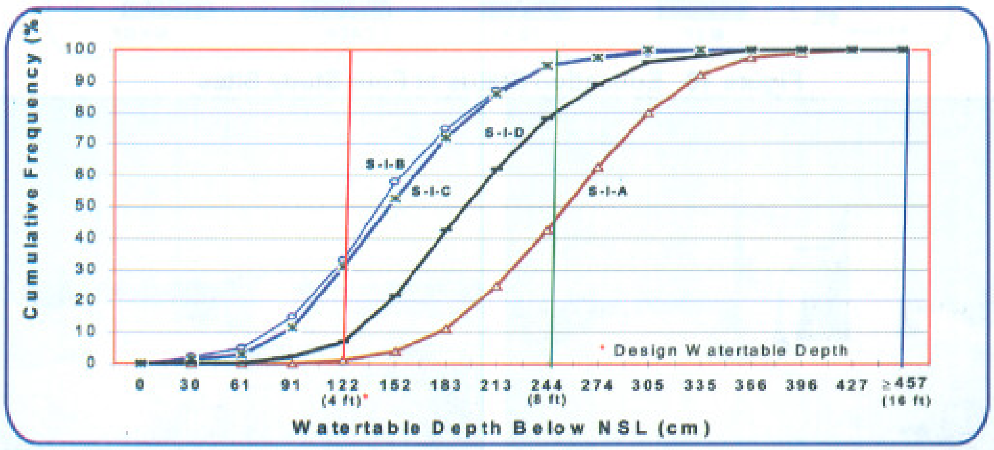
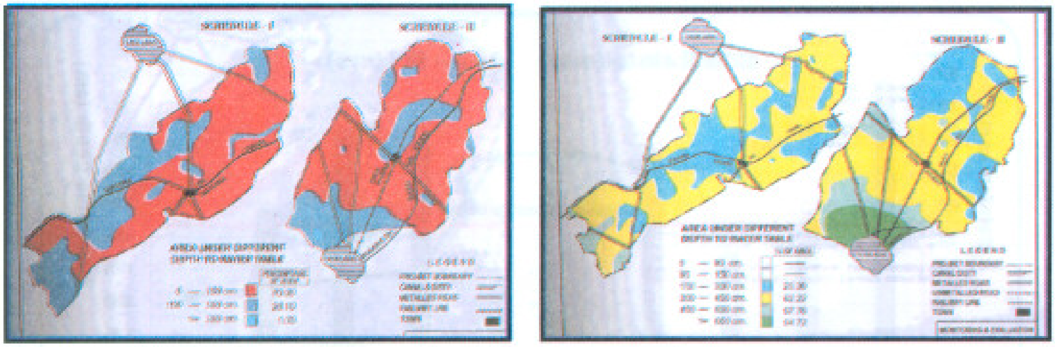


Figure 8 Frequency Analysis of Watertable Data of FDP for 1993-95 Period



(a) Pre-project (1984) *(b) Post-project (2000)*

Figure 9 Watertable Depth Map of FDP Area (WAPDA, 2001)

By the same token, entering button on left side of other aspects in the main database system screen (Figure 4) will allow the user to move around the data with respect to that aspect of four subsurface drainage projects selected for this study. The sample output files of other aspects are shown in Figures 10 to 14 as below;

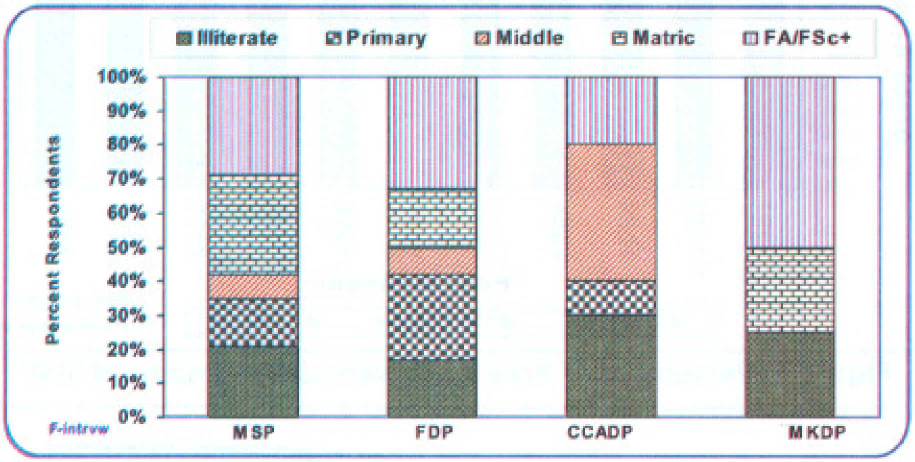
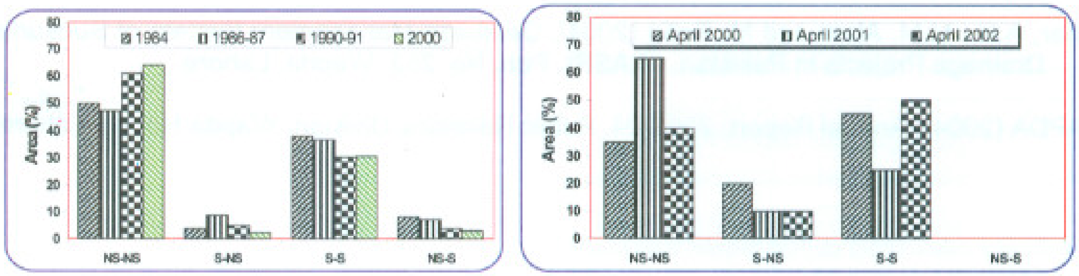


Figure 10 Education Status at Four Study Sites

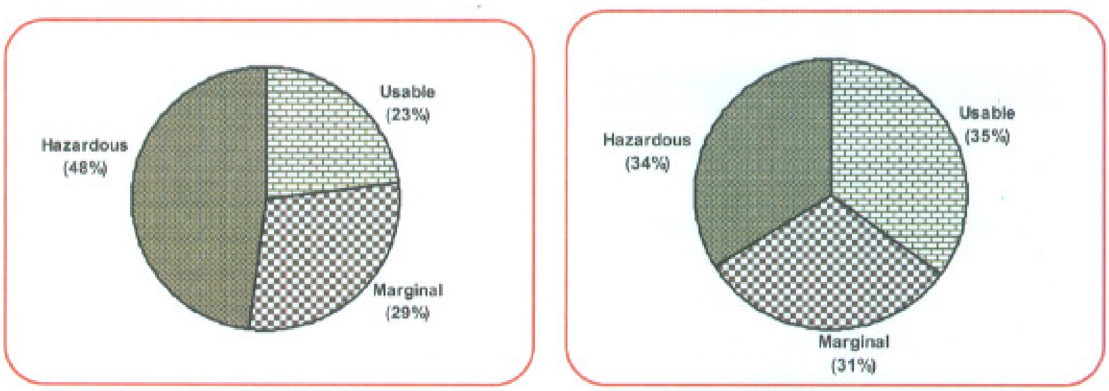
Figure 11 O&M Problems of Sumps at FDP Study Site

Figure 12 Operation of Sumps/Outlets at Various Study sites



(FDP) ***(MKDP)***

Figure 13 Profile Salinity Status



(a) Pre-project (1985) ***(b) Post-project (2000)***

Figure 14 Comparison of Shallow Water Quality at FDP

5. CONCLUSIONS

A simple user-friendly menu-driven database management system pertinent to ***I***mpact of ***S***ubsurface Drainage Systems on ***L***and ***a***nd ***W***ater Conditions (ISLaW) has been developed for use in waterlogging & salinity management issues of drainage areas. The ISLaW database has been developed by integrating four software namely; Microsoft Excel, MS Word, Acrobat and MS Access. The information in the form of tables & figures with respect to various drainage projects has been presented in MS Word files. The major data sets of various subsurface drainage projects included in the database are: i) technical aspects, ii) groundwater & soil salinity aspects, iii) socio-technical aspects, iv) agro-economic aspects, and v) operational aspects. The various ISLaW files can be accessed just by clicking at the Menu buttons of screen of the database system. This database not only gives information on the functioning of various subsurface drainage projects with respect to above mentioned aspects, but also serves as a resource document for these data for future studies at other drainage projects. Although some of the data might have previously been analyzed & presented in other documents, conclusions may differ as we have given our own interpretation to the data supplied. The developed ISLaW database system is useful for planners, designers and Farmers Organisations for the improved operation of existing as well as planning for future drainage projects.

6. REFERENCES

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