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Conservation of Water Resources of Pakistan

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CONSERVATION OF WATER RESOURCES OF PAKISTAN

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ABSTRACT

Despite having the world's largest and contiguous irrigation system, Pakistan is facing water shortage resulting in food crises of un-precedent magnitude in forthcoming years. Surface water availability for irrigation has been more or less stagnant for past so many years and ground water resource have also appeared to its maximum utilization. The overall water availability is in-fact declining due to progressive sedimentation of existing storage and gradual lowering of water table in the fresh ground water areas.

Water logging and salinity, a major threat to sustainability of irrigation system is rapidly deteriorating irrigated areas. Future shortfalls in water availability against requirements are expected to be about 40, 102 and 151 MAF in years 2000, 2013 and 2025, respectively, causing food, fibre and edible oil shortfall of magnitude of 23.5 million tons in year 2000 and 48.5 million tons in year 2013. Various management options for development, conservation and efficient utilization of water resources have been identified. These include construction of new storage, modernization of irrigation system, conservation of existing water storage and effective conjunctive use of surface and ground water resources.

INTRODUCTION

Water is life-blood for human beings. Pakistan has world's largest irrigation network in the form of canals, distributaries and water courses, with its own inherent benefits, operational and management problems. In the recent past relevant works have been carried out to increase the existing system efficiencies through options such as lining of canals, water courses improvement, farmers participation etc. The surface water resources are provided by the River Indus and its tributaries with an average annual supplies of 145 MAF, of which 104 MAF is diverted for different purposes as direct off-take or by way of storage reservoirs, 41 MAF outflows to the sea.

Water Sector Investment Planning Study (1990) has reported food, fibre and edible oil shortfall of 23.5 million tons in year 2000 and 48.5 million tons in year 2013. The water availability would fall short of requirements by 40.3, 107.3 and 150.8 MAF in years 2000, 2013 and 2025 respectively. (Mohtadullah, 1997).

In arid and semi arid regions the greatest threat to the sustainability of irrigated agriculture comes from accumulation of salts in soils. Presently about 104 MAF of water is diverted from the rivers into the canals of the Indus basin for irrigation over 35 million acres of land. This water contains about 28 million tons of salts (GOP, 1994). The area which lies at the tail of distributaries with limited canal supplies give rise to secondary salinization having adverse effect on crop yields.

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The overall irrigation efficiencies are reportedly low, of the order of 35 to 40%. Most system losses are due to canals, water courses seepage and field application. In addition to river diversion, over 40 MAF are pumped annually from ground water by about 15000 public and 400,000 private tubewells. Much of this is recovered from system losses due to seepage in areas underlain by fresh ground water aquifers. Seepage from channels in areas under lain by saline ground water aquifer is completely lost to irrigation and adds to the drainage surplus (World Bank, 1996).

The total 314,259 sq. miles area of the country is divided into three hydrological regions which include the Indus Basin, the closed basin of Kharan Desert and the Makran coastal area streams discharging into Arabian Sea. The flows of the Indus river system dominate surface water resources of Pakistan. The desert area in South lying outside the Indus Basin have no surface water resources.

With the population of 131.6 million in 1995-96, Pakistan ranks as the ninth most populous country in the World. The population is estimated to have been growing at a rate of 3.1% since 1961. The rising volume of population and the associated social and economic activities all depend, directly or indirectly on the exploitation of water as a resource. The population of Pakistan nearly doubled over first half of this century, as reported by Pakistan Economic Survey.

OVERALL WATER SCARCITY

Pakistan as a whole is in water short environment and its irrigation is based on the distribution of available water to the maximum possible area. An analysis of the situation at the full potential development stage shows that even if entire available surface and ground water is utilized, there would still remain a deficit of over 10 MAF in the year 2000 (Mohtadullah, 1993). In addition to agriculture use, more water should be required for Municipal and industrial uses.

In Pakistan, annual per capita water availability was about 2500 M^3 in 1951, which would drop to around 1000 M^3 by the year 2000, a level commonly taken to indicate scarcity of water. It means that water resources in Pakistan are quite limited as compared to future demand (Asrar, 1997).

FUTURE WATER REQUIREMENTS AND AVAILABILITY

Scarce water availability and continuous degradation of soil due to water logging and salinity, water and wind erosion, sodicity, flooding and ponding, are some of the major factors in achievement of self sufficiency. Future water requirements and availability is given in Table-1 (Malik Bashir, 1995).

Table 1: Water Requirements and availability (MAF)

Year	2000	2013	2025
Population (Million)	148	207	267
Water Requirements			
Irrigation	143.1	206.4	
Non-Irrigation	5.9	8.7	
Total Requirements	149.0	215.1	277.4*
Water availability			
Total Surface & Groundwater	108.7	112.4	125.6
Shortfall	40.3	102.7	150.8

(* At watercourse head, **Evaporated)

Water availability for the future has been estimated at 108.7, 112.4 and 125.6 MAF if 3 dams namely Kalabagh, Basha and Skardu are constructed in year 2005, 2013 and 2025 respectively. Without requisite water supply, food and fiber deficit would be irrecoverable.

DEPLETION OF RESERVOIR CAPACITY

Reservoir sedimentation is one of the major problems, as the available capacity of existing reservoirs continues to diminish with accumulation of sediment in the storage space. Existing reservoir storage capacities are given in Table-2. Tarbela stores about 1/6 of the flows of river Indus while the entire sediment is retained due to about 98% trap efficiency. Average inflow of sediment at Tarbela is 0.55 MST per day and storage lost is about 0.11 MAF per year. Average sediment into Mangla reservoir is 0.164 MST per day and storage lost is 0.034 MAF per year. The pivot point of Delta in Tarbela reservoir is advancing towards the dam at a rate of about 1 km per year. Presently it is about 13.7 km away from the dam. The pivot point of delta is about 11.5 km away from Mangla Dam. The Sediment of Tarbela is much coarser and harder as compare to Mangla and other reservoirs. It is relatively more difficult to flush and problematic for turbines and structures. Figure-1 presents the longitudinal profile of sediment deposited in the Tarbela reservoir while Figure-2 presents that of Mangla reservoir.

Table-2 Storage Capacity of Reservoirs

Dams	Year of Completion	Original Gross Storage Capacity (MAF)	Remaining Capacity in Year 1997 (MAF)	Reduction In Capacity (MAF)
Mangla	1967	5.88	4.81	1.07
Tarbela	1974	11.62	9.11	2.51
Chashma	1971	0.87	0.39	0.48
Total:		18.37	14.31	4.06

About 18.37 MAF water was available for irrigation purpose in early seventies from three major storage reservoirs Tarbela, Mangla and Chashma while in 1997 it is reduced to 14.31 MAF . On

one hand storage capacity is reducing while on other hand more water is required to meet with the growing demands due to increase in population. Serious regulation problems would arise due to this loss and the system would be unable to deliver the quantum to flow to which we are used to at present.

WATER CONSERVATION STRATEGY

To overcome water shortage, it is necessary that serious measures should be taken for conservation and management of available water resources. The main issues that need to be addressed for conservation of water resources are:

1. Construction of New Storage Dams
2. Reservoirs Sediment Management
3. Ground Water Development
4. Effective Disposal of Saline Drainage Effluent
5. Evaporation Losses Control in Reservoirs
6. Judicious use for Conservation of Water

CONSTRUCTION OF NEW STORAGE DAMS

In an agricultural country like Pakistan, storage dams are life line to the nation. These reservoirs store water and regulate releases for irrigation supplies after saving precious river waters from going into sea and play an important role in mitigating floods. Low cost hydro electric power is secondary benefit of such multipurpose projects. While our hydroelectric resources are plentiful, we are not equally fortunate to have many storage sites. For future development, the available storage sites on river Indus and its tributaries are given in Table-3. Figure-3 presents the location plan of storage reservoirs on river Indus and its tributaries. Figure-4 gives plan of profile of storage sites on river Indus. Except Kalabagh, Basha and Skardu the other sites do not have much storage. However they have considerable hydropower potential. We therefore need to develop optionally and prudently our limited number of storage sites to obtain maximum benefits both in the power and the water sectors.

The proposed Kalabagh and Basha dams together can provide 12 MAF out of which 50% would be a replacement storage lost in sedimentation. Another 2.4 MAF is needed to remove the existing stress of low water allowance for the crops and 1 MAF would be needed for municipal and industrial uses. Storage in addition to the two large reservoirs therefore will be only 2.5 MAF for enhancing cropping intensity and yields to meet the demands of rapidly increasing population. It has therefore to be well understood that there is no option of selection between the two dams, the country needs both of them for sustainability and survival of irrigated agriculture (Abdul Khaliq Khan, 1998). It is only Kalabagh dam which can supply additional irrigation water to NWFP lands in D.I. Khan district.

Kalabagh's prime role would be to regulate the Indus river for irrigation releases, Tarbela project would be operated as single purpose hydropower peaking scheme, with the minimum pool level say as 1450 ft. This would fit in well with the generation expansion plan, and would also ensure the security of the intakes from clogging by keeping the minimum pool at a high level. The generation capacity of Kalabagh would be 3600 MW and Basha would be 3500 MW. the total hydropower potential of the Indus river main stream is of the order of 30585 MW and that of tributaries 11130 MW. We must tap this renewable environmentally clean source of power.

Table-3 FUTURE STORAGE SITES

Name of Dam	River	Dam Height (Ft)	Reservoir Capacity (MAF)
INDUS			
Kalabagh Dam	Indus	260	6.1
Basha Dam	Indus	660	5.7
Skardu Dam	Indus	600	15.4
Yugu Dam	Indus	540	4.78
Thal (Off Channel)	Indus	-	2.5
Raised Chashma	Indus	12 ft Raising	0.86
TRIBUTARIES OF INDUS			
Gomal Zam	Gomal	420	0.9
Munda Dam	Swat	586	0.5
Raised Mangla	Jhelum	11 ft Raising	0.8
Kurram Tangi	Kurram	340	0.83
Kalam Dam	Swat	525	0.256
Khazana	Panjkora	380	0.55
Naran	Kunhar	640	0.25
Patrind	Kunhar	425	0.26
Dhok Pathan	Soan	300	12.00
Rohtas Off Channel	Jhelum	-	4.0

RESERVOIR SEDIMENT MANAGEMENT

All reservoirs formed by dams on natural streams are subject to some degree of sediment inflow and deposition. Pakistan is facing serious problem of sedimentation which is continuously depleting the useful storage of reservoirs, therefore the preventive measures should be adopted to conserve water by controlling the reservoir sedimentation by:

- Watershed Management: Trapping sediments upstream from reservoir.
- By passing incoming sediments past the reservoir.
- Sluicing: Passing incoming sediment through the reservoir
- Flushing accumulated deposit from reservoir.
- Mechanical removal of existing deposits from reservoir.

Watershed Management: Watershed management is the major tool to trap the sediment by constructing structures i.e. retaining walls, check dams and vegetation. Various grass types, willow and other types of trees are effective in trapping sediment.

WAPDA undertook the activity of watershed Management, particularly in the context of Tarbela and Mangla reservoirs. Mangla reservoir has gross storage capacity of 5.88 MAF. Due to the sediment load brought down by the river the reservoir started loosing its capacity from the first impounding. Original design estimated sediment rate was 42000 AF/year.

It is estimated that on successful completion of scheme, the rate of sedimentation of Mangla reservoir will be reduced by 30%. The result of the Hydrographic survey after 27 fillings of the reservoir, since commencement of its operation in 1967 show the annual rate of sediments is of the order of 34125 AF which is 18.5% less than as originally estimated.

Similarly in Tarbela Dam about 8% of the total watershed is in active monsoon belt that produce about 20% percent of the total suspended sediment load annually. This can be reduced by 40% (Tarbela Watershed Management, PC-1). Most of the sediment is contributed by snow melt from glaciers.

Tarbela Dam Sediment Management Study (1997) suggested that unless remedial action is taken, the reservoir will be largely filled up with sediment by the year 2040. The structures and power house start facing problems due to sediment by year 2010. It is proposed that the reservoir will be flushed through low level tunnels to be situated on the left abutment, between the service spillway and the auxiliary spillway. Mathematical and physical model studies are underway to assess the flushing of Tarbela reservoir. If proved feasible and implemented, a part of Tarbela storage can be made sustainable.

Large scale dredging, as required at Tarbela and Mangla is not feasible. The experience of dredging can be used in small reservoirs like Simly and Khanpur or to alleviate problem caused by localized deposits in approach channel or tailraces for low head hydropower such as Chashma Hydropower.

GROUND WATER DEVELOPMENT

Ground water in Pakistan is an important source for irrigation, domestic and industrial water supplies. The Indus plain comprise alluvium predominantly sandy silts to depth in excess of 1000 ft. in Punjab and Upper Sindh, tapering down to some 200 ft. in the Lower Sindh. In total, about 24.7 million acres are underlain by usable ground water. The remaining area is underlain with highly saline unusable ground water. Figure-5 shows areas of good quality ground water and saline water. Recharge to ground water is estimated at about 45.57 MAF per annum. Most of this recharge is from surface irrigation supplies (Federal Planning Cell, 1990).

The Government does not have effective control over ground water pumpage. Nearly 44 MAF of ground water is being pumped for conjunctive use with surface water by Public and private tubewells, mostly in fresh ground water. The ground water contributes over 40% of the total irrigation supplies. This uncontrolled abstraction may deplete the ground water, as in 14 out of 45 canal commands, the water table is already declining (Mohtadullah, 1993) e.g. Water table depletion rate in Lahore is 2 ft. per year. It is required to check uncontrolled abstraction and planned development of ground water aquifers.

Methods of ground water recharge are given below:

i) Construction of Delay action dams.
ii) Artificial recharge of underground formation
iii) Multiple storage on a single river for recharge
iv) Use of river flood water for ground water recharge
v) Use of surface runoff to infiltrate into ground through inverted filters.

EFFECTIVE DISPOSAL OF SALINE DRAINAGE EFFLUENT

The disposal of saline effluent into streams or through existing wet lands causes increase in salt levels and changes water quality. The connection of wetlands to large catchment increases the risk of pollution by dumping of chemicals. Evaporation ponds are a hazard, particularly when subject to rainfall or storm water inflows which can cause to overtop or spread. Lateral seepage and the contamination of ground water and low laying land may be a problem in some localities.

The sub-surface drainage effluent generated in saline ground water area, is about 3.5 MAF of which about 1.5 MAF is in the Punjab and 2.0 MAF is in Sindh (Shams-ul-Mulk, 1993). This effluent is disposed into various water bodies including canals, rivers and ponds.

Disposal option currently in use is a disposal within the system which is not environmentally accepted on a large scale and the other one is disposal outside the system like Left Bank Outfall Drain.

The main water quality concerns include:

i) Disposal of untreated industrial and municipal effluent in rivers, drains and irrigation channels: This results in degradation of surface water quality. The dissolved and suspended salts in the industrial effluent range from 500 PPM to over 50,000 PPM.

ii) Disposal of the pumped saline water in the drains, canals and river, affect the quality of surface water particularly during the low flow regime. Saline effluent from Punjab's irrigated areas is estimated as 2.94 MAF.

iii) Disposal of untreated effluent from the cities and towns into drains, canals and rives: The pollution loads from major cities include 443 tons BOD/day from Karachi, 247 Tons BOD/day from Lahore and 42 tons BOD/day from Multan and Rawalpindi/Islamabad. About 500 cusecs of domestic water from each of the two big cities if treated can be used effectively.

iv) Excessive application of fertilizers and pesticides by farmers effect the quality of ground water, particularly in the shallow aquifers.

EVAPORATION LOSSES CONTROL IN RESERVOIRS

The total loss of water in an irrigation system comprising of the storage, conveying system and irrigated area may be as much as 65% of the stored water in the reservoir; of this about 15 to 20% evaporation is from the reservoirs alone.

Basically there are three methods available for controlling evaporation from the reservoir.

i) Those that reduce the surface area.
ii) Those that mechanically cover the surface.
iii) Those that cover the surface with a thin film.

The method covering the surface with a thin film appears most economical and offers the greatest potential for evaporation reduction in small reservoirs..

Presently cetyl alchol also called Hexadecanol ($C_{16}H_{33}OH$) is being used for evaporation reduction in Australia, U.S.A., India, East Africa and Israel. Cetyl alchol can be dispensed in the form of pellets, powder, emulsion or solution. Spreading rate of solution is very fast.

JUDICIOUS USE FOR CONSERVATION OF WATER

Judicious use of water is one of the best way to conserve the water resources. There is an urgent need to conceive and implement coherent and holistic strategies for scientific management of water resources which includes demand side management, water quality control and control on wastage of water in fields.

DEMAND SIDE MANAGEMENT

The stress on the plant due to water deficit affects badly on crop yields which can be overcome by demand side management. It include the following alternatives:

- Staggering of cultivation to reduce peak water requirements.
- Growing water efficient crops in order to optimize allocation of scarce water resources.
- Agriculture practices to optimize water use. A recent study (NDC 1997) has indicated that 30 to 40% water saving could be affected for rice cultivation in Sindh by modifying irrigation from continuous (Parcho) irrigation to weekly water application.
- Reduction of irrigation area by excluding area covered by saline, poor or marginal soils.

- Allocation of water to preferential crops during sensitive stages of growth.
- Application of modern irrigation techniques such as drip, sprinkler and burried pipes.

WATER QUALITY CONTROL

- Preventive measures should be adopted for reducing drainage surplus in the saline ground water areas.
- Proper legislation and strict enforcement of water quality standards for the industrial and the municipal effluent.
- Phased treatment of industrial effluent, starting with the treatment of the most harmful effluent in the first phase.
- Proper planning for setting up of industries; their sitting, grouping and waste water treatment needs.
- Checking the excessive application of fertilizers and pesticides. Farmers should be trained in the optimal use of these inputs.
- An appropriate inspection mechanism for checking water quality at key points to avoid the stream and reservoir pollution.

CONTROL ON THE WASTAGE OF WATER IN THE FIELD

To get threshold output from the fields, the leakage and seepage of water from water course should be reduced to its permissible limits which can be obtained by the following recommendations.

1. Cleaning, de-silting, lining, straightening, re-aligning, re-shaping, re-modeling and renovation of common water courses.
2. Usage of scientific water and soil management techniques and modern agriculture system.
3. Precision levelling of fields to avoid flooding and dry pockets.
4. Important knowledge, benefits of mechanized farming procurement of agriculture machinery and equipment training in its operation, repair and maintenance and issue of the same on hire.

CONCLUSIONS

Due to rapid increase in population during the last 50 years, Pakistan is facing serious water shortage resulting in food crises. Food and edible oil imports would be increased by the end of the century. Despite having the world largest irrigation system, Pakistan is facing problems, like water deficiency, low irrigation efficiency, environmental degradation, slow agri growth and irrigation system management.

The overall water scarcity, escalating future demand and stagnating water availability, large annual and seasonal fluctuations in river flows, inadequate storage capacity and progressive reduction in the capacity of the existing reservoirs due to sedimentation, over exploitation of fresh aquifers and degradation of water quality are the emerging threats.

For the susceptibility of the irrigated agriculture and to mitigate the ill-effects of secondary salinity developing at an alarming rate, the nation need good quality water to reclaim the root zone and to maintain optimum salt balance. Without additional storage facility the extra good quality water is simply not possible to obtain.

Estimated water deficiency is about 40 and 107 MAF in 2000 and 2013 and also food and fiber estimated shortages are 23.5 and 48.5 million tons in 2000 and 2013 respectively. Kalabagh Dam with 6.1 MAF live storage capacity is technically economically feasible and economically viable. The other storage reservoir can be Basha and Skardu.

RECOMMENDATIONS

1. Earliest possible construction of not only Kalabagh but also multipurpose dams to conserve substantial quantity of 40 MAF of water flowing to the sea.
2. Implement reservoir sediment management programme.
3. Optimize water conveyance and application efficiency including use of new technology such as drip, sprinklers and burried pipes.
4. The water course improvement programme with optimum lining should be accelerated and made more cost effective.
5. Preserve quality of water by enforcement of environmental protection laws.

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Fig:1 TARBELA DAM PROJECT

RESERVOIR LONGITUDINAL BED PROFILE

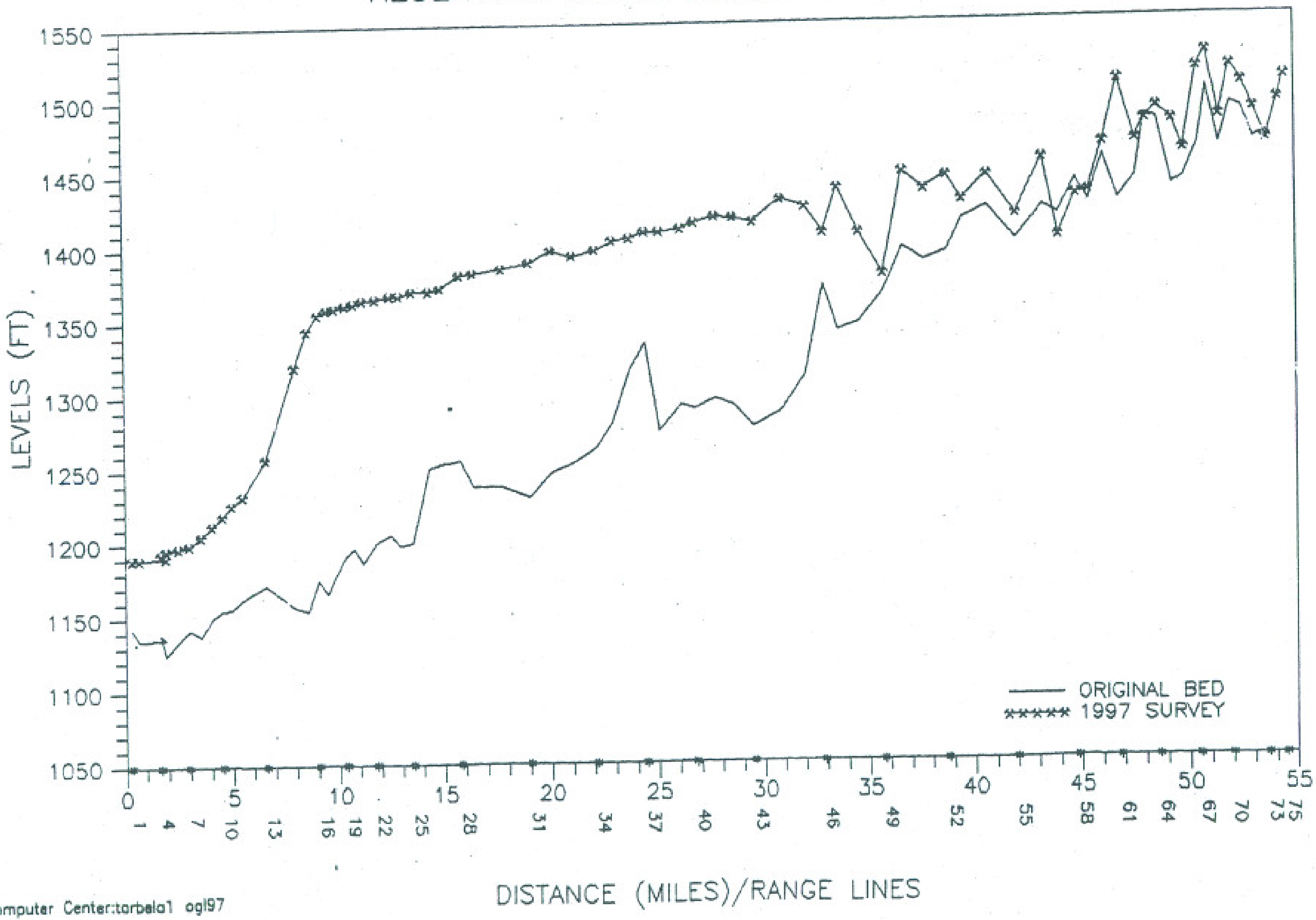

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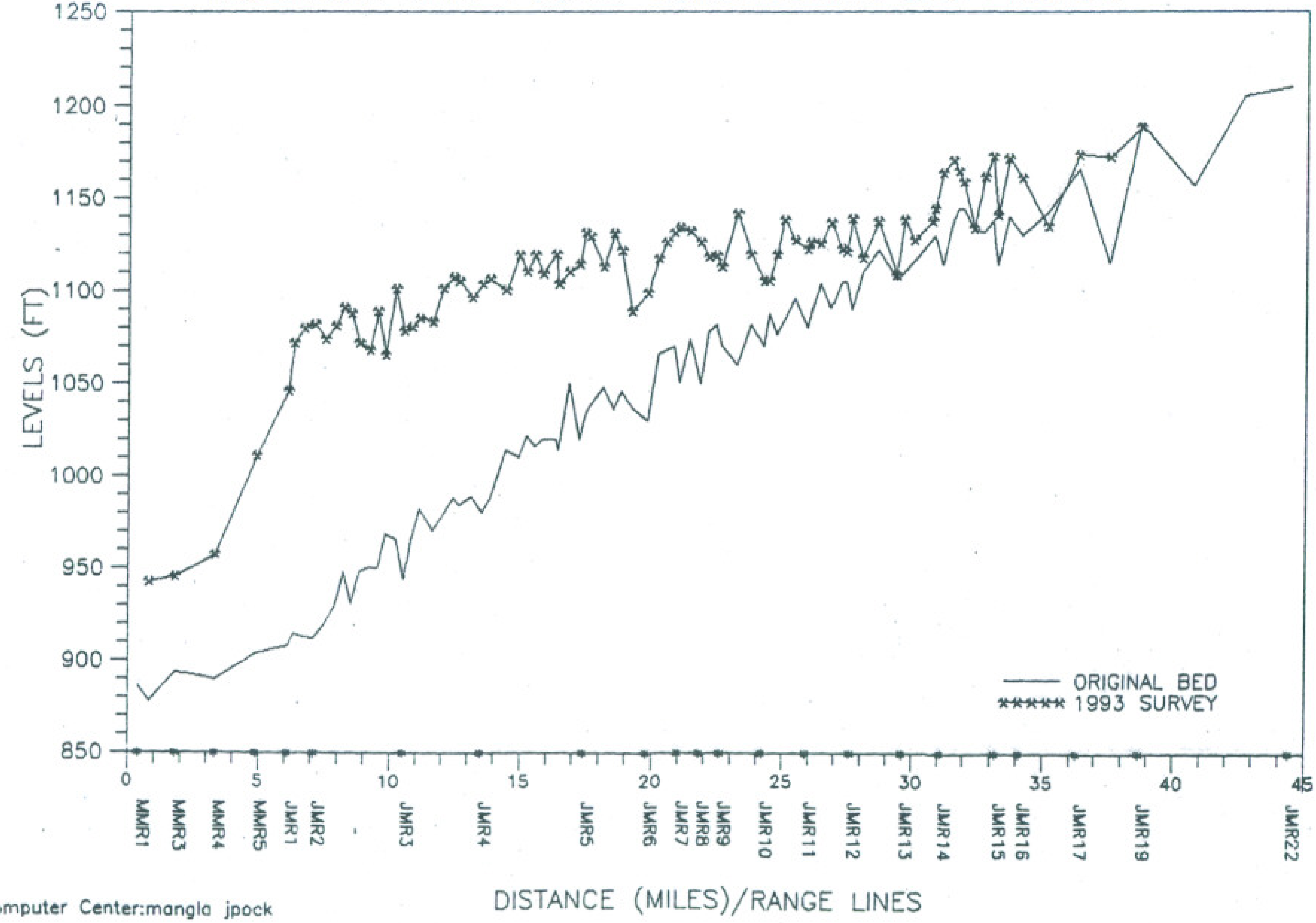
Fig:2 MANGLA DAM PROJECT

RESERVOIR MAIN POCKET LONGITUDINAL BED PROFILE



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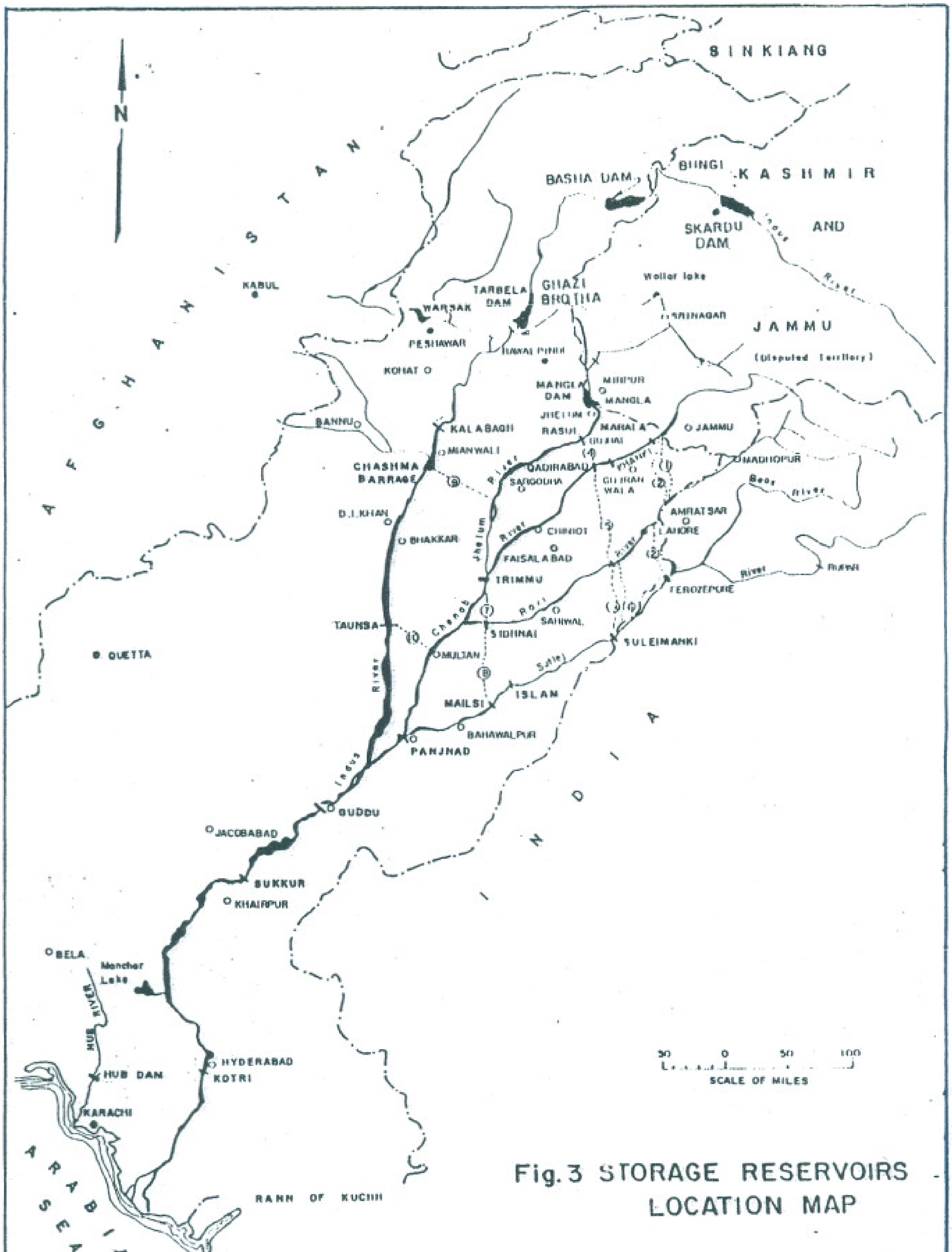

Fig. 3 STORAGE RESERVOIRS LOCATION MAP

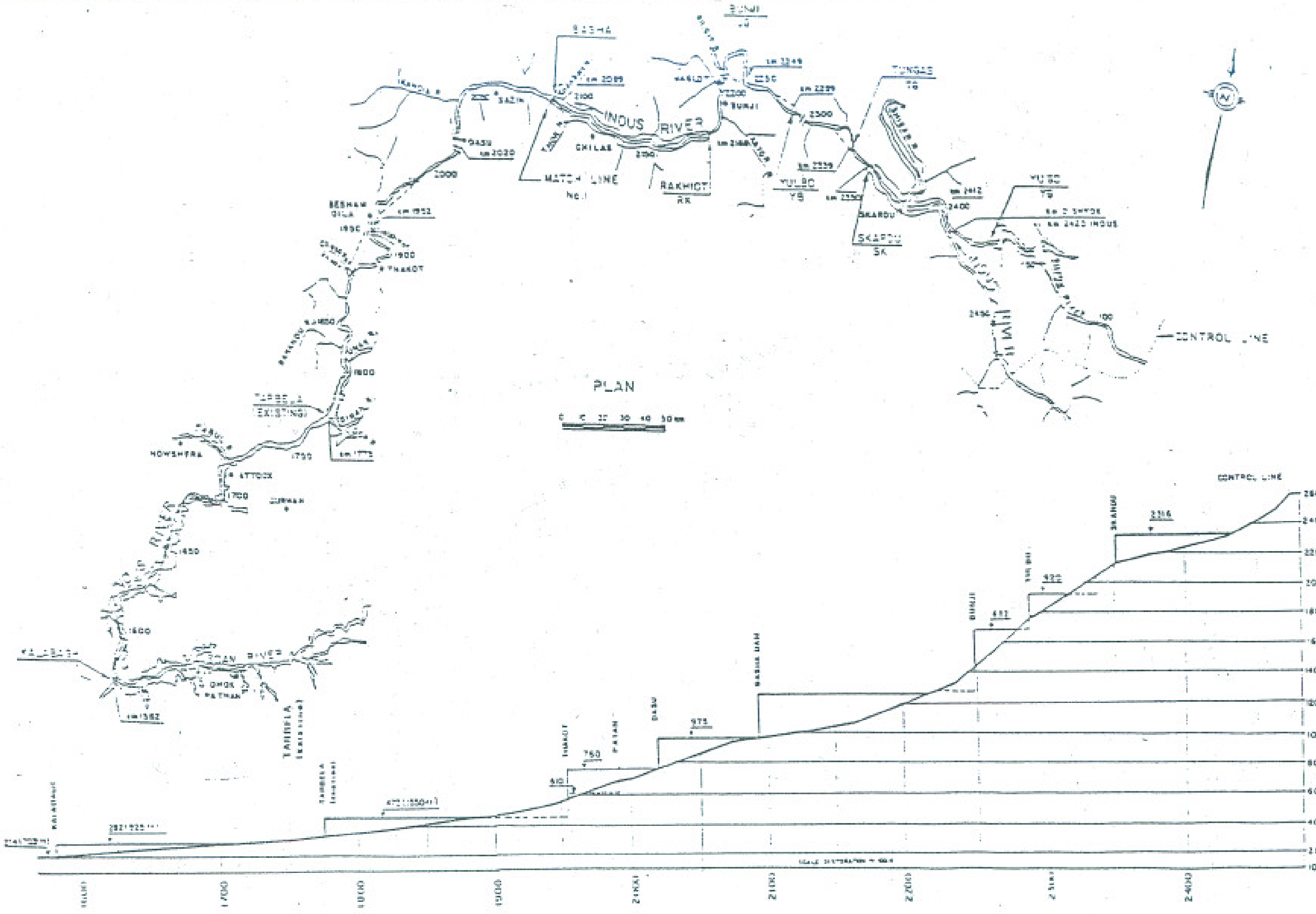

Fig. 4 PLAN AND PROFILE OF STORAGE SITES ON RIVER INDUS

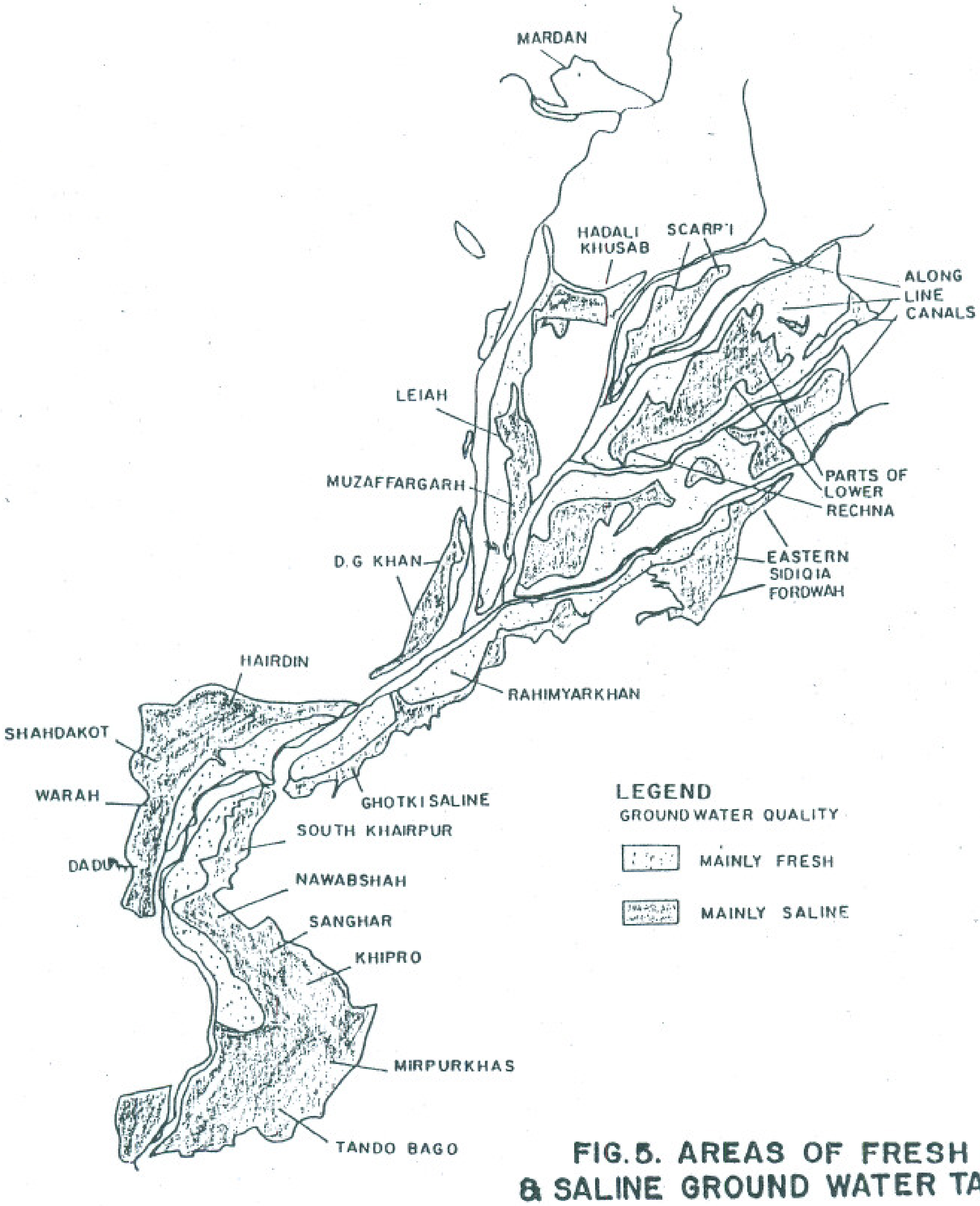

FIG.5. AREAS OF FRESH & SALINE GROUND WATER TABLE