The Present & Future of Silt Excluding Devices

By

*MOHI-UD-DIN KHAN

Introduction.

West Pakistan is an arid country. The economy of this wing depends mostly on irrigated agriculture. The rivers of the Indus Basin which flow through West Pakistan have played a great part in supporting great civilizations such as Harappa and Mohenjodaro as far back as 5000 years ago. At present West Pakistan has the biggest contiguous irrigation system in the world. As civilizations have depended mostly on rivers in areas like West Pakistan, they have been appropriately termed as "hydraulic civilizations".

West Pakistan is fully utilizing all the flow supplies of the rivers, Indus, Jhelum, Chenab, Ravi and Sutlej except in the flood months. The existing culturable commanded area in the Indus Basin is 33 million acres against the present annual irrigation of 23 million acres. Even in the existing irrigated area the yields of crops are far below the standards based on modern agricultural methods. The major cause of low production is the insufficient quantity of irrigation water. The culturable commanded area under canals is less than 50 % of the total culturable area in West Pakistan. The position is quite critical as West Pakistan has to depend on storage dams as the existing method of diverson of water by barrages and canals no longer serves the purpose. The division of rivers has further accentuated this problem. The usable flow with storage on the western rivers on Indus, Jhelum and Chenab is 110 million acre feet against the existing average withdrawal of about 71 million acre feet. A vital factor is that all the best storage sites even on western rivers which are allocated to West Pakistan are in the upper reaches in the Indian held Kashmir. We have to make the best use of whatever storages are possible in West Pakistan under the circumstances. Efficient silt exclusion was possible from the barrages on the rivers but storage dams, due to their inherrent nature, have a short life. It is a matter of great concern for West Pakistan particularly as heavy amounts have to be spent on new dams. Silt exclusion if possible from any storage reservoir in West Pakis-

Director, Design & Research, Irrigation, West Pakistan, Lahore.

tan has immense value. An attempt is made to examine possibilities of silt exclusion at dams in this paper.

The Chief Engineer (Water) WAPDA read a paper in a symposium on Storage Reservoirs sponsored by Economic Commission for Asia and the Far East, Japan, 1961. He stated that storage reservoir projects in Pakistan are uneconomic as there are no good dam sites and they have limited life due to heavy rate of sedimentation. On river Indus he mentioned various dams investigated such as Kalabagh, Darband, Kotkai and Tarbela. He stated that though Kalabagh dam is more economical in capital cost, it has a shorter life than Tarbela. Out of the sites investigated on Indus he recommended Tarbela particularly as it has possibilities of off-channel storages which do not exist at other sites. To further elucidate this fact, a comparative study of the dams in Pakistan with some of the dams in Asia and Africa with similar economics is given in Appendix I. The usable life of Tarbela Dam is 60 years. In comparison, the life of the Boulder dam is 445 years. Similarly the life of the Bhakra, Aswan and Kariba dams run into hundreds of years as the storage at these sites is generally higher than the annnal runoff. In the case of Tarbela, the storage is only a fraction of the annual runoff.

It is said that rivers are the enemies of lakes and that the death of a storage starts the day it is born. A note of warning was sounded by UNESCO regarding conventional storages. A UNESCO symposium published in 1961 where scientists from all over the world assembled made recommendations as below :—

> "By refusing to learn from the lessons of history, modern man is making a number of serious mistakes in his efforts, often astronomically costly, to put the arid lands of his planet to productive use. For example, the most common method employed the world over to 'make the desert bloom' is a gigantic masonry dam, backing up waters into an artificial lake which then supplies to irrigation canals. But, on the basis of this geographical and historical survey "evidence is growing that such a system may be fundamentally wrong". Under modern methods, only clear water from a dam's reservoir is used. The silt is replaced on farmlands by artificial fertilizer and is now only a nuisance—it collects behind the dam and clogs the reservoir. "North America already has examples of reservoirs which have silted up completely in a few years.".

The above quotation shows that conventional dam sites are not taken for granted all over the world. As Mangla Dam and Tarbela Dam are also conventional dams with comparatively shorter lives than other conventional dams, an unconventional dam is being suggested in this paper so that it could be discussed in the symposium.

1. Storage for quick benefits.

Hard pressed for water. West Pakistan shall have to go in for a storage which is both economical and can be completed with speed. A new concept, which is being discussed in this paper, though unconventional has to be examined in all its details. This concept involves silt excluding devices at a low dam by creating a floodway on one side of the reservoir area to sluice the sediment. The reservoir would thus become an indirect storage. The operation of the reservoir is to be done on the same lines as that at Aswan low Dam by filling the reservoir when heavy sediment period is practically over. This approach has immence economic importance to developing countries which have no good dam sites and are in urgent need of storage. One such dam on river Indus at Chashma is being discussed in this paper. Exhibit I shows Chashma and other dam sites.

2. Chashma Dam on River Indus.

It may be mentioned here that the idea of a storage in this reach of the river Indus is not new. Around 1950-51 a proposal was made to have an earth dam across river Indus opposite Mianwali. This proposal was considered in 1953 by the Link Committee of West Pakistan Irrigation Department also. Recently an irrigation canal to irrigate areas on the right bank of the Indus was investigated from Kalabagh which proved very uneconomic due to the difficult nature of the terrain through which it had to pass. A barrage at Chashma 35 miles downstream of Kalabagh would do away with this difficult head reach of the canal and make irrigation on the right bank of Indus economically feasible. A barrage on Indus was suggested for this purpose as well as for taking off Chashma-Jhelum Link. This canal is more economical and has many other advantages as compared with Kalabagh-Jhelum Link. The idea of storage at Chashma has been put forth to make it multi-purpose and meet the acute shortage of water on the Indus in critical months and the need for immediate development for self-sufficiency in food.

The barrage proposed for Chashma-Jhelum Link was to have a pond level of R.L. 639. It is seen from the storage elevation curve of Chashma dam (Exibit II) that this barrage can give a storage of 3.2 m.a.f. with a pond level of 660. This is probably one of the highest storage with the minimum height of dam available anywhere. The peculiar topography of the site with hills and high ground on the west and a high bank on the east with a wide valley in between has made this possible. As the Indus is a perennial river with a large discharge, the head across this dam and the dykes in the river bed too do not exceed 40 feet. The proposal becomes simple and is no more than a barrage for 40 feet head across, which is not unusual as we have reached nearly 20-30 feet in some of our modern barrages. The dyke in the river bed silt and sand could also withstand this head across without any elaborate upstream blanketing or cut-off. The section through the river is shown as Exhibit III. It is also seen from the plan of the reservoir that 660 contour is mostly below the high bank except in a length of a few miles close to the dam. A low dyke is proposed upto Kundian on the east and near Isakhel on the west. As the reservoir depletes the level will come down and by the end of October, there will be substantial depletion.

3. Salient features of the design of Chashma Barrage.

The barrage would be located near the right bank of the river. An interesting feature of river Indus in this reach is that there is a deep channel hugging the Khaisora range on the west, a distance of 12 miles upstream of the proposed barrage. The river has never left this range according to past history. The barrage will be about a mile long to pass maximum flood discharge of river Indus below HFL of 639. The minimum water level at this site is RL 620 and the crest level could be kept at the average bed level to work as efficient scouring sluices. The standard span of the qatos would be 30 feet. The height of the gates could be economised by a brest wall or as an alternative a buttress and slab dam could be con sidered. A suitable site has to be fixed after making detailed field investigations of soil, etc. To quote an example, the Nangal dam which was constructed on river Sutlej, India, recently has a height of 95 ft. designed for a maximum head across of 54′. It has 26 bays of 30 ft. span.

As an alternative to a barrage, a spillway in the side of the Khaisora range by cutting the rock could also be examined. The main spillway provided in the Kalabagh dam project for a discharge of 1,400,000 cusecs with a high flood level of 950 had a waterway of only 800 feet with height of gates 38 feet. On the same lines a narrow spillway could be provided by cutting the rock in the side of Khaisora range. This will be efficient for sluicing the sediment through the dam but enough safeguards have to be provided to keep the head regulators taking off on either side free from sediment.

The marginal bund at Chashma is a common feature in all barrages on Indus, the one at Taunsa is 8 miles long. This would form the dyke across river Indus and also serve as the left bank of Chashma-Jhelum Link. This is about 6 miles long with an average height of 40 feet. This includes 10′ of free board over the maximum pond level of 660. The cross section of the river, Exhibit IV, would clear the position. The work of 6 miles dyke to an average height of 40 feet in the bed of the river Indus is not a difficult work as it is known that an earth dam of 11 miles length and 70-feet height was constructed in Ceylon as far back as 504 B.C. No specialised techniques are involved in a dyke of this nature as it comes within the category of low dams. There shall be two head regulators at the barrage, one for Chashma-Jhelum Link on the left and another on the right for Right Bank Canal which connects the existing Paharpur Canal and the future High Level Canal for irrigation of new areas in Dera Ismail Khan and Dera Ghazi Khan districts. This will provide crossing on river Indus which will shorten the distance to Dera Ismail Khan by about 100 miles during floods as the only route now available to Dera Ismail Khan Is via Kalabagh or by ferry at Darya Khan which is very tedious.

The greatest attraction of Chashma site is that stone is available on the right bank along Khaisora range at very economic rates and could be used extensively not only in the barrage construction but for the dyke etc.

The economics of having a gravity cable way from the right bank could also be examined.

4. Hydraulic model studies for silt excluding devices at Chiniot Dam.

Recently a low dam on the Chenab river at Chiniot where the river cuts across a low ridge of hills was investigated in detail. The storage proposed at this site was 1 million acre feet. The dam consisted of three portions in three gorges at Chiniot. The first portion was 1.440 feet long to a maximum height of 65 feet. The second portion was 1,800 feet long to a maximum height of 77 feet. The third portion was 750 feet long to a maximum height of 42 feet. Under-sluices were proposed in the masonry portion of the dam to keep the pond area flushed. As the maximum proposed pond level was above 25 feet over the low pond level, dykes of a length of 13.1 miles on the left side to a maximum height of 42 feet and 12 miles on the right in addition to strengthening the existing bund of 20 miles were required.

Though Chiniot dam was dropped from the Replacement Plan, it would be highly unfair to condemn the idea of storages at low dams like Chiniot as it is this suggestion which encouraged us in making detailed investigations and enabled us to put-forth other feasible storages like Chashma. During the scrutiny of Chiniot Dam Project in 1959 in London as a part of the Replacement Plan, a suggestion was made by Mr. Haigh, a former Chief Engineer of the Irrigation Department, West Pakistan, to exclude the silt in the Chiniot pond by construction of stone dykes in the middle of the river to form a floodway isolated from the reservoir on either side which would flush the sediment and keep it clear of the reservoir. This was also tested on a hydraulic model in the Irrigation Research Institute, Lahore. "The model representing the reservoir area (extending upto 23 miles above the dam) 4 miles stretch of river and its flood plain above the upper limit of the two dykes on the flanks of reservoir and Chiniot hills was constructed on 1/330 horizontal and 1/50 vertical scales. The reservoir area was moulded according to contour plan. The bed of the river was mobile and sediment according to average sediment conditions at Chiniot during the years 1955-58 was injected by sand feeding machine at the head of the model.

The rate of deposition of sediment from the upper end of storage level towards the lower end of the reservoir will depend upon the fall of particles, depth of reservoir, rate of change of depth of reservoir, temperature, sediment charge and flow in the river and bed configuration of the reservoir, *etc.* The maximum deposition takes place at the place where the upper end of storage is stationary for the maximum period. Thus the maximum deposition near mile 5 and 20 is obvious. The deposit on the dead pool area will move gradually downward by the river flow during October to July period and part of it may escape through under-sluices. Thus the rate of deposition in the river itself above the reservoir is low compared to the conventional reservoir and the courser material will reach near the periphery of the reservoir level. There is retrogression of levels at all stages of flow upto fourth mile which shows that the flushing effect of the under-sluices, the bottom of which is located 20 feet below the bed of the river is discernable upto 4th mile.

In the case of a barrage due to comparatively low pondage the river attains its new regime after a few years when pre-barrage slopes are attained. In the case of the Chiniot dam the new regime will be attained after a few decades as the pondage is substantial and is much higher than the case of headworks and higher pond level applied only during 9 months of the year. The running of the model for 20 seasons shows that the total sediment entering the pond in a season is more than that escaped out of the sluices. In spite of the higher velocity generated in the middle compartment the silting tendencies are boosted up as the silt deposition area has decreased considerably. The average deposition over the berms in middle compartment after 20 years is of the order of 4-6 feet. However, some steepening of the slopes is likely to accure at the end of each season which means that the tractive force will increase at the end of each season and it is very likely that after 2-3 decades that pre-barrage slopes will be attained when the conditions will be established and no more silting of the reservoir will take place."

5. *Proposed silt excluding devices at Chashma.* Due to excellent topography at Chashma, the storge available is much more than at Chiniot and the pond level is below the ground level. As there is a range of hills and high ground on the right side with the river hugging towards them, an indirect storage could be formed by creating a floodway along the right bank. Another redeeming feature of river Indus is that there is considerable flow from October to August through the floodway when the pond level is dropped to keep the sediment properly flushed as compared with Chiniot dam which would be practically dry in this part of the year. The quantity of silt in the Indus is about half that of the Chenab in August per cusec of discharge. A model study of this along with other investigations would show how soon the pre-barrage slopes would be attained and what would be the special steps to be taken in this period to keep the floodway efficient. The delta formation would develop between the high pond level of 660 and the normal pond level of 639. The stone dyke on the left would restrict any accertion as it creates a floodway upto Kalabagh as it is connected to the guide bank of Kalabagh Headworks. As the downstream floor level of Kalabagh Headworks is at RL 670 which is 10 ft. higher over than the maximum pond level, it should not affect the modularity of Kalabagh Headworks.

All that is required is a stone dyke parallel to Khaisora range and the high ground on the right to form a floodway. The cost of the stone dyke with top at RL 665 is Rs. 60 to 70 million which is not a big percentage of the cost of Chashma dam project. This has considerable benefits of sediment exclusion and of increasing the life of the reservoir. A tip wagon track would be laid on the top of the stone dyke to carry stone for future maintenance. It is seen from the plan, Exhibit, that a stone dyke could be constructed and an excellent floodway could be formed along the Khaisora range to flush the sediment in the river Indus during the flood season. The height of stone dyke would be about 30 feet at the barrage gradually reducing towards the upstream. The idea is to pass the floods during July and August through this floodway with pond level of 639 and start storing only in the end of August or early September when the sediment is much less as can be seen from Appendix II. With these measures it can be expected that the life of Chashma reservoir could be increased many times that of a conventional storage.

6. *Operation of Chashma Barrage.* The operation proposed is similar to that of the existing Aswan Low Dam in U.A.R. which starts filling the pond some-where in October when the blue Nile subsides and the sediment content is considerably reduced. The Aswan dam stores only a fraction of the discharge passing the site. As the water escapes through the sluices in the dam, this sluicing action of the large quantity of water has kept the reservoir silt free without any other silt exclusion devices. At Chashma we want to provide a regular floodway through which the sediment shall be canalised in addition to sluices in the dam. A significant point at Chashma is that during the end of August and early September the river has a discharge of 1 to 2 hundred thousand cusecs and the reservoir on the left of the stone dykes is filled from surface water by a separate head regulator situated in the still pond area. There is not much sediment in this water. The heavier bed load that may deposit in the floodway in spite of continuous flow in the floodway could be washed away due to continuous flow from October to August through the floodway when the pond level is dropped after October. As the reservoir on the left of the floodway would be drained out by October, it is possible to raise bumper rabi crops and also early Kharif crops. This will also keep down weed growth.

The release of water from Chashma would help not only the maturing of Kharif crop but also the sowing of Rabi crop both in the existing areas and new areas and as such are very valuable as the barrages on the Indus suffer mostly in these periods. This has resulted not only in limited areas under irrigation but low yields also.

The reservoir is full by the middle of September. By October the pond would have sufficiently released its storage and in Rabi the rest of the storage will also be released. So before the middle of Rabi we would have completely depleted the storage upto RL 630 to command only the Right Bank Canal and Chashma-Jhelum link in winter. This is 9 feet lower than the summer pond level. It may be possible to raise the pond level to RL 639 again in the middle of winter when freshets in the river pass due to winter rains. This will give some storage which could be released in the end of winter for maturing winter crops.

7. *Seepage from the Reservoir.* The seepage from the reservoir does not effect the right side as most of the length is covered by Khaisora

range. The seepage on the left side could be more as the soil on the left side consists of sand but the quantity of the seepage is not likely to be much as the maximum pond level is below the ground level. The pond level is dropped down by the end of September and it is lowered considerably by the end of October. So in this period of 1 to 2 months the contribution of the pond to thc sub-soil water table could be easily taken care of by a net-work of drains which are already proposed in the Dullewala and Mohajir Branch area. The Chashma-Jhelum Link which runs in deep cutting could also act as an excellent drain. If necessary tubewells could also be put in, the seepage is likely to be considerably reduced after the first few years of the operation of the reservoir due to staunching action of the silty water. This may make it possible after a few years operation to raise the pond to 665 which gives a storage of 3·9 m.a.f. The barrage sohuld be in the first instance designed for this extra 5 feet head across.

Conclusions

In the Tipton and Hill feasibility report of 1954, an effective storage of 4·2 m.a.f. was provided. As the rate of sedimentation was found to be much more than assumed by T & H (with the little data they had a basis had to be fixed to get the same amount of water by increasing the height of dam. Taking note of the short life of Tarbela dam. WAPDA has already proposed that Tarbela should be built at least for 8·4 m.af. and suitable provision be made in the first instance to have the foundations such that the dam could be raised to its maximum capacity of 11·2 m,a.f. The basis of making this provision is that 197 million acre feet years storage should be provided at Tarbela as originally estimated in the T & H feasibility report. Similarly Mangla dam has also been proposed for 5·4 million acre feet against the original 4·75 million acre feet which-would also economise on the reduction of the capacity of the spillway. The foundation of Mangla shall also be kept such that it can be ultimately raised to 8·3 m.a.f. On the same analogy Chashma barrage could be provided the necessary flexibility so that a storage could be created at this site. As Tarbela is not likely to materialize before 1973, an early storage on Indus at Chashma would go a long way in meeting the shortages on Indus barrages. The yield of crops on the existing barrages is low because of shortage of water in critical periods. At present all development on Indus has been withheld for want of water. It is idle to think of consumptive uses based on Blaney Criddle method and crash programme for agricultural development on Indus unless we construct a storage dam like Chashma which would materialize at least by the time Mangla dam is completed in 1967.

The concept of Chashma barrage and Chashma-Jhelum Link was included in the Indus Basin Replacement Plan on the suggestion of the Irrigation Department. The Department is carrying out certain investigations regarding Chashma storage though it does not have enough facilities for this work. It is hoped that this symposium would serve as a reservoir of ideas and would enable the Congress to appreciate the vital importance of this storage in the water resources development of West Pakistan.