(l) Wali Dad dam

Catchment area of the proposed dam is wholly situated at Brewary Limestone. Both sides of the river are composed of outcrops, and rise steeply, that vegetation is not observed. The river forms narrow gorge of its width of three to four meters composed of limestone 2 km upstream from the dam site. Relatively large gravel and cobble stone are deposited in the narrow gorge caused by a mountainside collapse. Few vegetation cover is observed in the catchment area.

Steep limestone walls of the both sides produces narrowest gorge of its width of 10 to 15 m and that is preferable to detention bund construction.

(m) Samaki dam

The catchment area of the proposed dam is broadly composed of Shaigalu Formation composed of shale and partly inbedded sandstone. Talus deposits were accumulated on the mountain foots along the river. Vegetation is well growing on the talus deposits thickly deposited in the river.

Detention bund is not recommended because of steep riverbed gradient of 1:10.

(n) Iskalkoo dam

Proposed dam site is situated in Kirthar Formation compose of limestone and Nari Formation composed of shale and Mudstone. Talus deposits have been thickly accumulated on the hillfoot along the river. Vegetation is well growing on the talus deposits.

Series of lower height detention bunds are proposed to control erosion by loosening riverbed slope and to prevent the movement of riverbed deposits.

I.4.4 Design of Dam, Sediment Control Devices

(1) Brewary dam

(i) Geology of catchment area

Karaksha nullah is located at the center of the catchment area which forms 14 km from south-west to north east, and 3 km from north-west to south-east. Shirinab formation, comprising of alternate beds of limestone and shale is exposed in the upstream of the catchment area. The limestone is thin to medium bedded, and the shale is calcareous. The Chiltan formation comprising of massive, thickly bedded is exposed in the downstream of the catchment area. It has conformable contact with the lower Shirinab formation. Piedomont deposit is thickly deposited and forms rolling terrains.

(ii) Topo-geology of dam site

Proposed dam site is situated in Brewary limestone, which dominantly consists of nodular to massive limestone with subordinate shale. Dam site is located at a very narrow gorge about 6.0 m width composed of limestone of Brewary limestone. Rock is exposed on the both abutments. Because the strike of the beds is almost perpendicular, limestone beds continue on the both the abutments and can be correlated. It is observed that the bed rock exists 8 to 10 m depth from the river bed according to the drilling profile 15 m downstream of the dam body. Limestone in abutments is moderately hard to hard, moderately fractured and jointed without infilling.

Reservoir is comprised of partly Brewary limestone and Ghazig shale. The right side ridge, composed of Brewary limestone, is almost straight having dip slope face towards the reservoir. The left side ridge is composed of Ghazig shale having an irregular gentle escarpment face towards reservoir. Piedomont deposits and talus were thickly deposited at the mountain foot of the right side ridge.

(iii) Design of dam

Dam site is situated in narrow gorge composed of limestone. Gravity dam is proposed because base foundation rock exists 7.5 m depth from the river bed surface, and distance of both abutments is 6 to 15 m. Fill type dam is not suitable due to excessive rock excavation to secure spillway channel. Recharge through dam foundation is not expected because of rock foundation, so that recharge downstream of the dam site is accelerated through intake facilities. Overflow depth is 3.2 m considering existing gorge width, and foundation replacement with lean concrete materials to the depth of 15 m river deposits is required for the 19.5 m length energy dissipater to ensure the bearing capacity of the foundation.

Vertical pipe (ø250mm) with intake pipe (ø125mm) is planed to be installed at the upstream face of dam for outlet device. And discharge should be controlled by operating sluice valve which is installed at the end of driving canal.

Dam type	Catchment area(km^2)	Crest length (m)	Dam height (m)	Embankment volume (m^3)	Total storage volume (m^3)	Effective storage volume (m^3)	Sediment volume (m^3)	Flood discharge (m^3/sec)
Gravity	25.9	22.0	32 2	10,500	749,000	360,000	389,000	165

(iv) Design of recharge devices

Rechargeable water is estimated at 3,240 m^3/day and permeability is also estimated at 2.50×10^{-3} cm/s. Then required area for recharge is 1,500 m^2. Infiltration pond should be located adjacent to plunge pool in consideration of connection with basin and river.

(v) Design of sediment control devices

The land slope is not steep and density of vegetation is not poor in this basin. Further, watershed management program is now on going. Then it is realized the necessity of setting erosion control facilities is low in this delay action dam project.

(2) Dara dam

(i) Geology of catchment area

The catchment area is broadly composed of well bedded limestone (Chiltan limestone). Piedomont deposit is observed at foothills of the limestone, which is easily eroded by stream flow. Several narrow gorges with their width of 5 to 10 m were developed in the middle and upstream in the catchment area. Some slumping of the weathered limestone were also occurred at the fold and fault portions. Ghazig shale is mostly observed along the Kazha Shela nullah located to the north of the dam site.

(ii) Topo-geology of dam site

Proposed dam site is located at the fan head of the alluvial fan. Right side abutment is composed of interbedded shale, and Hanna Urak conglomerate is exposed. These forms hilly undulation terrains. Left side abutment is composed of Chiltan limestone, which are naudulated. River deposits or alluvial fan with thin silt layers were developed with their depth of around 20 m from the river bed at the dam site. Silt and clay layers with depth of between 20 to 30 m exist below the river deposits. The layer contains a few limestone concretions. The unconsolidated deposits continued upto the depth of 40 m.

(iii) Design of dam

Left side abutment is composed of outcrops of limestone and right side of conglomerate which has sufficient bearing capacity for a dam foundation. Dam axis is proposed at downstream of confluence of two major tributaries to enlarge dam storage capacity. Dam axis bends to upstream direction at the right side abutment. Dam foundation is composed of the permeable river deposits of its depth of 20 m and hydraulic conductivity of 1.49×10^{-3} cm/sec. Homogeneous type fill dam is suitable to reduce hydraulic gradient along the dam foundation against piping. River deposits is available for the semi pervious embankment materials.

Downstream recharge through intake conduits is proposed because of gradual reduction of seepage flow through the dam foundation due to siltation. Spillway channel is at the right side abutment comprising of conglomerate. Crest length of 41 m (overflow depth is 1.8 m) is required considering topographical condition. Flood flows toward large alluvial fan and energy dissipater is not facilitated.

Dam type	Catchment area(km^2)	Crest length (m)	Dam height (m)	Embankment volume (m^3)	Total storage volume (m^3)	Effective storage volume (m^3)	Sediment volume (m^3)	Flood discharge (m^3/sec)
Fill type	16.6	405.0	22.8	297,000	589,000	240,000	349,000	196

Inclined pipe is planed to be installed on the left bank in the reservoir in consideration of slope condition and shortening conduit length. Proposed dimensions of outlet devices are summarized as follows.

Inclined Pipe	Intake Pipe	Conduit Type A	Conduit Type B	Conduit Type C
ø400 x L 24m	ø250 x 6 sets	ø400 x L 50m	ø400 x L 120m	ø400 x L 35m

(iv) Design of recharge devices

Rechargeable water is estimated at 9,856 m^3/day and permeability is also estimated at 1.00×10^{-3} - 1.50×10^{-3} cm/s. Then required area for recharge is 11,400 m^2. Infiltration pond is desirable to be located on the top of alluvial fun which is at about 1.0 km downstream from the dam site.

(v) Design of sediment control devices

It is recommended sediment control devices should be constructed at about 2.5 km and 3.3 km upstream from the dam site. At 2.5 km point, it is preferable to adopt detention bund. However, at 3.3 km upstream site, narrow valley is formed by the rock which extend from mountain side into river and it is possible to obtain large capacity for sediment storage. Then, it is useful to adopt gravity dam which height is 5 m from the river bed.

(3) Murgi Kotal dam

(i) Geology of catchment area

The upstream area bounds with the catchment areas of the dams of Bostan and Dara. Murgi Kotal nullah flows down toward south-west with its length of around 9 km, and the catchment area has its width of 2 km in average. The catchment area is wholly situated in Chiltan limestone formation at the left side and limestone of Alozai Gr. at the right side, and partly in Ghazig shale. River deposits comprising of mixture of gravel, cobble stone and sand with some silt occupied the river bed. Piedomont deposits were developed at foothills. Thin bedded limestone which was thinly bedded and closely fractured with thin marly bands forms mountainous hilly and rolling terrains.

(ii) Topo-geology of dam site

Proposed dam site is located in a gorge about 80 m width, and composed of Chiltan limestone. Limestone is exposed on the both abutments. Limestone beds continue on both the abutments, however, river deposits accumulated in the river bed is more than 40 m in thickness. Limestone exposed at the right side abutment is almost straight having dip slope face towards river bed. Limestone at the left side abutment was naudulated. River deposits comprising of gravel and boulder were thickly deposited.

River deposits comprising of fine materials of 10 m thick were accumulated in the reservoir due to the dam construction. Piedomont deposit and talus deposits were developed surrounding the reservoir area. These materials are susceptible to erosion during floods, and some slumping of the deposit is likely to occur by inundation of the reservoir area.

(iii) Existing dam condition

The reservoir has been full of sediments composed of clayey silts at the upstream of the dam embankment with its depth of around 10 m. The strata in the upper 10 m depth are unconsolidated and have low relative densities. As the composition of the upper deposits, the strata changes to boulder, gravel, which seems original river deposits or alluvial fan deposits. Four number of Dutch cone penetration tests (CPT) were performed between the depths of 11 to 14 m. CPT at 1 m interval refused beyond penetration depth of 15 cm and gave high value of N of more than 50 (Standard penetration Test). No water table was found in the bore hole in the deposits in the reservoir.

Alluvial fan deposits observed closing to the downstream of the existing dam embankment is composed of gravel and few sandy clay.

(iv) Design of dam

Dam site is located at the fan head of alluvial fan and constructed in limestone gorge of its width of 80 m. Gravity dam is not suitable owing to poor bearing capacity of 40 m river deposits. There are two alternatives of the dam axis, located upstream and upstream of the existing dam. Particular features are specified as follows:

Upstream: Embankment volume is 280,000 m^3. Removal of sediment of 110,000 m^3 in the reservoir is considerably large. Spillway is located at the right side of the reservoir.

Downstream: Embankment volume is 460,000 m^3. Spillway construction located at the right limestone abutment costs a great deal because of hard rock excavation

Comparing with the alternatives, upstream dam is economically preferable. Dam foundation is composed of the permeable river deposits of its depth of 40 m. Homogeneous type fill dam is suitable to reduce hydraulic gradient along the dam foundation against piping. River deposits is available for the semi pervious embankment materials.

Downstream recharge through intake conduits is proposed because of gradual reduction of seepage flow through the dam foundation due to siltation. Spillway channel is at the left side of the reservoir. Excavated materials of spillway channel are utilized for the dam embankment.

Dam type	Catchment area(km^2)	Crest length (m)	Dam height (m)	Embankment volume (m^3)	Total storage volume (m^3)	Effective storage volume (m^3)	Sediment volume (m^3)	Flood discharge (m^3/sec)
Fill type	19.7	130.0	35.6	278,000	1,147,000	260,000	887,000	131

Inclined pipe is planed to be installed on the left bank in the reservoir in consideration of slope condition and shortening conduit length. Proposed dimensions of outlet devices are summarized as follows.

Inclined Pipe	Intake Pipe	Conduit Type A	Conduit Type B	Conduit Type C
ø400 x L 25m	ø250 x 8 sets	ø400 x L 84m	ø400 x L 163m	ø400 x L 47m
(ø400 x L 30m)	(ø250 x 8 sets)	(ø400 x L 75m)	(ø400 x L 130m)	(ø400 x L 315m)

Note) Upper : Downstream Lower : Upstream

(v) Design of recharge devices

Rechargeable water is estimated at 7,776 m^3/day and permeability is also estimated at 1.00×10^{-3} cm/s. Then required area for recharge is 9,000 m^2. Infiltration pond should be located on the right bank top of alluvial fun which is at about 200 m downstream from the dam site.

(vi) Design of sediment control devices

It is proposed that 4 detention bunds will be built. The first will be located at about 2.0 km upstream, the second at about 3.0 km, the third at 5.0 km and the last at 7.0 km upstream respectively from the delay action dam site.

(4) Kach dam

(i) Geology of catchment area

Geological formations mainly consist of limestone slab, sandstone and conglomerate. The conglomerates, sandstone and shale beds belonging to the Urak group are the youngest rocks of the area and occupy synclinal structures.

Spintangi limestone is exposed approximately 700 - 800 m upstream of the dam site. Spintangi limestone belongs to early to middle Eocene age and is overlain by Urak group and underlain by Ghazij shales.

(ii) Topo-geology of dam site

Most of the dam and reservoir area is occupied by exposed shales of Ghazij formation. The shale beds from an anticlinal bend across the stream, and form semi-rounded hills of low relief. Most of the hill slopes over the shale deposits are talus, indicating high erosive nature of the shale. Surface run-off from these slopes brings heavy silt load into the reservoir in addition to the transported sediments brought by the flood from the catchment area.

(iii) Existing dam condition

The remnants of the dam embankment overtopped by the floods present a dilapidated scape. The overtopping due to floods has eroded a considerable portion of the dam crest. An approximately 22 m deep cut has been created along the crest in the form of a vertical cut. Cut-off concrete core wall has also been destroyed by water pressure of the storaged water.

The reservoir has been full of sediments composed of clayey silts and disintegrated shale. These deposits contain excessive moisture and unconsolidated. Bed load materials comprising of cobble, gravel, sand and silt mixture with occasional boulder has been thickly deposited at the upstream of the reservoir area.

Spillway of the existing dam was located in the hills near the right abutment. Overflow crest portion stands completely destroyed by flood. Spillway channel comprised a cut section in the shale formation without any protection on the bed and the side slopes. The flood water had eroded the entire channel.

A circular wet type RCC intake structure of 3.35 m diameter and 23.0 m height was also damaged by soil pressure. One inlet was near bed level and two other inlets at various levels were provided with manual operation. The 450 mm diameter RCC pipe is connected to the steel pipe outlet from the intake structure. This pipeline joins at a distance of about 5.5 km another similar pipeline from the Sra Khula dam for conducting combined flow. It was being used by the local population of the nearby village at the point of the first breakage at a distance of about 500 m downstream from the toe of the dam embankment.

(iv) Design of dam

Comparing to two alternatives of the dam axis, rising of existing dam crest is economically preferable. Particular features are specified as follows:

Rising crest: Embankment volume of dam is 480,000 m^3. In addition, 123,000 m^3 is required for the embankment of existing spillway channel.

Downstream: Embankment volume of 600,000 m^3 is almost as same volume as the total embankment of the rising crest plan In addition to the dam construction, rehabilitation works of the existing dam is necessary to prevent outflow of sediment accumulated in the reservoir.

Unconsolidated shale surface is susceptible to a erosion and bearing capacity is also insufficient for the gravity dam construction. Downstream recharge through intake conduits is proposed because of impermeable foundation. Dam axis is 50 m downstream of the existing dam crest. Zone type fill dam of its dam height of 45.9 m is proposed. Impervious zone is banked at the upstream side and semi-permeable zone at the downstream side of the embankment. Drainage is accelerated through vertical drain located at the downstream of the impervious zone. Overflow depth of 2.5 m is required considering topographical condition of the right side abutment. Spillway channel is protected with concrete to prevent an erosion by floods.

Dam type	Catchment area(km^2)	Crest length (m)	Dam height (m)	Embankment volume (m^3)	Total storage volume (m^3)	Effective storage volume (m^3)	Sediment volume (m^3)	Flood discharge (m^3/sec)
Fill type	56.5	330.0	45.9	480,000	2,387,000	1,200,000	1,187,000	329

Inclined pipe is planed to be installed on the left bank in the reservoir in consideration of slope condition and shortening conduit length. Proposed dimensions of outlet devices are summarized as follows. In addition, there is a canal of Seragurg Irrigation Scheme in the downstream area of Kach site. Then it is necessary to supply irrigation water to this canal after completion of Kach dam.

Inclined Pipe	Intake Pipe	Conduit Type A	Conduit Type B	Conduit Type C
ø250 x L 12m	ø150 x 3 sets	ø250 x L 130m	ø250 x L 177m	-
(ø250 x L 29m)	(ø150 x 9 sets)	(ø250 x L 125m)	(ø250 x L 180m)	-

Note) Upper : Existing site Lower : Downstream site

(v) Design of recharge devices

Rechargeable water is estimated at 5,184 m^3/day and permeability is also estimated at 1.00×10^{-3} cm/s. Then required area for recharge is 6,000 m^2. Infiltration pond is planed to be located on the left bank point which is at about 3.5 km downstream from the dam site.

(vi) Design of sediment control devices

Detention bunds should be proposed at the downstream site of Inzar Nullah and Spol Nullah respectively. In Kuchnai Nullah basin, its geographical feature is not steep and density of vegetation is rather thick. Also some loose stone check dams have been built in small tributary. Then it is low in priority to set up erosion control facility.

On the other hands, in the small sub-basin located in upstream from the delay action dam on the left bank, landslide is heavily proceeding by weathering and mining. And also, vegetation is scarce in whole basin. Then, it is supposed that sediment yield and washout will increase year by year. Therefore, it is recommended strongly that conservation works as counter trench, loose stone check dam and forestation should be operated.

(5) Jigda dam

(i) Geology of catchment area

The catchment area is also composed of Murgha Faqirzai shale, and Piedomont deposit at the foothills along the river bed. Small particles of gravel and sand river deposits were accumulated in the relatively wider river bed. Silt and clay content is very small in the river deposits at the upstream of the catchment area.

(ii) Topo-geology of dam site

The dam site is situated in Murgha Faqirzai shale, and Piedomont deposits were developed at the foothills. Shaighalu sand is also thinly inbedded. Since the shale was severely weathered or eroded by water, the surface was cracked, and vertically dipping. Gravel, sand and boulder stone originated from the shale fully occupied the river bed with their depth of around 10 m at the dam site. Weak foundation composed of silt and clay river deposits exists 5 to 8 m below the river bed.

Reservoir is bounded by hills predominantly formed of thin Piedomont deposit at the left side, and weathered shale at the right side.

(iii) Design of dam

Dam site is occupied by exposed shale and forms hilly terrains. Shale surface was severely weathered and cracked. River deposits is permeable (Hydraulic conductivity: 1.15×10^{-3} cm/sec) and has around 10 m in thick. Homogeneous type fill dam is suitable to reduce hydraulic gradient along the dam foundation against piping. River deposits and excavated materials of the spillway are available for the semi pervious embankment materials. Downstream recharge through intake conduits is also accelerated because of poor seepage capacity of the 10 m thick foundation and also gradual reduction of seepage flow through dam foundation due to siltation. Spillway is constructed at left side of the dam embankment. Spillway channel slope composed of shale is protected with the stone masonry. Overflow depth of 1.5 m and crest length of 46 m is required considering topographical condition of the abutment. Flood is diverted to the adjacent valley composed of shale, so that energy dissipater is not facilitated.

Dam type	Catchment area(km^2)	Crest length (m)	Dam height (m)	Embankment volume (m^3)	Total storage volume (m^3)	Effective storage volume (m^3)	Sediment volume (m^3)	Flood discharge (m^3/sec)
Fill type	20.8	210.0	23.9	114,000	508,000	290,000	218,000	142

Inclined pipe is planed to be installed on the right bank in the reservoir in consideration of slope condition and shortening conduit length. Proposed dimensions of outlet devices are summarized as follows.

Inclined Pipe	Intake Pipe	Conduit Type A	Conduit Type B	Conduit Type C
ø400 x L 33m	ø250 x 7 sets	ø400 x L 80m	ø400 x L 123m	ø400 x L 36m

(iv) Design of recharge devices

Rechargeable water is estimated at 14,904 m^3/day and permeability is also estimated at $1.15x10^{-3}$ cm/s. Then required area for recharge is 15,000 m^2. There is one karez system on each side of the river respectively. Then, for the purpose of groundwater recharge and strengthening karez function, recharging facilities are proposed to be set up. On the right bank, infiltration pond which capacity is 6,000 m^2 is located at about 1.2 km downstream. From dam to pond it is not avoidable to pass river bed, then in this section, pipeline should be adopted as link canal. On the left bank, infiltration pond which capacity is 9,000 m^2 is planned. In addition, two karez systems which locate downstream from infiltration ponds are planed to be rehabilitated. These total length of karez are 2100 m.

(v) Design of sediment control devices

Jigda delay action dam has only fifteen years capacity for sediment. Therefore it is necessary to secure fifteen years sediment capacity for sediment control devices. In addition, it is impossible to construct these devices in the middle of river named Takhoi and Tembai area where some cultivated land and orchards are scatters on the riverside in the consideration of backwater by debris. Then it is limited to select the sites for debris and it is supposed to list just three sites, at the point of about 2.5 km, 3.0 km and 8.0 km upstream from the dam site. In consideration of the sediment capacity, it is proposed to select wet stone masonry type which height is 5 m.

(6) Sanzali dam

(i) Geology of catchment area

Upstream of the catchment area is composed of Subrecent-recent deposition comprising of rounded gravel, sand and clay. Rest of the catchment area is composed of Bostan formation. Subrecent-recent deposition forms mountainous hilly and rolling terrains, and was heavily eroded by precipitation. Slope failures of the Bostan formation are observed along the river, and it causes huge sedimentation in the reservoir associated with the dam construction. Because of the susceptibility to erosion of the Bostan formation, few vegetation cover was observed especially in the upstream of the catchment area.

River deposits composed of gravel, sand, silt and clay were originated from the Subrecent-recent deposition. Fine particles of Bostan clay caused by erosion was not accumulated in the river bed, and transferred towards downstream as a suspended solid.

(ii) Topo-geology of dam site

Proposed dam site is situated in Bostan formation composed of silt, sand and radish clay. Since Bostan clay is susceptible to erosion, the configuration around the dam site forms rolling and hilly terrains. Gravel and clay river deposits were accumulated in the river bed with their thickness of 2 to 3 m. The base foundation of Bostan clay has depth of more than 40 m at the dam site, and thin sandstone layer of 2 m thickness is inbedded at the depth of 13 to 15 m from the river bed. Groundwater was observed on the clay foundation, 1.5 m below from the river bed. Both abutments were deeply eroded by precipitation, however clayey foundation was well consolidated. Thus bearing capacity of the foundation is enough to construct the dam embankment.

(iii) Design of dam

Dam is constructed on the impermeable sand, clayey layers of its hydraulic conductivity of 1.54×10^{-4} cm/sec at the dam center. Besides, dam is constructed on pervious foundation at the left abutment, homogeneous type fill dam is suitable to reduce hydraulic gradient along the dam foundation against piping. River deposits and a part of the excavated materials of the spillway are available for the semi pervious embankment materials. Downstream recharge through intake conduits is accelerated because of poor seepage capacity of the dam foundation. Spillway is constructed at right side gorge of the dam site. Spillway channel base and side slopes are protected with the stone masonry due to susceptibility to erosion of the unconsolidated sand and clay foundation. Overflow depth of 1.5 m and crest length of 26 m is required considering topographical condition of the gorge. Spillway channel traverses existing karez, 40 m length energy dissipater is facilitated to protect the karez.

Dam type	Catchment area(km^2)	Crest length (m)	Dam height (m)	Embankment volume (m^3)	Total storage volume (m^3)	Effective storage volume (m^3)	Sediment volume (m^3)	Flood discharge (m^3/sec)
Fill type	10.4	210.0	14.0	114,000	508,000	290,000	218,000	142

Inclined pipe is planed to be installed on the right bank in the reservoir in consideration of slope condition and shortening conduit length. Proposed dimensions of outlet devices are summarized as follows.

Inclined Pipe	Intake Pipe	Conduit Type A	Conduit Type B	Conduit Type C
ø200 x L 24m	ø125 x 3 sets	ø200 x L 22m	ø200 x L 90m	ø200 x L 27m

(iv) Design of recharge devices

Rechargeable water is estimated at 2,592 m^3/day and permeability is also estimated at 1.00×10^{-3} cm/s. Then required area for recharge is 3,000 m^2. Infiltration pond is planed to be located on the right bank where is at about 1.5 km downstream from the dam site. With this device, it is possible to recharge groundwater and strengthen the function of existing karez. In addition, two karez systems which locate downstream from infiltration ponds are planed to be rehabilitated. These total length of karez are 2700 m.

(v) Design of sediment control devices

It is recommended that 4 detention bunds will be built. The first and second will be located at about 2.5 km and 3.0 km upstream in main stream, the third and fourth will be at about 100 m upstream respectively from the confluence of Zebra Nullah and Aghbargai Nullah. In addition, devastation in this river basin is widely proceeding and it is recommended that watershed conservation in the basin wide by counter trench and loose stone check dam and forestation should be operated.

(7) Sakhol dam

(i) Geology of catchment area

The catchment area is composed of Chiltan limestone, Shirinab formation, Spin Tangi limestone and Bostan formation, having the age from Permo-Jurassic to Recent. The catchment area forms mountainous hilly and the materials for sedimentation was derived from surrounding out-crops of older rocks. Piedomont deposits were accumulated at the foot of limestone mountains. Talus deposit and river deposit are observed in the wider valley. Sand dune was developed at the lower part of the proposed dam site.

(ii) Topo-geology of dam site

Dam site is situated in 1,000 m wide fan head at where semi impermeable river deposits comprising of gravel, sand, clay has been accumulated in 100 m thick. Both abutments are composed of out-crops of the limestone. The water impounded in the dam reservoir will seep into reservoir bed and ultimately drain into the area downstream of the dam site.

(iii) Design of dam

The hydraulic conductivity of the dam foundation shows 3.06×10^{-4} cm/sec. Homogeneous type fill dam is suitable to reduce hydraulic gradient along the dam foundation against piping.

River deposits are available for the semi pervious embankment materials. Downstream recharge through intake conduits is also accelerated because seepage flow through the dam foundation is gradually reduced due to siltation in the reservoir. Spillway is constructed at center of the dam axis. Spillway channel base and side slopes are protected with the stone masonry due to susceptibility to erosion of the river deposits. Overflow depth of 1.5 m and crest length of 42 m is required considering topographical condition. Earth canal of its height of 2.0 m is excavated downstream of the spillway channel to protect agricultural lands from inundation.

Dam type	Catchment area(km^2)	Crest length (m)	Dam height (m)	Embankment volume (m^3)	Total storage volume (m^3)	Effective storage volume (m^3)	Sediment volume (m^3)	Flood discharge (m^3/sec)
Fill type	22.3	1,090.0	14.5	187,000	545,000	210,000	335,000	199

Hill slope is less than 15 degree and safe against destruction of pipe by differential settlement and land sliding. Then it is possible to collect water by perforated conduit which will be settled from the bottom of reservoir up to low water level point. Proposed dimensions of outlet devices are summarized as follows.

Inclined Pipe	Intake Pipe	Conduit Type A	Conduit Type B	Conduit Type C
-	-	ø150 x L 190m	ø150 x L 68m	ø150 x L 18m

(iv) Design of recharge devices

Rechargeable water is estimated at 976 m^3/day and permeability is also estimated at $1.00x10^{-3}$ cm/s. Then required area for recharge is 1,130 m^2. River deposit is thickly accumulated and alluvial fan spreads widely toward downstream. Then it is possible that infiltration pond will be located closed to the dam. And it is capable discharge water will be lead by driving canal without link canal. In addition, three karez systems which locate downstream from infiltration ponds are planed to be rehabilitated. These total length of karez are 2500 m.

(v) (Design of sediment control devices)

In Sakhol basin, land slope is gentle and vegetation density is not dispersed. Gradient of river bed is rather gentle. In addition, the area which provide sediment yield is hardly found. On the other hand, judging from conditions of sediment in the reservoirs of existing dams which are adjacent to above proposed dams, it is supposed the amount of sediment discharge is not plenty. Therefore, it is low priority to construct erosion control facilities in this basins.

(8) Mangi dam

(i) Geology of catchment area

The catchment area of the proposed dam is composed of Nimragh limestone at the upstream, left side ridge, and Shirinab formation comprising of limestone with abundant interbedded shales in the remaining. Nimragh limestone is exposed in the eastern mountainous range, and yields some springs. Alluvial fan deposit is observed at the dam site and also upstream of the catchment area, where is bounded by mountainous hills predominantly formed of out-crops of Nimragh limestone. Piedomont deposit originated from Nimragh limestone composed of gravel, sand and silt has gentle slope. Sarbund delay action dam is located at the upstream of the proposed dam.

(ii) Topo-geology of dam site

Dam site is situated in 700 m wide fan head at where semi impermeable river deposits comprising of gravel, sand, clay has been accumulated in 27 m thick. Right side abutment is composed of out-crops of naudulated limestone. Left side abutment is composed of Piedomont deposit originated from Shirinab formation. River deposits composed of boulder, gravel, sand and clay is thickly accumulated at the dam site. Base rock of shale (Shirinab formation) is observed at the depth of 17 m from the river bed.

(iii) Design of dam

The hydraulic conductivity of the dam foundation shows 1.06×10^{-4} cm/sec. Homogeneous type fill dam is suitable to reduce hydraulic gradient along the dam foundation against piping. River deposits are available for the semi pervious embankment materials. Downstream recharge through intake conduits is also accelerated because seepage flow through the dam foundation is gradually reduced due to siltation in the reservoir. Spillway is constructed at the left abutment. Spillway channel behind overflow section is protected with concrete to prevent erosion because of high susceptibility to erosion of the foundation. Overflow depth of 2.0 m and crest length of 85 m is required considering topographical condition.

Dam type	Catchment area(km^2)	Crest length (m)	Dam height (m)	Embankment volume (m^3)	Total storage volume (m^3)	Effective storage volume (m^3)	Sediment volume (m^3)	Flood discharge (m^3/sec)
Fill type	39.4	530.0	12.7	171,000	1,011,000	420,000	591,000	6,000

Inclined pipe is planed to be installed on the right bank in the reservoir in consideration of slope condition and shortening conduit length. Proposed dimensions of outlet devices are summarized as follows.

Inclined Pipe	Intake Pipe	Conduit Type A	Conduit Type B	Conduit Type C
ø500 x L 16m	ø300 x 3 sets	ø500 x L 145m	ø500 x L 72m	ø500 x L 57m

(iv) Design of recharge devices

Rechargeable water is estimated at 12,960 m^3/day and permeability is also estimated at $1.00x10^{-3}$ cm/s. Then required area for recharge is 15,000 m^2. Conditions of river deposit and topographical feature is as same as those of Sakhol. Then it is possible that infiltration pond will be located closed to the dam. It is capable discharge water will be lead by driving canal without link canal. In addition, two karez systems which locate downstream from infiltration ponds are planed to be rehabilitated. These total length of karez are 6000 m.

(v) Design of sediment control devices

Conditions of Sakhol and Mangi river basin are generally similar on topographical feature and vegetation. Therefore, it is low priority to construct erosion control facilities in these basins.

(9) Kad Kocha II dam

(i) Geology of catchment area

The catchment area is composed of Chiltan limestone, Shirinab formation, Spin Tangi limestone and Bostan formation, having the age from Permo-Jurassic to Recent. The catchment area forms mountainous hilly and the materials for sedimentation was derived from surrounding out-crops of older rocks. The upstream area mostly forms a narrow valley. The lower part of the dam site received fine sediments like clay and silt and some coarser materials like sand and gravel are due to flood storms, which could not be rolled out, but less Piedomont conditions exists in the dam site, while desert condition where in Seolian sand and silt also started accumulating in the downstream of the dam site. No perennial flow was observed in the area. Soil production is not so high due to deposition of sandy, silty formation and shortage of water.

(ii) Topo-geology of dam site

Dam site is situated in 700 m wide fan head at where semi impermeable river deposits comprising of gravel, sand, clay has been accumulated more than 40 m thick. Proposed dam is constructed across the wider valley of its width of around 400 m. Both abutments are composed of out-crops of the limestone. River deposits are composed of boulder stone, gravel, sand and silt. Boulder size is relatively large, 20 to 40 cm. The water impounded in the dam reservoir will seep into reservoir bed and ultimately drain into the area downstream of the dam site.

(iii) Design of dam

The hydraulic conductivity of the river surface shows $3.18x10^{-5}$ cm/sec. Homogeneous type fill dam is suitable to reduce hydraulic gradient along the dam foundation against piping. River deposits are available for the semi pervious embankment materials. Downstream recharge through intake conduits is also accelerated because seepage flow through the dam foundation is gradually reduced due to siltation in the reservoir. Spillway is constructed at the right side river bed. Stone masonry is constructed between the embankment and spillway channel. Spillway channel is connected to scoured portion of the existing river. Minimum flow section of overflow depth 2.5 m and crest length 50 m is planned to avoid excessive rock excavation.

Dam type	Catchment area(km^2)	Crest length (m)	Dam height (m)	Embankment volume (m^3)	Total storage volume (m^3)	Effective storage volume (m^3)	Sediment volume (m^3)	Flood discharge (m^3/sec)
Fill type	15.2	595.0	14.0	152,000	368,000	140,000	228,000	389

Inclined pipe is planed to be installed on the left bank in the reservoir in consideration of slope condition and shortening conduit length. Proposed dimensions of outlet devices are summarized as follows.

Inclined Pipe	Intake Pipe	Conduit Type A	Conduit Type B	Conduit Type C
φ600 x L 11m	φ350 x 3 sets	φ600 x L 20m	φ600 x L 65m	-

(iv) Design of recharge devices

Rechargeable water is estimated at 12,960 m^3/day and permeability is also estimated at $1.00x10^{-3}$ cm/s. Then required area for recharge is 15,000 m^2 like Mangi dam. Conditions of river deposit and topographical feature is similar to Mangi dam. However, there is narrow gorge just downstream. Then it is proposed that infiltration pond will be located after passing this gorge.

(v) Design of sediment control devices

Conditions of Sakhol, Mangi and Kad Kocha II river basin are generally similar on topographical feature and vegetation. Therefore, it is low priority to construct erosion control facilities in Kad Kocha II basins.

(10) Ghazlona dam

(i) Geology of catchment area

The catchment area of the proposed dam is broadly composed of Ghazig shale, and sandstone is partly inbedded. Bostan formation overlain the shale is observed at the most upstream of the catchment area. Some steep slumping were occurred on the shale, on contrary to this, widely surface erosion were developed on the Bostan formation.

River deposits were thinly accumulated in the river bed due to steep river gradient. Out-crops of shale are observed in the river bed in the middle and upstream of the catchment area.

(ii) Topo-geology of dam site

Proposed dam site is situated in Ghazig shale formation, which dominantly consists of cracky and vertically dipping direction. Surface of the shale was severely weathered or eroded by water. Both of abutments form hilly configuration, and deeply eroded gullies were developed, especially at the right side slopes. Gravel, sand and boulder originated from the shale occupy the river bed with their depth of 3 to 4 m at the dam site.

(iii) Design of dam

Homogeneous type fill dam is suitable to reduce hydraulic gradient along the 5 to 6 m thick dam foundation against piping. River deposits composed of shale are available for the semi pervious embankment materials. Compaction criteria for weathered shale materials is carefully examined to prevent settlement of embankment by saturation. Downstream recharge through intake conduits is also accelerated because seepage flow through 5 to 6 m dam foundation is not so high, and these is gradually reduced due to siltation in the reservoir. Spillway is constructed at the left side abutment. Spillway channel slope composed of shale is protected with stone masonry. Overflow depth 1.5 m and crest length 35 m is planned considering topographical condition of the abutment. Flood is diverted to the adjacent valley composed of shale, so that energy dissipater is not facilitated.

Dam type	Catchment area(km^2)	Crest length (m)	Dam height (m)	Embankment volume (m^3)	Total storage volume (m^3)	Effective storage volume (m^3)	Sediment volume (m^3)	Flood discharge (m^3/sec)
Fill type	9.1	195.0	20.9	76,000	331,000	140,000	191,000	109

Inclined pipe is planed to be installed on the left bank in the reservoir in consideration of slope condition and shortening conduit length. And from about low water level up to dam crest level, air vent pipe will be settled on embankment slope by concrete anchor block. Proposed dimensions of outlet devices are summarized as follows.

Inclined Pipe	Intake Pipe	Conduit Type A	Conduit Type B	Conduit Type C
ø200 x L 38m	ø125 x 5 sets	ø200 x L 28m	ø200 x L 100m	ø200 x L 18m

(iv) Design of recharge devices

Rechargeable water is estimated at 662 m^3/day and permeability is also estimated at 1.00×10^{-3} cm/s. Then required area for recharge is 770 m^2. Recharging capacity is supposed to be small near dam site because of narrow flowing width in the river and its shallow aquifer. Then infiltration pond is planed to be located on the right bank where is at about 1.3 km downstream from the dam site.

(v) Design of sediment control devices

Two detention bunds should be proposed at the point of about 2.0 km and 3.5 km upstream from Ghazlona dam site.

(11) Ghutai Shela dam

(i) Geology of catchment area

Catchment area is situated in consolidated and unconsolidated Piedomont deposits (Fanglomerate). Gravel and cobble stone are deposited in the river bed. Piedomont deposits have been eroded by precipitation and form undulated terrains. The upstream area bounds with the catchment areas of Brewary dam and composed of Ghazig Shale.

(ii) Topo-geology of dam site

Dam site is located at the fan head, and composed of Subrecent deposits forming hilly terrains. Gravel and sand deposits with its thickness of 28 m have been accumulated in the river bed. Base rock foundation composed of consolidated Subrecent deposits is observed under the river deposits. Both side of dam abutments are also composed of consolidated Subrecent deposits comprising of gravel and fine materials. Piedomont deposits are accumulated in the reservoir area.

(iii) Design of dam

Unconsolidated and permeable river deposits of its hydraulic conductivity of 9.50×10^{-3} cm/sec has been accumulated 28 m in thick. In this connection, homogeneous type fill dam is suitable to reduce hydraulic gradient along the dam foundation against piping. River deposits are available for the semi pervious embankment materials. Downstream recharge through intake conduits is also accelerated because the seepage flow capacity is gradually reduced due to siltation in the reservoir. Spillway is constructed at the right side abutment. Overflow depth of 1.7 m and crest length of 6.0 m is planned considering topographical condition of the abutment. Energy dissipater is not facilitated.

Dam type	Catchment area(km^2)	Crest length (m)	Dam height (m)	Embankment volume (m^3)	Total storage volume (m^3)	Effective storage volume (m^3)	Sediment volume (m^3)	Flood discharge (m^3/sec)
Fill type	1.8	155.0	13.0	33,000	80,000	42,000	38,000	28

Inclined pipe is planed to be installed on the left bank in the reservoir in consideration of slope condition and shortening conduit length. Proposed dimensions of outlet devices are summarized as follows.

Inclined Pipe	Intake Pipe	Conduit Type A	Conduit Type B	Conduit Type C
ø200 x L 15m	ø125 x 4 sets	ø200 x L 80m	ø200 x L 90m	ø400 x L 70m

(iv) Design of recharge devices

Rechargeable water is estimated at 4,815 m^3/day and permeability is also estimated at $9.50x10^{-3}$ cm/s. Then calculated necessary area for recharge is 590 m^2. However, it is desirable water depth in reservoir should be kept within 1.0 m in the consideration of economical factor and easiness in operation/maintenance. Therefore recharging area is planed to be 4,900 m^2. Near dam site, recharging effect is not expectable to be high because of thick silt/clay accumulation. Then infiltration pond should be located at the about 500 m downstream from the dam site on right bank.

(v) Design of sediment control devices

Two detention bunds are planed at the point of about 2.0 km and 3.0 km upstream from the dam site.

(12) Wali Dad dam

(i) Geology of catchment area

Catchment area of the proposed dam is wholly situated at Brewary Limestone and partly alternatives of sandstone and shale. Mostly equal river bed of its river bed width of 20 to 30 m continues from proposed dam sits to two to three kilometers upstream. The river forms narrow gorge of its width of three to four meters composed of limestone 2 km upstream from the dam site. Gravel and cobble stone have been deposited in the river bed, however, fine material is not observed.

(ii) Topo-geology of dam site

Proposed dam site forms narrow gorge of around 12 m width composed of Chiltan limestone at the both abutments. Limestone is exposed on the both abutments, and limestone beds continue on the both the abutments and can be correlated. It is observed that the bed rock exists five to six meters depth from the river bed. Limestone in abutments is moderately hard to hard, moderately fractured and jointed without infilling. Gravel and cobble stone have been accumulated in the river bed at the dam site. Reservoir area is also situated in limestone area.

(iii) Design of dam

Proposed dam site is located at a narrow gorge of limestone, 400 m upstream of the existing dam site. Rock foundation exists 5 m depth from the river surface, and both of dam abutments are composed of outcrops of limestone with its distance of 10 to 15 m. In this respect, gravity dam is selected. Fill type dam is not suitable due to excessive rock excavation to secure spillway channel. Recharge through dam foundation is not expected because of rock foundation, so that recharge downstream of the dam site is accelerated through intake facilities. Overflow depth is 2.0 m considering existing gorge width, and length of energy dissipater is 16.0 m

Dam type	Catchment area(km^2)	Crest length (m)	Dam height (m)	Embankment volume (m^3)	Total storage volume (m^3)	Effective storage volume (m^3)	Sediment volume (m^3)	Flood discharge (m^3/sec)
Gravity	5.4	20.0	23.0	3,700	139,000	90,000	49,000	86

Vertical pipe (ø300mm) with intake pipe (ø200mm) is planed to be installed at the upstream face of dam for outlet device. And discharge should be controlled by operating sluice valve which is installed at the end of driving canal.

(iv) Design of recharge devices
Rechargeable water is estimated at 7,020 m^3/day and permeability is also estimated at 1.00×10^{-3} cm/s. Then required area for recharge is 8,125 m^2. It is not expected to recharge through the river bed because of its shallow aquifer. Therefore infiltration pond should be located at the point of about 3.0 km downstream from the dam site. And also, pipeline as link canal is adopted in consideration of sheer cliffs on both banks.

(v) Design of sediment control devices
Three detention bunds are planed at the point of about 2.0 km, 2.5 km and 3.0 km upstream from the dam site.

(13) Samaki dam

(i) Geology of catchment area
The catchment area of the proposed dam is broadly composed of Shaigalu Formation composed of shale and partly inbedded sandstone. Shale and sandstone strata have the prevalence of folded structures. Talus deposits were accumulated on the mountain foots along the river. Dam site is located at the confluence of the two tributaries. River gradient is relatively steep, 1:10. River deposits have thickly accumulated in the river bed

(ii) Topo-geology of dam site
Dam site is composed of shale and sandstone, and forms mountainous hilly terrains. Shale has been weathered and cracky, vertically dipping direction. A thin layer of shale is well jointed and severely weathered on their surface. Both site of dam abutment has undulated terrains. River deposits comprising of gravel and stone of shale and sandstone have been accumulated at

the depth of 17 m in the river bed.

(iii) Design of dam

Homogeneous type fill dam is suitable to reduce hydraulic gradient along the 17 m semi pervious dam foundation against piping. River deposits are available for the semi pervious embankment materials. Downstream recharge through intake conduits is also accelerated because seepage flow through dam foundation is not so high, and these is gradually reduced due to siltation in the reservoir. Spillway is constructed at the right side abutment composed of hard shale. Spillway channel slope is only protected with stone masonry. Overflow depth 2.0 m and crest length 12 m is planned to prevent excessive rock excavation. Energy dissipater is constructed to control flow discharge and to prevent scouring of the dam embankment.

Dam type	Catchment area(km^2)	Crest length (m)	Dam height (m)	Embankment volume (m^3)	Total storage volume (m^3)	Effective storage volume (m^3)	Sediment volume (m^3)	Flood discharge (m^3/sec)
Fill dam	2.5	80.0	15.5	35,000	153,000	100,000	53,000	53

Inclined pipe is planed to be installed on the left bank in the reservoir in consideration of slope condition and shortening conduit length. Proposed dimensions of outlet devices are summarized as follows.

Inclined Pipe	Intake Pipe	Conduit Type A	Conduit Type B	Conduit Type C
ø200 x L 15m	ø125 x 4 sets	ø200 x L 20m	ø200 x L 85m	ø400 x L 10m

(iv) Design of recharge devices

Rechargeable water is estimated at 1,296 m^3/day and permeability is also estimated at 1.00×10^{-3} cm/s. Then required area for recharge is 1,500 m^2. Infiltration pond is planned to be located on the top of alluvial fan where is at about 50 m downstream from the dam site.

(v) Design of sediment control devices

No detention bund is proposed.

(14) Iskalkoo dam

(i) Geology of catchment area

Proposed dam site is situated in Kirthar Formation compose of limestone and Nari Formation composed of shale and Mudstone. Several layer of shale and sandstone are well jointed, and talus deposits have been thickly accumulated on the hillfoot along the river.

(ii) Topo-geology of dam site

Dam site is located at Nari Formation composed composed of shale and mudstone, and forms mountainous hilly terrains. Shale is well jointed and its surface has loosened solid rocks. Dam abutments form mountainous hill and terrains. Consolidated clayey layer is observed on the right side and lower part of the river bed. River deposits composed of gravel and cobble stone of shale and sandstone have been accumulated with their thickness of 6.5 to 30 m from the river bed surface. Kirthar limestone is observed under the river deposits.

(iii) Design of dam

Homogeneous type fill dam is suitable to reduce hydraulic gradient along the 5 m semi pervious dam foundation against piping. River deposits are available for the semi pervious embankment materials. Downstream recharge through intake conduits is also accelerated because seepage flow through dam foundation is not so high, and these is gradually reduced due to siltation in the reservoir. Spillway is constructed at the right side abutment. Inflow and chute sections of the spillway channel, comprising of weathered is protected. Overflow depth 2.0 m and crest length 28 m is planned considering narrow abutment width of 40 m Energy dissipater is constructed to control flow discharge and to prevent scouring of the dam embankment.

Dam type	Catchment area(km^2)	Crest length (m)	Dam height (m)	Embankment volume (m^3)	Total storage volume (m^3)	Effective storage volume (m^3)	Sediment volume (m^3)	Flood discharge (m^3/sec)
Fill dam	5.8	100.0	16.0	46,000	170,000	80,000	90,000	133

Inclined pipe is planed to be installed on the left bank in the reservoir in consideration of slope condition and shortening conduit length. Proposed dimensions of outlet devices are summarized as follows.

Inclined Pipe	Intake Pipe	Conduit Type A	Conduit Type B	Conduit Type C
ø200 x L 10m	ø125 x 3 sets	ø200 x L 20m	ø200 x L 85m	ø200 x L 500m

(iv) Design of recharge devices

Rechargeable water is estimated at 2,592 m^3/day and permeability is also estimated at 1.00×10^{-3} cm/s. Then required area for recharge is 3,000 m^2. Infiltration pond is planned to be located on the top of alluvial fan where is at about 500 m downstream from the dam site because of its shallow aquifer in the river. And pipeline is proposed as link canal in consideration of steep mountain slope.

(v) Design of sediment control devices

Two detention bunds are planed at the point of about 2.0 km and 2.5 km upstream from the dam site. And also two detention bunds are proposed in the tributary which meet on left bank at the point of 500 m upstream from dam site.

Table I.4.1 Design Flood Discharge

Dam Site	Catchment area	Geological condition	Height of top catchment	Height of dam site	Height difference of catchment	River length	Average gradience	Tc	Design discharge(m^3/s)					
	(km^2)		(m)	(m)	(m)	(m)	(degree)	(hr)	R.P. 30 discharge	Specific discharge ($m^3/s/km^2$)	R.P. 50 discharge	Specific discharge ($m^3/s/km^2$)	R.P.100 discharge	Specific discharge ($m^3/s/km^2$)
1 Murghi Kotal	19.65	B	2,710	1,600	1,110	11,500	5.5	5.5	100.5	5.1	112.4	5.7	130.1	6.6
2 Wali Dad	5.35	C	3,000	1,980	1,020	5,000	11.5	11.5	66.7	12.5	74.3	13.9	85.5	16.0
3 Ghazlona	9.09	C	2,454	1,905	549	5,600	5.6	5.6	84.3	9.3	93.9	10.3	108.1	11.9
4 Samaki	2.52	C	2,210	1,905	305	2,500	7.0	7.0	41.1	16.3	45.8	18.2	52.7	20.9
5 Jigda	20.8	C	2,380	1,870	510	9,900	2.9	2.9	110.5	5.3	123.2	5.9	141.8	6.8
6 Sanzali	10.44	C	2,070	1,700	370	7,800	2.7	2.7	61.9	5.9	69.0	6.6	79.5	7.6
7 Brewary	25.88	C	2,890	1,740	1,150	13,500	4.9	4.9	128.0	4.9	142.7	5.5	164.6	6.4
8 Kach Kach	56.50	C	3,350	1,865	1,485	12,600	6.7	6.7	256.4	4.5	285.7	5.1	328.9	5.8
(downstream)	57.20	C	3,350	1,760	1,590	14,600	6.2	6.2	259.6	4.5	289.2	5.1	333.0	5.8
9 Dara	16.55	B	2,640	1,840	800	5,500	8.3	8.3	150.7	9.1	168.6	10.2	195.2	11.8
10 Ghutai Shela	1.79	D	2,120	1,660	460	4,000	6.6	6.6	21.5	12.0	23.9	13.4	27.5	15.4
11 Sahkol	22.30	C	2,210	1,753	457	6,700	3.9	3.9	153.7	6.9	171.6	7.7	198.1	8.9
12 Khad Kucha II	15.16	C	2,485	1,811	637	8,000	4.6	4.6	295.8	19.5	332.9	22.0	388.3	25.6
13 Mangi	39.40	A	2,030	1,646	384	11,200	2.0	2.0	300.5	7.6	340.1	8.6	399.9	10.2
14 Iskalkoo	5.75	D	2,330	2,202	384	3,000	7.3	7.3	68.2	11.9	76.7	13.3	89.3	15.5

Note
A : fratured sandstone and shale　C : non-fractured rock
B : fractered limetone　D : umconsolidate rock

Table I.4.2 Features of Proposed Delay Action Dams

	Dam Name	District	Dam Type	Crest Length (m)	Dam Height (m)	Spillway Length (m)	Spillway Crest Length (m)	Design Flood Discharge (m^3/sec)	Specific Flood Discharge (m^3/sec/km^2)	Total Storage Volume (m^3)	Embankment Volume (m^3)	Sediment Volume (m^3)	Specific Sediment Volume (m^3/km^2/year)	Catchment Area (km^2)
1	Brewary DAD	Quetta	Gravity	42.0	32.4	19.5	15.0	165.0	6.4	749,000	9,600	360,000	500	25.9
2	Ghutai Shela DAD	Quetta	Earth dam	155.0	13.0	100.0	6.0	28.0	15.7	80,000	33,000	38,000	700	1.8
3	Wali Dad DAD	Quetta	Gravity	20.0	23.0	27.0	15.0	86.0	16.1	139,000	3,700	49,000	300	5.4
4	Dara DAD	Quetta	Earth dam	405.0	22.8	220.0	41.0	109.0	6.6	589,000	285,000	349,000	700	16.6
5	Murghi Kotal DAD	Quetta	Earth dam	130.0	35.6	300.0	36.0	131.0	6.7	1,147,000	278,000	887,000	1,500	19.7
6	Kach DAD	Quetta	Earth dam	330.0	45.9	276.0	42.0	333.0	5.9	2,387,000	480,000	1,187,000	1,700	56.5
7	Jigda DAD	Pishin	Earth dam	210.0	23.9	80.0	46.0	142.0	6.8	508,000	114,000	218,000	700	20.8
8	Sanzali DAD	Pishin	Earth dam	297.0	19.2	400.0	26.0	80.0	7.7	394,000	106,000	234,000	1,500	10.4
9	Ghazlona DAD	Qila Abdullah	Earth dam	195.0	20.9	65.0	35.0	109.0	12.0	331,000	76,000	191,000	700	9.1
10	Samaki DAD	Qila Abdullah	Earth dam	80.0	15.5	150.0	12.0	53.0	21.0	153,000	35,000	53,000	700	2.5
11	Sahkol DAD	Mastung	Earth dam	1090.0	14.5	47.0	42.0	199.0	8.9	545,000	187,000	335,000	500	22.3
12	Mangi DAD	Kalat	Earth dam	530.0	12.7	120.0	85.0	400.0	10.2	1,011,000	171,000	591,000	500	39.4
13	Khad Kucha II DAD	Mastung	Earth dam	595.0	14.0	53.5	50.0	389.0	25.7	368,000	152,000	228,000	500	15.2
14	Iskalkoo DAD	Kalat	Earth dam	100.0	16.0	90.0	20.0	133.0	23.1	170,000	46,000	90,000	500	5.8

Source : JICA Study Team

1) Earth dam means homogeneous type fill dam. Kach dam has impervious zone in the center, and semi-pervious zone at both side of the embankment.

Table I.4.3 Calculation of Proposed Intake Diameter

Dam	Full Water Level (EL.m)	Low Water Level (EL.m)	Water Depth (m)	Proposed Diameter (mm)	Calculated Discharge (m^3/s)	Design Discharge (m^3/s)
Brewary	1,758.7	1,754.5	4.2	125	0.049	0.038
Dara	1,851.8	1,849.5	2.3	250	0.144	0.114
Murgi Kotal	1,665.5	1,663.5	2.0	250	0.135	0.090
Kach	1,879.7	1,875.5	4.2	150	0.070	0.060
Jigda	1,870.9	1,867.2	3.7	250	0.183	0.172
Sanzali	1,680.5	1,678.5	2.0	125	0.034	0.030
Sakhol	1,952.3	1,950.9	-	-	-	0.011
Mangi	1,655.5	1,653.8	1.7	300	0.179	0.150
Kad Kocha II	1,827.3	1,826.2	1.1	350	0.196	0.150
Ghazlona	1,906.7	1,904.0	2.7	100	0.025	0.008
Ghutai Shela	1,659.9	1,658.5	1.4	150	0.057	0.056
Wali Dad	1,865.3	1,860.3	5.0	200	0.136	0.081
Samaki	1,955.4	1,950.8	4.6	100	0.033	0.015
Iskalkoo	2,213.0	2,210.5	2.5	125	0.038	0.030
Kach (downstream)	1,793.0	1,785.8	7.2	125	0.064	0.060

Note) $Q = A \times 0.62 \times (19.6 \times H/2)^{1/2}$

Table 1.4.4 Design of Recharge Devices

Design of Infiltration Pond

Dam Site	Water (m³/day)	Permeability (cm/s)	Required Area (m²)	Width (m)	Length (m)	Calculated Area (m²)	Water Depth (m)	Pond Depth (m)
Brewry	3,240.0	2.50E-03	1,500	15	100	1,500	2.160	2.700
Dara	9,856.0	1.00E-03	11,407	110	105	11,550	0.864	1.400
Murgi Kotal	7,776.0	1.00E-03	9,000	100	90	9,000	0.864	1.400
Kach	5,184.0	1.00E-03	6,000	80	75	6,000	0.864	1.400
Jigda (Right)	5,961.6	1.15E-03	6,000	40	150	6,000	0.994	1.500
Jigda (Left)	8,942.4	1.15E-03	9,000	60	150	9,000	0.994	1.500
Sanzali	2,592.0	1.00E-03	3,000	60	50	3,000	0.864	1.400
Sakhol	976.0	1.00E-03	1,130	40	30	1,200	0.864	1.400
Mangi	12,960.0	1.00E-03	15,000	130	116	15,080	0.864	1.400
Kad Kocha II	12,960.0	1.00E-03	15,000	100	150	15,000	0.864	1.400
Ghazlona	661.5	1.00E-03	766	30	26	780	0.864	1.400
Ghutai Shela	4,815.0	9.50E-03	4,815	70	70	4,900	1.000	1.500
Wali Dad	7,020.0	1.00E-03	8,125	100	85	8,500	0.864	1.400
Samaki	1,296.0	1.00E-03	1,500	40	40	1,600	0.864	1.400
Iskalkoo	2,592.0	1.00E-03	3,000	60	50	3,000	0.864	1.400

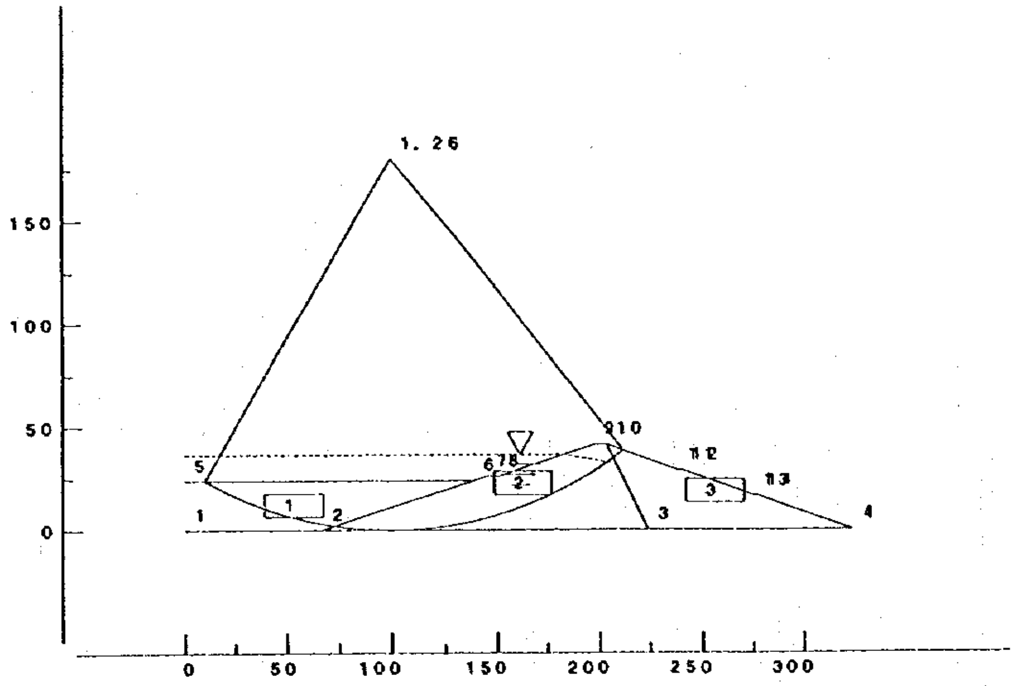
Design of Link Canal

Dam Site	Water (m³/day)	Design Discharge (m³/sec)	Width (m)	Water Depth (m)	Height (m)	Gradient	Velocity (m/sec)	Calculated Discharge (m³/sec)
Brewry	3,240.0	0.038	-	-	-	-	-	-
Dara	9,856.0	0.114	0.200	0.197	0.400	1/100	1.465	0.114
Murgi Kotal	7,776.0	0.090	0.200	0.165	0.400	1/80	1.497	0.090
Kach	5,184.0	0.060	0.200	0.130	0.300	1/70	1.430	0.061
Jigda (Right)	5,916.1	0.068	0.200	0.138	0.400	1/70	1.479	0.070
Jigda (Left)	8,942.4	0.104	0.200	0.183	0.400	1/90	1.484	0.104
Sanzali	2,592.0	0.030	0.200	0.075	0.300	1/40	1.450	0.030
Sakhol	976.0	0.011	-	-	-	-	-	-
Mangi	12,960.0	0.150	-	-	-	-	-	-
Kad Kocha II	12,960.0	0.150	0.200	0.236	0.500	1/120	1.472	0.152
Ghazlona	661.5	0.008	0.100	0.050	0.200	1/40	1.084	0.009
Ghutai Shela	4,815.0	0.056	0.200	0.120	0.400	1/60	1.476	0.056
Wali Dad	7,020.0	0.081	-	-	-	-	-	-
Samaki	1,296.0	0.015	0.100	0.065	0.300	1/30	1.400	0.015
Iskalkoo	2,592.0	0.030	-	-	-	-	-	-

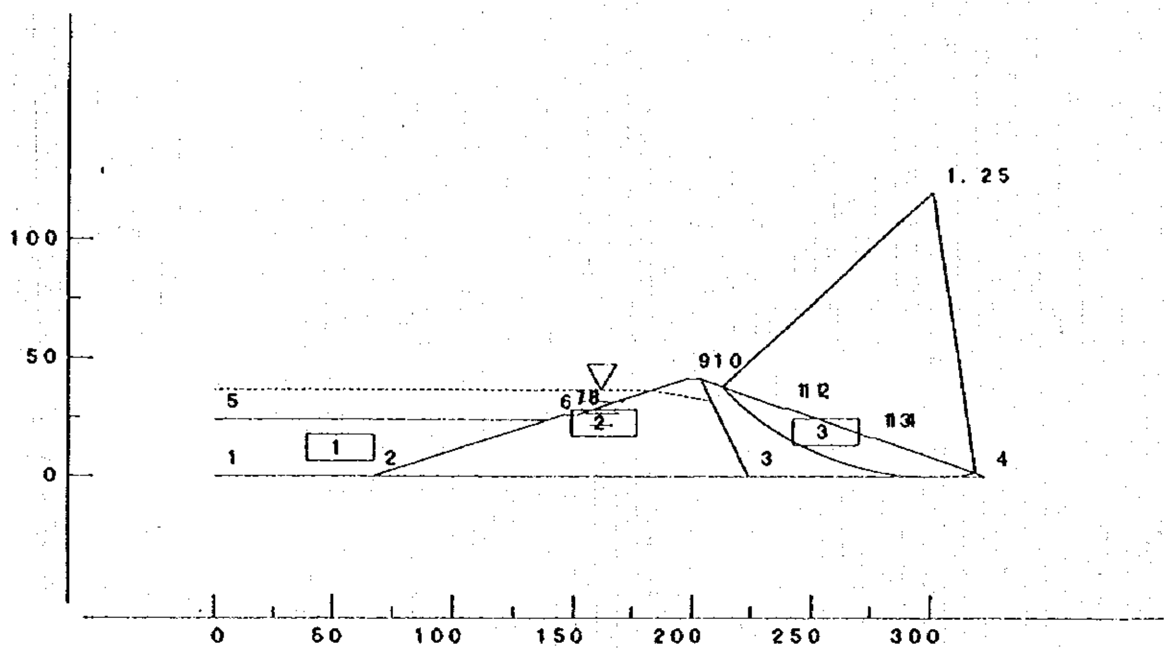
Table I.4.5 Sediment Volume of Erosion Control Devices

Site	Crest Length (m)	Gradient	Sediment Vol. (m^3)
Dara			
D.Bund 1	15.6	1/ 20	5,270
D.Bund 2	27.4	1/ 20	3,888
Total			9,158
Murgi Kotal			
D.Bund 1	56.2	1/ 20	5,994
D.Bund 2	35.8	1/ 20	3,780
D.Bund 3	27.0	1/ 25	4,838
D.Bund 4	56.3	1/ 20	6,228
Total			14,612
Kach			
D.Bund 1	53.4	1/ 45	11,867
D.Bund 2	53.0	1/ 65	12,227
Total			24,093
Jigda			
D.Bund 1	68.9	1/ 30	39,000
D.Bund 2	139.7	1/ 20	37,850
D.Bund 3	120.0	1/ 20	35,000
Total			111,850
Sanzali			
D.Bund 1	30.3	1/ 45	9,720
D.Bund 2	27.3	1/ 35	7,056
D.Bund 3	30.3	1/ 40	8,208
D.Bund 4	41.5	1/ 40	13,212
Total			38,196

Site	Crest Length (m)	Gradient	Sediment Vol. (m^3)
Ghazlona			
D.Bund 1	32.7	1/ 40	7,812
D.Bund 2	57.5	1/ 20	7,290
Total			15,102
Ghutai Shela			
D.Bund 1	30.0	1/ 15	3,240
D.Bund 2	50.0	1/ 15	5,400
Total			8,640
Wali Dad			
D.Bund 1	20.0	1/ 15	2,160
D.Bund 2	20.0	1/ 15	2,160
D.Bund 3	20.0	1/ 15	2,160
Total			6,480
Iskalkoo			
D.Bund 1	30.0	1/ 10	2,160
D.Bund 2	30.0	1/ 10	2,160
D.Bund 3	30.0	1/ 10	2,160
D.Bund 4	30.0	1/ 10	2,160
Total			8,640



Upstream (Ordinary seepage flow in embankment in full water surface)



Downstream (Ordinary seepage flow in embankment in full water surface)

Fig. I.4.1.1 Sliding Calculation of Kach Dam

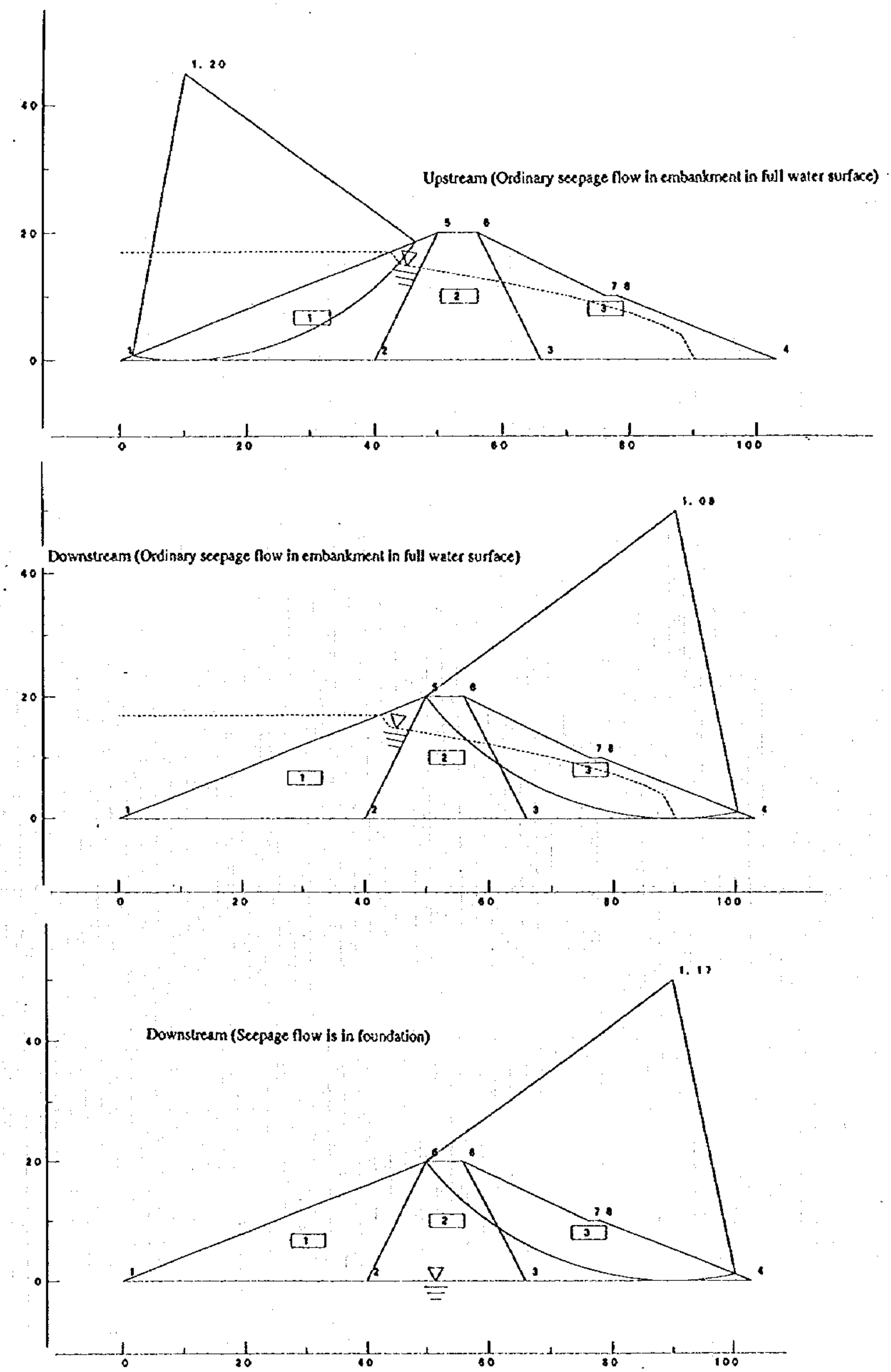


Fig. I.4.1.2 Sliding Calculation of 20 m Height Dam

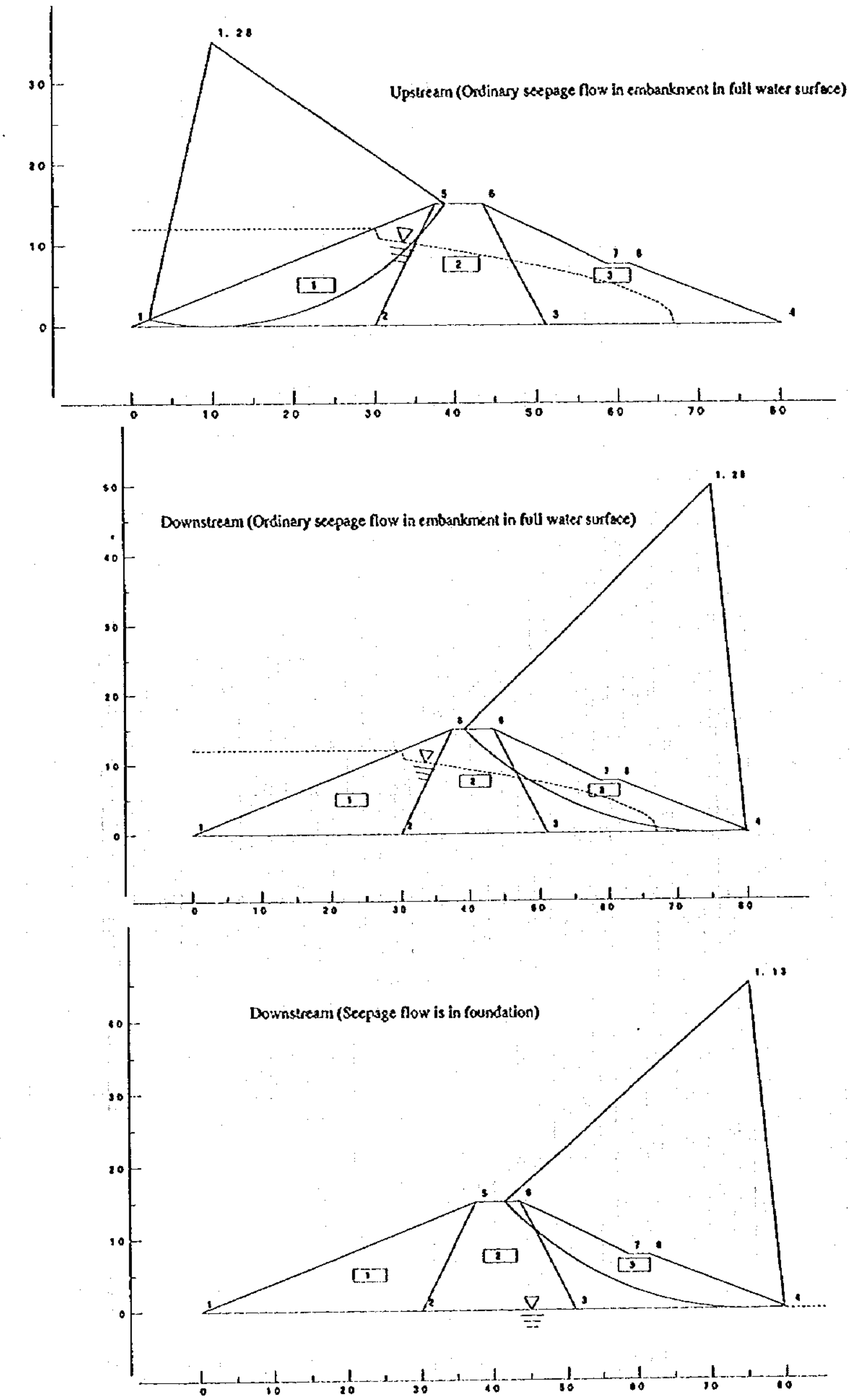
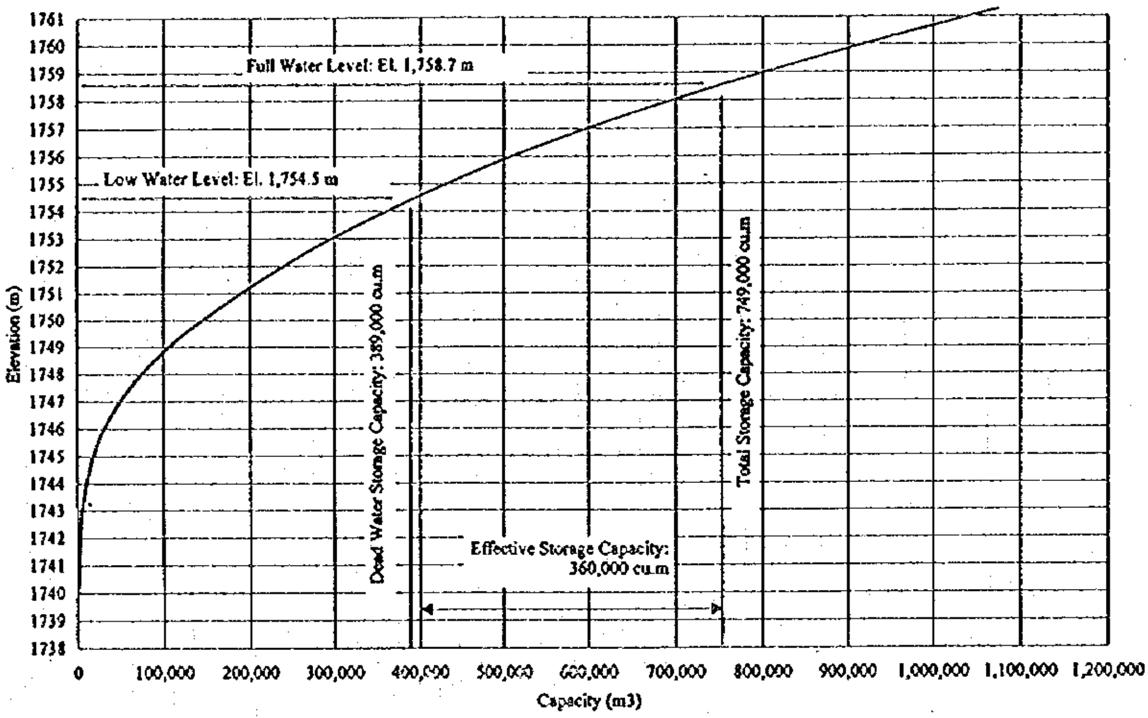


Fig. I.4.1.3 Sliding Calculation of 15 m Height Dam

Elevation-Capacity of Brewary DAD



Elevation-Capacity of Dara DAD

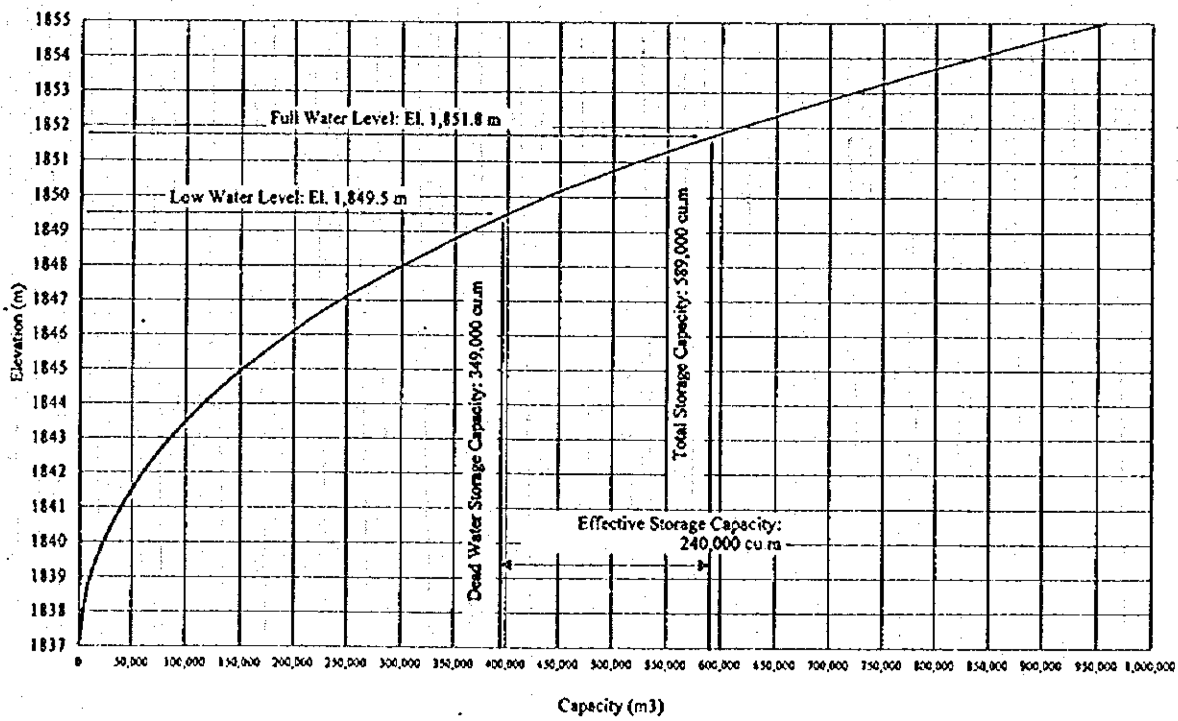
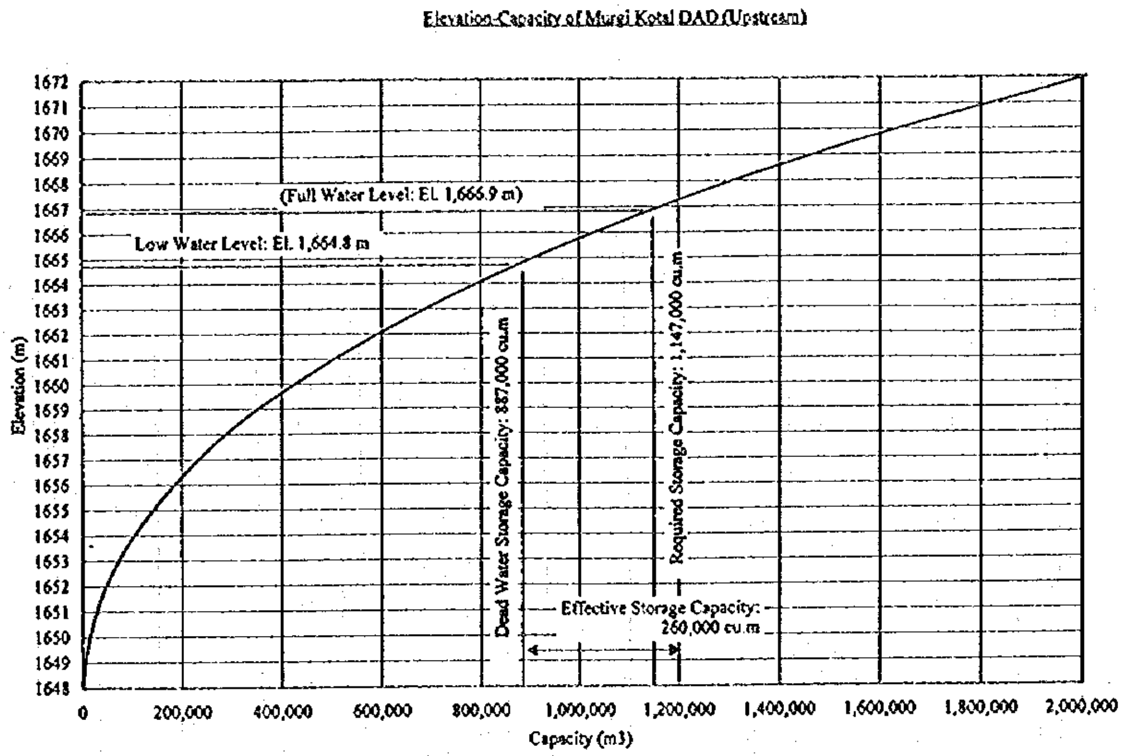


Fig. I.4.2.1 Elevation - Capacity Curve of Proposed Delay Action Dams (1/8)



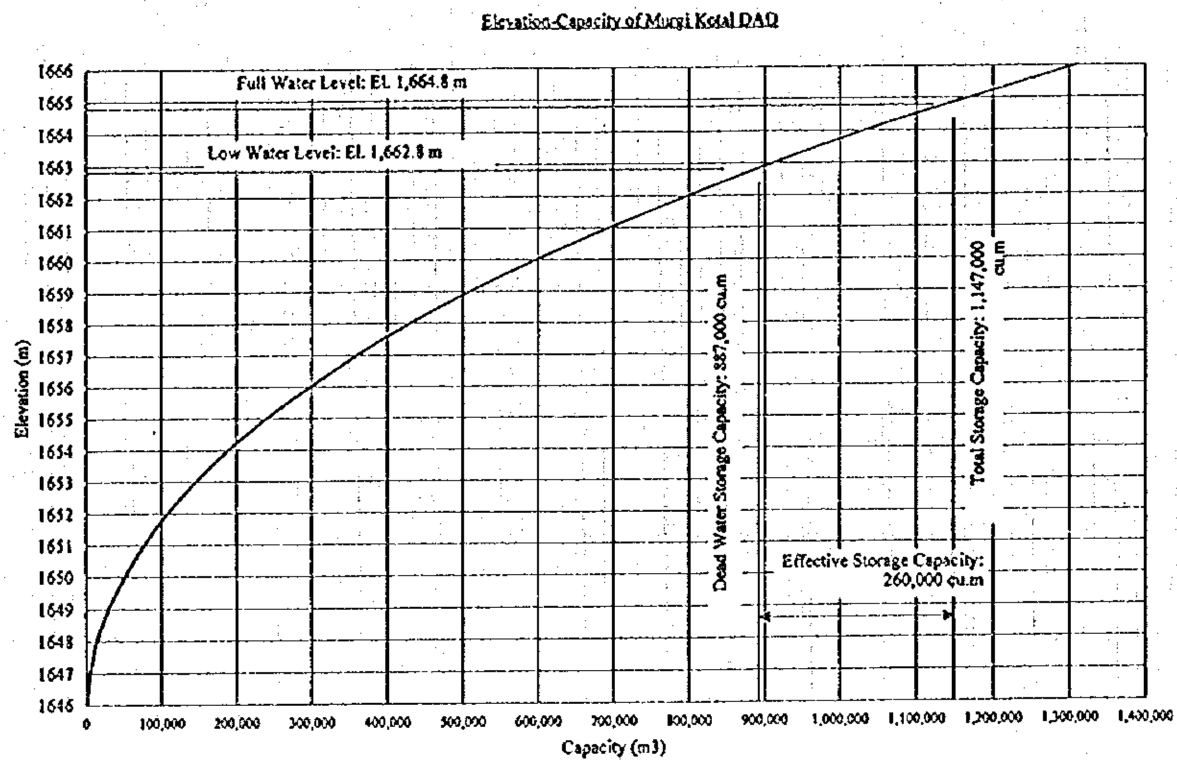
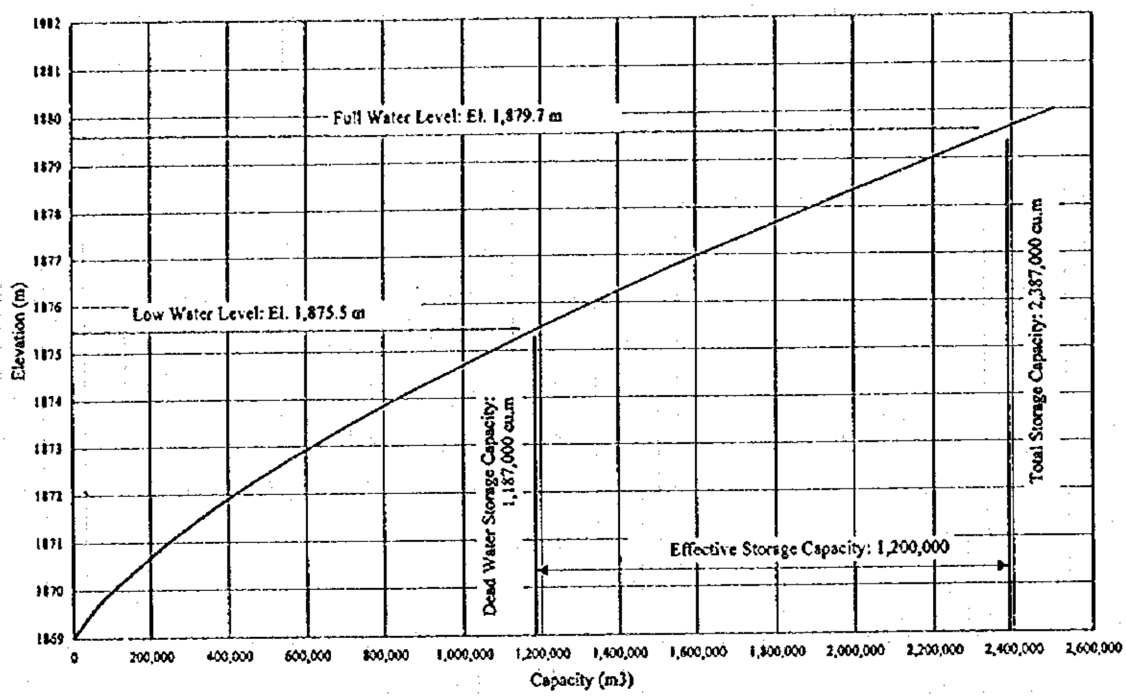


Fig. 1.4.2.2 Elevation - Capacity Curve of Proposed Delay Action Dams (2/8)

Elevation-Capacity of Kach DAD



Elevation-Capacity of Kach (Downstream) DAD

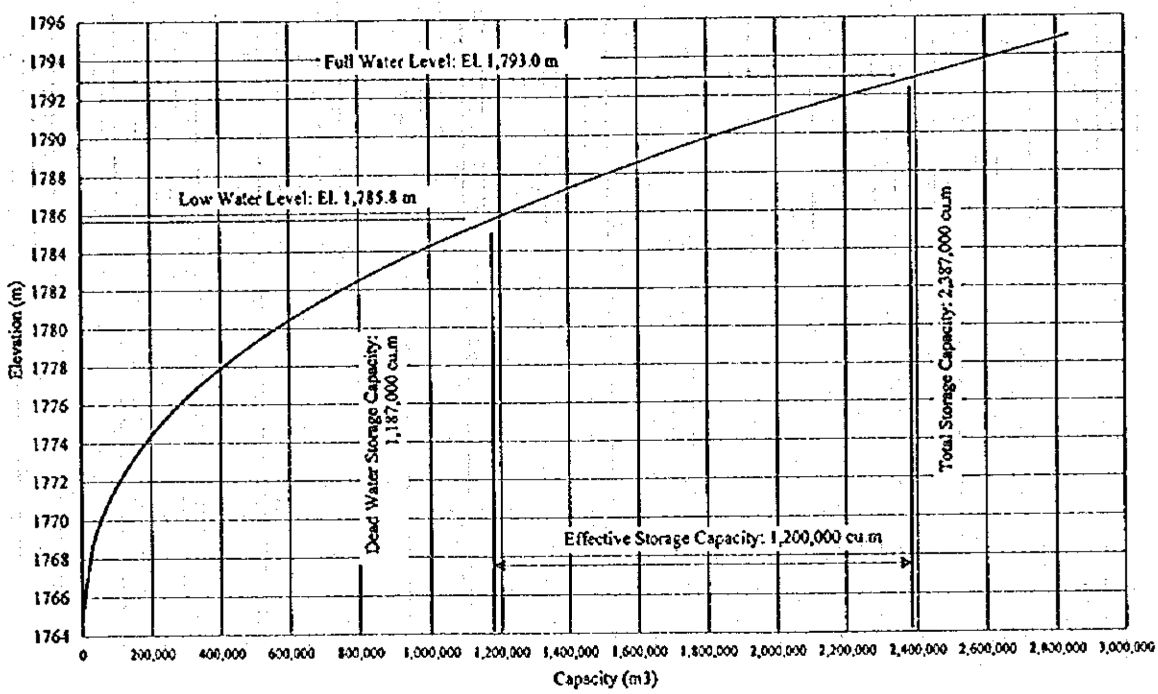
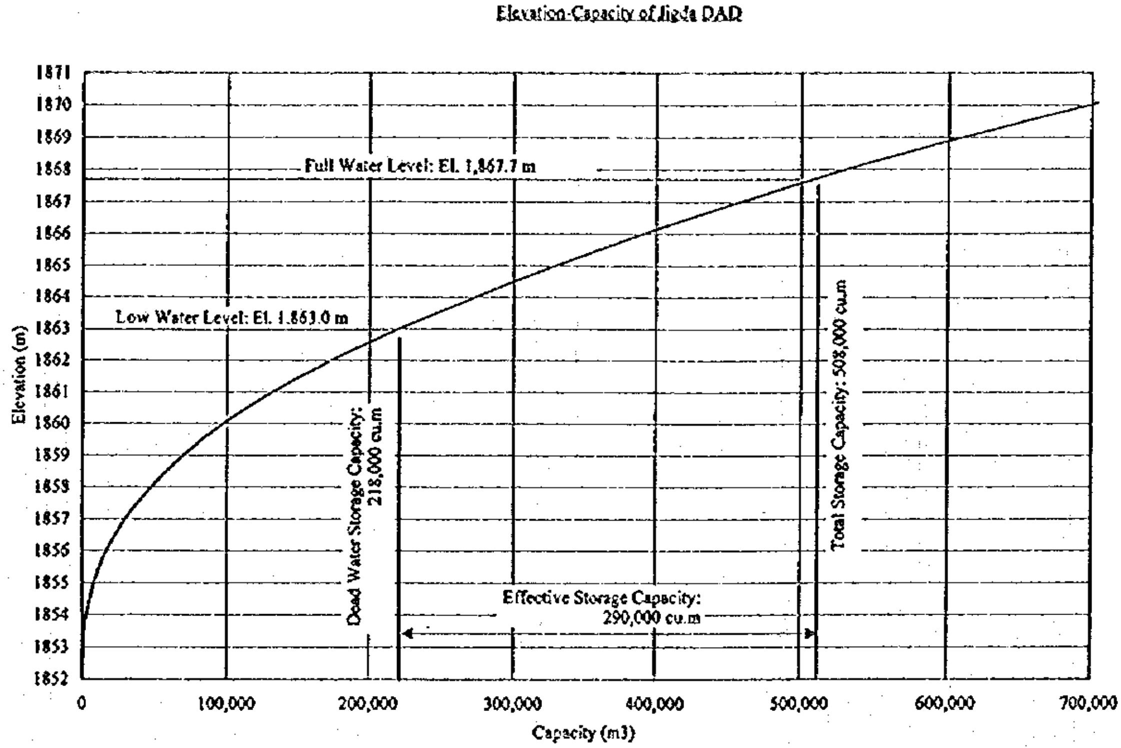


Fig. I.4.2.3 Elevation - Capacity Curve of Proposed Delay Action Dams (3/8)



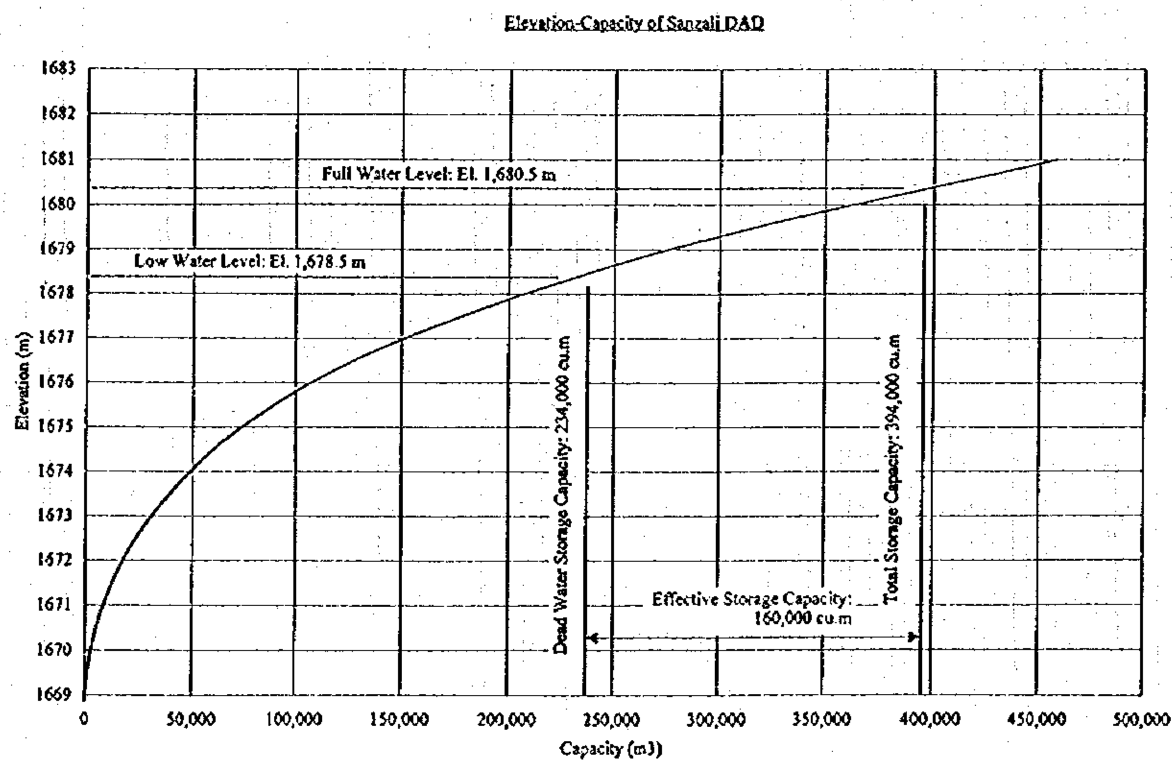
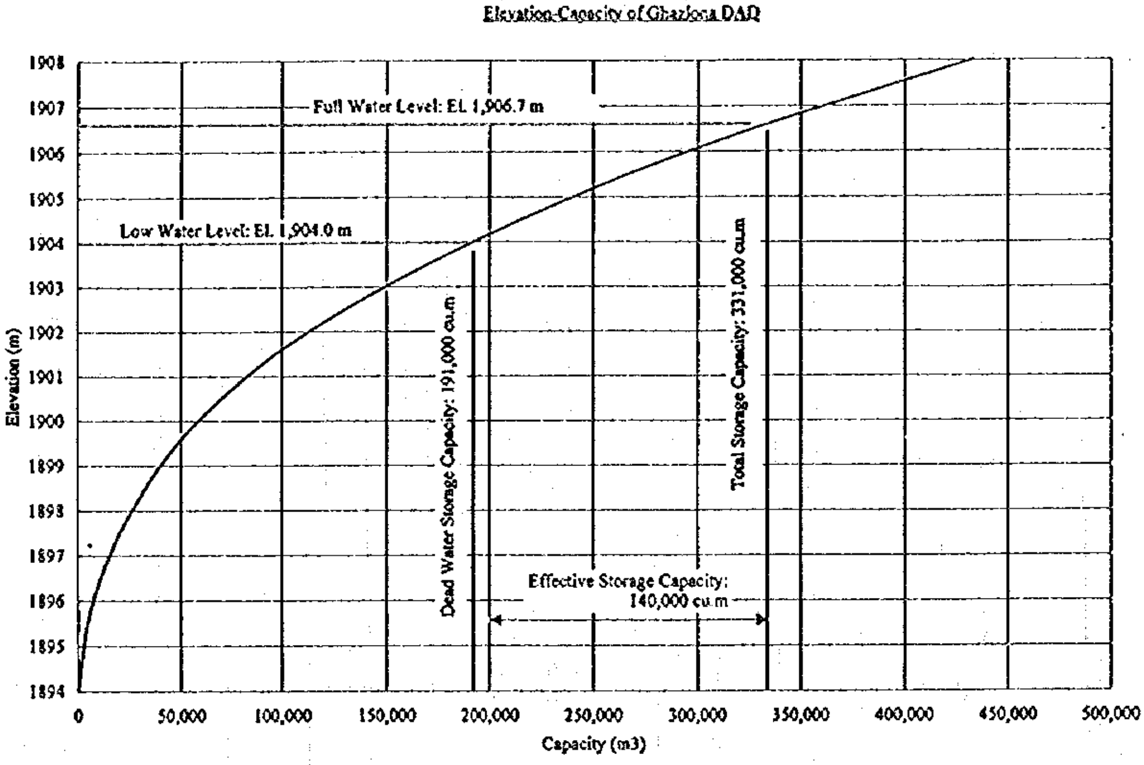


Fig. I.4.2.4 Elevation - Capacity Curve of Proposed Delay Action Dams (4/8)



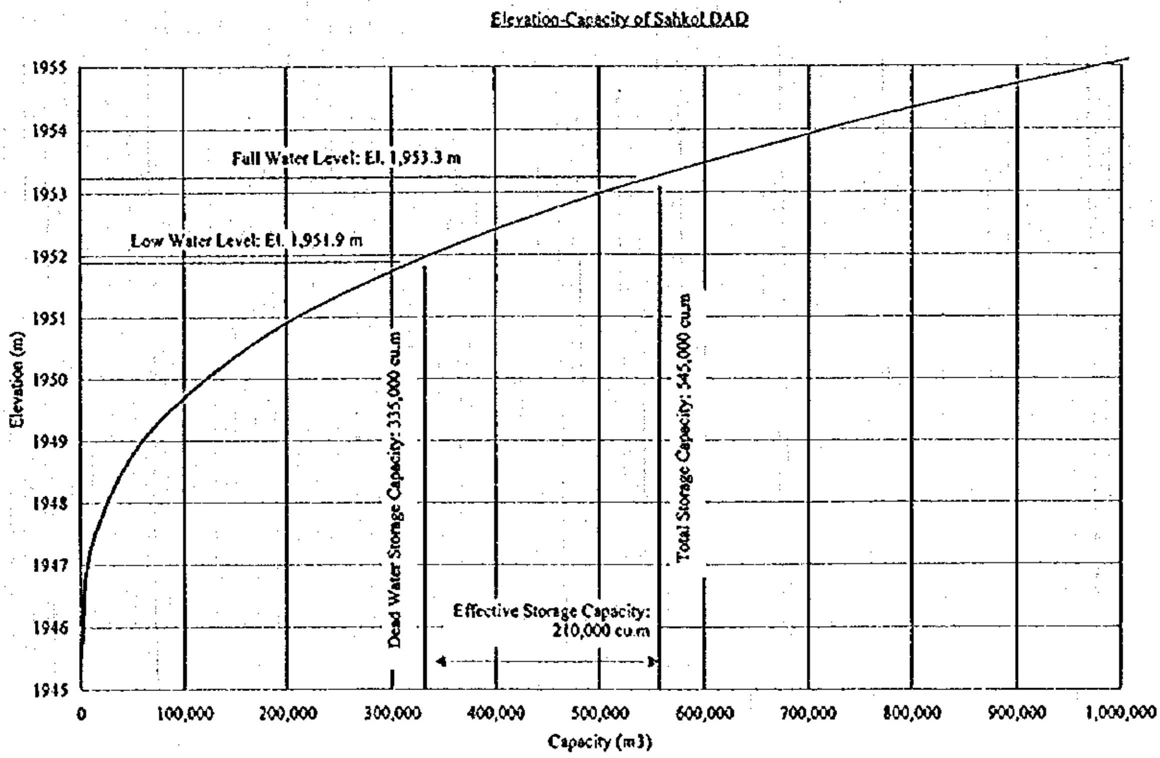
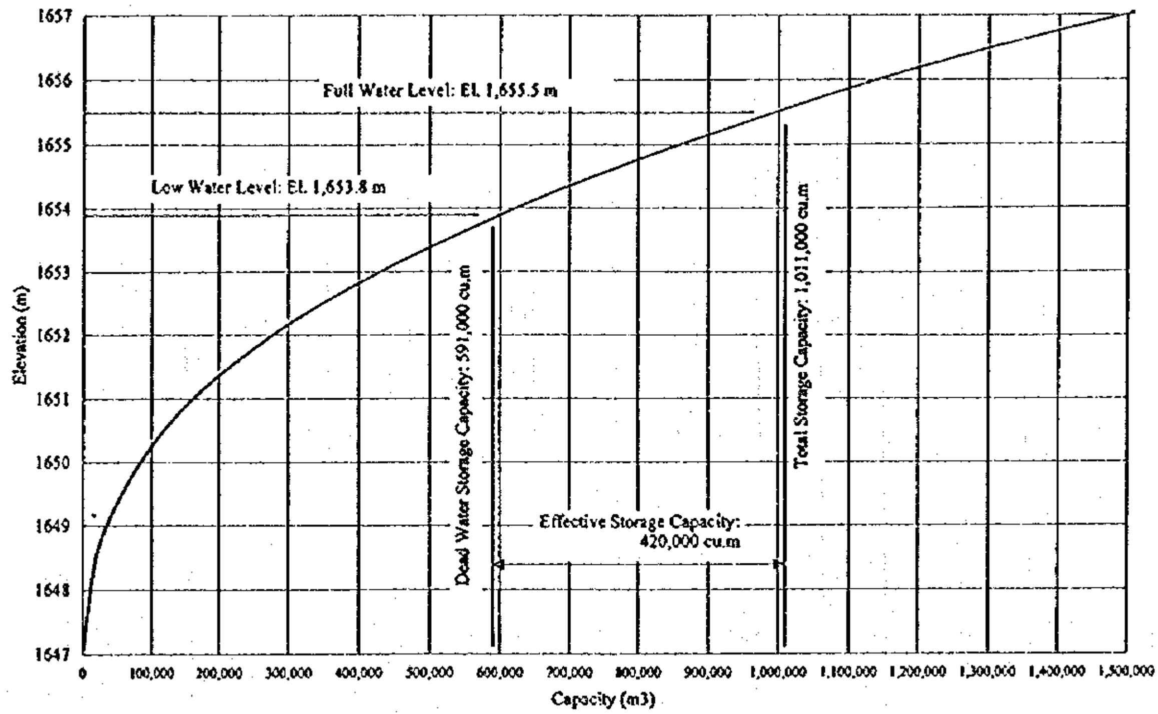


Fig. I.4.2.5 Elevation - Capacity Curve of Proposed Delay Action Dams (5/8)

Elevation-Capacity of Mangi DAD



Elevation-Capacity of Kad Kocha II DAD

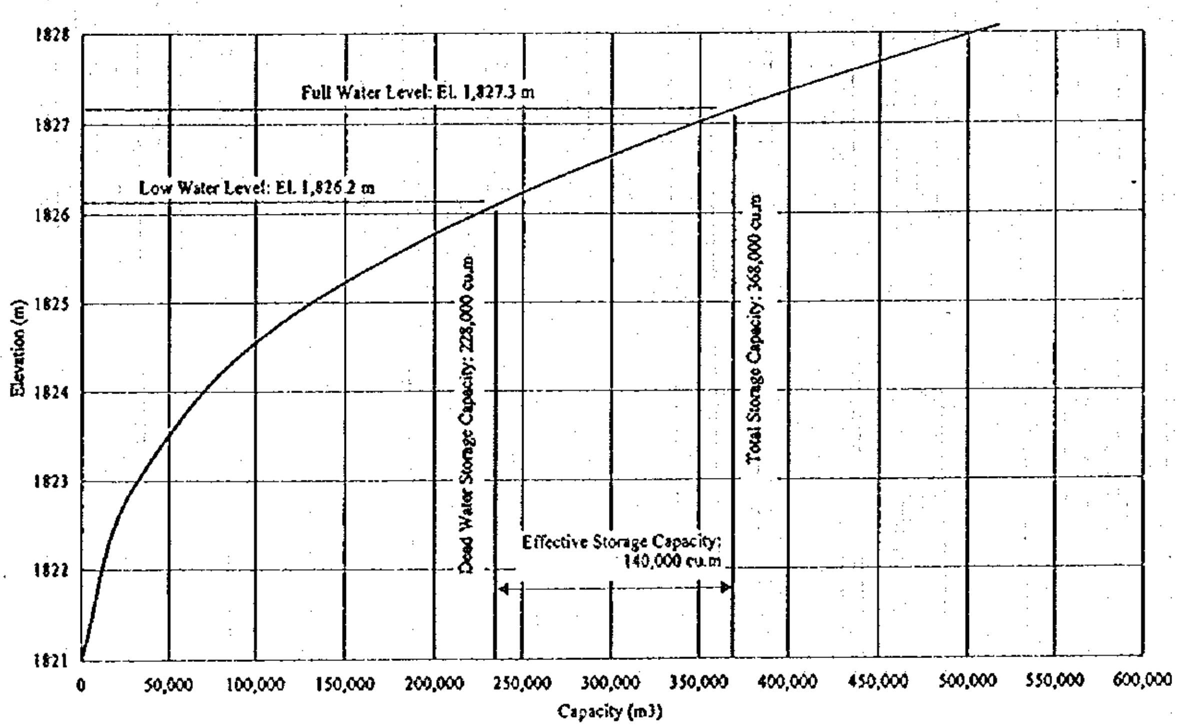
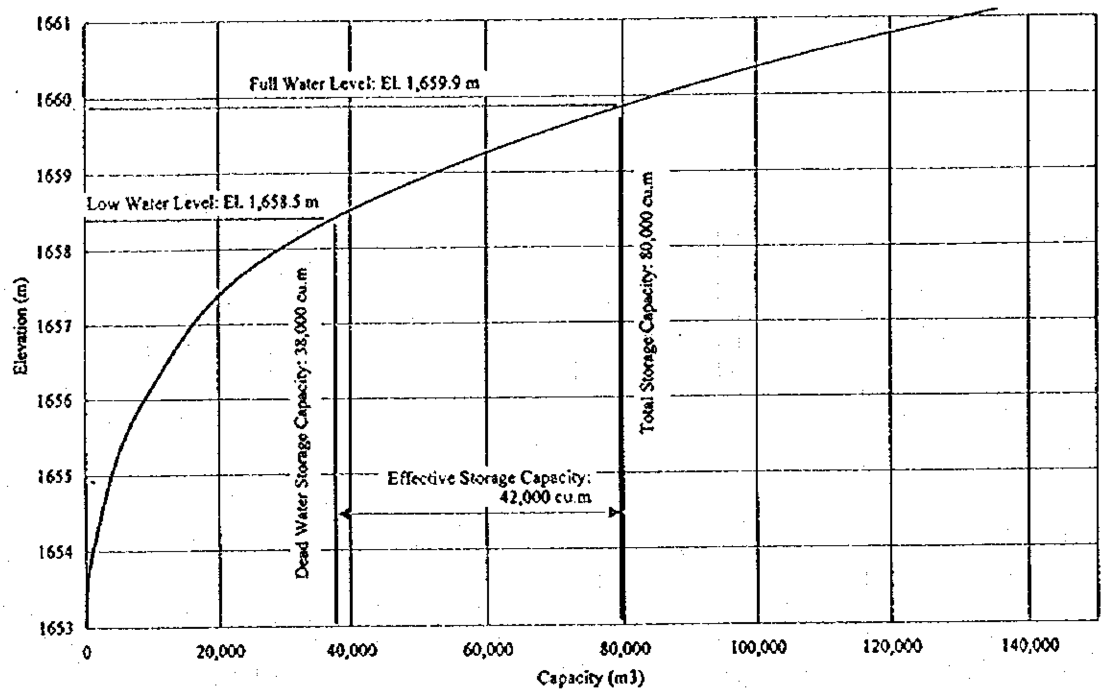


Fig. I.4.2.6 Elevation - Capacity Curve of Proposed Delay Action Dams (6/8)

Elevation-Capacity of Ghutai Shela DAD



Elevation-Capacity of Wali Dad DAD

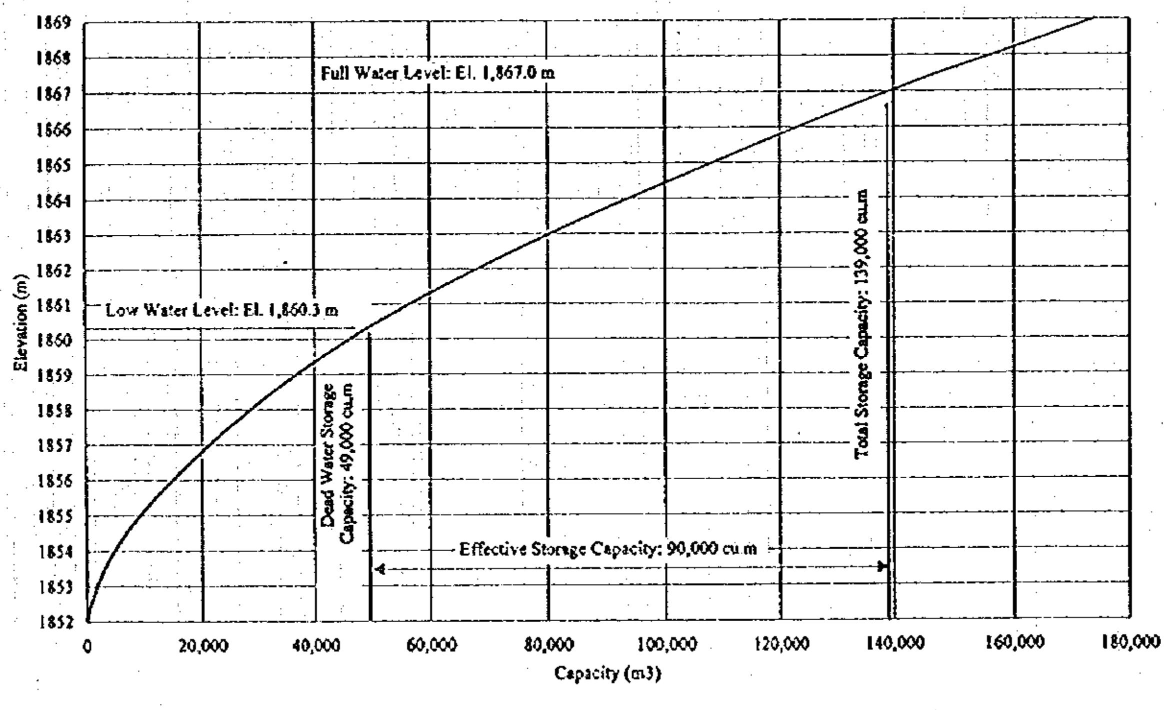
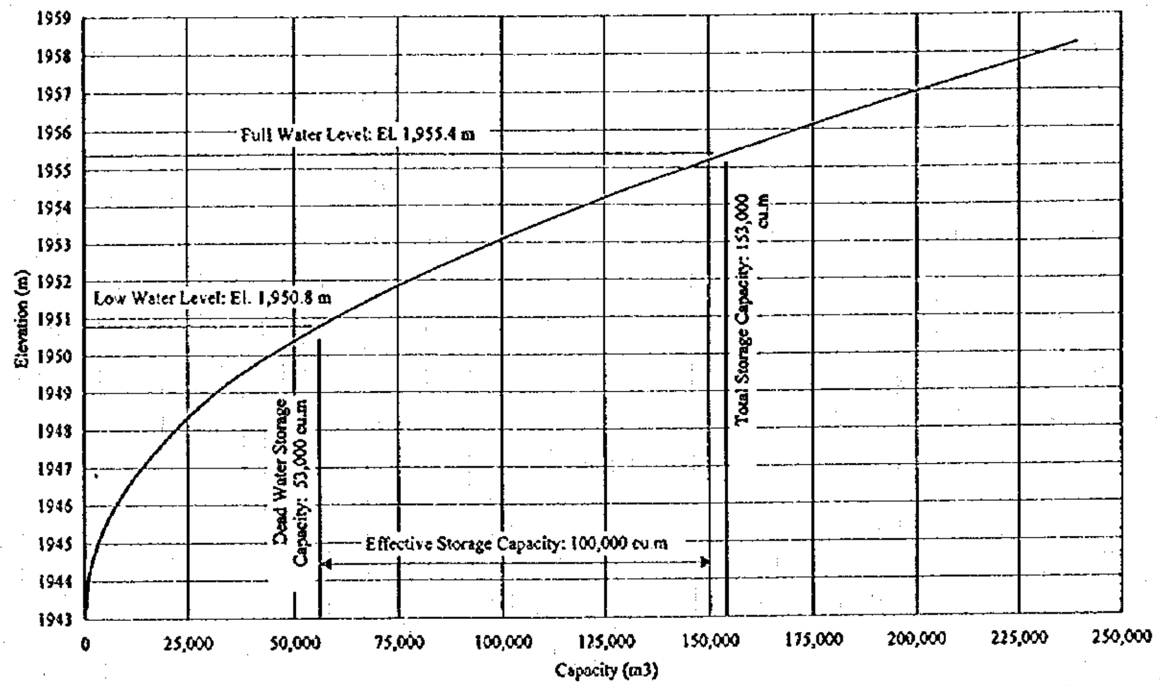


Fig. I.4.2.7 Elevation - Capacity Curve of Proposed Delay Action Dams (7/8)

Elevation-Capacity of Samaki DAD



Elevation-Capacity of Iskalkoo DAD

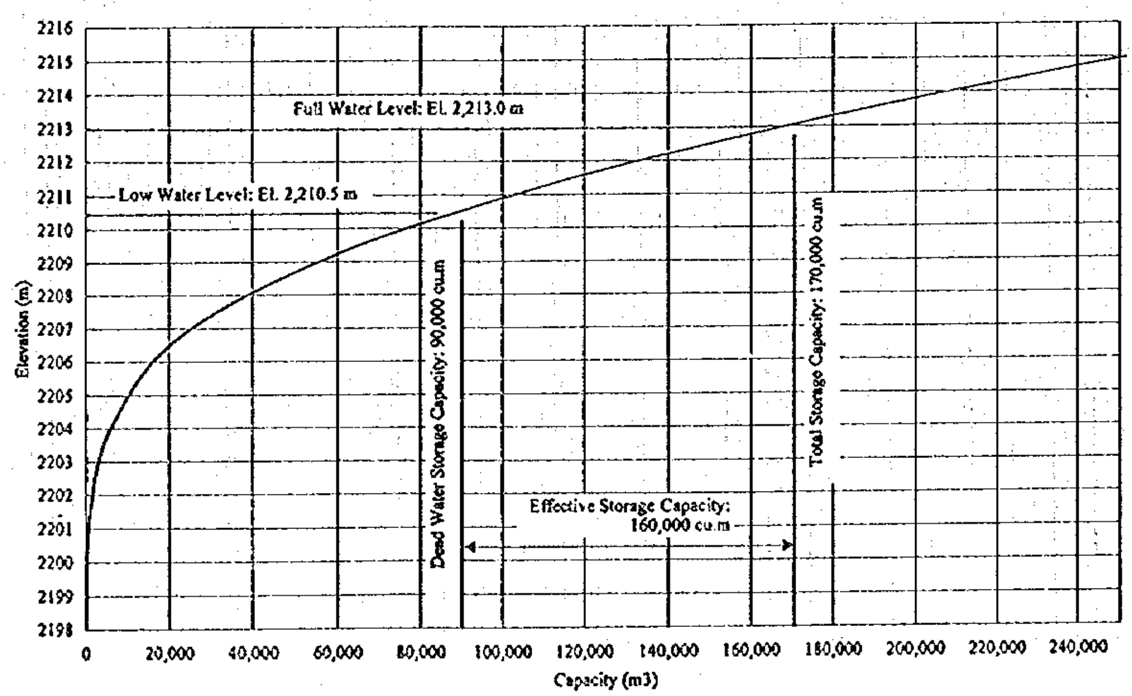


Fig. I.4.2.8 Elevation - Capacity Curve of Proposed Delay Action Dams (8/8)

I.5 Watershed Management

The most of the immediate priorities in rural areas of the Study Area are related to water shortage and degradation of the surrounding watershed areas. Delay action dams contributes to recharge of the groundwater, and to mitigate flood damages, etc. However, the excessively high sediment production of the dam catchment area reduces the dam capacity, furthermore causes dam failures resulting from an overflow from the dam crest.

People's participation is inevitable to successfully continue watershed management with cooperation of FAO. FAO set the following watershed management objectives under the Integrated Area Development Program in Balochistan, and has launched their activities in and around the Study Area through the Forest Department.

1) recharge of groundwater aquifers,
2) control of floods and the resulting damage to the agriculture crops,
3) development of surface water resources for agriculture crop production,
4) rehabilitation of degraded watersheds and range lands, and
5) enhancement of fuel wood production.

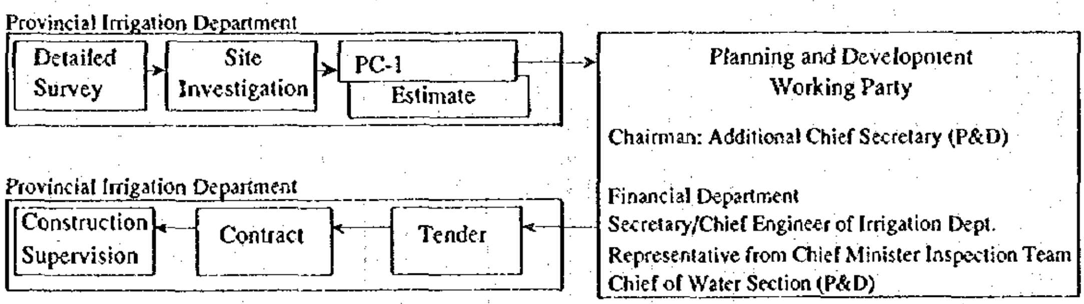
Regarding the watershed management of the Integrated Area Development Program in Balochistan, the following activities are being carried out by FAO.

1) treatment of hilly areas with conservation contour trenches at a spacing of 3 x 8 m, planting of bushes and indigenous species in the trenches, grass tufts planted on the berms of the trenches.
2) treatment of the alluvial fans with hillside ditches at a spacing of 30 m, planting pits dug out in the pitches at a spacing of 3 m with the soil piled in the ditch on one side of the pit to break the continuity of the water flow in the ditch, planting of bush and tree in the ditches.
3) treatment of the streams with check dams at a proper spacing. Check dams are aims at increasing the residence time of the flow and thus enhancing infiltration and groundwater recharge.
4) construction of small earth dams with the aims of recharging the groundwater, as well as providing a surface water resources for irrigation, water supply, livestock drinking, etc.
5) water harvesting and spreading contribute to flood mitigation, water supply for irrigation use. Flood protection dikes is effective for crop protection, soil erosion from the agricultural lands, etc.

Because the watershed management needs several years and continuous efforts are required, it is necessary that the Irrigation Department and the Forest Department positively pursue the watershed management together with technical and financial assistance to the beneficiaries.

I.6 Implementation Procedure for the Construction of Delay Action Dams

Proposed site is identified by field engineer or by notable of the area. Detailed survey is carried out, and then PC-1 and estimate are prepared by the Irrigation Department. The PC-1 is processed with the Planning and Development Department, which considers its approval in a committee named "Planning and Development Working Party". The Irrigation Department then puts the work to tender and awards contract subject to a availability of funds. Construction of the work is supervised by staff of the Irrigation Department of the respective Division and Circle.



I.7 O&M Planning

I.7.1 Operation and Maintenance of Delay Action Dams

The Irrigation Department is responsible for plans, designs, supervisory works, construction, and furthermore for operation and maintenance of the delay action dams. Reservoir operational work is not frequently required for the dams of which groundwater recharge is naturally accelerated through dam and reservoir foundation. For the dams of which impounding capacity is being allocated for the irrigation system by gravity, or constructed on impervious foundation, frequent reservoir operational work by the Irrigation Department is inevitable to regularly release impounding water in the reservoir toward downstream of the reservoir through the outlet conduits.

Maintenance works for embankment, spillway and other allied structures are conducted by the Irrigation Department. Generally two (2) percent of the capital cost of the dam construction based on demand and nature of work required at sites is allocated for the O&M activities at present. Rehabilitation works of the spillways are mostly required for O&M because of their severe erosion on the canal beds and collapse of gabion protection walls.

I.7.2 Construction Machinery and Equipment for Dam Construction and O&M

(1) Present condition

The Irrigation Department owns construction machinery and equipment for the construction works as tabulated below. These machinery is mainly used for the O&M activities of canal system, small dams, flood protection embankment, flood irrigation schemes and delay action dams, and also used for the dam construction on rental basis to the contractor. Machinery and equipment are maintained at workshop in Quetta, Irrigation Department, Machinery & Equipment Section is responsible for the works.

Machinery and Equipment of Irrigation Department

Machinery	Description	Number of Machinery	Location	Operation period (years)	Manufactures	Present condition (Operational/Repair)
Bulldozer						
Caterpiller D6D	140 HP	21		11	USA/UK/Japan	18 out of order/under repair
Caterpiller D7G	200 HP	2		17	USA	2 out of order/under repair
Caterpiller D4H	116 HP	2		1	Japan	1 out of order/under repair
J.I Case 1450B	140 HP	4		10	USA	3 out of order/under repair 1 beyond economic repair
Fiat 14C	200 HP	20		18	Italy	14 out of order/under repair 5 beyond economic repair
Backhoe	-	2	D.M.Jamali	10	Japan	Fair/requires repair
		2	- do -	2	Japan/Komatsu	Good
		2	- do -	2	Japan Hitachi	- do -
		2	Loralai	10	Japan	Fair/requires repair
Wheel Loader	-	1	Pishin	16	USA	Working condition
		3	D.M.Jamali	2	Japan/Furukawa	- do -
		1	Hub	16	USA	- do -
Vibratory	-	6	D.M.Jamali	2	Japan/Sakai	Working condition
Compaction roller		1	Loralai	13	USA	- do -
Dumptruck	-	2	D.M.Jamali	18	USA	Working condition
		1	Loralai	13	USA	- do -
		2	Hub	13	USA	- do -
		4	Quetta (Workshop)	12	USA	1 out of order 3 poor condition
Trailer/transport	-	1	D.M.Jamali	17	Germany	Poor condition
		1	Quetta (Workshop)	15	USA	Good
Trucks	-	1	D.M.Jamali	4	USA	Good
		8	Quetta (Workshop)	18/16	USA/JAPAN (Nissan)	4 poor condition 4 out of order
Motor Grader	-	4	D.M.Jamali	2	Japan/Mitsubishi	Good
Compressor	-	5	Quetta (Workshop)	18	Japan/Mitsubishi	1 poor condition 4 out of order
Generator	-	1	Quetta (Workshop)	15	-	Out of order
Water Truck	-	1	D.M.Jamali	17	USA	Poor condition
		8	Quetta (Workshop)	21/12/15	UK/USA/Japan (Hino)	7 poor condition 1 out of order
		3	D.M.Jamali	2	Pakistan	Good

Source: Irrigation Department, Balochistan (as of December 1996)

Most of the machinery were used for a long period, more than 10 to 15 years, so that the working capacity have been deteriorated despite of proper maintenance works by the Irrigation Department. Maintenance equipment facilitated in the workshop of the Irrigation Department are as follows:

Maintenance Equipment and Tool of Irrigation Department

Name of Shop	Machinery/ equipment	Function of Machinery	Status of machinery
Machine Shop	1.Lathe machine 16'	Turning, plishing, etc	In working order
	2.Lathe machine 4'	- do -	- do -
	3.Radial drill machine	Heavy duty cutting & boring	Not working
	4.Milling machine	Making of gears	- do -
	5.Surface grinder	For surface grinding	- do -
	6.Tool grinder	For tool grinding	In working order
	7.Grinding machine	For ginding	- do -
	8.Hydraulic track pinn press	Track chain repair	- do -
	9.Drill machine		- do -
	10.Hydraulic press	Straightening of lineament	- do -
	11.Crank rebuild machine	Rebuilt of crank shaft	Not working
	12.Hacksaw machine	For metal cutting	In working order
Welding shop	1.Electric welding plant	For welding	In working order
	2.Spot welder	- do -	- do -
	3.Gas welding plant	For gas welding	- do -
	4.Mobile welding plant	For mobile welding	Not working
Compressor shop	1.Compressor (3 nos.)	For air system	In working order
Hydraulic shop	1.Hose cutting machine	For hose cutting	In working order
	2.Nipple press machine		- do -
	3.Washing unit (2 nos.)	For washing parts	Not working
Brake shop	1.Brake service machine	Wheel drum polishing	In working order
Engine overhaul shop	1.Head shop	Engine head seats setting & polishing	In working order
	2.Valve grinding machine	Valve refacing	- do -
	3.Cylinder boring machine	Block cylinder boring	- do -
	4.Spray washing machine	For engine washing	- do -
Calibration shop	1.Calibration machine	Fuel injection pump repair	In working order
	2.Injector tester	- do -	- do -
	3.Nozzle tester (2 nos.)	Engine nozzle tester	- do -
Electric shop	1.Electric test bench	Checking short circuit, armature, dynamo and generator	In working order
	2.Battery charger (2 nos.)	Charging of battery	- do -
Tire shop	1.Tire rim remover	Rim remove	In working order
Black smith shop	1.Drill machine	-	In working order
	2.Air blower	-	- do -
Service station	1.Lifting jacks	For vehicle lifting	In working order
	2.Water pump	For service	- do -

(2) Machinery and equipment for proper dam design and construction work

The following are machinery and equipment for proper dam design and construction work:

Machinery and Equipment required for Proper construction and O&M

Items	Descriptions	Machinery/Equipment	Remarks
Earth works	Excavation works Loading works Spreading works Compaction works	Bulldozer Backhoe Breaker Wheel loader Motor grader Vibratory roller Tamping roller Hand tamper Compactor	Specification and numbers of machinery are determined referring to an earth volume, earth moving plan and implementation schedule of dam projects. When earth works are in a consecutive working process of excavation, loading, transportation and compaction, combination of machinery shall be properly planned.
Hauling works	Soil materials Construction materials Transportation of construction machinery	Dumptruck Tractor Common truck Truck with crane Trailer	Dumptrucks and tractors are used for the hauling of earth materials for embankment, stone masonry, slope protection. While, common trucks are for construction materials and equipment such as cement, forms, reinforcing bar and steel products. Specification and number of machinery shall meet the requirement of earth moving plan and material supply schedule.
Concrete mixing works	Concrete mixing Concrete transportation Concrete placing	Concrete plant Agitator truck Vibrator	Concrete is supplied for spillway and masonry structures. Specification of concrete mixing plant is determined in line with concrete placing plan in each project site.
Temporary works	Water supply facilities Generation Air supply facilities	Submersible pump Water tank Water spreading truck Generator Compressor	Water supply facility is planned for moisture control, concrete mixing and maintenance of construction machinery. Generator is for the operation of pump and other machinery, and compressor is used for breaker or other construction purposes. These facility capacity shall be examined to meet their requirements.

Soil Tests for Dam Embankment

Items		Test Items	Coarse materials
	Physical properties	Specific gravity	Basic data to analyze soil test results
		Water content	Soil properties (compression, strength)
		Grain size analysis	Uniformity coefficient, permeability, average grain size
		Liquid limit, plastic limit	Classification of soil
	Dynamic properties	Compaction test	Utilization to compaction criteria
		Permeability test	Permeability to determine compaction criteria
		Unconfined compression test	Bearing capacity of dam foundation
		Triaxial compression test	Dam stability analysis
		Direct shearing test	- ditto -

I.8 Monitoring Plan of Delay Action Dam

I.8.1 General

Considerably high agricultural productivity, as well as maintaining normal living standard have been achieved by utilization of the groundwater through tube wells and open wells, especially in arid or semi-arid area. Sustainable groundwater development can be attained together with proper preservation of the groundwater resources. Excessive extraction by pumpage beyond the possible recharge capacity to the aquifer promptly induces shortage of groundwater, and also causes the lowering of groundwater table.

Balochistan Province is located in semi-arid region with mean annual precipitation between 150 to 200 mm. Almost all rivers and streams are ephemeral, accordingly dependence upon groundwater resources has been risen up day by day to develop agricultural productivity and to maintain living standard. Rapidly increasing water demand and promptly falling groundwater table is mainly because of high population growth and electrification, especially in rural areas in and around Quetta City.

The Government of Balochistan issued edicts which restricted further groundwater extractions aiming at agricultural development by means of tube well construction in the Quetta, Pishin and Mastung Districts. In the meanwhile, the Government has launched a series of delay action dams construction projects to explore and to improve groundwater recharge, especially in northern regions of the Pishin Lora and Zob Basins. However, it was also discussed about sustainability, durability and effectiveness of the delay action dams from the quantitative and economical points of view because of their susceptibility to siltation in the reservoir areas and also negligible availability of run-off from the catchment areas compared with basin basis drawdown of the groundwater level. Besides delay action dams, other alternative artificial recharge devices, e.g. injection wells, diversion weirs, flood dispersion dikes have been constructed to accelerate groundwater recharge. Unfortunately, available data are available to assess the effectiveness or magnitude of these schemes at present is very limited and insufficient.

In this respect, it is imperative to establish monitoring systems/regulations regarding groundwater recharge to contribute to planning and design of these artificial recharge devices for further groundwater development. Furthermore, planning be included for a long term operation and maintenance, and that monitoring of the performance of the recharge devices be carried out routinely and systematically over a long term.

I.8.2 Present Monitoring System

Water and Power Development Authority (Hydrological Unit, WAPDA) has undertaken groundwater level monitoring in the areas of Quetta, Pishin and Mastung valleys. Presently, the Bureau of Water Resources established under the Irrigation Department is responsible for these monitoring works since 1994. Observation wells and piezometers at locations 31, 33, 42, have been installed for groundwater level monitoring in Quetta Northern valley, Northern Pishin Sub-basin and Mastung valley, respectively. Water level observation was conducted by autographic water level recorders or manual measurement with the intervals of quarterly basis. Surface flow has been observed by WAPDA for several years, and succeeded to the Bureau of Water Resources at the observation stations.

Because monitoring of the water level is being continued at critical locations in dedicated monitoring wells at where rapid drawdown has been observed due to excessive extraction by tube wells, it was also difficult to analyze water balance between groundwater recharge infiltrated through ground surface by precipitation, those through river run-off, and excessive pumpage. In addition to the above, monitoring has been carried out at the center of these valleys to predict the drawdown tendency of the groundwater basins by excessive extraction, but not for exploration of the groundwater recharge from basin peripheries. In this connection, monitoring devices should be located close to the artificial recharge devices i.e. delay action dams, infiltration wells, weir diversions, flood dispersion dikes and other structures to accurately analyze the effectiveness attributed to the construction of these devices. Monitoring should be continued to elaborate proper groundwater development plan, which reaches an appropriate and realistic equilibrium of the groundwater resources in this semi-arid areas.

I.8.3 Monitoring Plan

(1) Monitoring purposes

Monitoring wells and piezometers have been properly distributed in the valleys of Quetta, Pishin and Mastung, and observation data are being analyzed by the Bureau of Water Resources together with surface run-off data. However, as described above these information contributes to present rapid drawdown of groundwater surface by pumpage, but not for constructive groundwater restoration plan by recharge devices. Thus, it is recommended to establish supplementary monitoring equipment to examine the effectiveness of the groundwater recharge structures, i.e. delay action dams and other facilities. Furthermore, monitoring systems for pumpage volume of groundwater be simultaneously set up to not only estimate the water balance between input and output but observe present water use for irrigation and domestic uses, which is inevitable to realize sustainable groundwater use.

(2) Monitoring plan

(a) Basic approach

Movement of groundwater infiltrated through recharge devices depends on geo-hydraulic conditions in the underground between the structures and the beneficial areas. Proposed location, recharge ability of recharge device and its appurtenant structures such as infiltration pond, injection wells should be planned taking account of the geo-hydraulic conditions of the aquifer. Sufficient groundwater recharge is attained through the dam and reservoir foundation at where aquifer has high permeability and also has thick layers. On contrary to this, groundwater recharge is accelerated by supplementary recharge devices, e.g. infiltration pond, injection wells at where aquifer is less permeable and/or shallow. Accordingly, various monitoring methods are elaborated corresponding to the movement of groundwater.

On occasion of groundwater analysis, easiness to investigate flow route of groundwater and consecutive and plain groundwater surface result in agreeable flow simulation. Rolling fold and deep fault in base foundation occasionally directs to intricate approach of groundwater simulation. On the other hand, water surface close to the reservoirs is rapidly, eminently reflected ensuing impounding of the reservoir. However, water surface fluctuation far from reservoir is considerably small due to dispersion of the recharged flow, and also includes conjunctive flow from adjacent catchment areas. Closing to the beneficial areas, pumpage volume by tube wells dominates water fluctuation in and around the areas, accordingly groundwater recharge through reservoir is not estimated till the pumpage volume is not accurately measured.

As explained above, it is essential to precisely explore and investigate geo-hydraulic condition of the aquifer and pursue accuracy of water balance between recharge and extraction during monitoring. During a discussion on effectiveness of delay action dams, it is also important to compare the groundwater level improvement before and after the dam construction. For the proposed dams, it is suggested to carry out a groundwater level observation prior to or during the dam construction. While existing dams, recharge volume is estimated by means of the measurement of the water level fluctuation in the reservoir or in the ground downstream of the reservoir.

In the beneficial areas, water volume extracted for the uses of irrigation and domestic purposes has not been observed. Tube wells pumps are continuously operated during power supply by WAPDA. Thus, it is practicable to estimate pumpage volume referring to power supply duration and motor output of the tube well pumps in specified beneficial area. However, beneficial areas are located at the center of the basin and groundwater originated from the basin peripheries concentrately flows down to the center of the basin through alluvial aquifer. Thus, groundwater level is predominated by the flows from basin peripheries, gravitative infiltration of the precipitation through ground surface and seepage through river beds, alluvial fans during floods. Considering these conjunctive flows, it is impracticable to identify recharge flow through delay action dams and other structures.

In this regard, water level measurement at downstream of the dams are preferable to precisely estimate groundwater recharge capacity by delay action dams, as well as other structures.

(b) Monitoring of delay action dams

To directly estimate recharge capacity through delay action dams, infiltration pond and injection wells at the downstream of the reservoir, staff gauge is installed in the reservoir to observe river run-off, released volume of the reservoir including evaporation loss, and simultaneously siltation volume. Accurate relation curve between reservoir elevation and storage capacity is investigated to estimate these volumes.

On the other hand, recharge magnitude in specified areas is supplementarily estimated by means of direct measurement of groundwater level, and quantitatively calculated corresponding to the transmissivity or porosity of the aquifer. Fluctuation of the groundwater level is recorded by a series of piezometers located at downstream of the reservoir. Transmissivity or porosity is expected by pumping test during piezometer installation. These piezometers be free from any water flows from other catchment areas. In the case the groundwater recharge is accelerated through recharge devices, e.g. infiltration pond, injection wells and trenches, either current meter or triangle, square notch be installed to measure the release discharge at outlet structures of dam. However, both are not practicable due to their laborious works for continuous observation.

Consequently, observation of the reservoir water level is preferable to estimate recharge capacity by delay action dams, as well as river run-off estimate. Autographic recording is installed in the reservoir in the case of rapid drawdown of the water level in the reservoir due to high percolation rate of the reservoir foundation. Groundwater level downstream of the reservoir is observed by wells and piezometers to supplementarily examine the groundwater movement toward beneficial areas. Observation of siltation also provides inevitable information for the delay action dam planning.

(3) Conclusions

The Irrigation Department has succeeded groundwater monitoring work from the WAPDA. Monitoring is carrying out by means of observation wells and piezometers. While the observation stations are located in the specified areas, Quetta valley, Pishin, Mastung and Kalat sub basins, supplemental stations should be established, especially Kuchlagh, Shirinab and Mangochar sub basins. In addition, observation stations to examine the groundwater recharge effect by the delay action dams or other recharge devices should be installed in the vicinity area of these structures. Furthermore, mathematical model should be created to accurately assess groundwater sources and to utilize the analysis results for the delay action dam planning and design.

I.9 Further Study for Dam Construction

Necessary field investigation and design of the dam and its appurtenant structures, recharge devices, sediment control facilities are described in the Planning and Design Guideline for the Delay Action Dams in Annex M. The following are particularly required during detailed design of the delay action dam project.

(1) Geological investigation
- Test drilling to explore dam and recharge pond foundation
- Permeability test of the foundations at dam and recharge pond

(2) Topographic survey
- Survey of dam and reservoir area, and recharge pond
- Survey of detention bund site
- Survey of temporary yards for the construction
- Survey of route for road replacement
- Survey of borrow and quarry sites

(3) Material survey
- Test drilling and trench pits excavation to investigate material properties and available volume of the embankment.
- Soil tests for dam design

(4) Dam design
- Sliding analysis for dam embankment
- Earth moving plan, construction plan, machinery/equipment plan
- Temporary work plan

(5) Structure design
- Detailed design
- Temporary work plan

(6) Cost estimate
- Re-estimates of project cost according to detailed design

I.10 Soil Tests

Soil tests were conducted aiming at design of dam embankment of the delay action dams. Shearing strength and permeability are required for the analyses of the dam stability and seepage analysis. The following are the soil tests conducted by the Study Team.

1) Moisture content
Field moisture content is observed to decide necessary water volume to adjust the moisture content of the materials during the compaction period.
2) Specific gravity
3) Sieve analysis
4) Atterberg limits
5) Compaction test (dia. 15cm, 3 layers, 100%:25 nos, 300%:75 nos, 60%:15 nos.)

6) Permeability test : Samples be compacted in optimum moisture content and 4% dry side in respective compaction energy.
7) Triaxial compression test: Samples for triaxial compression test be compacted in optimum moisture content (different compaction energy) which gives maximum dry density.
   UU , $\overline{CU}$ tests for impervious materials, and UU, CD tests for semi-permeable materials.
   Maximum pressure is determined taking account of the maximum height of the dam of 30 m.

Test method was instructed in British Standard Methods of test for Soil for civil engineering purposes or ASTM Standards Section 4.

The following are remarkable conditions of the materials and dam construction:

a) Moisture content of the materials are in the dry condition through the year due to small precipitation, so that compaction is carried out in poor moisture content. Thus, permeability test was carried out in two moisture content of the material, i.e. under the optimum moisture content and its dry side (example 4% reduction). Furthermore, a series of compaction energy were provided to reduce required moisture content.
b) Improper compaction work is expected due to poor supervisory work of the contractor. Thus, shearing strength with reduced compaction energy of 60% be provided to secure the dam safety.
c) The materials near the dam sites are mostly composed of semi-permeable materials. Impermeability of the dam embankment is required to prevent piping in the dam body and also through the permeable foundation which is composed of river deposit.
d) Homogeneous type dam is presently recommended for the dam to attain small hydraulic gradient. However, it is also necessary to design the zone type fill dam when the dam height is higher than 20m and also the impervious foundation exists in shallow depth.

(1) Field moisture content

Results of the field moisture content are tabulated in Table I.10.2. As shown in the table, field moisture content of the river deposit surrounding the proposed dam sites are lower than 5.0 % in mostly all the sites. These moisture contents are rather lower than the optimum moisture contents of 10 to 15 % for semi pervious materials and 15 to 20 % for impervious materials resulting from the compaction tests in Table I.10.6. In this respect, adequate water is required to properly conduct a compaction work of the dam embankment during compaction works, especially for the surface materials with a few contents of fine particles.

(2) Specific gravity

Results of the field moisture content are tabulated in Table I. 10.3. As shown in the table, specific gravity of each materials ranges 2.65 to 2.70 ton/m^3. All materials are suitable for the embankment.

(3) Sieve analysis

Results of the sieve analysis are tabulated in Table. I. 10. 1. As shown in the grain distribution curve, most of the materials show well grained and distributed in pervious to impervious materials except the impervious materials of Kach dam (C1). Impervious materials of Kach dam can be used for the center core and both sides of the dam embankment should be protected with pervious or semi pervious materials to secure dam safety.

(4) Atterberg limits

Liquid/plastic limits and Atterberg limits are tabulated in Table. I. 10.4. Most of the river deposits around the dam sites are categorized in GW group (well-graded gravel), GP group (poorly graded gravel) , GM group (silty gravel) and SM (silty sand). Materials categorized in GW and GP groups are not used for the homogeneous type fill dam because of their high permeability. GM, GC, SC, SM groups are suitable for the embankment of the homogeneous type fill dam. When GW and GP groups are utilized for the homogeneous type fill dam, mixture with fine material is required to satisfy the fines more than 12%.

Shale material located at Kach dam sites is categorized in CL group (lean clay). CL group is impervious, and low compressibility in saturated condition after compaction when PI (Plasticity Index) is larger than 20. However, CL group does not have a large shearing strength, zone type fill dam with core material of CL group is suitable for high dam. Soil Classification Chart is shown in Table I.11.2.

(5) Compaction test

Results of the compaction tests are tabulated in Table. I. 10.6. In addition, dry density of the embankment of the existing dams of Kach and Murgi Kotal are listed in Table I. 10.5. Optimum moisture contents of 10 to 15 %, and 15 to 20 % are given for semi impervious and impervious materials, respectively. Optimum moisture contents of the mixed materials, semi impervious and impervious materials ranges between those of semi impervious and impervious materials. Dry density shows so high weight, so that 20% reduction is required for the use of dam stability analysis, as well. The failure might cause volume measurement error of the samples.

(6) Permeability test

Results of the compaction tests are tabulated in Table. I.10.7. Samples were compacted in optimum moisture content and 4% dry side in respective compaction energy to prove the difference of the permeability under this condition. Resulting from the tests, 4 to 90 times difference was proved. River deposits have high permeability even after proper compaction for example 1×10^{-3} - 3×10^{-3} cm/sec according to the permeability test referred to Table. I.10.7. To improve the permeability of the dam embankment, it is effective to mix both materials of sandy and clayey soils. Permeability tests indicate that the permeability of mixture of both materials are improved twenty to hundred times as low as sandy materials. However, it is also important that a poor mixture of both materials induces concentration of seepage flow along sandy layers, consequently causes piping.

(7) Triaxial compression test

Results of the compaction tests are tabulated in Table. I.10.8. Compression tests indicate that effective angle of internal friction (ø') of 35 - 40° is expected for sandy materials (river deposits). While, effective cohesion (c') of 1 - 5 ton/m² and ø' = 18 - 25° are expected for clayey materials which contains fine materials more than 12%. Accordingly, c' : 1 - 5 ton/m² and ø' : 35° are expected for the mixed materials of both sandy and clayey materials. To improve safety factor against surface sliding of the dam embankment, it is effective to install high shearing strength material on the surface side of the embankment.

Detailed compression test shall be achieved for sliding analysis of the embankment during detailed design stage.

Table I.10.1 List of Soil Tests

	Moisture Content	Specific Gravity	Sieve Analysis	Atterberg Limits	Field Density	Compaction Test	Permeability Test		Triaxial Compression Test					
									Water content=Wopt			Wopt - 4%		
							Wopt	Wopt-4%	UU	CU	CD	UU	CU	CD
Kach	S1 C1 C2	S1 C1 E1 E2	S1 C1 E1 E2	S1 C1 E1 E2	E1 E2	S1 C1 100%,25nos	> S1 C1	> S1 C1	> S1 C1	C1	S1	S1 C1	C1	S1
						C1 300%,75nos	> C1		> C1	C1				
						S1+C1 100%,25nos	> S1+C1		> S1+C1		S1+C1			
Sakhol	S1 S2 C1	S1 S2 C1	S1 S2 C1	S1 S2 C1		S1 C1 100%,25nos	> S1 C1	> S1 C1	> S1 C1	C1	S1			
Kad Kucha	S1 S2 S3	S1 S2 S3	S1 S2 S3	S1 S2 S3										
Mangi	S1 S2 C1	S1 S2 C1	S1 S2 C1	S1 S2 C1		S1+C1 100%,25nos	> S1+C1	> S1+C1	> S1+C1		S1+C1			
						S1+C1 300%,75nos	> S1+C1		> S1+C1		S1+C1			
Ghazlona	S1 S2 C1	S1 S2 C1	S1 S2 C1	S1 S2 C1		S1 C1 100%,25nos	> S1 C1	> S1 C1	> S1 C1	C1	S1			
Jigda	S1 S2 C1	S1 S2 C1	S1 S2 C1	S1 S2 C1		S1 C1 300%,75nos			> C1	C1				
						S1+C1 100%,25nos	> S1+C1	> S1+C1	> S1+C1		S1+C1			
						S1+C1 300%,75nos	> S1+C1		> S1+C1		S1+C1			
						S1+C1 60%,15nos	> S1+C1	> S1+C1	> S1+C1		S1+C1			
Sanzali	S1 S2 C1	S1 S2 C1	S1 S2 C1	S1 S2 C1		S1 C1 100%,25nos			> S1 C1	C1	S1			
						S1 C1 300%,75nos								
						S1+C1 100%,25nos			> S1+C1		S1+C1			
Dara	S1 S2 C1	S1 S2 C1	S1 S2 C1	S1 S2 C1		S1 C1 100%,25nos	> S1 C1	> S1 C1	> S1 C1	C1	S1			
Murgi Kotal	S1 S2 C1	S1 C1 E1 E2	S1 C1 E1 E2	S1 C1 E1 E2	E1 E2	C1 300%,75nos	> C1		> C1	C1				
						S1+C1 100%,25nos	> S1+C1	> S1+C1	> S1+C1		S1+C1			
						S1+C1 60%,15nos	> S1+C1	> S1+C1	S1+C1		S1+C1			
									>					
Sample No.	27	29	29	29	4	25		31	22	8	14	2	1	1

S Sand (Semi-permeable) C Clay (Impermeable) S+C Mixed with Sand and Clay (3:2) E Embankment materials

Table I.10.2 Field Moisture Contents

Dam name	Field Moisture Contents (%)			
Dara	S1	S2	C1	
	1.0	2.0	1.0	
Murgi Kotal	S1	S2	C1	
	1.0	1.0	2.0	
Kach	S1	C1	C2	
	3.0	13.0	10.0	
Jigda	S1	S2	C1	
	5.0	6.0	2.0	
Sanzali	S1	S2	C1	
	2.0	2.0	2.0	
Sakhol	S1	S2	C1	
	2.0	1.0	3.0	
Mangi	S1	S2	C1	
	2.0	5.0	5.0	
Kad Kucha	S1	S2	S3	
	1.0	1.0	2.0	
Ghazlona	S1	S2	C1	
	9.0	9.0	6.0	

Table I.10.3 Specific Gravity

Dam name	Specific Gravity (ton/m^3)										
Brewary	PT-1	PT-2	PT-3	PT-4							
	2.698	2.683	2.658	2.663							
Dara	PT-1	PT-2	PT-3	PT-4	PT-5	PT-6	PT-7	S1	S2	C1	
	2.648	2.646	2.678	2.684	2.654	2.664	2.646	2.700	2.720	2.680	
Murgi Kotal	PT-1	PT-2	PT-3	PT-4	PT-5	PT-6	PT-7	S1	C1	E1	E2
	2.658	2.660	2.646	2.675	2.636	2.681	2.664	2.670	2.690	2.690	2.700
Kach	PT-1	PT-2	PT-3	PT-4	PT-5	PT-6	PT-7	S1	C1	E1	E2
	2.682	2.702	2.668	2.645	2.658	2.674	2.683	2.730	2.780	2.670	2.720
Jigda	PT-1	PT-2	PT-3	PT-4	PT-5	PT-6	PT-7	S1	S2	C1	
	2.636	2.659	2.661	2.680	2.691	2.648	2.658	2.260	2.670	2.690	
Sanzali	PT-1	PT-2	PT-3	PT-4	PT-5	PT-6	PT-7	S1	S2	C1	
	2.658	2.662	2.662	2.672	2.658	2.679	2.683	2.710	2.680	2.690	
Sakhol	PT-1	PT-2	PT-3	PT-4	PT-5	PT-6	PT-7	S1	S2	C1	
	2.671	2.645	2.664	2.658	2.665	2.673	2.655	2.680	2.690	2.690	
Mangi	PT-1	PT-2	PT-3	PT-4	PT-5	PT-6		S1	S2	C1	
	2.671	2.659	2.660	2.635	2.615	2.665		2.670	2.650	2.690	
Kad Kucha II	PT-1	PT-2	PT-3	PT-4	PT-5	PT-6	PT-7	S1	S2	S3	
	2.665	2.661	2.671	2.638	2.644	2.658	2.658	2.660	2.670	2.650	
Ghazlona	PT-1	PT-2	PT-3	PT-4	PT-5	PT-6	PT-7	S1	S2	C1	
	-	-	-	-	-	-	-	2.680	2.670	2.690	
Ghutai Shela	PT-1	PT-2	PT-3	PT-4	PT-5						
	2.649	2.691	2.668	2.638	2.671						
Wali Dad	PT-1	PT-2	PT-3	PT-4	PT-5	PT-6	PT-7				
	2.675	2.672	2.646	2.668	2.698	2.678	2.652				
Samaki	PT-1	PT-2	PT-3	PT-4	PT-5	PT-6	PT-7				
	2.713	2.665	2.693	2.671	2.684	2.663	2.671				
Iskalkoo	PT-1	PT-2	PT-3	PT-4	PT-5	PT-6	PT-7				
	2.684	2.678	2.650	2.618	2.636	2.648	2.655				
Tirkha	PT-1	PT-2	PT-3								
	2.678	2.658	2.688								
Khushab	PT-1	PT-2	PT-3	PT-4	PT-5	PT-6					
	2.658	2.683	2.683	2.685	2.666	2.693					

Table I.10.4 Atterberg Limits

Dam name		Atterberg Limits (%)										
Brewary		TP-1	TP-2	TP-3	TP-4							
	LL	11	26	28	31							
	PL	NP	21	22	24							
	PI	NP	5	6	7							
Dara		TP-1	TP-2	TP-3	TP-4	TP-5	TP-6	TP-7	S1	S2	C1	
	LL	16	12	14	14	13	13	12	NP	NP	NP	
	PL	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	
	PI	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	
Murgi Kotal		TP-1	TP-2	TP-3	TP-4	TP-5	TP-6	TP-7	S1	C1	E1	E2
	LL	33	32	10	12	26	12	33	NP	31	NP	NP
	PL	19	21	NP	NP	21	NP	19	NP	23	NP	NP
	PI	14	11	NP	NP	5	NP	14	NP	8	NP	NP
Kach		TP-1	TP-2	TP-3	TP-4	TP-5	TP-6	TP-7	S1	C1	E1	E2
	LL	33	12	16	28	10	12	18	NP	56	52	51
	PL	22	NP	NP	22	NP	NP	NP	NP	27	35	34
	PI	11	NP	NP	6	NP	NP	NP	NP	29	17	17
Jigda		TP-1	TP-2	TP-3	TP-4	TP-5	TP-6	TP-7	S1	S2	C1	
	LL	15	19	10	12	8	14	13	NP	NP	26	
	PL	NP	NP	NP	NP	NP	NP	NP	NP	NP	21	
	PI	NP	NP	NP	NP	NP	NP	NP	NP	NP	5	
Sanzali		TP-1	TP-2	TP-3	TP-4	TP-5	TP-6		S1	S2	C1	
	LL	9	12	10	20	10	12		NP	NP	29	
	PL	NP	NP	NP	16	NP	NP		NP	NP	22	
	PI	NP	NP	NP	4	NP	NP		NP	NP	7	
Sakhol		TP-1	TP-2	TP-3	TP-4	TP-5	TP-6	TP-7	S1	S2	C1	
	LL	10	12	14	10	14	11	10	NP	NP	NP	
	PL	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	
	PI	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	
Mangi		TP-1	TP-2	TP-3	TP-4	TP-5	TP-6		S1	S2	C1	
	LL	20	10	10	11	12	18		NP	NP	32	
	PL	NP	NP	NP	NP	NP	16		NP	NP	20	
	PI	NP	NP	NP	NP	NP	2		NP	NP	12	
Kad Kocha II		TP-1	TP-2	TP-3	TP-4	TP-5	TP-6	TP-7	S1	S2	S3	
	LL	8	12	12	8	10	12	18	NP	NP	NP	
	PL	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	
	PI	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	
Ghazlona		TP-1	TP-2	TP-3	TP-4	TP-5	TP-6	TP-7	S1	S2	C1	
	LL								NP	NP	23	
	PL								NP	NP	19	
	PI								NP	NP	4	
Ghutai Shela		TP-1	TP-2	TP-3	TP-4	TP-5						
	LL	33	30	13	12	13						
	PL	24	22	NP	NP	NP						
	PI	9	8	NP	NP	NP						
Wali Dad		TP-1	TP-2	TP-3	TP-4	TP-5	TP-6	TP-7				
	LL	16	12	18	29	10	12	18				
	PL	NP	NP	NP	22	NP	NP	NP				
	PI	NP	NP	NP	7	NP	NP	NP				
Samaki		TP-1	TP-2	TP-3	TP-4	TP-5	TP-6	TP-7				
	LL	10	14	26	10	12	32	33				
	PL	NP	NP	22	NP	NP	26	23				
	PI	NP	NP	4	NP	NP	6	10				
Iskalkoo		TP-1	TP-2	TP-3	TP-4	TP-5	TP-6	TP-7				
	LL	28	19	12	32	8	10	13				
	PL	21	17	NP	20	NP	NP	NP				
	PI	7	2	NP	12	NP	NP	NP				
Tirkha		TP-1	TP-2	TP-3								
	LL	19	12	17								
	PL	17	NP	NP								
	PI	2	NP	NP								
Khushab		TP-1	TP-2	TP-3	TP-4	TP-5	TP-6					
	LL	12	10	8	12	9	22					
	PL	NP	NP	NP	NP	NP	19					
	PI	NP	NP	NP	NP	NP	3					

LL:Liquid Limits   LL:Liquid Limits   PI:Plastic Index
NP:Non Plastic

Table I.10.5 Field Density Test

Dam Name	Sample	Dry Density (t/m^3)	Field Moisture Contents (%)
Kach	E1	1.974	12.76
	E2	1.539	9.12
Murgi Kotal	E1	1.962	0.49
	E2	1.614	3.22

Table I.10.6 Compaction Test

Dam Name / Materials	Compaction Energy 0.6 (15 blows per layer) Wopt (%)	Dry density (t/m^3)	1.0 (25 blows per layer) Wopt (%)	Dry density (t/m^3)	3.0 (75 blows per layer) Wopt (%)	Dry density (t/m^3)
Murgi Kotal						
S1	-	-	10.5	1.93	-	-
C1	-	-	15.4	1.82	12.0	1.94
S1+C1	14.0	1.86	12.0	1.91	-	-
Kach						
S1	-	-	9.8	2.06	-	-
C1	-	-	22.0	1.64	16.5	1.78
S1+C1	-	-	14.5	1.78	-	-
Jigda						
S1	-	-	12.3	1.94	9.5	2.10
C1	-	-	15.3	1.84	11.0	2.00
S1+C1	13.8	1.91	12.2	1.97	9.3	2.06
Sanzali						
S1	-	-	12.0	1.90	11.0	1.94
C1	-	-	11.0	1.94	9.8	2.03
S1+C1	-	-	9.2	2.00	-	-
Mangi						
S1	-	-	9.0	2.05	-	-
C1	-	-	14.0	1.77	-	-
S1+C1	-	-	10.8	1.99	9.2	2.10

Note: Container ASTM, 2.5 kg rammer, 305mm drop height
Wopt means Ortimum moisture content

Table I.10.7 Permeability Tests

Dam Name / Materials	Compacted under Optimum Moisture Content (Compaction Energy) 60%	100%	300%	Compacted under Optimum Moisture Content-4% (Compaction Energy) 60%	100%	300%
Murgi Kotal						
S1	–	3.86×10^{-3}	–	–	3.43×10^{-4}	–
C1	–	2.5×10^{-7}	2.03×10^{-6}	–	4.70×10^{-6}	–
S1+C1	6.3×10^{-5}	1.74×10^{-4}	–	4.5×10^{-4}	4.26×10^{-4}	–
Kach						
S1	–	3.60×10^{-5}	–	–	3.30×10^{-3}	–
C1	–	4.99×10^{-7}	6.36×10^{-9}	–	9.50×10^{-7}	
S1+C1	–	6.4×10^{-5}	–	–	–	–
Jigda						
S1	–	3.86×10^{-3}	–	–	1.57×10^{-2}	–
C1	–	9.33×10^{-7}	–	–	0.62×10^{-5}	–
S1+C1	7.4×10^{-5}	1.91×10^{-4}	2.24×10^{-6}	1.97×10^{-4}	2.09×10^{-4}	–
Mangi						
S1	–	1.41×10^{-7}	–	–	2.43×10^{-5}	–
C1	–	1.80×10^{-3}	–	–	8.20×10^{-3}	–
S1+C1	–	2.84×10^{-7}	2.05×10^{-6}	–	2.43×10^{-4}	–

Table I.10.8 Shearing Strength

Dam Name / Materials		Shearing Strength (Compacted Wopt)					
		15 blows per layer		25 blows per layer		75 blows per layer	
		Cohesion	Internal angle	Cohesion	Internal angle	Cohesion	Internal angle
Murgi Kotal							
S1	UU	-	-	17.85	0.0	-	-
	CD	-	-	0.0	36.0	-	-
C1	UU	-	-	6.12	0.0	2.86	25.2
	CU	-	-	0.82	31.0	4.08	31.0
S1+C1	UU	4.08	9.5	5.10	24.4	-	-
	CD	0.0	36.0	0.102	33.0	-	-
Kach							
S1	UU	-	-	0.00	36.9	-	-
	CD	-	-	0.00	40.0	-	-
C1	UU	-	-	1.43	0.0	0.92	4.4
	CU	-	-	1.22	18.0	1.84	20.0
S1+C1	UU	-	-	0.61	17.7	-	-
	CD	-	-	4.08	17.0	-	-
Jigda							
S1	UU	-	-	1.02	24.4	-	-
	CD	-	-	4.59	30.0	-	-
C1	UU	-	-	5.00	0.0	-	-
	CU	-	-	1.53	25.0	0.92	31.0
S1+C1	UU	16.32	0.0	14.28	0.0	3.06	31.4
	CD	0.15	37.0	0.306	34.0	0.204	38.0
Sanzali							
S1	UU	-	-	8.16	31.7	-	-
	CD	-	-	0.00	45.0	-	-
C1	UU	-	-	0.82	27.6	-	-
	CU	-	-	0.82	25.0	-	-
S1+C1	UU	-	-	8.57	0.0	-	-
	CD	-	-	0.0	42.0	-	-
Mangi							
S1	UU	-	-	1.02	17.7	-	-
	CD	-	-	0.15	39.0	-	-
C1	UU	-	-	1.50	22.0	-	-
	CU	-	-	0.51	29.0	-	-
S1+C1	UU	-	-	1.94	0.0	5.10	12.1
	CD	-	-	0.255	31.0	-	-

Dam Name / Materials		Shearing Strength (Compacted Wopt-4%)					
		15 blows per layer		25 blows per layer		75 blows per layer	
		Cohesion	Internal angle	Cohesion	Internal angle	Cohesion	Internal angle
Kach							
S1	UU	-	-	5.61	32.6	-	-
	CD	-	-	1.2	34.0	-	-
C1	UU	-	-	1.4	10.3	-	-
	CU	-	-	0.12	18.0	-	-

Note: Cohesion (t/m^2)

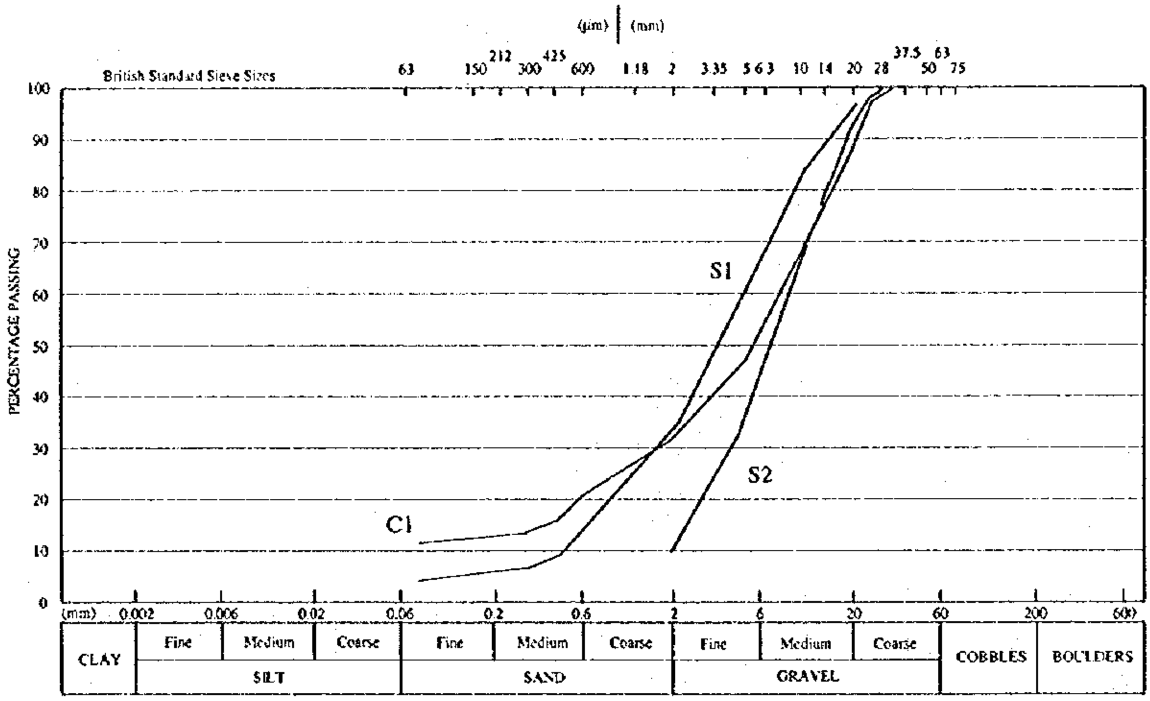


Fig. I.10.1.1 Particle Size Distribution (Dara Dam)

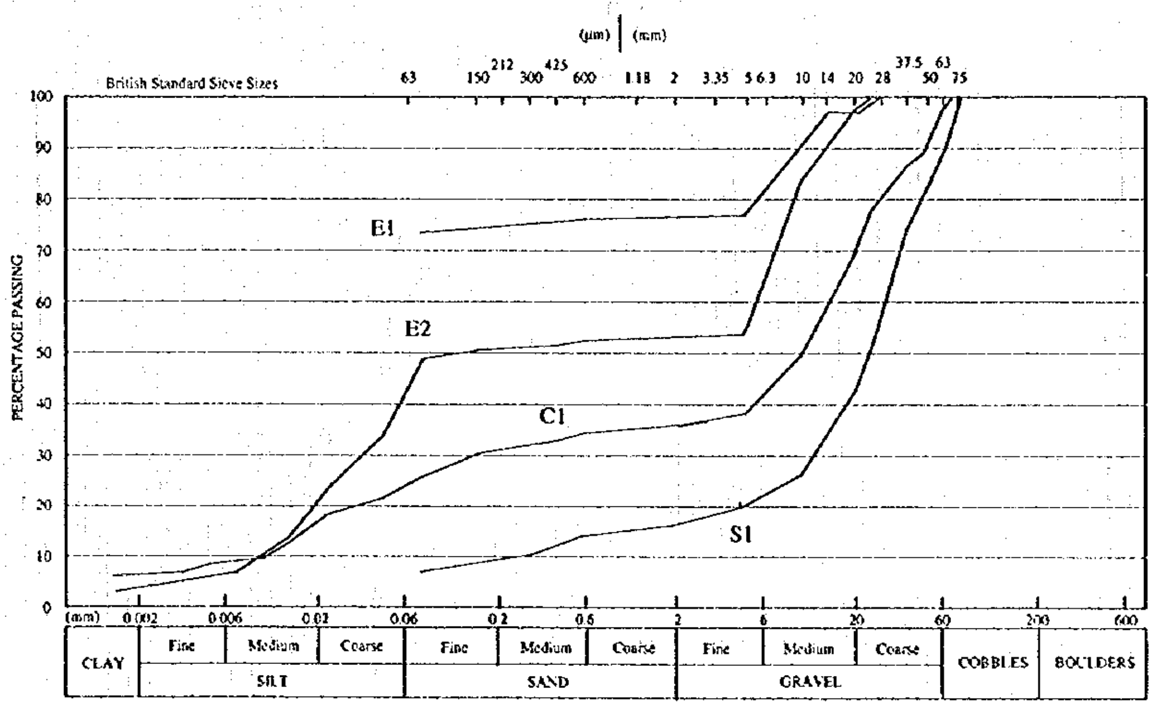


Fig. I.10.1.2 Particle Size Distribution (Murgi Kotal Dam)

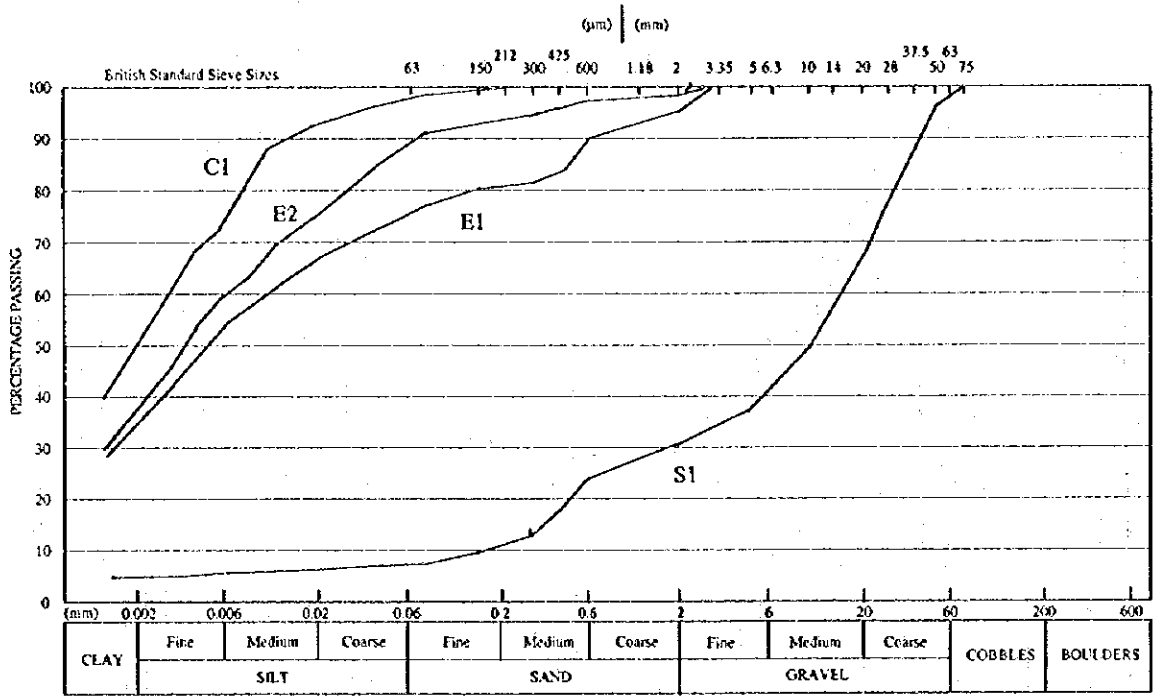


Fig. I.10.1.3 Particle Size Distribution (Kach Dam)

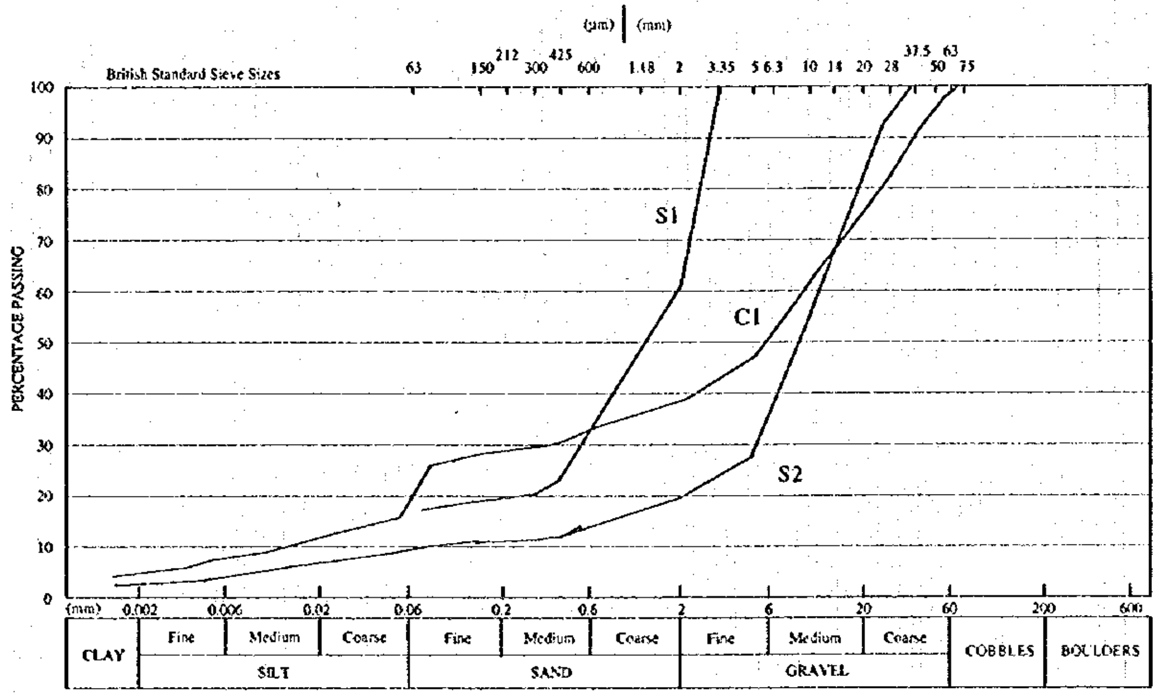


Fig. I.10.1.4 Particle Size Distribution (Jigda Dam)

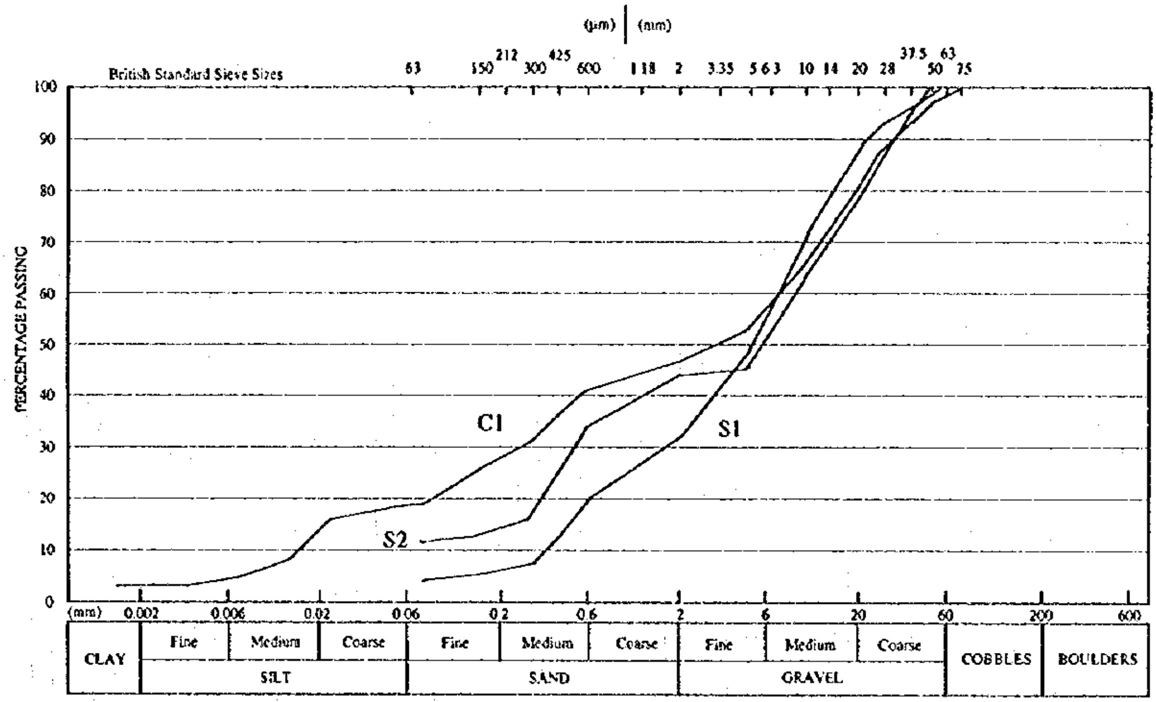


Fig. I.10.1.5 Particle Size Distribution (Sanzali Dam)

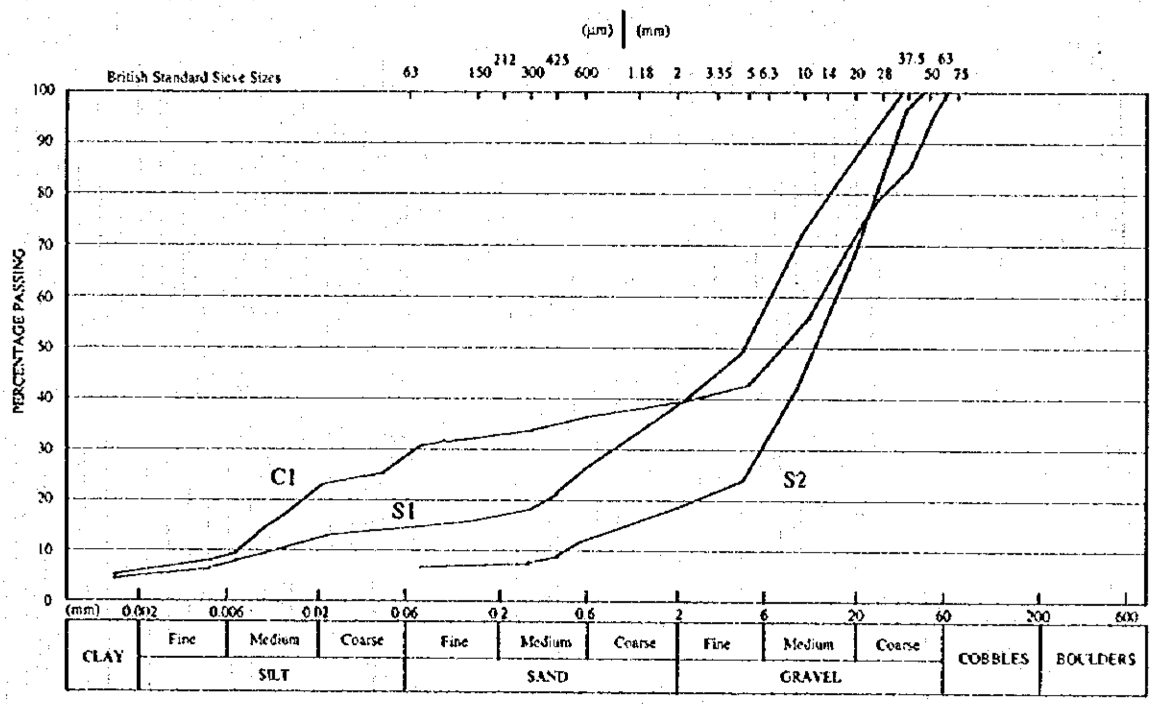


Fig. I.10.1.6 Particle Size Distribution (Ghazlona Dam)

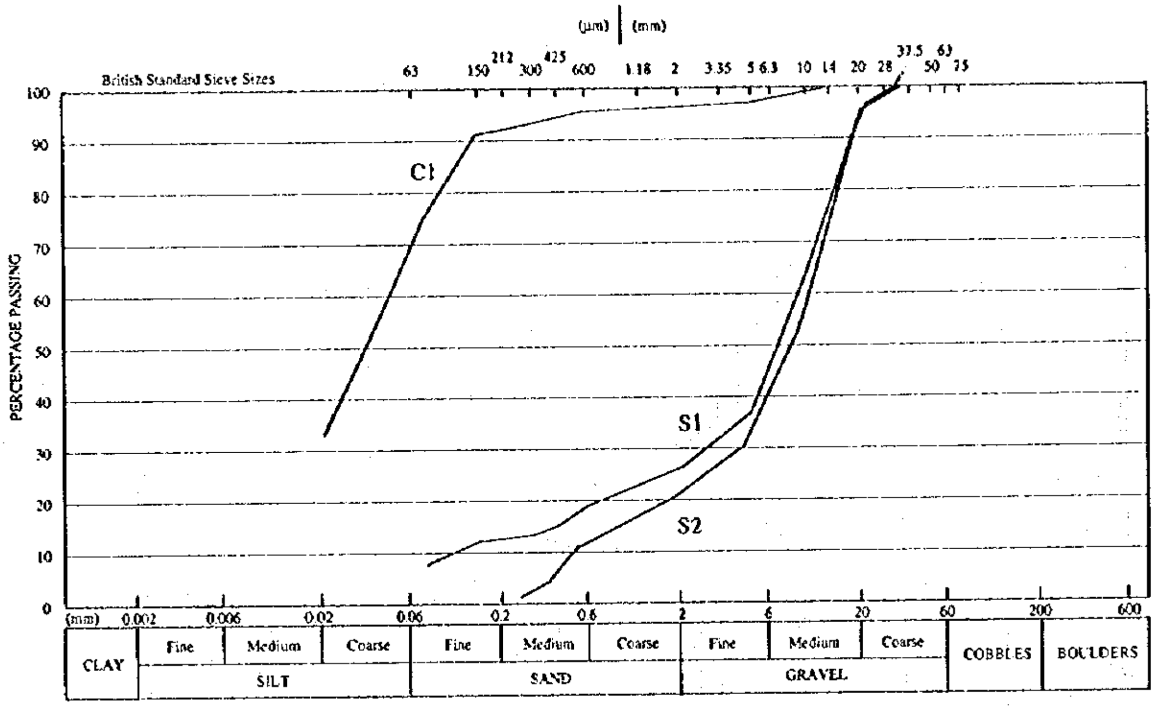


Fig. I.10.1.7 Particle Size Distribution (Sakhol Dam)

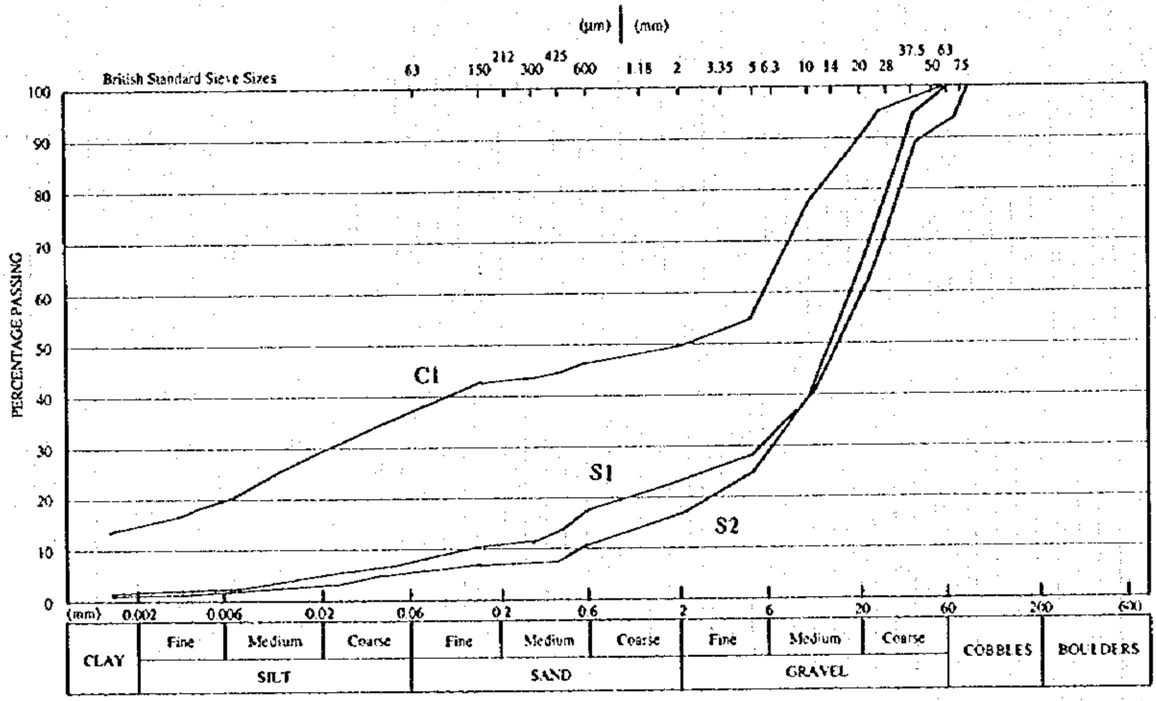


Fig. I.10.1.8 Particle Size Distribution (Mangi Dam)

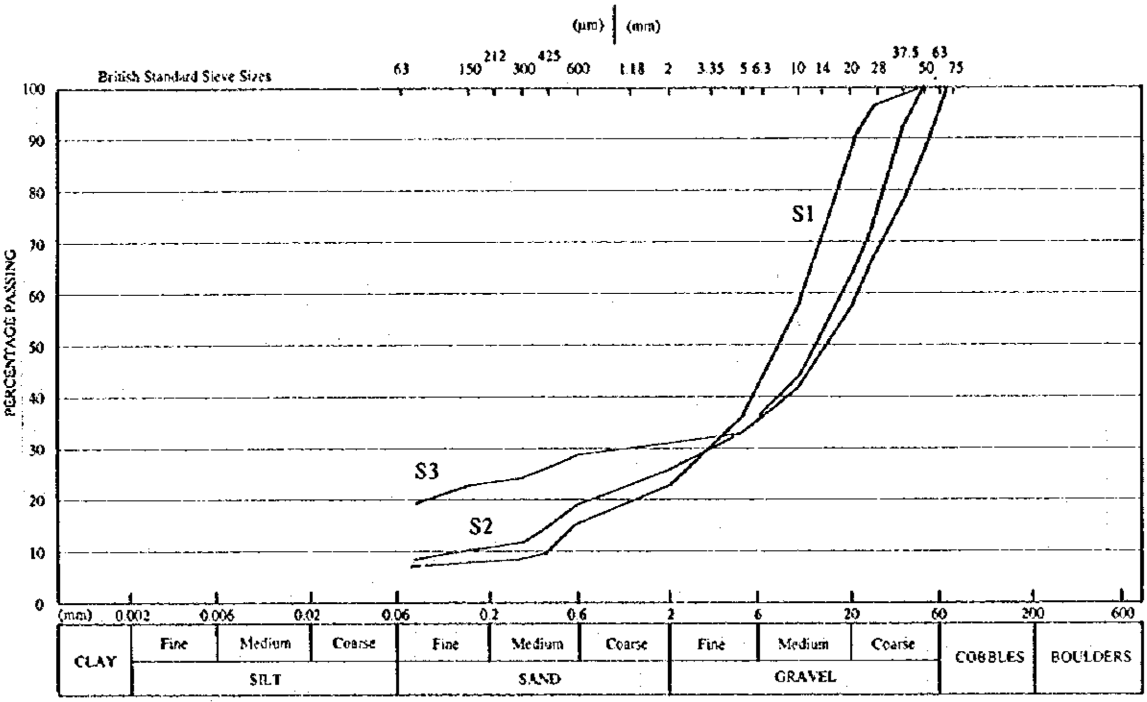


Fig. I.10.1.9 Particle Size Distribution (Kad Kocha II Dam)

I.11 Procurement Plan of Embankment Materials

Resulting from the soil test in paragraph I.10, procurement plan of the embankment materials of the proposed dams is established as shown in Table. I.11.1. The following are remarkable point on the procurement plan.

1) Materials categorized in GW, GP groups shall be mixed with fine materials or GM, GC, SC, SM, CL group materials to attain low permeability for the homogeneous type fill dam.
2) Embankment material shall be compacted in the wet side of the optimum moisture content to secure shearing strength and impermeability.
3) Filter zones are introduced out side of drain to prevent internal erosion or piping. Filter zones should function to prevent movement of soil particles.
4) Thickness of the fine gravel filter should be more than 30 cm in embankment slope made up of coarse materials. In embankment slope formed of fine material, filter materials after grading control should be spread to a thickness of 30 cm or more.
5) Excavated materials from spillway site is available for dam embankment materials. Detailed procurement plan shall be established referring to the soil test results and also earth moving plan including stock piling and soil mixture works.
6) In the procurement plan, excavated material from the dam foundation is not used for the dam embankment because the surface soil includes organic matters.
7) With respect to availability of excavated material from the spillway site to dam embankment, it is roughly estimated in accordance with topographic condition, thickness of the top soil, vegetation, cost for earth moving distance so on. Detailed study shall be carried out during detailed design stage.

Table I.11.1 Procurement Plan for Embankment Materials

Dam Name	Embankment												Spillway			Coffer Dam		
	Embankment (GROSS)	Embankment (NET)	Riprap Volume	Riprap Area	Toe Drain (Gravel)	Stone Masonry (Drain)	Toe Drain Filter	Horizontal/ Vertical Drain (Gravel)	Horizontal/ Vertical Drain Filter	Total Excavation	Trench Excavation	Foundation Excavation	Excavation (Soil)	Excavation (Weathered rock)	Excavation (Rock)	Embankment	Riprap Volume	Riprap Area
(unit)	(m3)	(m3)	(m3)	(m2)	(m3)	(m3)	(m3)	(m3)	(m3)	(m3)	(m3)	(m3)	(m3)	(m3)	(m3)	(m3)	(m3)	(m2)
(Calculation)	①	②=①+⑨-③-⑤-⑦	③	④	⑤	⑥		⑦		⑧=⑨+⑩	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯
Dara	(269,800)	272,000	9,500	(15,800)	8,600		2,500			38,200	(22,800)	(15,400)		80,400	(used for riprap/drain materials)			
Murgi Kotal (Upstream)	(278,000)	280,700	4,300	(7,100)		360		2,400	1,600	107,000	(11,000)	(96,000)	156,000	(used for dam embankment)				
(Downstream)	(458,000)	442,620	6,100	(10,200)	4,300			4,840	4,840	13,300	(4,700)	(8,600)		(used for riprap/drain materials)	8,600			
Kach (Rising crest)	(480,000)	460,740	9,200	(15,300)		140		5,030	5,030	18,600	(0)	(18,600)	159,000	(used for dam embankment)		125,000	3,200	5,300
(Downstream)		593,000	11,200	(19,900)				6,000	6,000	19,700	(0)	(19,700)	78,000 (90% is used for dam embankment, remaining is disposed)					
Jigda	(114,000)	114,200	4,400	(7,400)	3,600		1,100			17,600	(9,300)	(8,300)		11,800	(used for dam embankment)			
Sanzali	(106,000)	110,600	4,500	(7,400)	3,800		2,100			22,900	(15,000)	(7,900)	53,000 (70% is used for dam embankment, remaining is disposed)					
Sakhol	(187,000)	212,300	11,700	(19,600)	6,000		2,500			66,200	(45,500)	(20,700)						
Mangi	(170,800)	168,500	8,500	(14,200)	7,900		3,300			30,900	(17,400)	(13,500)	5,100					
Kad kocha II	(152,000)	162,900	8,800	(14,700)	9,700		4,100			47,600	(33,500)	(14,100)	11,300	(used for dam embankment)				
Ghazlona	(76,000)	74,600	3,200	(5,300)	2,600		800			10,800	(5,200)	(5,600)		14,700	(used for dam embankment)			
Ghutai Shela	-	32,600	2,100	(3,500)	1,900		800			15,500	(8,000)	(7,500)	7,900	(used for dam embankment)				
Samaki	-	35,400	1,500	(2,400)	1,100		500			7,400	(1,900)	(5,500)			7,700 (used for riprap/drain materials)			
Iskalkoo	-	46,400	2,000	(3,200)	1,100		500			7,000	(3,300)	(3,700)		7,200	(used for dam embankment)			

Notes:
1) Excavated materials of dam foundation is not used for dam embankment.
2) Excavated materials of trench is available for dam embankment after temporarily stocked.
3) Concrete materials such as cement and aggregates are procured around Quetta city.
4) Procurement plan is to be modified in accordance with detailed geological investigation and dam design.
5) River deposits around dam sites are available for dam embankment.
6) Embankment volume (Gross) includes foundation excavation and drain materials, but excludes trench excavation.

Table I 11.2 Soil Classification Chart (Design of Small Dams)

CRITERIA FOR ASSIGNING GROUP SYMBOLS AND GROUP NAMES USING LABORATORY TESTS [a]				SOIL CLASSIFICATION: GROUP SYMBOL	SOIL CLASSIFICATION: GROUP NAME [b]
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve	GRAVELS More than 50% of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS Less than 5% fines [c]	$Cu \geq 4$ and $1 \leq Cc \leq 3$ [e]	GW	Well-graded gravel [f]
			$Cu < 4$ and/or $1 > Cc > 3$ [e]	GP	Poorly graded gravel [f]
		GRAVELS WITH FINES More than 12% fines [c]	Fines classify as ML or MH	GM	Silty gravel [f,g,h]
			Fines classify as CL or CH	GC	Clayey gravel [f,g,h]
	SANDS 50% or more of coarse fraction passes No. 4 sieve	CLEAN SANDS Less than 5% fines [d]	$Cu \geq 6$ and $1 \leq Cc \leq 3$ [e]	SW	Well-graded sand [i]
			$Cu < 6$ and/or $1 > Cc > 3$ [e]	SP	Poorly graded sand [i]
		SANDS WITH FINES More than 12% fines [d]	Fines classify as ML or MH	SM	Silty sand [g,h,i]
			Fines classify as CL or CH	SC	Clayey sand [g,h,i]
FINE-GRAINED SOILS 50% or more passes the No. 200 sieve	SILTS AND CLAYS Liquid limit less than 50	inorganic	PI > 7 and plots on or above "A" line [j]	CL	Lean clay [k,l,m]
			PI < 4 or plots below "A" line [j]	ML	Silt [k,l,m]
		organic	$\frac{\text{Liquid limit - oven dried}}{\text{Liquid limit - not dried}} < 0.75$	OL	Organic clay [k,l,m,n] Organic silt [k,l,m,o]
	SILTS AND CLAYS Liquid limit 50 or more	inorganic	PI plots on or above "A" line	CH	Fat clay [k,l,m]
			PI plots below "A" line	MH	Elastic silt [k,l,m]
		organic	$\frac{\text{Liquid limit - oven dried}}{\text{Liquid limit - not dried}} < 0.75$	OH	Organic clay [k,l,m,p] Organic silt [k,l,m,q]
Highly organic soils		Primarily organic matter, dark in color, and organic odor		PT	Peat

a. Based on the material passing the 3-in (75-mm) sieve.
b. If field sample contained cobbles and/or boulders, add "with cobbles and/or boulders" to group name.
c. Gravels with 5 to 12% fines require dual symbols
   GW-GM well-graded gravel with silt
   GW-GC well-graded gravel with clay
   GP-GM poorly graded gravel with silt
   GP-GC poorly graded gravel with clay
d. Sands with 5 to 12% fines require dual symbols
   SW-SM well-graded sand with silt
   SW-SC well-graded sand with clay
   SP-SM poorly graded sand with silt
   SP-SC poorly graded sand with clay

e. $Cu = D_{60}/D_{10}$ $Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

f. If soil contains ≥ 15% sand, add "with sand" to group name.
g. If fines classify as CL-ML, use dual symbol GC-GM, SC-SM.
h. If fines are organic, add "with organic fines" to group name.
i. If soil contains ≥ 15% gravel, add "with gravel" to group name.
j. If the liquid limit and plasticity index plot in hatched area on plasticity chart, soil is a CL-ML, silty clay.
k. If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel" whichever is predominant.
l. If soil contains ≥ 30% plus No. 200, predominantly sand, add "sandy" to group name.
m. If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.
n. PI ≥ 4 and plots on or above "A" line.
o. PI < 4 or plots below "A" line.
p. PI plots on or above "A" line.
q. PI plots below "A" line.