Annex M
Planning and Design Guideline for Delay Action Dams

ANNEX M PLANNING AND DESIGN GUIDELINE FOR DELAY ACTION DAMS

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Definitions

The following terms and expressions are to be understood as defined.

Dam category (Large dam, small dam)

The dams are categorized in the small dams and large dams corresponding to their height of lower or higher than 15 meters in accordance with the criteria of the International Commission on Large Dams (ICOLD). In relation to this, the Federal Government of Pakistan has launched to establish Safety Council for Dams and Reservoirs since 1995, acting as a coordinating body to examine and/or secure dams and reservoirs in whole of the Pakistan. The following are its applicability of large dam under the Council:

Any large dam, appurtenant works:

1. which does or will impound water and which has a height of 50 feet (15 meters) or more from the natural bed of stream measured at the downstream toe of the dam
2. which has a height between ten (10) and fifteen (15) meters provided it satisfies one of the following conditions:

2-1 the length of the crest on the dam exceeding 500 meters (1,640 ft.),

2-2 the capacity of the reservoir formed by the dam exceeding one (1) million cubic meters (400 acre feet),

2-3 the maximum flood discharge dealt with by the dam exceeding 2,000 cubic per second (700,000 cubic ft. per second),

2-4 the dam has known difficult foundation problems,

2-5 the dam is of unusual design,

2-6 hydroelectric scheme having dam or dikes storage of 15 meter height or more.

Appurtenant structures:

All structures, components and facilities functimately pertaining to the dam, including, but not limited to, spillway, outlet works, intakes and conduits, transmission channel, recharge devices in relation to the dam.

Contractor:

The private company, government organization unit responsible for the construction of the dam and/or reservoir as a whole or as a part.

Reservoir:

man-made lake created by construction of a dam body across a river and refers to the part for storaging river water.

Dam:

Any barriers, fill or structure that does or may impound water, inclusive of all appurtenant structures, dam foundation and abutments.

Delay action dam:

Any barriers, fill or structure that does or may impound water aiming at recharge of the groundwater surrounding and/or downstream of the dam through the dam and reservoir foundation, and/or recharge devices, e.g. infiltration pond, injection wells or natural river bed, alluvial fan, as well.

Dam body, embankment:

Body of dam constructed on the foundation.

Dam foundation:

Ground directly below and around the dam body. The foundation must have sufficient resistivity against outer pressure exerted by the dam body.

Spillway:

Outlet works for safely discharging river flow lower than the design flood discharge to ensure the dam and reservoir safety during the flooding period.

Dam type:

Homogeneous type:	More than 80% of the maximum section of the embankment is composed of homogeneous material.
Zone type:	A fill consisting of an inner or enclosed impervious earth materials supported by outer zone of relatively pervious materials. Rock fill dam is categorized into zone type dam.
Facing type:	Upstream of the dam is faced with impervious material other than soil.
Core type:	A fill dam provided by core which is composed of impervious materials (asphalt, concrete, etc.) other than soil.
Concrete dam:	Concrete dams are structurally categorized in concrete gravity dam, concrete arch dam, concrete buttress dam, and timber dams. This guideline is limited in scope to consideration of the more common type of concrete gravity dam.

Fill materials:

Genetic term for soil and rock materials.

Impervious materials:

Generic term for fill material where hydraulic conductivity after compaction is lower than 1×10^{-5} cm/sec.

Semi-impervious materials:

Generic term for fill material where hydraulic conductivity after compaction is between those of pervious and impervious materials.

Pervious materials:

Generic term for fill material where hydraulic conductivity after compaction is higher than 1×10^{-3} cm/sec.

Height of dam top:

The uppermost surface of the crest of the dam body. Although thickness of protection layer above the impervious layer is included in the height, hand rail, parapet wall and the part of the dam crest used as a road are not included.

Height of nonoverflow section:

The uppermost surface of the impervious zone excluding thickness of protection layer.

Height of dam:

Vertical distance from the foundation ground surface to the height of dam top. The foundation ground means the deepest part of the foundation crossed by a cut-off wall. When the bottom width of the cut-off wall is larger than 10m, the same means the deepest bottom surface. In case of the dam without cut-off wall, the dam height accounts for the longest vertical distance from the upstream end of the dam crest to the foundation ground.

Design flood discharge:

Discharge used for calculation of the design flood level and determination of flow capacity of the spillway.

Reservoir water level:

Design flood level: Maximum water level directly upstream of the nonoverflow section of the dam when design flood discharge flows through the dam spillway. In case of the dams with large storage effect (routing) the water depth attributable to the said routing effect can be deducted.

Full water level: Maximum water level directly upstream of the nonoverflow section during non-flood periods.

Low water level: The lowest water level to be stored effectively in the reservoir in accordance with dead storage and/or sediment volume.

Storage capacity:

Total storage capacity: The storage between the river bed and the normal full water level.

Effective storage capacity: The storage between the low water level and the full water level.

Flood control storage: The storage required for temporary storing of flood discharge for the purpose of flood control. Capacity of flood routing is exclusive from flood control storage.

Seepage line:

Condition of seepage flow in the dam body is mainly governed by permeability and the hydraulic gradient, and is generally flow with free water surface. This free water surface is referred to as the seepage line.

Quantity of seepage:

The leakage from the dam embankment, foundation and original ground at the side banks of the river.

Rapid drawdown:

Rapid drawdown of the water level implies the situation where internal water level of the embankment does not decrease together with drawn of the reservoir water level.

Liquefaction:

If shear strength of soils of the dams or their foundation ground is lost by excess pore pressure developed by an earthquake, the soil is said to have been liquefied.

Cut-off trench:

The excavation at the foundation of the impervious portion of the dam body is referred to as the cut-off trench.

Weak foundation:

Weak foundation is defined as that of an N-value of the standard penetration test of less than 20, and is composed of clay, silt or organic materials.

Outlet works for reservoir level control:

Outlet works are installed to evacuate reservoir storage for inspection and repair of the dam embankment or other facilities.

Intake facilities:

Intake facilities perform release of the storage water for groundwater recharge purpose, and also for the irrigation or other purposes.

Temporary diversion works:

Temporary diversion works are to be designed in order to divert flows at the dam sites during the construction period.

Foundation treatment:

Foundation treatment shall be conducted using the proper method in order to achieve the required design objectives. Installation of cut-off trench is generally applied for the delay action dams, besides using grouting.

Diverted material:

Diverted material is that of excavated in the construction of the dam body, spillway, and appurtenant structures, and utilized for the dam embankment and other filling materials.

Banking factor:

This is a variation rate for the earth volume between the natural condition (in natural ground), loose condition after excavation and compacted condition.

PLANNING AND DESIGN GUIDELINE FOR DELAY ACTION DAMS

I. PLANNING CONCEPT

1. Study on Recharge Potentiality of Delay Action Dams

1-1 Hydro-geological Potentiality

Delay action dam contributes for the groundwater recharge through the dam and reservoir foundation together with that through river bed downstream of the dam embankment. Permeability of the foundation and river deposits shall be ensured to practically estimate the recharge effect.

Seepage discharges through dam and reservoir foundation on various permeability and foundation depth corresponding to the field survey result are illustrated below. Reading of discharge per meter of the embankment, the total seepage flow can be calculated by multiplying the bottom length of the dam embankment.

Resulting from this seepage discharge, sufficient seepage through dam foundation is not expected in the case that the hydraulic conductivity of the foundation is less than 1.00×10^{-3} cm/sec. On contrary to this, it is proved that the maximum velocity of the foundation flow increases 1.0×10^{-3} to 2.6×10^{-3} cm/sec when hydraulic conductivity is 1.00×10^{-2} cm/sec, thus it is accompanied with piping at where unconsolidated particles being accumulated.

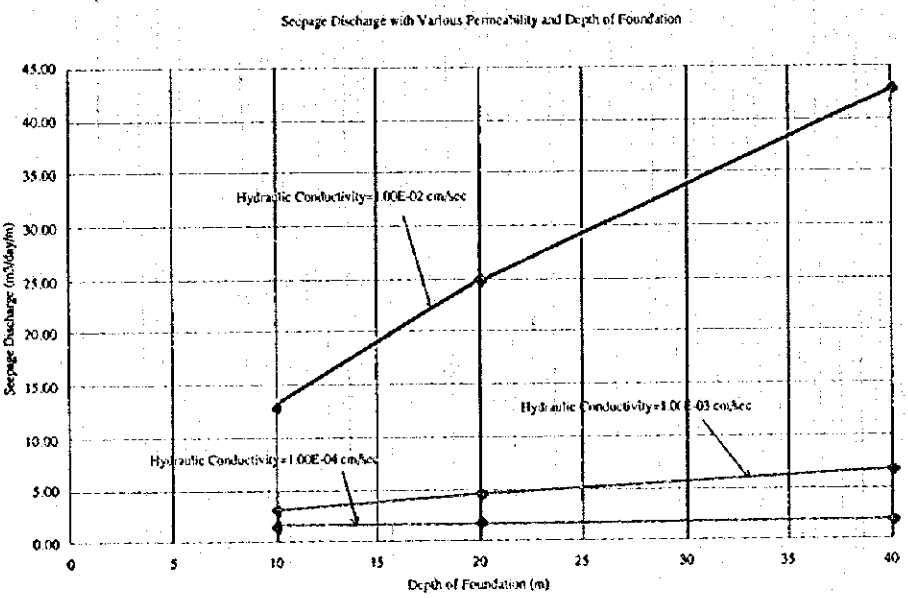


Fig. 1 Simulation Result of Seepage Discharge

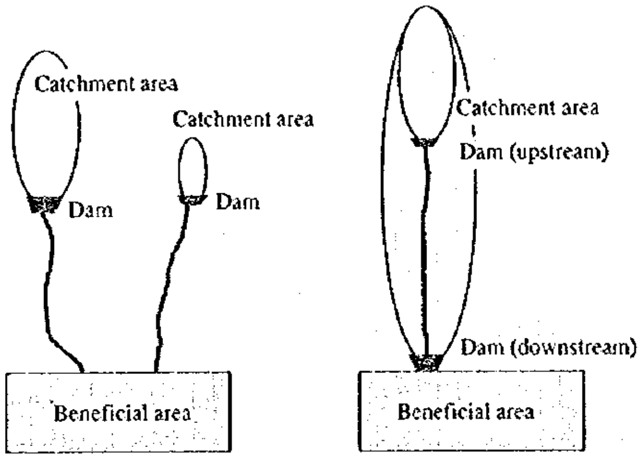
According to the field survey, particles accumulated in the river beds and alluvial fans are mostly classified into well-graded gravel or silty gravel, and hydraulic conductivity ranges from $2x10^{-4}$ to $2x10^{-3}$ cm/sec due to a few content of silt. On the other hand, transmissibility of the river bed and alluvial fans ranges 10 to 200 m^2/day, accordingly, high permeability can be expected. In this regard, hydro-geological survey on the permeability factors of hydraulic conductivity and transmissibility of the river bed and alluvial fans shall be conducted to ensure the groundwater recharge effect by the dam construction during the dam planning and design.

1-2 Meteoro-hydrological Potentiality

Annual run-off coefficient of 5 to 10 % is expected in the Pishin Lora basin referring to the run-off records observed at Chapper Lift station. Run-off coefficient varies by season, lower value ranging from 5 to 8 % is observed during winter and higher value of 10 to 15 % in summer due to characteristic rainfall pattern in the Study area. Rainfall distribution in different basin in the Pishin Lora basin is listed below:

Basin	Annual rainfall (mm/year)	Relation with rainfall in Quetta
Pishin Sub-Basin	238.5	1.04
Kuchlagh Sub-Basin	208.8	0.91
Quetta Sub-Basin	230.1	1.00
Kolpur Sub-Basin	196.6	0.85
Patki Shah Nawaz Sub-Basin	162.3	0.71
Shirinab Sub-Basin	162.3	0.71
Mastung Sub-Basin	151.1	0.66
Mangochar Sub-Basin	136.9	0.59
Sardar Sub-Basin	151.1	0.66
Kalat Sub-Basin	190.8	0.83
KopotoSub-Basin	190.8	0.83

Effective run-off of 10 % and annual rainfall distribution listed above shall be carefully examined to estimate the recharge capacity through dam foundation. In general, the dam site located at hilly area and beneficial areas located at flat area has topographically certain distance, thus, run-off from smaller catchment area does not sufficiently contribute to groundwater recharge at the beneficial areas due to water transmission losses such as evaporation from shallow layers and dispersion of seepage flow under the ground between the dam site and beneficial areas. (see Case-1, 2). Accordingly, dam site which has larger catchment area shall be prioritized. In addition, the project is implemented giving a priority to higher benefited project, in general. In this connection, dam project with smaller catchment area is not proceeded if the benefit area is located far from the dam site.

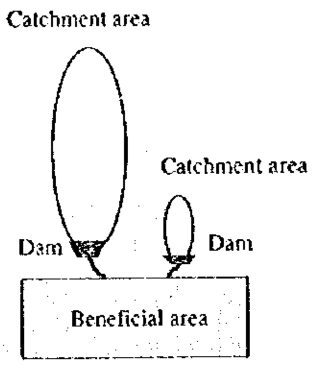


Case - 1 Case - 2

In the case that the dam is located close to the beneficial areas (Case-3), obvious disadvantage for groundwater recharge corresponding to the area of each dam catchment is not observed because of a few water losses along the short aquifer. However, the dam construction cost per one (1) storage capacity is gradually increased if reservoir capacity becomes smaller because of low efficiency of storage capacity at lower elevation compared with dam height, as well as uniformed initial construction cost and indirect cost for the dam construction. In this regard, dam project with smaller catchment area shall be abandoned taking these topographical and budgetary effectiveness into account. (see Fig. 2)

Fig. 3 explains relation between water availability corresponding to the catchment area and unit recharge cost estimated based on dam construction cost and storage capacity, i.e. recharge volume. Three (3) cases depending upon the characteristics of the annual rainfall amount in different locations are indicated in the figure. It is concluded that:

1) increase ratio for 1.0 m^3 water recharge cost is gradually declined when a larger catchment area is attained.
2) assuming that the dam catchment area is the same, the water availability is varied in relation to the annual rainfall amount, so that the appropriate catchment area is estimated in certain deviation according to the dam site location.



Case - 3

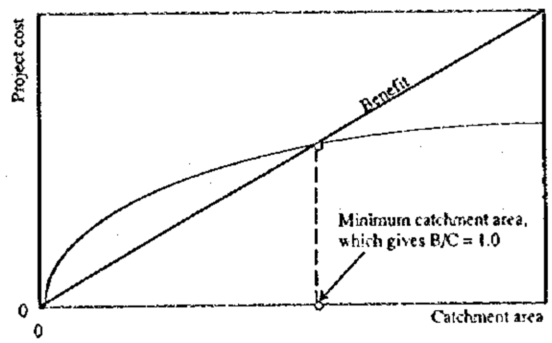


Fig. 2 Relation Curve between Project Cost nd Benefit (Catchment area)

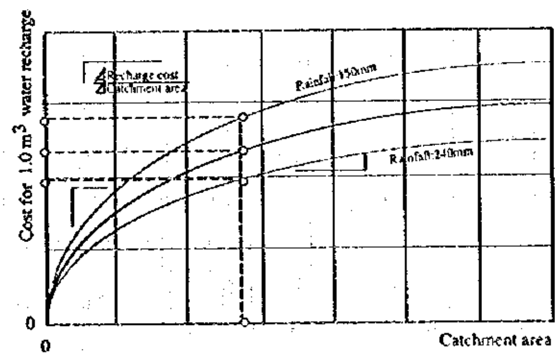


Fig. 3 Relation Curve of Water Availability and Project Cost

As described above, the economical viability on dam site selection regarding hydrological potential is carefully examined during project planning.

1-3 Effective Storage Capacity

The largest storage capacity estimated in the following three cases is applied for effective storage capacity of respective dam.

1. Simulation of effective storage capacity

Considering the insufficient of the meteorological and hydrological data in the Study area, an effective storage capacity is estimated with the following assumptions:

(1) Simulation of storage capacity on monthly basis

Effective storage capacity is estimated by an accumulated balance of between run-off and release water, i.e. outflow through conduits for ground water recharge. Water balance is calculated for consecutive several years based on the run-off discharge from the catchment and expected recharge capacity. Seepage flow through the dam and reservoir foundation is eliminated from the balance calculation because of its reductive amount due to siltation accumulated in the reservoir during several years after the dam completion.

Monthly precipitation data are available instead of daily precipitation. Run-off coefficient of 10 %, and recharge capacities of 2,500, 5,000, 7,500, 10,000 m^3/day are predicted for the balance calculation. A series of the recharge capacities are applied for the simulation taking account of the expected recharge capacity of the recharge device, e.g. infiltration pond, etc. corresponding to its permeability.

(2) Simulation of storage capacity on daily basis (Flood protection)

Delay action dam also contributes to flood protection along with routing in the reservoir. Thus, it is recommended to determine the storage capacity corresponding to flood mitigation capacity. Statistical daily precipitation data are available to estimate the required storage capacity. Daily precipitation of five (5) year return period is applied to estimate storage capacity considering magnitude of flood damages.

Run-off coefficient is susceptible to water content, land scape, etc. Exposed rock, thin soils are conductive to run-off. On contrary to this, deep dry soils and pervious gravels are not conductive to run-off in lowland. Furthermore, intense precipitation may cause run-off by exceeding the infiltration capacity of the soils. It is assumed that the coefficient ranges from 20 to 25 % during intensive precipitation referring to the high run-off coefficient of 60 % which was equivalent to a depth of 3.63 inches observed at the Hub dam site (catchment area: 3,8875 sq. miles) in August 1984 and annual average run-off of 10 to 12 % in the summer season in the Study area. Storage capacity is provided as same amount of total run-off during 24 hours precipitation.

(3) Storage capacity of 3 months run-off

River flow during flood is turbid with suspended materials consisting of silt and clay. Resulting from the inflow of these materials, reduction of the seepage capacity of the infiltration pond is observed due to clogging of the porous surface by fine materials. To prevent inflow of these turbid materials into infiltration pond, release of storaged water be refrained for certain period. On the other hand, it is not recommended to release turbid water without proper reservoir operation through the year.

Annual distribution of precipitation is around 70 % during winter season from December to March. Precipitation in the beginning of the winter does not contribute for run-off for the reason that it is consumed to rise moisture content of the ground. In this connection, run-off for three months from January to March is stored in the reservoir.

Flow chart of the storage capacity simulation is illustrated in Fig. 4. Simulation results on above three cases are explained in Fig. 5, and details on monthly basis simulation (case 1) are presented in

Fig. 6 in accordance with the several combinations of catchment areas and recharge capacities. These simulations were made applying the precipitation data observed at Quetta. In this connection, it is necessary to consider the locality of precipitation intensity. Fig. 7 gives average annual precipitation (case 1), daily rainfall intensity in the five (5) -year return period (case 2) and average three monthly precipitation (case 3) in Pishin Lora Basin and whole of the Balochistan.

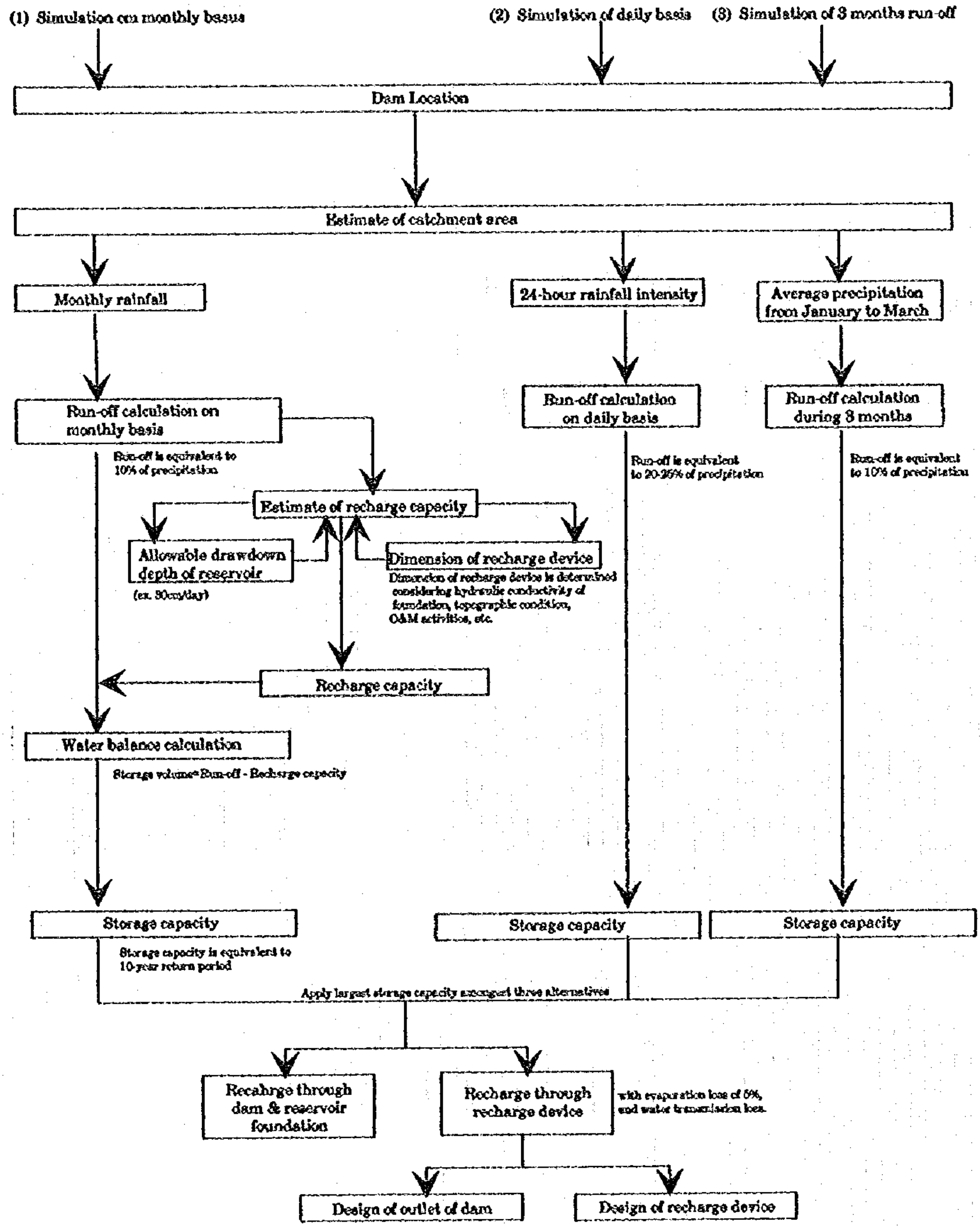


Fig. 4 Flow Chart for Effective Storage Capacity

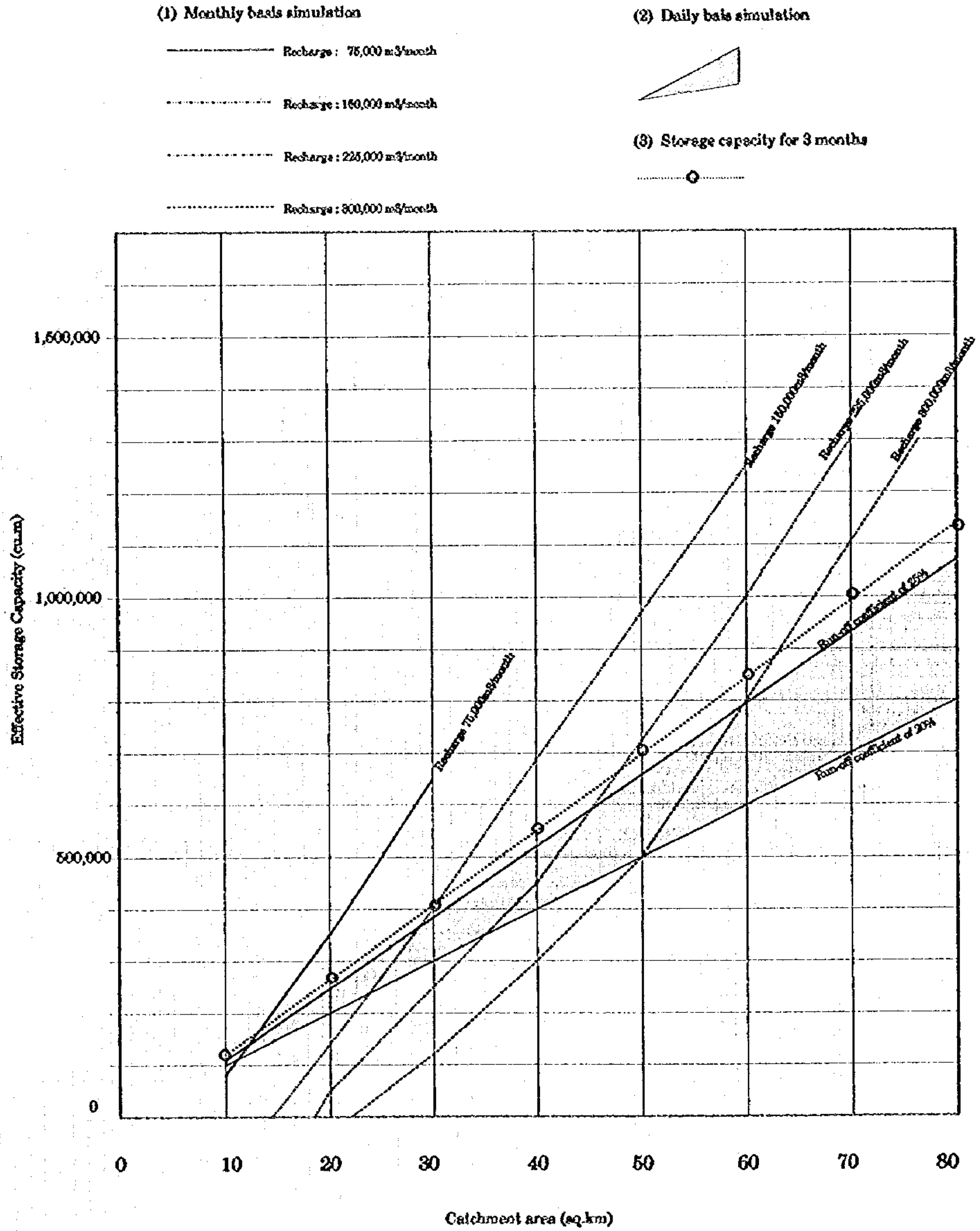
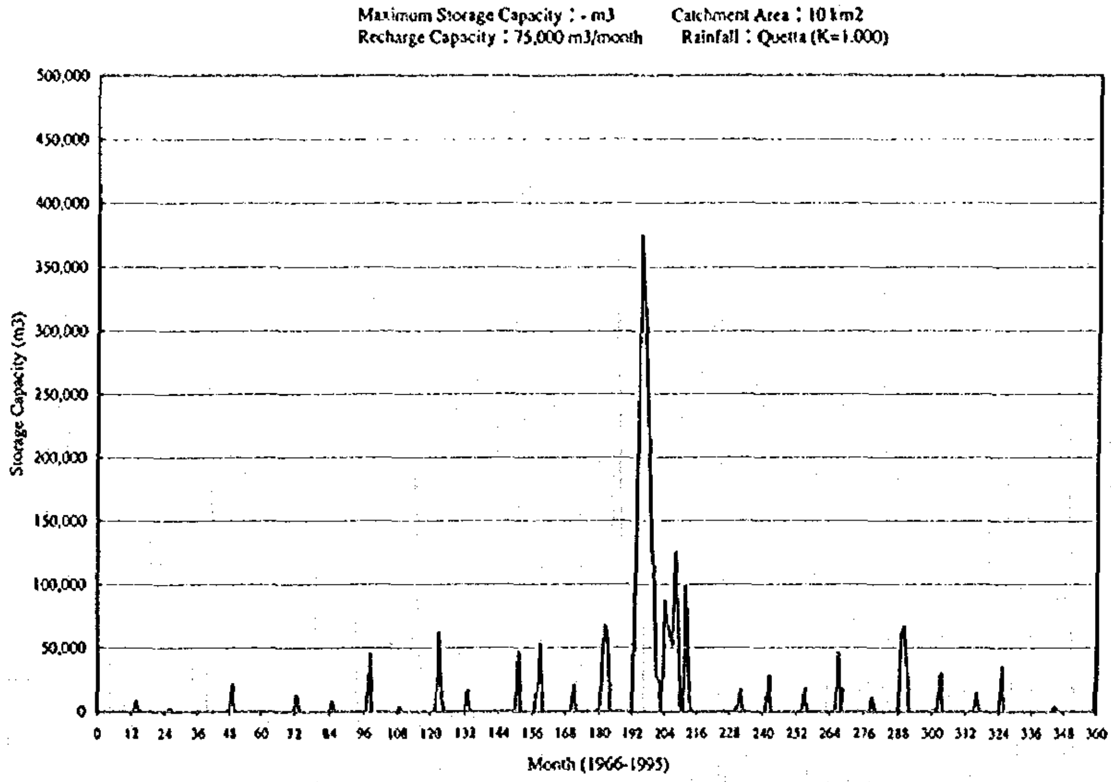


Fig. 5 Required Stirage Capacity - Catchment Area



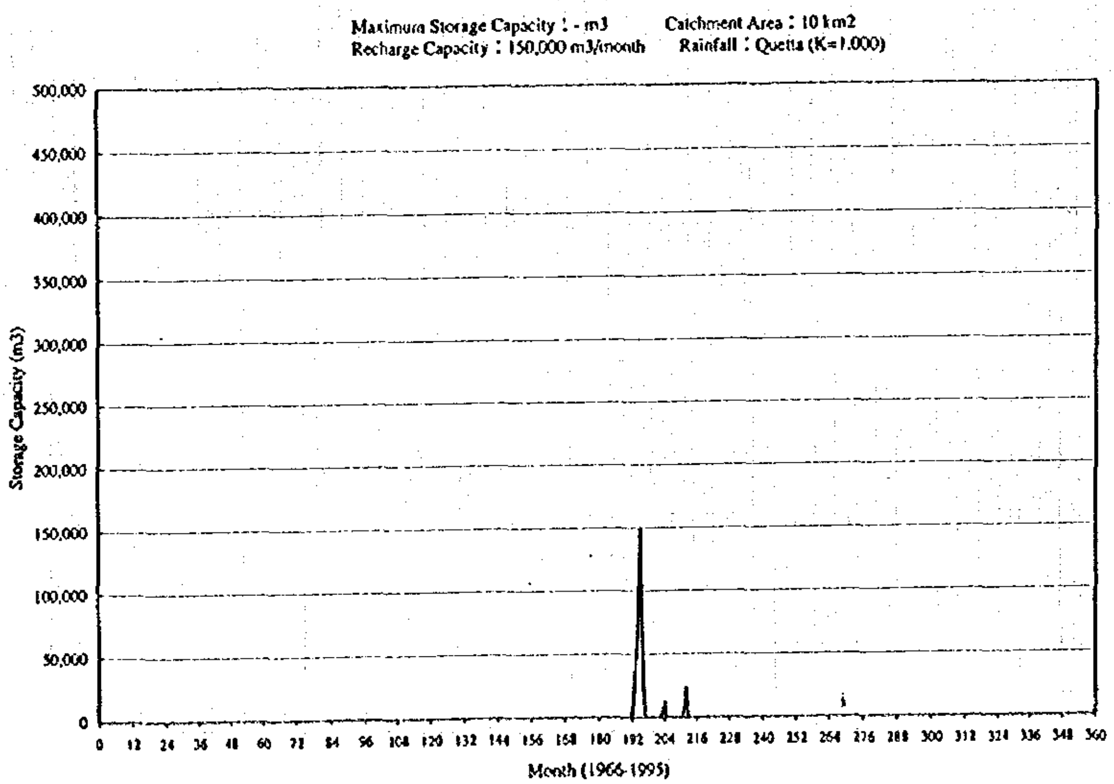
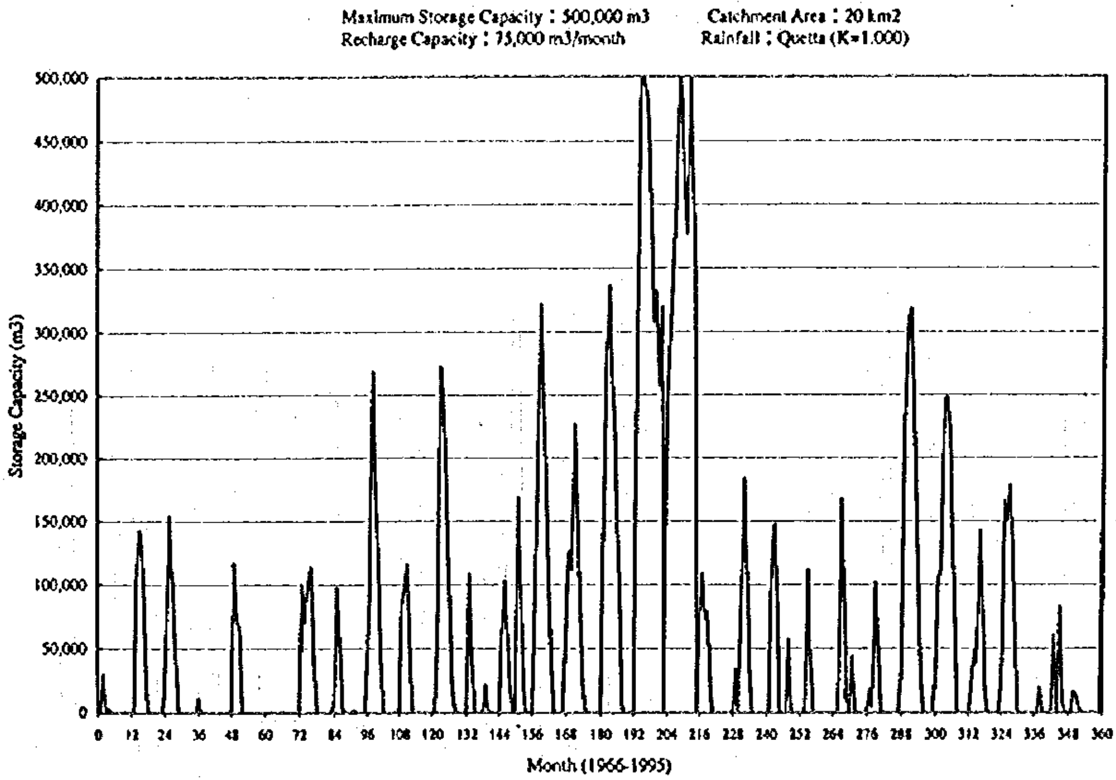


Fig. 6.1 Simulation of Reservoir Storage Capacity (Catchment area : 10 km^2)



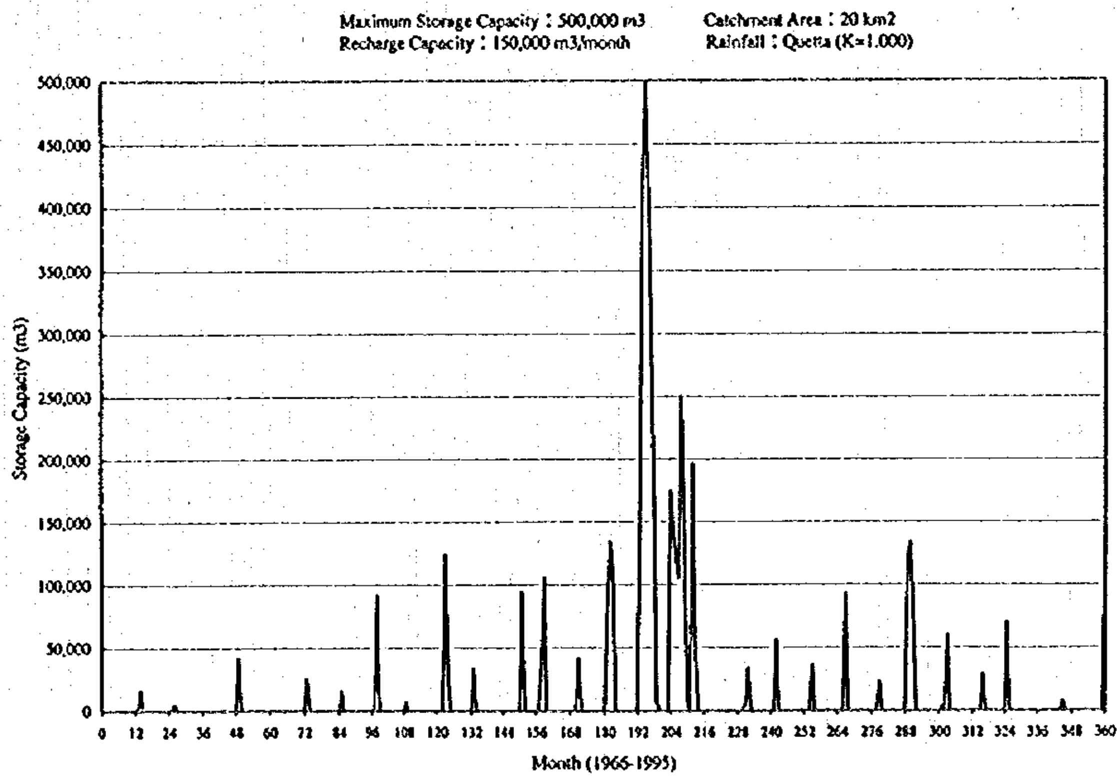
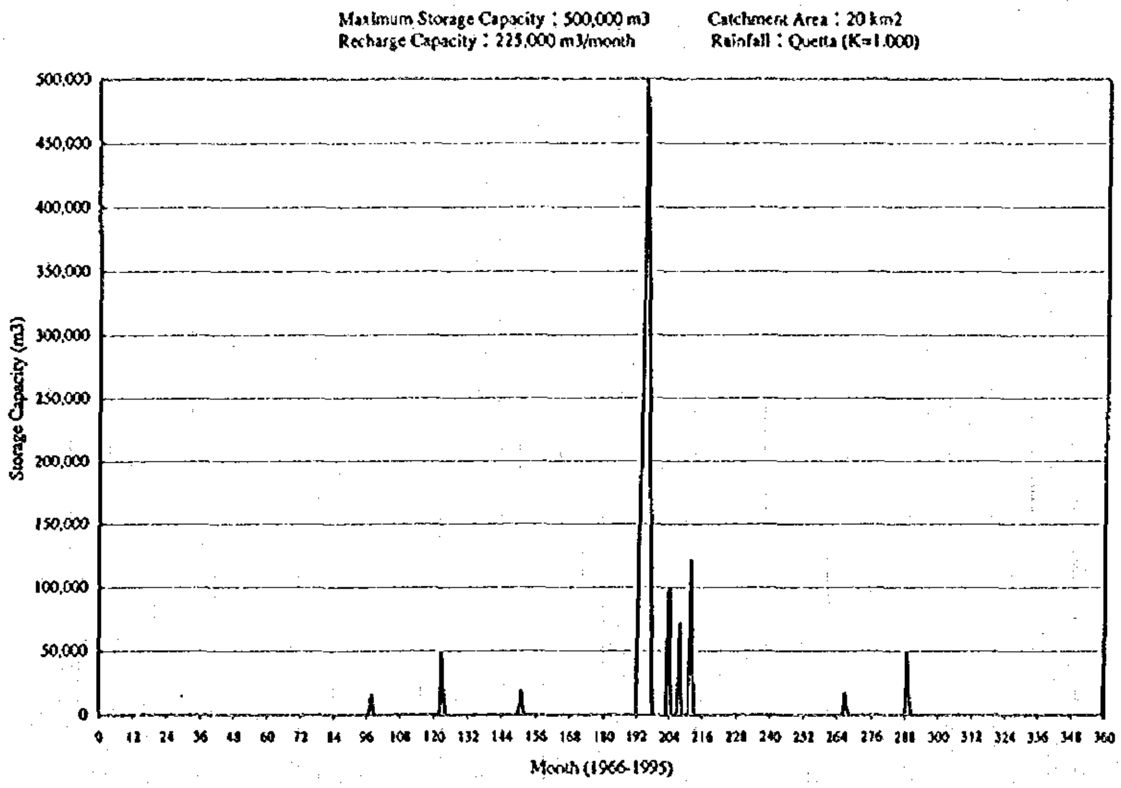


Fig. 6.2 Simulation of Reservoir Storage Capacity (Catchment area : 20 km^2)



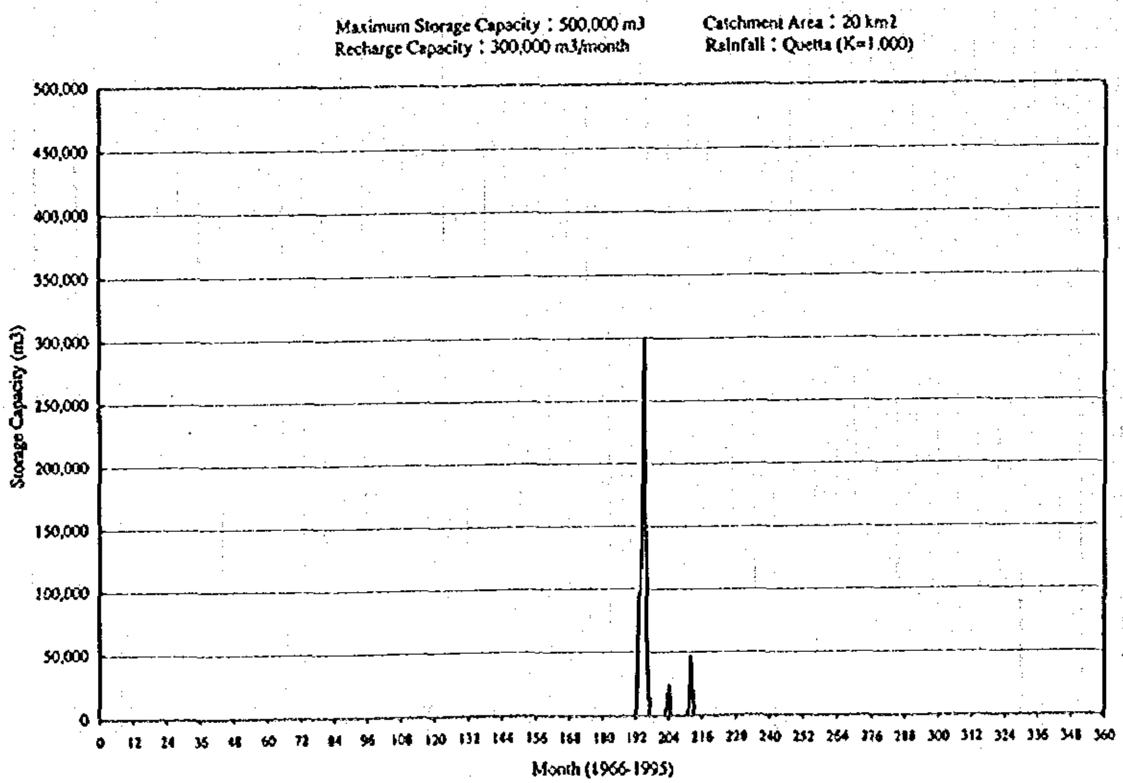
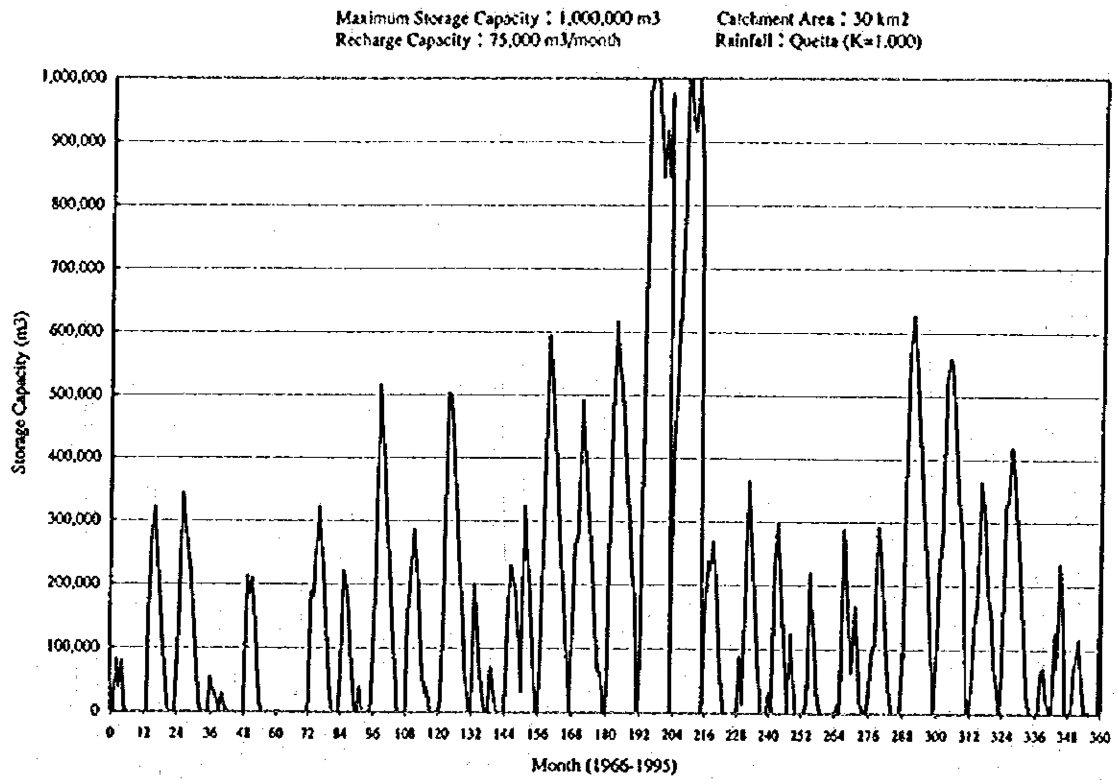


Fig. 6.3 Simulation of Reservoir Storage Capacity (Catchment area : 20 km^2)



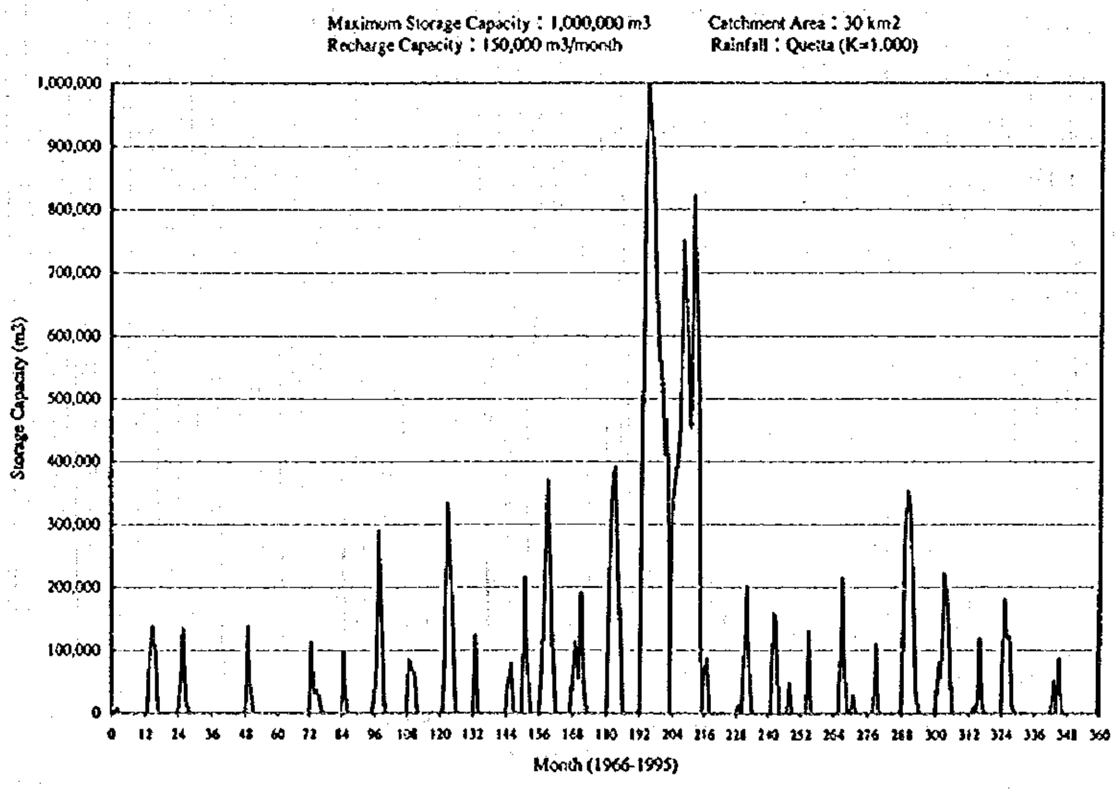
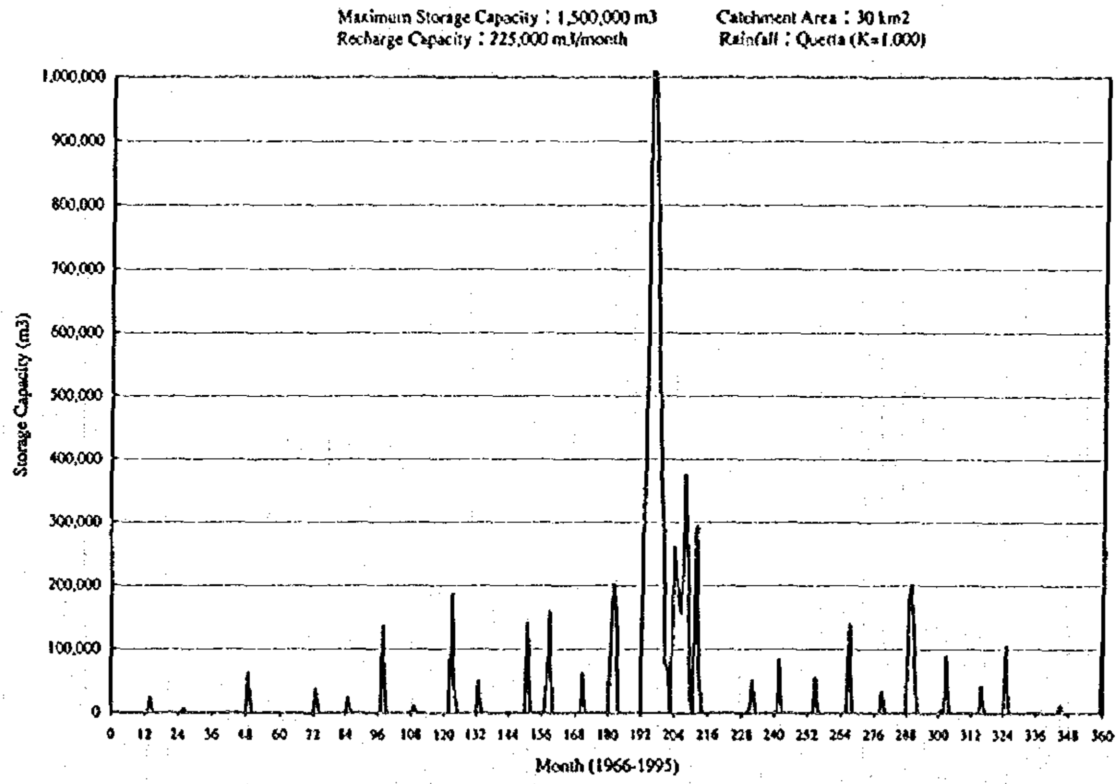


Fig. 6.4 Simulation of Reservoir Storage Capacity (Catchment area : 30 km^2)



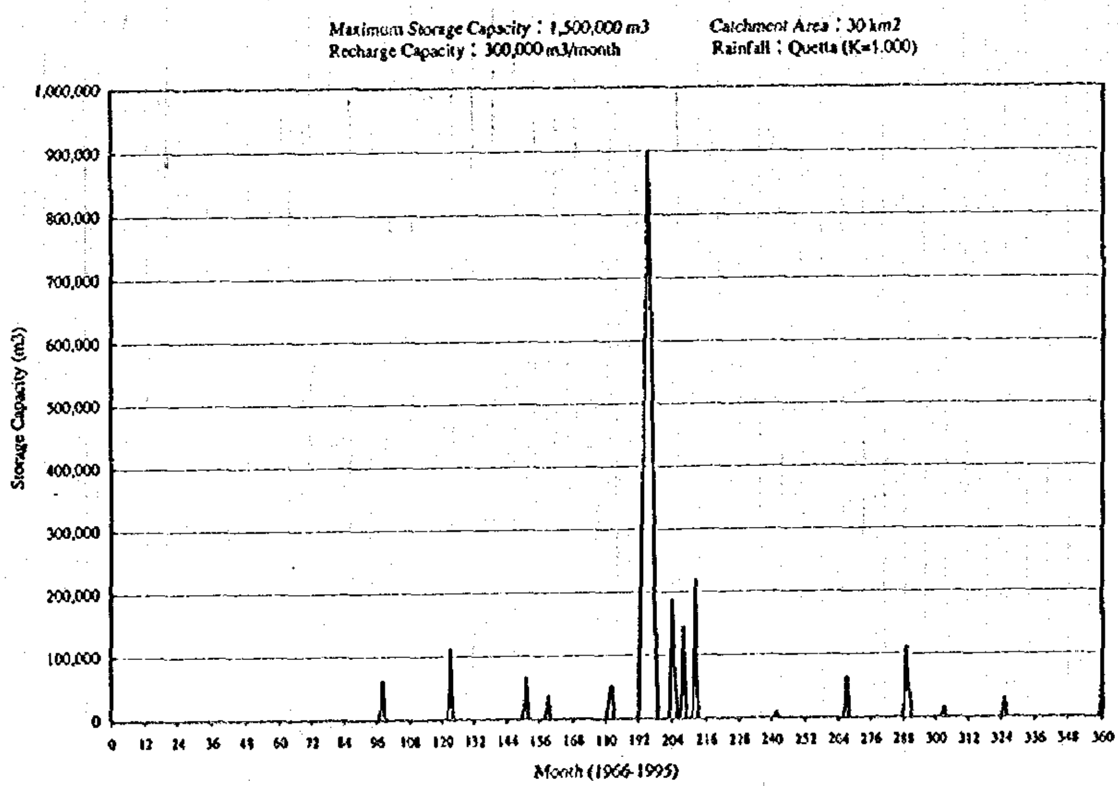
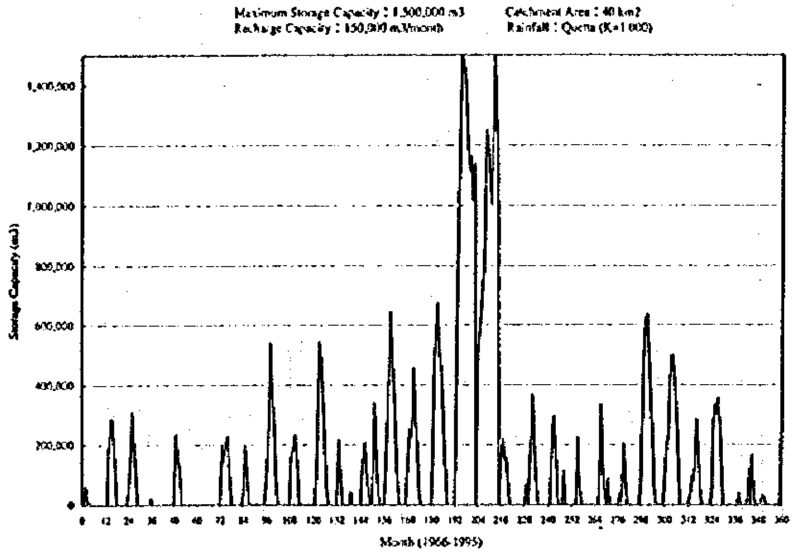
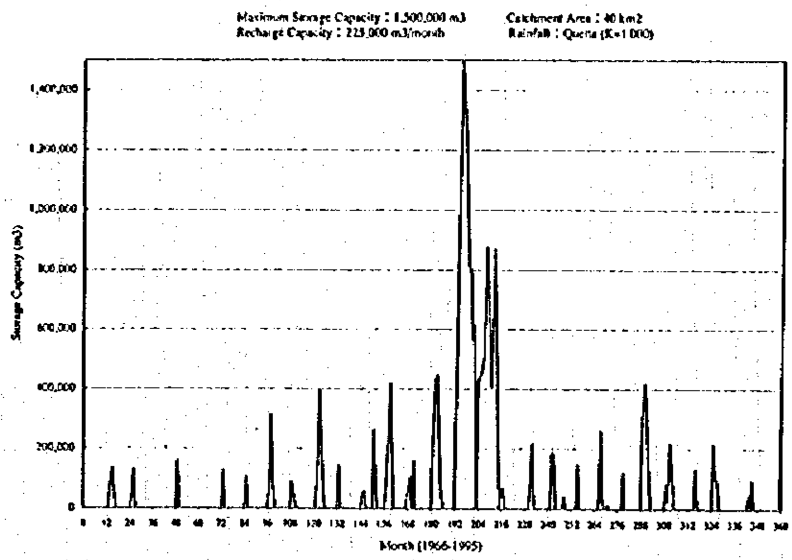


Fig. 6.5 Simulation of Reservoir Storage Capacity (Catchment area : 30 km^2)





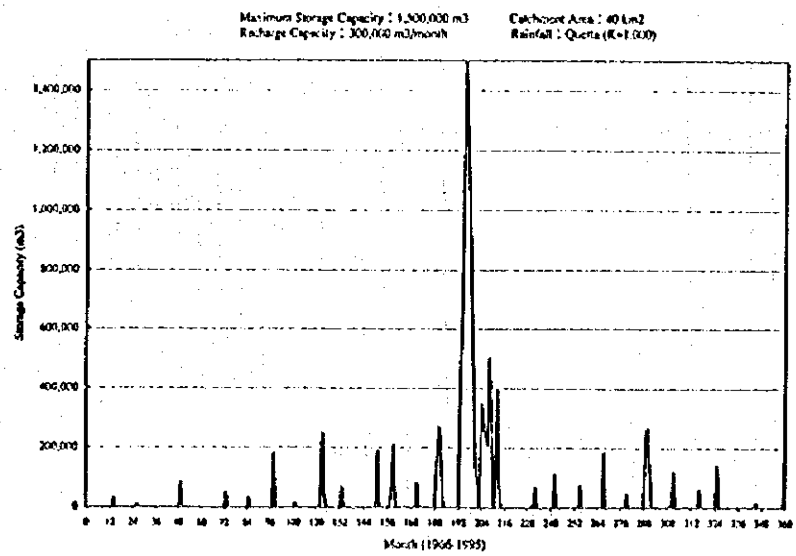


Fig. 6.6 Simulation of Reservoir Storage Capacity (Catchment area : 40 km^2)

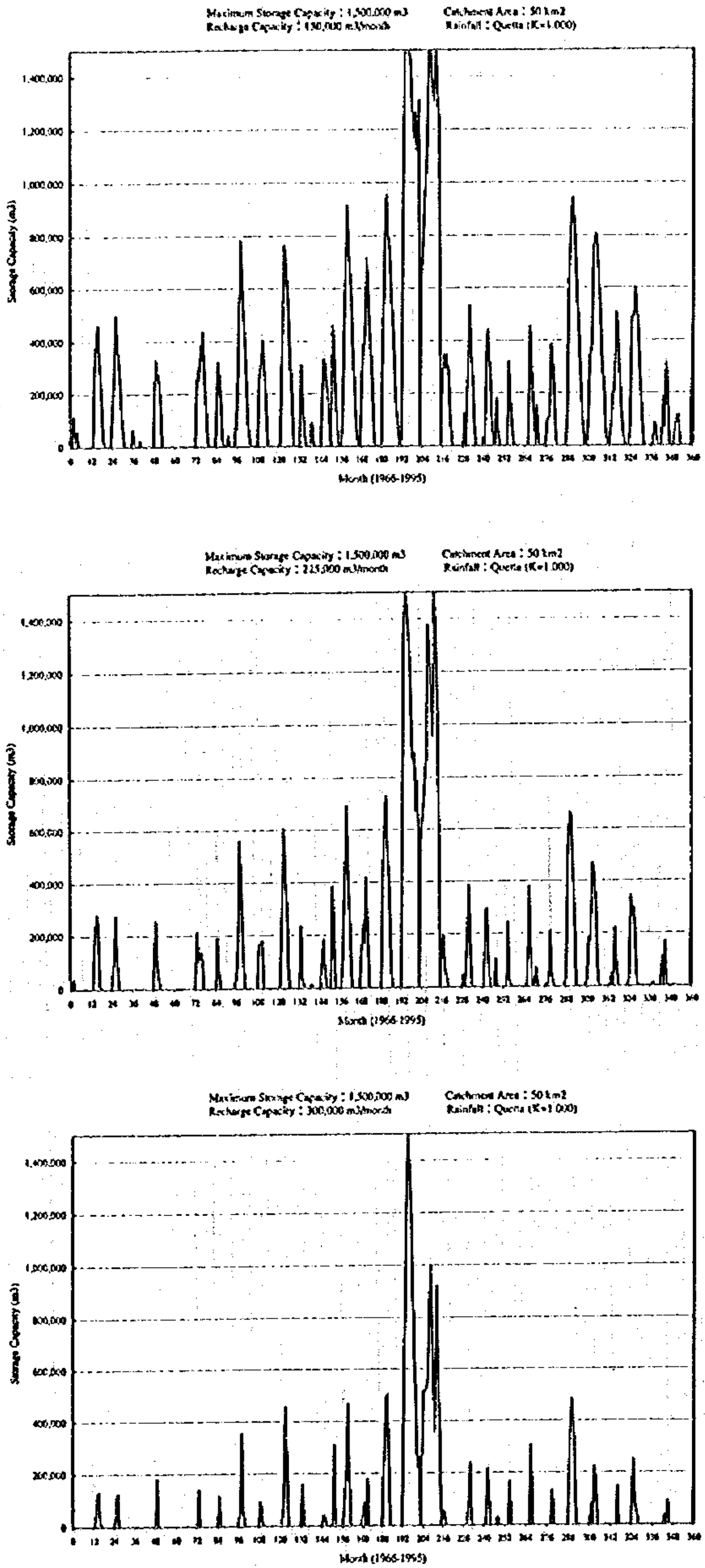


Fig. 6.7 Simulation of Reservoir Storage Capacity (Catchment area : 50 km^2)

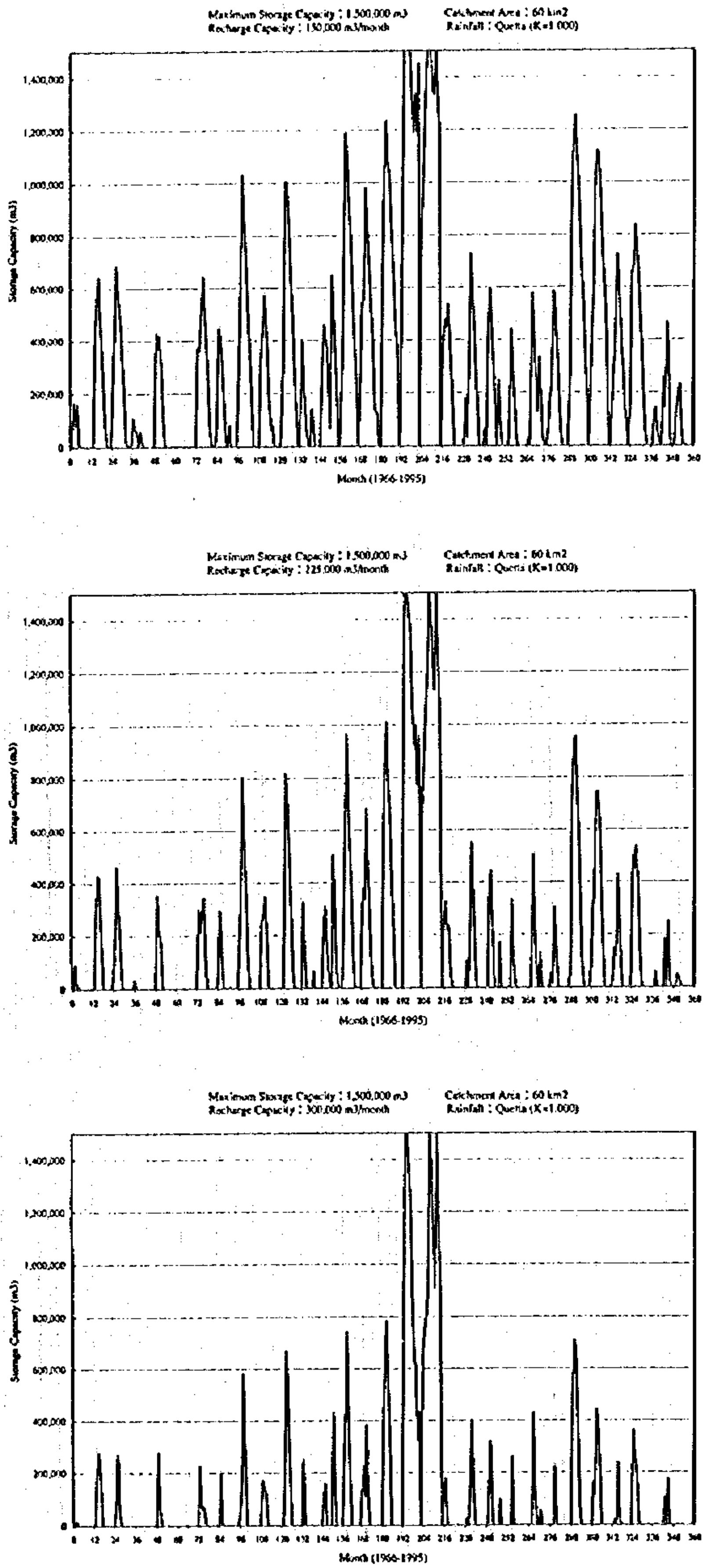


Fig. 6.8 Simulation of Reservoir Storage Capacity (Catchment area : 60 km^2)

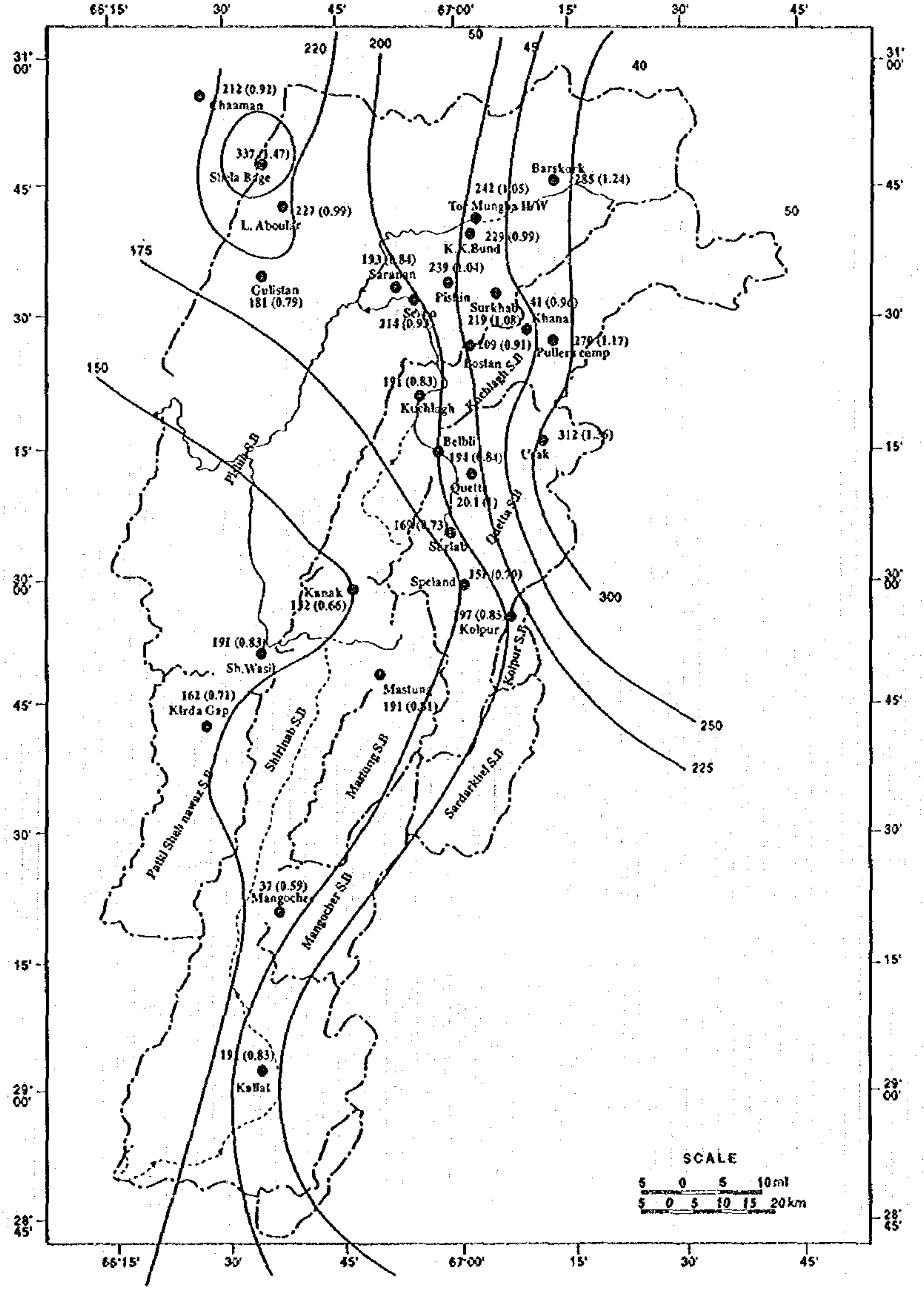


Fig.7.1 30 Years Average Annual Precipitation in Pishin Lora Basin

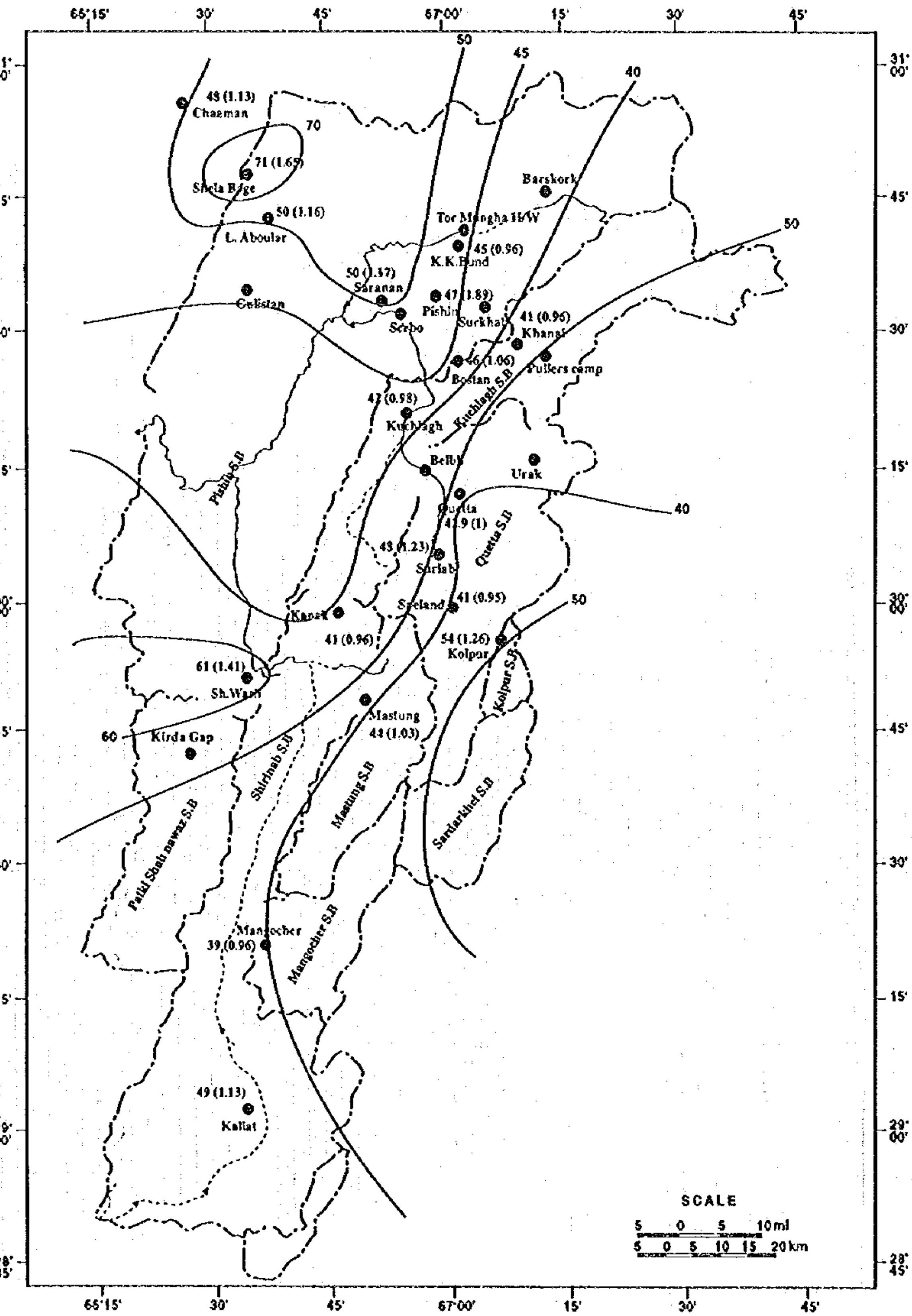


Fig.7.2 Daily Precipitation in 5 Years Return Period in Pishin Lora Basin

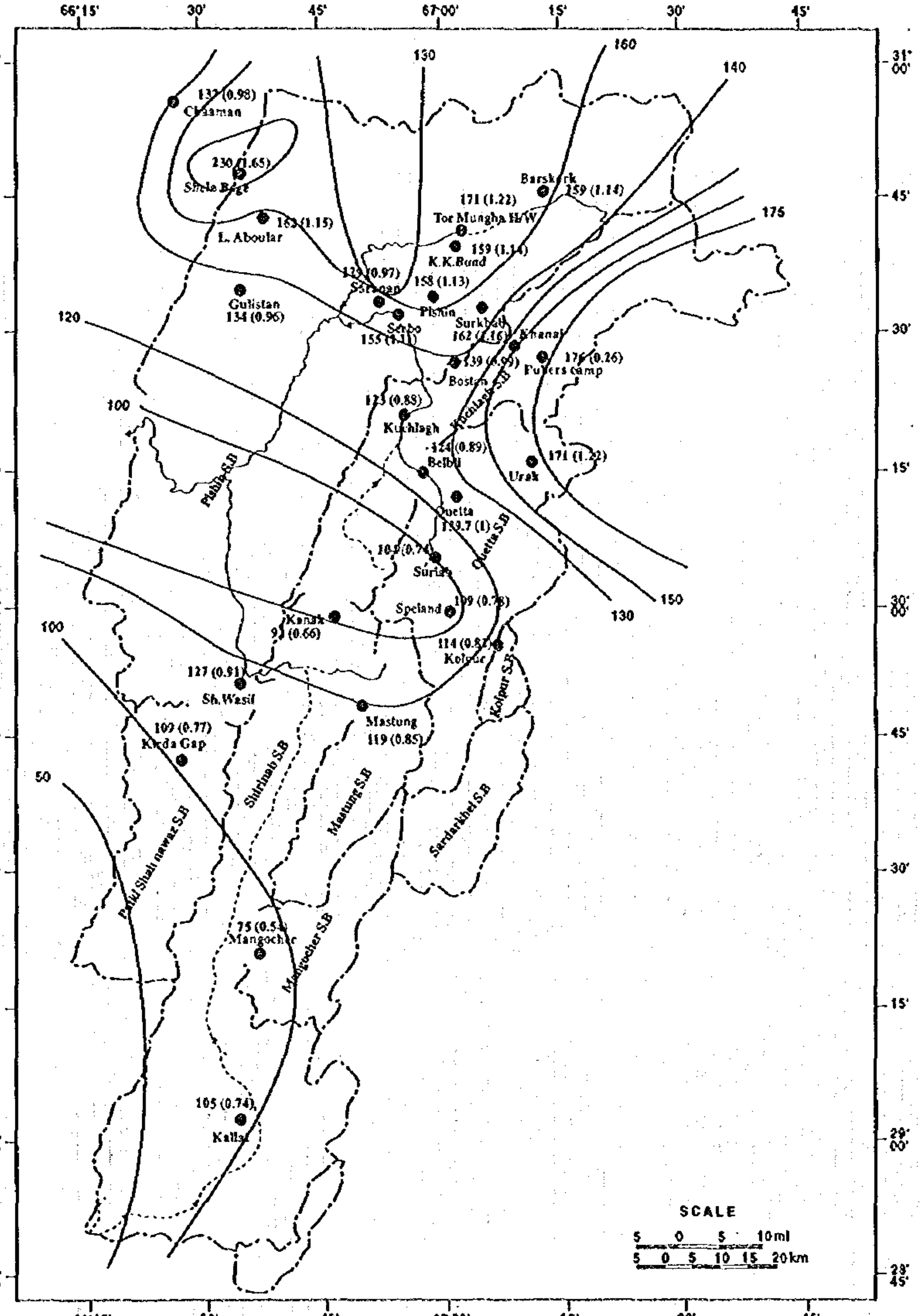


Fig.7.3 30 Years Average Three Monthly Precipitation in Pishin Lora Basin

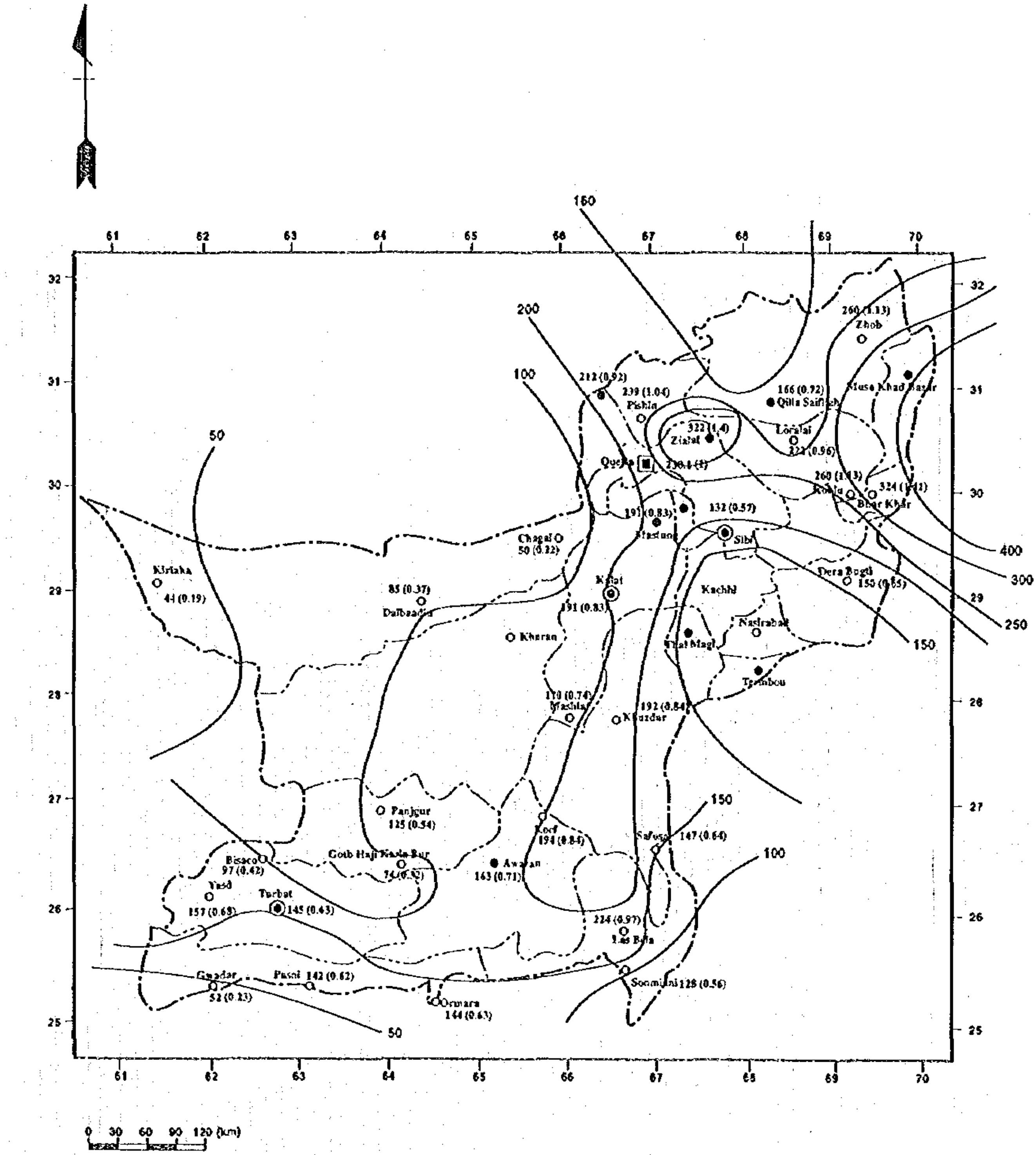


Fig. 7.4 30 Years Average Annual Precipitation in Balochistan

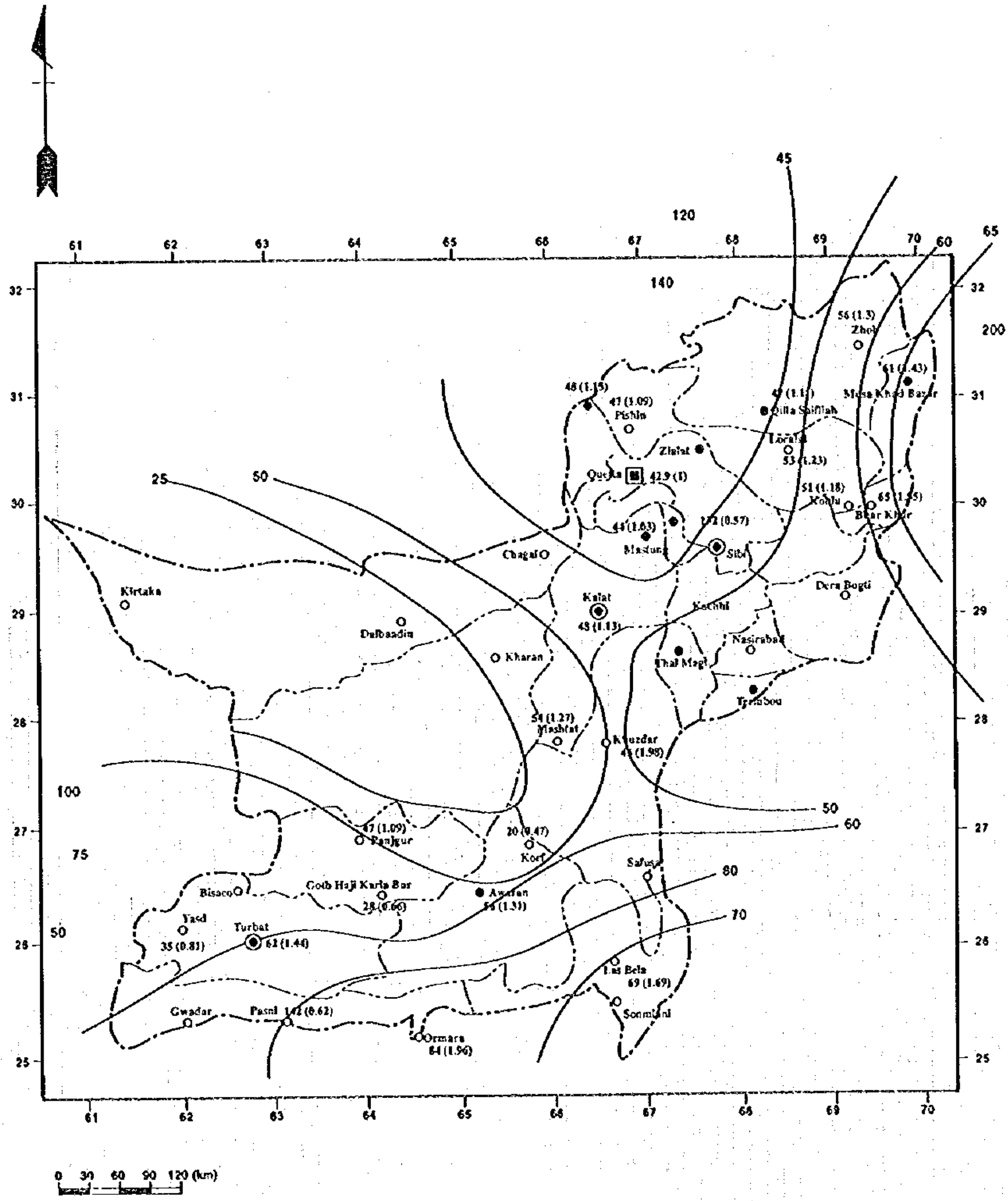


Fig. 7.5 Daily Precipitation in 5 Years Return Period in Balochisan

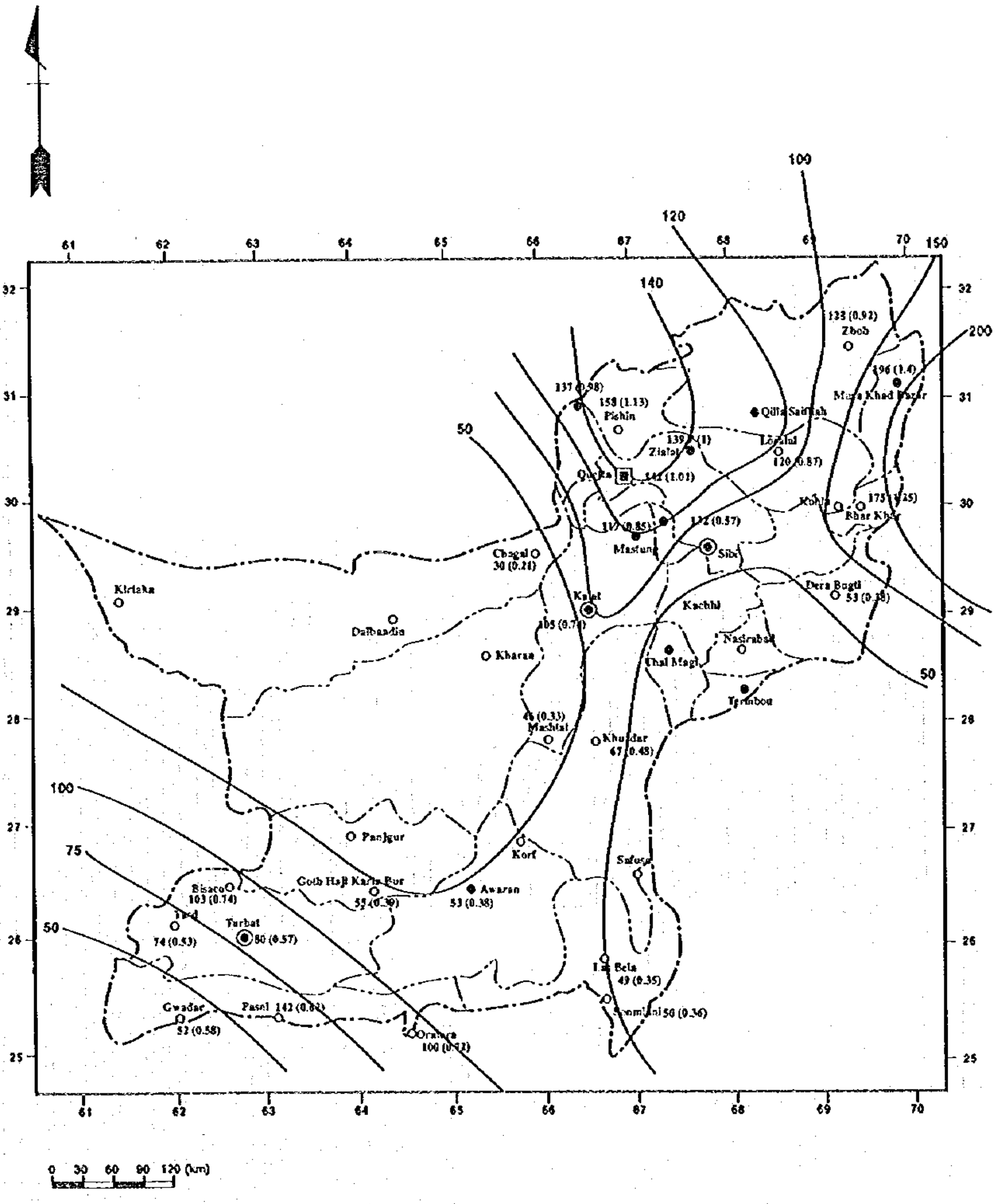


Fig. 7.6 30 Years Average Three Monthly Precipitation in Balochisan

2. Dam Site Selection on Topo-Geological Aspect

Dam foundation shall be possess required strength and be sufficiently safe against sliding failure or seepage failure. It is mostly important to investigate strength of the foundation against load and seepage, and to examine fill materials such a shearing strength during the planning and design stage, especially for a gravity dam.

In the topographical point of view, a wide valley with gentle longitudinal gradient is preferable for the reservoir, while a narrower valley is preferable for the dam construction to economize dam construction cost. However, wider crest length is also required to effectively, promptly recharge storaged water into the ground. It is also recommended to secure longer crest length to mitigate reduction of the seepage ability caused by accumulation of the sediment upstream of the dam embankment, as explained in the following paragraph, increase of the sediment depth extremely reduce the seepage ability of the reservoir foundation. In this connection, appropriate dam planning taking account of minimization of the construction and maximization of the groundwater recharge is required during dam site selection.

3. Other Constraints for Dam Planning

3-1 Sediment

As described in Planning and Design Guide Line for Delay Action Dams, the specified sediment volume ranges 500 to 2,100 $m^3/km^2/year$ according to the survey records in the Study area. Hydraulic conductivity of sediment is expected around $1.0x10^{-5}$ to $1.0x10^{-4}$ cm/sec because it mostly consists of fine sand and silt, and is gradually consolidated by weight itself. Inflow of sediment into the reservoir occurs during flood, that it is not practicable to remove sediment particles. Excessive accumulation of the sediment in the reservoir induces overflow of the flood, and resulting dam collapse.

Accordingly, it is recommended:

1) to install conduits through dam foundation in order to outflow storaged water for accelerating groundwater recharge through river bed,
2) to secure flood discharge capacity of the spillway, and
3) to allocate sediment volume in total storage volume of the reservoir.

3-2 Salinity Contamination

Recharge of high salinity water is restricted. Provided the surface water is contaminated with saline, concentration and seasonal fluctuation, permissible concentration for irrigation and domestic use shall be examined. Salinity concentration in the reservoir is gradually increased by evaporation, that *proper gate operation scheme is established to mitigate concentration of salinity in the reservoir.*

3-3 Flood Irrigation

Prior to the project implementation, investigation of the existing flood irrigation shall be conducted. The investigation includes topographic survey covering whole flood irrigation areas, flood irrigation method and O&M activities, household survey of beneficiaries, agricultural productivity, cropping pattern, etc. Public consultation survey is also established to mutually recognize the project scheme and obstructive issues by the project implementation.

Direct transmission of the water to the beneficiaries by open channel or conduits is available on condition that the regulation regarding water utilization and water distribution is observed.

4. Evaluation of DAD Scheme

4-1 Economic Evaluation

The economic feasibility of the proposed DAD scheme shall be examined. The purposes of the economic evaluation are to concrete the proposed plan and then to put it into implementation. The common indicators of the project evaluation, such as Net Present Value (NPV), Benefit Cost Ratio (B/C) and Internal Rate of Return (IRR), are calculated on cash flow of the costs and benefits of the scheme for the project life. The project cost is composed of the construction cost and O&M cost on the proposed DAD scheme. The financial cost excluding transfer costs is multiplied by Standard Conversion Factor (SCF) to convert into the economic cost.

The anticipated benefits on groundwater recharge by the DAD scheme are increments in economic value under with project condition compared to under without project condition. The groundwater exploitation potential under without project condition is assumed to decrease at optimum level in water balance. Under with project condition, the total volume of natural and artificial groundwater recharge can be used for irrigation and domestic purposes. The water penetrated at the dam site will certainly reach the specified beneficial area and be used there at present use level at the maximum. The some portion of the recharged water conserves groundwater resources in the basin. The value of this unspecified groundwater recharge is evaluated using unit water value equivalent to minimum artificial recharge cost in the basin.

The dams have additional functions of flood control. The mitigation of flood damage is evaluated by the expected annual flood damage calculated with former flood damages and probability of rainfall.

4-2 Social Soundness

The development plan should be formulated in consideration of participation and cooperation of beneficial people and communities. In the planning stage of the DAD scheme, it is preferable to inform the draft plan and make interview to the anticipated beneficiaries. The final DAD plan should be socially sound and acceptable so that the scheme may go successfully and enduringly.

4-3 Environmental Consideration

The delay action dams, in itself, provide positive impact on the physical environment due to groundwater conservation. If any negative environmental impacts are predicted in the environmental impact assessment on the DAD scheme, the original plan should be modified to minimize such impacts.

II. TECHNICAL GUIDE LINE FOR DAM DESIGN, CONSTRUCTION, AND O&M

A Dam Planning

1. Project Purpose

Delay action dams are proposed to store the river run-off aiming at acceleration of groundwater recharge. Furthermore, flood mitigation is expected due to routing of the flood in the reservoir.

2. Allocation of Reservoir Storage Capacity

Reservoir storage capacity is calculated with following equation:

<u>Reservoir storage = Effective storage + Dead water storage (Sediment volume)</u>

Flood control volume is not allocated in the storage capacity. Effective storage capacity is estimated on the basis of the water balance calculation which is obtained with various discharge of inflow into the reservoir and water release composed of evaporation from the water surface of the reservoir and outflow corresponding to the recharge capacity through the dam foundation and through recharge device located at the downstream of the dam or natural river bed.

Reservoir storage capacity is determined to provide appropriate benefits according to the cost and benefit relation, i.e. the dam construction cost including O&M cost and agricultural, social benefits.

3. Survey Plan

Survey plan consists of the survey for the proposed dam and reservoir, sediment control dam (check dam, retention bund), watershed management and existing dam, as required.

3-1 Investigation plan

The investigation for project planning is carried out to collect necessary data for evaluating the possibility of the dam construction and selection of the proposed dam site, including sediment control dam planning and watershed management planning. In addition, investigation for the existing dam located in the same catchment area is carried out to collect the necessary data, e.g. flood analysis, sedimentation, recharge condition as well.

3-2 Investigation Items

(1) Investigation items for planning

a) Actual state of the existing dams in the project area
b) Actual state of the flow regime
c) Development potential of new dams
d) Present state of water use for agricultural and other social sector (Present condition of water shortage)
e) Long term prospect of water demand

(2) Investigation items for design

a) Meteorology, hydrology (temperature, rainfall and run-off, etc.)
b) River condition
c) Topography, geology
d) Embankment materials
e) Others (earthquake)

(3) Investigation items for construction

a) Meteorology, hydrology (temperature, rain days and run-off)
b) Distribution of the embankment materials
c) Labor procurement
d) General social factors
e) Land acquisition
f) Accessibility to the site

(4) Investigation items for O&M

a) Meteorology, hydrology
b) River conditions
c) Water use management of existing dams
d) O&M system of existing dam

(5) Investigation items for compensation

a) Condition of habitation and for improving the living conditions of the surrounding area of the dam

b) Housing land, farmland in the submerged area

(6) Investigation items for environment

Living environment:

a) Quality and quantity of river water
b) Present water utilization downstream of the proposed dam site
c) Groundwater level around the proposed dam site

Natural environment:

a) Land slide and slope failure (disaster prevention measures)
b) Sediment inflow and deposits, river channel evolution
c) Terrestrial plants, vegetation

Landscape:

a) Meteorological conditions
b) Topography, geology
c) Basic conditions for afforestation (technical aspects of afforestation)
d) Adaptability of plants to be introduced for afforestation

3-3 Data Analysis

(1) Meteoro-hydrological data

Purpose	Required data	Remarks
Design flood and diversion work	i) Annual maximum hourly rainfall	Except excessively short duration rainfall
	ii) Annual maximum 24-hour rainfall	Run-off is analyzed with hydrograph
Estimation of long term discharge	i) Daily rainfall, daily mean discharge Pan evaporation data	If only short period of daily rainfall record is available at dam site, all available daily rainfall data in adjacent areas are collected.
	ii) Monthly rainfall, monthly discharge	
Estimation of wave height	Annual dominant wind direction and yearly wind velocity	Data from adjacent areas is sufficient.
Estimation of workable days for construction	Number of days with less than specified rainfall and daily mean temperature	Data from adjacent areas is sufficient.

(2) River conditions

Investigation items include discharge, water quality, river bed condition. These data are available for the study of sediment volume, back water and sediment upstream of the reservoir, maintenance of normal river function, such as water quality, discharge, etc. Major causes of water pollution consist of:

a) turbid water brought by flood
b) domestic sewage
c) mining waste water, and
d) eutrophication of the reservoir

Investigation on the river bed condition includes preparation of river longitudinal profile and cross sectional maps, and river bed materials study.

(3) Topography

Topographic investigations are important to determine storage capacity and main structure of the dam, reservoir, and also grasp problematic points regarding the dam foundation to secure the dam safety.

Topographic investigation	Classification of land form
Topo-map for river basin	<u>Classification of land form</u>
Area coverage includes proposed dam sites, reservoir areas (preferably covers entire river basin)	Area coverage includes overall river basin for each proposed dam site with indication of problematic locations. Area coverage includes proposed dam site, storage, borrow area and its surroundings.
Topo-map for dam site (counter interval of 1-2 m, mapped on the ground survey)	<u>Geologic investigation</u> As a result of land form classification, if proposed dam site is unsuitable for construction because of geologically
Longitudinal leveling for dam site Cross leveling for dam site Topo-map for reservoir base	unfavorable conditions such as collapse, landslide and active fault, it shall be abandoned.
Topo-map for borrow area	In the case excavation of foundation or special treatment is considered as safe and more economical than changing the dam site, detailed geological survey shall be carried out.
Topo-map for related structures (spillway, intake facilities, etc.)	

4) Geological investigation

	Preliminary study	Detailed study	Remarks
Purpose	Dam site selection Study of load resistance Study of availability of materials	Collection of geological data required for detailed design and cost estimates Final selection of borrow area, estimate of available quantity of materials	Subsurface survey to investigate the recharge capability not only dam site but downstream of the dam are required.
Dam site	Geological map Surface geology (Study on topography, tratigraphy, structure, hydrogeology) Subsurface geology (Hydrogeological map, seismic prospecting) Foundation test (Deformation, shearing test) (Result) Elaboration of geologic map and profile, permeability, and foundation excavation line	Subsurface geology (Drilling) Foundation test (Deformation and shearing test) Sampling test (Geophysical constant and unconfined compression strength) (Result) Completion of geological map and profile Base rock surface contour map, slice geological map, rock classification profile, permeable profile)	At least one drilling test is required to survey the depth of the foundation, permeability of foundation.
Borrow area	Surface geology (Type of materials and distribution) Subsurface geology (Result) Elaboration of borrow site geologic map with description of material classification and quantity	Surface geology Subsurface geology Fill materials (Drilling) Borrow site (Available quantity shall be estimated) (Result) Geological map, geological longitudinal and cross section map	Improvement of textures of soil materials Estimate of construction cost
Around reservoir	Analysis of seepage Suitability of natural ground	Analysis of seepage (If seepage toward unsuitable direction, countermeasures shall be taken.) Stability of natural ground for unstable area, detailed geologic survey are required.	Ground water observation is carried out.

4. Dam Site and Dam Type

4-1 Dam Site

An appropriate dam site shall be selected considering followings:

1) Dam site should be close to the beneficial area to effectively elevate the groundwater level at the beneficial area.

2) The project must be integrated with other related project. In the case that several dams are proposed in a river basin, the dam sites shall be proposed in due consideration of total recharge ability, dam life corresponding to sedimentation, and cost economization as well.

3) A wide valley with gentle longitudinal gradient is preferable for a reservoir site, while a narrow valley is preferable for a dam site in the economical point of view. While the dam is constructed aiming at the groundwater recharge through dam foundation and river bed, wider dam foundation is considerably effective to accelerate groundwater recharge. In the case that the sufficient length of the dam foundation is not obtained according to the economization of the construction cost as well as technical consideration for the dam safety, recharge device such as intake conduits shall be installed.

4) Regarding dam construction, existence of embankment materials, accessibility to the dam and borrow site are also important to select the dam site.

4-2 Dam Type

Dam type is determined through detailed study regarding the topographic, geological and meteorological condition, availability of construction materials, as well as dam height, length and construction period. Fill type dam is preferable for poor foundation comparing gravity dam because of its smaller stress on the foundation. While when the construction cost of the spillway occupies the most of the construction cost, economical comparison shall be achieved for the dam type selection.

(1) Gravity dam

Concrete dam is mainly categorized in gravity dam, arch dam, hollow dam and so on. In these types, gravity dam has high reliability against flood flow and earthquake. Furthermore, gravity dam construction tends to be easy in the aspects of concrete works and construction control compared to other types.

(2) Fill dam

In the case of a dam of lower height, the homogeneous type is advantageous in its simpler construction work. The types of fill dam other than the homogeneous type, are generally selected for the dams higher than 25 m for the reasons such as shearing strength of the materials, effect of pore pressure, etc. Zone type fill dam is widely adopted for a higher dam due to more prompt dissipation of pore pressure by means of the impervious zone and use of the materials of higher shearing strength.

5. Design Flood Discharge

Regarding design flood discharge, it is proposed that the design flood of 100 year discharge is considered for a gravity dam and fill type dam.

Design flood discharge is given in the following equation:

$$Qp=3.09 \times A \times P(T, a24) \times PR \times Tc^{-0.8}$$

where Qp: flood peak (cusecs)

A: catchment area (square miles)

P(T, a24): rainfall depth of return period T years and duration 24 hours (inches)

$P(T, a24)=P(T, p24) \times ARF$

P(T, p24): 24 hours point rainfall depth of return period T years (inches)

ARF (areal reduction factor)

PR: percent runoff (following table)

Tc: time of concentration (hours)

$Tc=(11.9 \times L^3/H)^{0.385}$

L: catchment length (miles)

H: elevation difference of catchment (feet)

(height of top catchment - height of interest point)

Percentage Runoff

Description (return period)	2	5	10	30	50	100	200	500	1000
Hills:									
ractured sandstone and shale	50	53	55	60	62	65	67	70	75
fractured limestone	55	58	60	65	67	70	72	75	80
non-fractured rock	65	68	70	75	77	80	82	85	90
Alluvial fan/piedmont	25	28	30	35	37	40	42	45	50
Lowland/valley floors	0	0	0	0	5	10	12	15	20
Dense vegetation/cult	-5 for any return period								
Dense forest	-10 for any return period								

Notes: Percentage runoff shall be calculated by weighting the topographic percentage runoffs according to their proportional areas as shown below:

6. Sediment Volume

Sediment is to be estimated for a period of 30 years. Nature of the sedimentation depends on such fundamental elements as meteorology, topography and geology of the catchment area, scale, frequency and duration of flood, and grading of sand, gravel.

The following are also referred to the estimates of the sedimentation of the dam reservoir, based on sedimentation observation records adjacent to the Study Area.

Observation Records of Sedimentation

River name	Observation point	Catchment area (km^2)	Annual rainfall (mm)	Suspended sediment load (million tons)	Suspended sediment load (ton/km^2)	Bed load volume 1) (ton/km^2)	Sediment 2) (ton/km^2)	Sediment 3) (m^3/km^2)
Khost	Chappar Rift	1,321.0	254	0.41	310	341	256	242
Khost	Chappar Rift	25.6						511
Beiji	Ghatti Bridge	9,609.0	323	4.5	469	516	387	366
Pishin Lora	Burj Aziz Khan	7,601.0	220	3.05	400	440	330	313
Average								307

Notes: 1): Bed load is equivalent to 10 % of suspended sedimentation load.
2): Sedimentation of dam is calculated in accordance with its trap efficiency in the reservoir of 75 %.
3): Unit weight of sediment of 1.56 ton/m^3 is applied.
4): Data of Khost (Chapper Rift, A=25.6km^2) is cited from the Research Study on Survey and Evaluation of Delay Action Dams in Balochistan, Pakistan Council of Research in Water Resources.
Sedimentation of dam is calculated in accordance with its trap efficiency in the reservoir of 100 %
Unit weight of sediment of 1.040 ton/m^3 is applied.

Resulting from the above, sedimentation volume of the reservoir is estimated at 390 to 510 $m^3/km^2/year$ (450 $m^3/km^2/year$ in average) assuming that the bed load volume is 15 % equivalent to those of suspended sediment load and trap efficiency of 100 % is applied because all flood run-off be storaged in the reservoir during the reservoir being empty before flood.

On the other hand, the following were the sediment volume in the existing delay action dams of Murgi Kotal, Kach, Wali Dad, and Wali Tangi storage dam. Resulting from the field survey, design specific sedimentation volume of 700 to 2,000 $m^3/km^2/year$ be applied during the dam planning for the rehabilitation of those dams. It is also concluded the less sediment flow was expected in the catchment area of the Wali Dad dam because of its low sediment productivity due to massive rock-ribbed configuration in the catchment area.

Survey of Sedimentation

Dam name	Catchment area (km^2)	Sediment volume (m^3)	Trap efficiency (%)	Duration time (years)	Specific sediment ($m^3/km^2/year$)
Murgi Kotal dam	19.65	124,400	45	8	1,760
Kach dam	56.50	494,000	-	4	2,190
Wali Tangi dam	18.13	-	-	-	723
Wali Dad dam	5.35	12,500	80	10	292

Source: JICA Study Team

Notes: Trap efficiency was estimated according to average C/I ratio of each reservoir (Sedimentation, Design of Small Dams)

Data of Wali Tangi dam is cited from Feasibility Study for Flood Protection of Hanna-Urak Valley

Data of Kach dam is cited from Prefeasibility Study for Rehabilitation of Kach Dam, 1987

Resulting from the above, design sedimentation volume is estimated considering the annual rainfall, river slope, and actual field reconnaissance.

Quetta valley	Northern Quetta Valley	Pishin, Qila Abdullah	Mastung, Kalat
700 $m^3/km^2/year$	1,200-2,100 $m^3/km^2/year$	700 $m^3/km^2/year$	500 $m^3/km^2/year$

Remarks: Sediment volume in table is adopted in the case that actual sediment survey is not conducted.

The table above is not applied for the dams situated in Bostan Formation.

In the case that the catchment area is composed of outcrops of hard rock, specific sediment volume of 300 $m^3/km^2/year$ is applied at minimum.

7. Soil Materials

Test Items on Fill Type Dam Materials

Materials	*Test Items*	Impervious *materials*	Semi *impervious* materials	Pervious *materials*	Remarks
Test for physical properties	Specific gravity of soil particles	A	A	A	Grain size of less than 4.76mm (Sample composed of fine grained soil is arranged in non-dry condition for testing)
	Field water content	A	A	A	
	Grain size analysis	A	A	A	
	Liquid limit	A	A	B	
	Plastic limit	A	B	B	
	Organic matter content	B	B	-	
	Field density	B	B	B	
Test for dynamic properties	Compaction test	A	A	A	When non-standard mold is used, allowable max. grain size is less *than 1/5 of inner mold diameter.*
	Cone index	B	-	-	Inner diameter of mold for compaction is more than 10cm
	Permeability test	A	A	B	
	Consolidation test	A	B	B	Compression index is determined.
	Shearing test	A	A	A	When Md<10, dmax<=Md/10 When Md>=10, dmax<=Md/10-5
	Fine grained test	B	B	B	Md:mold diameter dmax: allowable max grain size

Notes: A: to be implemented B: to be implemented if necessary
Source: Fill Dam (Ministry of Agriculture, Forestry and Fisheries, Japan)

B. Dam Design

1. Seismic Coefficient

Seismic coefficient is determined in accordance with statistical analysis of the earthquakes occurred in and around the project area, and is defined maximum earthquake probably occurs within 100 year in the future. Seismic coefficient is estimated respectively, e.g. dam type (gravity dam, rock fill type dam, earth dam) and foundations (rock, unconsolidated rock, sand-gravel, soil, etc.). Regarding dam type, proportion of safety allowance of 1.2 is defined for homogeneous earth type dam based on those of 1.0 for gravity dam and zone type fill dam. In respect to the foundation, proportion of safety allowance of 1.2 is defined for unconsolidated rock foundation, 1.4 for sand-gravel, soil foundation based on that of 1.0 for consolidated rock foundation.

Based on the earthquake records observed around Quetta, earthquake coefficient of 0.44 is given when magnitude is 7.5, assuming the hypocentral distance of 50 km in horizontal and 30 km in depth of focus. Besides, Earthquake coefficient of 0.11 is given when magnitude is 7.0. It is recommended that the earthquake coefficient of 0.44 be applied for the dam stability analysis to mitigate seismic risk for further 100 years. On the other hand, it is also suggested to reduce the coefficient for the analysis for the reasons that the project life of the delay action dams is 30 years, and damages incurred by dam collapse is less expected than those of storage dams because the reservoir is ordinarily empty.

Isoseismals of Pakistan is illustrated in Fig. 8 on Modified Mercalli scale of intensity. The following gives relation between Modified Mercalli scale of intensity and gravity factor.

Modified Mercalli scale of intensity and gravity factor

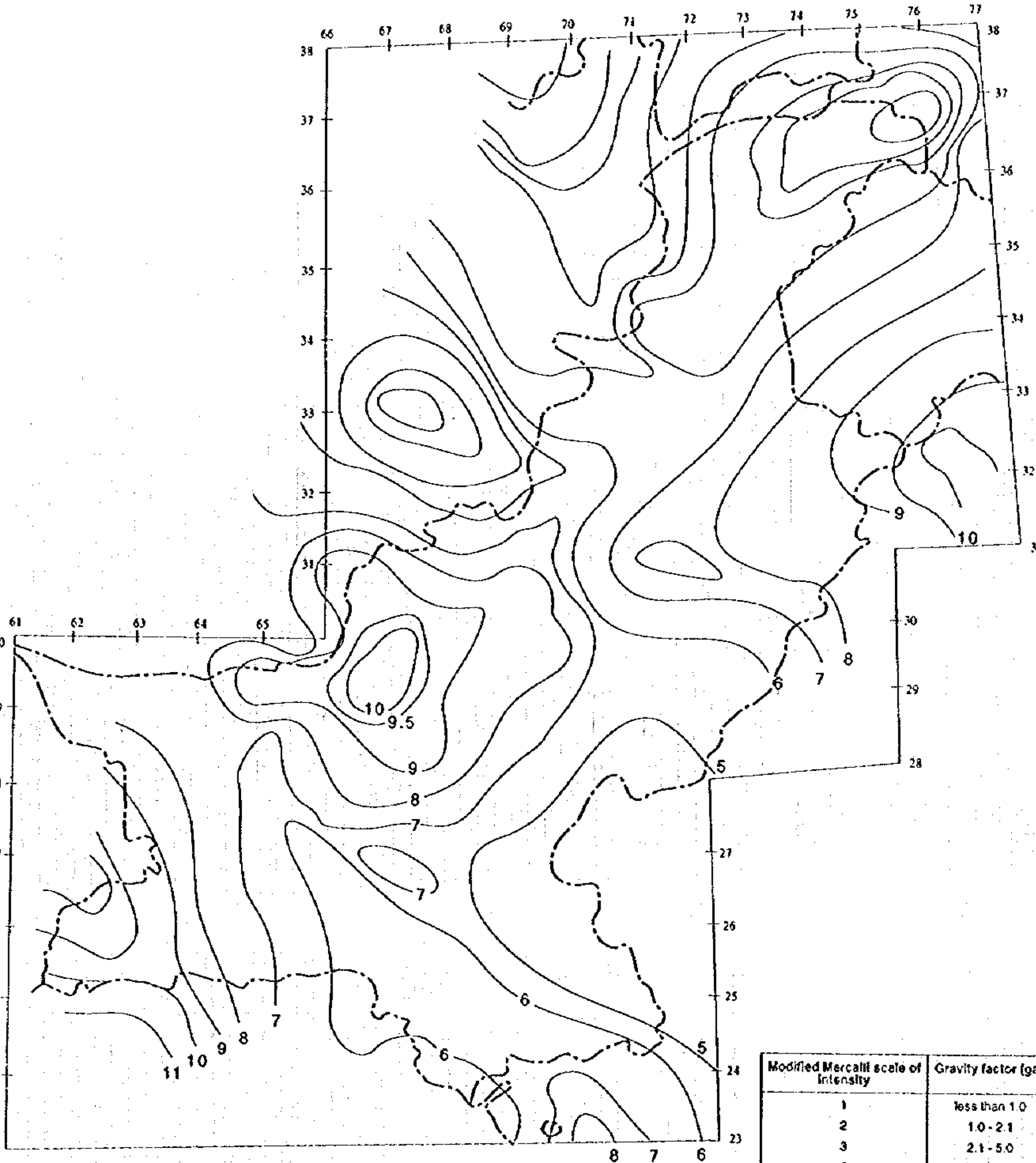
Modified Mercalli scale of intensity	Gravity factor (gal)
1	less than 1.0
2	1.0 - 2.1
3	2.1 - 5.0
4	5.0 - 10.0
5	10.0 - 21.0
6	21.0 - 44.0
7	44.0 - 94.0
8	94.0 - 202.0
9	202.0 - 432.0
10	larger than 432.0
11	not defined
12	not defined

Source: The Meteorological Agency, Japan

During dam stability analysis, the following seismic coefficient shall be given for the minimum although isoseismic distribution is varied depending on the area. Furthermore, larger seismic coefficient shall be rightly applied on the basis of the area map as shown in Fig. 8, in the case that the dam is constructed on the week foundation.

Dam type		Seismic coefficient
Gravity dam		0.20
Fill dam	Homogeneous type	0.24
	Others (Zone type)	0.20

Note: 50% of the above coefficient is applied for the dam sliding calculation case of full water surface of the reservoir due to low probability of occurrence of earthquake during full water surface.



Modified Mercalli scale of Intensity	Gravity factor (gal)
1	less than 1.0
2	1.0 - 2.1
3	2.1 - 5.0
4	5.0 - 10.0
5	10.0 - 21.0
6	21.0 - 44.0
7	44.0 - 94.0
8	94.0 - 202.0
9	202.0 - 432.0
10	larger than 432.0
11	not defined
12	not defined

source: The Meteorological Agency, Japan

Fig. 8 Isoseismals of Pakistan on Modified Mercalli Scale of Intensity

2. Elevation of Non-overflow Section and Dam Crest

Elevation of the dam crest is as follows:

Fill type dams

(unit: m)

Design of Small Dams (USBR)	Engineering manual for Irrigation & Drainage (MAFF)	Technical manual for Flood control dam (MC)
Hf+1.22 (4 feet) (Fetch is less than 1.61km, 1 mile)	Hf+hw+he+1 (when hw+h2<2, Hf+3) Hs+hw+he/2+1 (when hw+h2/2<2, Hs+3)	Hh+0.6
Hh+0.92 (3 feet) (Fetch is less than 1.61km, 1 mile)	Hh+hw+1 (when hw<1, Hh+2)	
Hf: Normal full water level (m) Hh: Design flood level (m) (Delay Action Dams) Hf+3.06 (10 feet) or Hf+3.67 (12 feet) Hf: Normal full water level (m)	Hf: Normal full water level (m) Hs: Surcharge water level (m) Hh: Design flood level (m) hw: Wind induced wave height from reservoir surface (m) he: Earthquake induced wave height from reservoir surface by earthquake (m) Hd: Overflow depth when design flood discharge overflows spillway (m)	Hh: Design flood level (m)

Source: USBR:(United States Department of the Interior, Bureau of Reclamation)
MAFF (Ministry of Agriculture, Forestry and Fisheries, Japan)
MC (Ministry of Construction, Japan)

Note: Design discharge is obtained by adding 20 percent of 200 year flood for fill type dam. (MAFF, MC)
Design of small dams instructs criteria for the dams not exceeding 15 m (50 feet) in height. (USBR)

<u>Gravity dams</u>

Design of Small Dams (USBR)	Engineering manual for Irrigation & Drainage (MAFF) Technical manual for River erosion control(MC)	
	- without flood control gate	- with flood control gate
	Hf+hw+he (when hw+h2<2, Hf+2)	Hf+hw+he+0.5 (when hw+h2<1.5, Hf+2)
	Hs+hw+he/2 (when hw+h2/2<2, Hs+2)	Hs+hw+he/2+0.5 (when hw+h2/2<1.5, Hs+2)
Hh+0.92 (3 feet)	Hh+hw (when hw<1, Hh+1)	Hh+hw+0.5 (when hw<0.5, Hh+1)
Hh: Design flood level (m) (Delay Action Dams) not applicable	Hf: Normal full water level (m) Hs: Surcharge water level (m) Hh: Design flood level (m) hw: Wind induced wave height from reservoir surface (m) he: Earthquake induced wave height from reservoir surface by earthquake (m)	Hf: Normal full water level (m) Hs: Surcharge water level (m) Hh: Design flood level (m) hw: Wind induced wave height from reservoir surface (m) he: Earthquake induced wave height height from reservoir surface by earthquake (m)

Source: USBR:(United States Department of the Interior, Bureau of Reclamation)
MAFF (Ministry of Agriculture, Forestry and Fisheries, Japan)
MC (Ministry of Construction, Japan)

Note: Design discharge is obtained by 200 year flood for gravity dam. (MAFF, MC)
Design of small dams instructs criteria for the dams not exceeding 15 m (50 feet) in height.

In addition to the above estimation of the dam crest elevation, minimum free board of 3.06 m (10 feet) high from spillway crest must be applied for the dams. Elevation of Non-overflow Section is summarized as below according to the dam height.

Dam height	lower than 15m	higher than 15m
Fill type dam	Hf + 3.00 m and Hh + 1.00 m	Engineering Manual for Irrigation/Drainage
Gravity dam	Hf + 3.00 m and Hh + 1.00 m	Engineering Mannual for Irrigation/Drainage

3. Stability Analysis of the Embankment

(1) Fill type dam

Analysis method for the sliding failure is broadly categorized in sliding surface method and stress analysis. The circle arc method is employed for the fill type dam. However, the sliding wedge method is adopted in case that the estimated sliding line passing through the weakest portion of the dam embankment and also foundation is not circular. In addition, safety against surface sliding also estimated. The following show cases for examination of the sliding failure described in several design manuals. Application of mechanical properties of fill materials for stability analysis is below.

(Application of Shear Test Values)

The shear stress is estimated by the following shear tests due to the specified condition of the quantitative pore pressure.

(1) Total Stress Analysis

When the pore pressure immediately after the dam construction can not be estimated quantitatively, total stress analysis is applied for the dam stability. The safety factor for the slope stability can be estimated by the total stress analysis using c (cohesion) and Ø (angle of shear resistance) obtained from unconsolidated undrained test. For slope safety factor calculation, pore pressure is not considered in the equation, accordingly "c" and "Ø" already include the effect of the pore pressure at shear.

(2) Effective Stress Analysis

When the pore pressure immediately after the dam construction can be quantitatively estimated with considerable accuracy, strength parameters (c') and (Ø') of the effective stress expression are obtained from the consolidated undrained test (pore water pressure be observed during shear), or consolidated drained test. Thereafter, the safety factor is estimated by the effective stress analysis.

Besides, the effective stress strength parameters (c') and (Ø') can be obtained by the consolidated drained tests or consolidated undrained tests for the stability analysis after pore pressure generated during the construction has dispersed. Effective stress strength parameters can be applied for the stability analysis of the embankment during the dam operation. Consolidated drained test is applied for the impervious materials because the excessive pore pressure does not occur in the impervious materials during the construction period and also seepage-flow. Accordingly, consolidated drained test is applied for these materials.

Stability of the upstream slope of the embankment during the rapid drawdown of the reservoir level is estimated by the effective stress analysis with (c') and (Ø') obtained from the consolidated drained test for the impervious materials, and consolidated drained test or the consolidated undrained test (pore pressure shall be observed during shear) for the impervious materials.

Cases for Examination of Sliding Failure (Fill Type Dams)

Design of Small Dams (USBR)	Engineering manual for Irrigation & Drainage (MAFF)	Technical manual for Flood control dam (MC)

Design of Small Dams (USBR)

Stability shall be examined with "Slip-circle" method. Besides, slope of up and downstream is given *for stable foundations.*

HOMOGENEOUS EARTH DAMS

Materials	Up	Down
Detention or storage purposes		
(GW,GP,SW,SP)	not suitable	
(GC,GM,SC,SM)	1:2.5	1:2.0
(CL,ML)	1:3.0	1:2.5
(CH,MH)	1:3.5	1:2.5
Storage purpose		
(GW,GP,SW,SP)	not suitable	
(GC,GM,SC,SM)	1:3.0	1:2.0
(CL,ML)	1:3.5	1:2.5
(CH,MH)	1:4.0	1:2.5

ZONE TYPE FILL DAMS
(Following Table)

Engineering manual for Irrigation & Drainage (MAFF)

Safety factor of 1.2 shall be satisfied in all cases below:

1. Design flood level
   (Effective stress, both slopes)
   (Seismic factor is not applied)
2. Surcharge water level
   (Effective stress, both slopes)
   (Design seismic factor of 50%)
3. Normal full water level
   (Effective stress, both slopes)
   (Design seismic factor of 100%)
4. Intermediate water level
   (Effective stress, upstream slope)
   (Design seismic factor of 100%)
5. Empty
   (immediately after completion)
   (Effective stress, both slopes)
   (Design seismic factor of 50%)
6. Rapid drawndown
   (Total stress, upstream slope)
   (Design seismic factor of 100%)
7. Rapid drawndown
   (Effective stress, upstream slope)
   (Design seismic factor of 50%)

Technical manual for Flood control dam (MC)

1. Normal full water level (SF>1.20)
   (Effective stress)
   (Design seismic factor of 50%)
2. Empty (SF>1.20)
   (Design seismic factor of 100%)
3. Empty (SF>1.10)
   (immediately after completion)
   (Effective stress)
   (Design seismic factor of 50%)

SF: Safety Factor

Slopes of up and downstream is given below, depending on material except that the dam is constructed on weak foundation

Materials	Up	Down
(GW,GP)	3.0	2.5
(GM,GC,GO,GV)	3.0	2.5
(SM,SC,SO,SV)	3.5	3.0
(ML, CL)	3.0	2.5
(MH,CH,OV,VH)	3.5	3.0

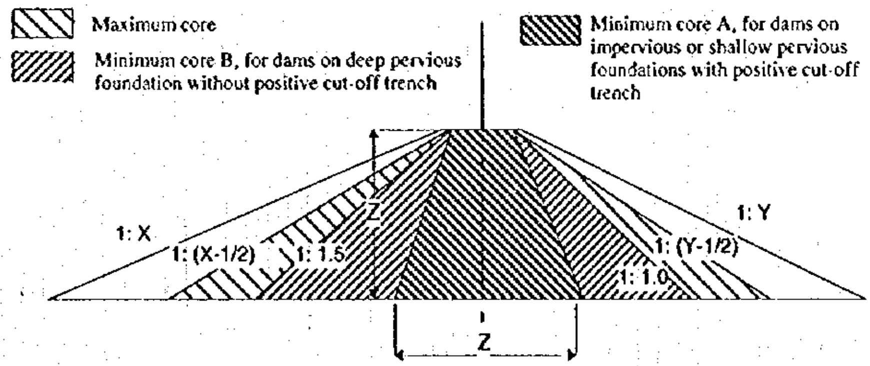
Source: USBR:(United States Department of the Interior, Bureau of Reclamation)
MAFF (Ministry of Agriculture, Forestry and Fisheries, Japan)
MC (Ministry of Construction, Japan)

Note: Design of small dams instructs criteria for the dams not exceeding 15 m (50 feet) in height.

Slope Gradient of Fill Dams (USBR)

Type	Purpose	Subject to rapid drawndown	Shell material classification	Core material classification	Up slope	Down slope
Zoned with minimum core A 1)	Any	Not critical	GW,GP,SW,SP	GC,GM,SC,SM,CL ML,CH,MH	1:2.0	1:2.0
Zoned with maximum core 1)	Detention or storage	No	GW,GP,SW,SP	GC,GM	1:2.0	1:2.0
				SC,SM	1:2.25	1:2.25
				CL,ML	1:2.5	1:2.5
				CH,MH	1:3.0	1:3.0
Zoned with maximum core 1)	Storage	Yes	GW,GP,SW,SP	GC,GM	1:2.5	1:2.0
				SC,SM	1:2.5	1:2.25
				CL,ML	1:3.0	1:2.5
				CH,MH	1:3.5	1:3.0

Source: USBR:(United States Department of the Interior, Bureau of Reclamation)
Notes: 1) "Minimum" and "maximum" size cores are illustrated below.



Examination of Sliding Failure of Bostan Dam

Water level	Consider earthquake	Not consider earthquake
Normal full water surface	1.00	1.50
	(1.00)	(1.50)
Empty (immediately after completion)	1.00	1.25
	(1.00)	(1.50)
Rapid drawndown	not applicable	1.20
		(1.20)

Source: Small Irrigation Schemes in Balochistan (Kuwait fund, 1990)
Case in normal full water surface is considered only for downstream slope.
( ) value is applied for the Mangi dam located at Sibi.

(2) Gravity dams

1) General Layout and Design

Nonoverflow Section

The shape of the maximum nonoverflow section is determined by the prescribed loading conditions, the shear resistance of the rock, and the height of the maximum section. The upstream face of a gravity dam is usually made vertical to concentrate the concrete weight at the upstream face where it acts to overcome the effects of the reservoir water-load. The downstream face will usually have a uniform slope which is determined by both stress and stability requirements at the base. This slope will be adequate to meet the stress and stability requirements at the higher elevations unless a large opening is included in the dam.

The crest thickness may be dictated by roadway or other access requirements, but in any case it should be adequate to withstand possible ice pressures and the impact of floating objects. When additional crest thickness is used, the downstream face should be vertical from the downstream edge of the crest to an intersection with the sloping downstream face. A batter may be used on the lower part of the upstream face to increase the thickness at the base to improve the sliding safety of the base. However, unacceptable stress may develop at the heel of the dam because of the change in moment arm for the concrete weight about the center of gravity of the base. If a batter is used, stress and stability should be checked where the batter intersects the vertical upstream face. The dam should be analyzed at any other changes in slope on either face.

Spillway Section

The overflow spillway section should be designed in a similar manner to the nonoverflow section. The curves describing the spillway crest and the junction of the slope with the energy dissipater are designed to meet hydraulic requirements.

The slope joining these curves should be tangent to each curve and, if practicable, parallel to the down stream slope on the nonoverflow section. The spillway section should be checked for compliance with stress and stability requirements. An upstream batter may be used on the spillway section under the same conditions as for the nonoverflow section.

2) Stability Analysis

a. Loading Combinations

Design for gravity dam should be based on the most adverse combination of probable load conditions. In many case, gravity dams have been designed without regard to silt load. However, on designing delay action dams, the ratio of sediment volume to total storage capacity is high enough and it is difficult to neglect the effect of sediment load. Therefore silt pressure should be considered in stability analysis.

Loading Combinations for Designing Gravity Dams

Case	Condition of water level	Loading Combination
1	Design flood level + hw	W, P, Pe, U
2	Surcharge water level + hw + he/2	W, P, Pe, U, I, Pd
3	Normal full water level + hw +he	W, P, Pe, U, I, Pd

Here,
hw: Wave height from reservoir surface induced by wind
he : Wave height from reservoir surface induced by earthquake
W : Weight of concrete structure
P : Hydrostatic pressure
Pe : Silt pressure
U : Uplift pressure
I : Earthquake load on concrete structure
Pd : Hydrodynamic pressure by earthquake

Note: Design discharge is obtained by 200 year flood for gravity dam. (MAFF, MC)
Design of small dams instructs criteria for the dams not exceeding 15 m (50 feet) in height.

b Stability Analysis

Stability analysis should be conducted against overturning and shearing. In general, it is not necessary to check resistance to the compression stress in the case that dam height is lower than about 15 m.

- Stability against Overturning
To fill the requirement for stability against overturning, position to which combined force works must be within the middle third of dam longitudinal length.

- Safety against Shearing
Shear friction factor of safety calculated by following formula must be within prescribe safety factor to meet the restriction for being safe against shearing. It is necessary to check shear-friction factor mentioned above on foundation and joint of dam and foundation.

$$Q = \{CA + (\Sigma N + \Sigma U) \cdot \tan\phi\} / \Sigma V$$

Here, Q : Shear friction factor of safety
C : Unit cohesion
A : Area of the section considered
ΣN : Summation of normal forces
ΣU : Summation of uplift forces
$\tan\phi$: Coefficient of internal friction
ΣV : Summation of shear forces

c. Safety Factor

Safety factor of 4.0 shall be satisfied for the shear friction of the foundation for the dam which height is more than 15 m. Besides of this, safety factor of 1.2 estimated disregarding shear strength shall be satisfied for the foundation and the dam which height is less than 15 m.

Cases for Examination of Sliding Failure (Gravity Dams)

Design of Small Dams (USBR)	Engineering manual for Irrigation & Drainage (MAFF) Technical manual for River erosion control(MC)
Strain stress is not occurred in the dam body and foundation and shear and compressive stress is within allowable stress.	Strain stress is not occurred in the dam body and foundation, shear and compressive stress is within allowable stress under the following conditions.
(Seismic factor is not applied)	1. Design flood level 2. Surcharge water level (Design seismic factor of 50%) 3. Normal full water level (Design seismic factor of 100%)
For small storage dams, where failure means loss of life or other catastrophic occurrences under normal loading:1) -Shear friction factor >4.0 under extreme loading:2) -Shear friction factor >1.5	Shear friction factor >4.0
For small dams with minimal storage where loss of life, extensive property damage, or any other catastrophic occurrence are not involved under normal normal loading: -Shear friction factor >2.0 under extreme loading: -Shear friction factor >1.25	

Source: USBR:(United States Department of the Interior, Bureau of Reclamation)
MAFF (Ministry of Agriculture, Forestry and Fisheries, Japan)
MC (Ministry of Construction, Japan)

Notes: 1):"Normal loading" normal waterhead, uplift, and silt
2):"Extreme loading" drains inoperative, earthquake in normal waterhead or drains inoperative in maximum water surface.

(Stability on Delay Action Dams)

Dam safety on sliding failure is essential to determine the section of the dam embankment. In general, safety factor of 1.2 is applied to secure dam safety. However, there are several factors to decide the safety factor in terms of:

- study case, i.e. water level in the reservoir and corresponding loads bearing on dam embankment and foundation,
- application of shear test values,
- earthquake coefficient,
- bearing capacity of foundation,
- dam height, dam type (homogeneous type, zone type, including gravity dam),
- circumstance downstream of the dam, i.e. human life, properties, and
- calculation method as explained in previous paragraph.

With respect the above, dam height is most essential factor to determine the dam section. Dams are generally categorized corresponding to the height, i.e. large dam of the height of more than 15 m, small of less than 15 m, which was laid down by ICOLD. In comparison with a large dam, dam safety of small dam is not seriously discussed in general because of its reliability against dam failure, which is much higher in terms of small internal/external loads, less hydraulic pressure, as well as less damages downstream of the dam in case of dam failure. On contrary to this fact, dam safety of a large dam is being delegated toward uniformity in dam criteria, owner liability in due consideration of technical, social and economic sophistication, and tenure of development stage of the country.

Regarding the delay action dams, several design criterias have been applied to examine the dam safety. However, these criterias for the dam safety were applied without respective characteristic of the dam and reservoir, such as impounding duration, dam height, embankment materials, dam classification, as well. To uniformly maintain the dam safety reliability, two of dam safety applications are proposed, i.e. for large dams and small dams.

(1) Large dams

Dam safety factor on sliding should satisfy the criteria of "Engineering manual for Irrigation & Drainage" described previous tables for both of fill dams and gravity dams. Safety factor of 1.2 for the fill type dam is applied on condition that the dam construction is carried out with careful supervisory works on quality control and working schedule. Besides as described in above, dam safety is discussed considering economization of the construction cost and also circumstance downstream of the dam, i.e. human life, properties. Most of the dams are to be constructed in remote area, so that the dam failure does not so seriously damage the human life and properties. In this connection, it is proposed that the safety factor of dam sliding can be reduced by 1.0 in the case that the external force of earthquake is considered in the dam sliding calculation. The details are as follows:

Examination of Sliding Failure of Delay Action Dams

Water level	Consider earthquake	Not consider earthquake
Normal full water surface	1.00	1.20
Empty (immediately after completion)	1.00	1.20
Rapid drawndown	not applicable	1.20

Note: The above is not applied for the storage purpose dam.

(2) Small dams

Regarding fill type dams, it is recommended to examine the sliding failure, especially for the dams constructed on the weak foundation. On the other hand, it is also admitted to apply the standard slopes of the dams prescribed in " Design of Small Dam, USBR" considering the dam location, embankment materials, bearing capacity of foundation, etc.

As to gravity dams, safety factor should be examined to satisfy the criteria in " Design of Small Dam, USBR" .

(Calculation of Dam Sliding)
The methods of simple adaptation of circle arc and Bishop method are generally applied for the stability analysis of the fill type dams. Equations are explained as follows.

These equation provide different safety factor in terms of application on statically indeterminate soil pressure acting on both sides of slice elements. Relatively smaller safety factor is given by simple adaptation in the case pore pressure is larger, and center angle of sliding arc is larger, and sliding arc passes deeper portion of ground. In the case of homogeneous dam, safety factor estimated by simple adaptation is 15 to 20 % smaller than that by Bishop method, and uneconomical dam section is given by simple adaptation. Bishop method is applied for the calculation of the dam failure of the delay action dams because the method is broadly applied for the calculation in Pakistan.

1) Simple adaptation of circular arc

-Total stress

$$Fs = \frac{S\ \{c\,l + (N\text{-}U\text{-}Ne)\tan f\}}{S\ (T+Te)}$$

-Effective stress

$$Fs = \frac{S\{c'\, l + (N-U-Ne) \tan f'\}}{S\,(T+Te)}$$

where,
c,c': Cohesion (c: total stress, c': Effective stress)
f, f': Internal friction angle (f: total stress, f': Effective stress)
l: Unit arc length of slice
b: Slice width
N: Normal force on sliding plane
Ne: Normal seismic force on plane
Te: Tangential seismic force on plane
U: Pore-pressure on plane

2) Bishop method

$$Fs = \frac{R\,S\,\{c'\,l\cos.a\;W \tan f')\,/\,ma\}}{S\,(W.x + Kh.W.y + P.a)}$$

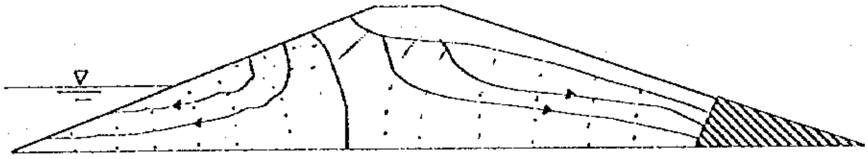
$$ma = \cos.a \frac{\tan f'.\sin.a}{Fs}$$

where,
c': Cohesion
f': Internal friction angle
l: Unit arc length of slice
W: Total weight of slice (soil + water)
Kh: Seismic force
R: Radius of sliding arc
a: Angle of plane against horizontal line
x: Horizontal distance between center of gravity of a slice and center of sliding arc
y: Vertical distance between center of gravity of a slice and center of sliding arc
P: Water pressure forcing to slice
a: Vertical distance between resultant point of water pressure and horizontal line through canter of sliding arc

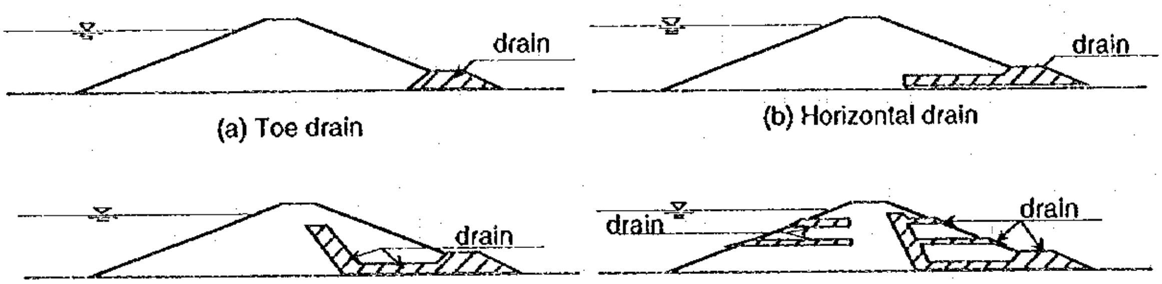
4. Drains

It may be rare phenomenon that the seepage of the embankment spouts out from the downstream slop because uniform seepage flow is not developed in the embankment due to short storage period of the reservoir. However, in the case that the siltation prevent anticipative seepage flow, seepage line rises in the embankment, thus, proper drainage should be enforced with installation of the drain at the toe of the downstream slope.

Rapid drawdown of the water level implies seepage flowing towards the reservoir side due to reduction of the upstream water pressure. Consequently, drains should be installed at the reservoir side in the dam embankment in the case that the upstream slope is comparatively steep. (Results of seepage line analysis of the embankment are described in I.3. Drains are illustrated below:



Flow net during rapid drawdown



(a) Toe drain

(b) Horizontal drain

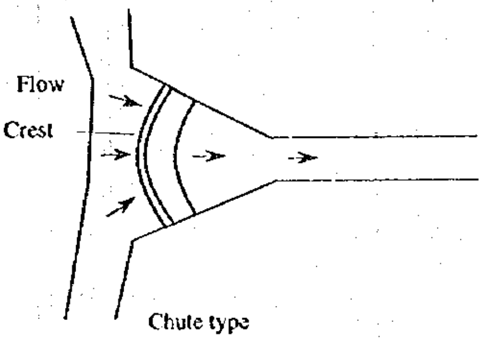
(c) Vertical drain

(d) Combined drain

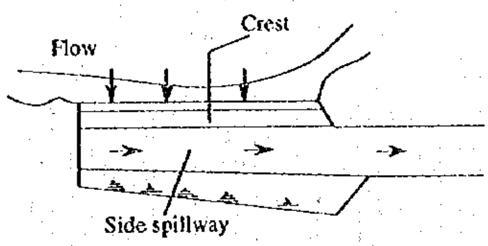
Classification of Drains

5. Spillway

Spillway is composed of inlet portion, guide portion and dissipater. The type of the spillway is determined in due consideration of the dam safety, economy and mostly topographic condition at the dam site. Inlet portion shall be overflow type, and either straight crest type or side spillway type is proposed for the dam. In determination of the spillway location, geologic conditions are the primary factor. However, topographic and hydraulic conditions, relation to other facilities and diversion of excavated materials to the embankment materials are also to be considered.



Chute type



Side spillway

Where the energy of flow in a spillway must be dissipated before the discharge is returned to the downstream river, the hydraulic jump stilling basin is an effective device for reducing the exit velocity to a tranquil state.

6. Intake Facilities

Because of the reduction of the seepage flow through the dam foundation together with the development of the sedimentation in the reservoir, and also impermeable foundation exists, outlet device shall be facilitated to divert the storaged water for the recharge purpose through downstream river bed.

6-1 Components of Intake Facilities (Fill type dam)

Intake facilities consist of the intake section, regulating section and driving canal. The intake portion is an inclined conduit or intake tower for the intake of water from the reservoir. The intake flow is regulated by gate, valves, located at the inlet or bottom outlet. The driving portion is installed to divert intake water under the dam body. Steel pipe and concrete pipe (reinforced concrete pipe) with concrete protection shall be installed in the dam foundation. The objectives of the intake facilities include temporary discharge during construction, discharge for dam inspection, repair and O&M. To attain these purpose, hydraulic study related to the reservoir storage volume and run-off shall be made to determine the conduit diameter in detail.

6-2 Type of Intake

(1) Fill type dam

Inclined conduit or intake tower type is proposed for the inlet device. The inlet type is selected referring to the following advantages and disadvantages of both intake types:

Inlet type	Advantages	Disadvantages
Inclined conduit	Construction cost is less than intake tower. Construction is easy and foundation with large bearing capacity is not necessary. Structure is stable and maintenance and operation are easy.	It become longer where slope of original ground is gentle. Operation of spindle is susceptible to malfunction when inlet gate is installed.
Intake tower	Control of the gate is easy. Location is not restricted.	Construction cost is somewhat higher and O&M is more difficult than inclined conduit. A firm rock foundation is required. Repair cost is also high.

(2) Gravity dam

Inlet with sluice gates for fully open or close operation is installed at the upstream slope of the dam body. Driving conduits are installed inside of the dam body.

7. Recharge Devices

It is recommended that the recharge of the storage water in the reservoir shall be accelerated at the downstream of the dam embankment for the reasons that the permeability of the dam and reservoir foundation ranges 2×10^{-3} to 2×10^{-4} cm/sec, which is classified in semi-permeability, and sediment accumulation upstream of the dam embankment decreases seepage capability through dam and reservoir foundation gradually. Accordingly, recharge wells, trench pits and recharge ponds are recommended to be constructed at the downstream of the dam embankment. It is also possible to achieve groundwater recharge through natural river bed although the high evaporation is expected. Features of the recharge devices shall be planned referring to the permeability of the river foundation, capability corresponding to the seepage flow area, topographic and geological condition as well as easiness of O&M activities.

Recharge device consists of two facilities, link canal and infiltration facility.

(1) Link canal

Storage water in reservoir is lead to infiltration facility by link canal. In this guideline, open canal system with concrete lining is proposed for link canal compared to earth lining canal which is easily suffered from streamflow/fluctuation of water level and also require heavy maintenance works.

The alignment and component of canal system should be determined taking into consideration as following conditions.

- Route of canal should be selected to reduce its length as much as possible.
- It is not preferable to be aligned in the river area for preventing flood damages. In case of setting alignment in the river area, it is necessary to select the route on higher part to avoid flood damages.
- Cross structure such as siphon and aqueduct shall be set up in case of passing valley or stream.
- Cross culvert for drainage should be certainly attached in.

(2) Infiltration Facility

Infiltration trench, injection well and infiltration pond/dike are generally proposed as artificial infiltration facilities. In these types, infiltration pond is recommendable from the aspect of profitability in capacity of infiltration, costs for construction and O/M activities. However, in case of being difficult to construct infiltration pond due to site condition, it is necessary to take setting up infiltration dike or trench into consideration.

The site of infiltration facility should be selected taking account of recharge capacity in aquifer and expanse conditions of alluvial fan. In general, it is preferable that this facility should be located at the elevated portion of alluvial fan.

Design water depth should be determined according to the infiltration rate. Freeboard of pond should be suggested to be 50cm in minimum.

The structure of infiltration pond is basically dig-out type. It is desirable that depth of cutting and height of embankment should be determined taking consideration of total balance of cutting and embanking volume in earth work. Side slope of pond is recommended to be 1:1.0 and inside slope should be protected with riprap to avoid erosion and slope collapse.

C. Dam Construction

1. Construction Plan

The major contents of the construction plan are:

1) investigation of the site and working conditions,
2) planning of scale and arrangement of the construction equipment and facilities,
3) construction method and work schedule,
4) planning of the construction machinery, materials and labours, and procurement schedule,
5) establishing standard values of quality control, and,
6) setting the standards for site supervision.

Properties of embankment materials, soil conditions in the borrow area, availability of the stock piles and availability of the construction machinery are primary factors to establish the construction plan and schedule.

2. Construction Supervision

Construction supervision is separated into the areas of work schedule supervision, quality control, dimension control and other miscellaneous forms of supervision.

2-1 Work Schedule Supervision

Supervision of the work schedule must be carried out by accurately measuring the progress of the construction and condition of the construction. The facilities and working methods must be continuously monitored since changes in the weather conditions and the river water level will greatly influence the construction.

2-2 Quality Control

(1) Fill type dam

Uniformity in the embankment must be maintained and shear strength and the values for the physical properties must satisfy the design values. The following are tests for the embankment materials:

Soil Tests for Dam Embankment

Items	Soil materials	Coarse materials
Prerequisite tests	Grading analysis Water content Specific gravity Field density (controlled by C or D value) Field permeability test Laboratory permeability test Standard compaction test	Grading analysis Specific gravity and water absorption Field density test
Tests as required	Consistency Shearing test Consolidation test	Field permeability test Laboratory permeability test Shearing test

Notes:C value: (Wet density of embankment)/(compacted wet density at moisture content of embankment)x100
D value: (Dry density of embankment)/(maximum dry density at standard compaction test)x100

(2) Gravity dam

Fluctuations in the cement quality exert a marked influence over the quality of the concrete. Therefore, it is recommended that control limitations be set with respect to the fineness of cement, the strength and heat of hydration for the purposes of cement quality control. Following are the testing method of aggregate and concrete.

Material Tests for Gravity Dam

Testing method of aggregates	Testing for concrete
Specific gravity	Sampling
Percent of water absorption	Specimen preparation
Abrasion resistance	Consistency
Soundness	Unit weight and air content
Sieving	Air content
Unit weight and solid content	Mix proportion analysis
Surface moisture	Mixing efficiency
Moisture-percent and surface moisture	Compressive strength
Volume of soft particles in aggregates	
Amount of material finer than 0.074mm	
Organic impurities	
Mortar strength (sand)	
Volume of clay mass	
1.95 floating grains	

2-3 Dimension Control

In order to complete the construction, it is necessary to determine suitable standard values for dimension control and the actual structure dimensions must be supervised so that discrepancies with the design dimensions can be eliminated.

3. Construction

3-1 Temporary Diversion Works

Half river section type and outflow conduits installed in the dam body is recommended for the temporary diversion works for the fill type dam and the gravity dam, respectively. Flow capacity is calculated in due consideration of:

1) the run-off characteristics of the catchment area, (frequency of flooding, peak discharge, total volume of flood run-off and duration of the flood),
2) topographic conditions of the dam site,
3) geologic conditions of foundation,
4) size and type of dam,
5) flow period for temporary diversion and embankment works, and
6) degree of obstruction if drainage performance of the temporary diversion works is insufficient.

3-2 Excavation of Dam Base

(1) Fill type dam

The foundation of the dam base shall have sufficient resistance force to withstand bearing capacity, shearing strength, piping, etc.

In the case of the homogeneous type dam, the following shall be secured during the embankment works:

1) Where the grain size distributions are extremely different, treatment shall be carried out by means of either the removal of part of the foundation or the preparation of a zone with suitable grain distribution.
2) For bedrock with many open cracks, the wash-out of fine particles through cracks shall be prevented by filling those cracks with sand, crushed gravels.
3) It is necessary to consider occurrence of uneven settlement. The surfaces are to be smoothed by excavation.

Cutoff trench excavation shall be made until the prescribed depth where the specified shearing strength is ensured.

(2) Gravity dam

The foundation of the dam base shall have sufficient resistance force to withstand bearing capacity, shearing strength, etc. Weathered rock, floating rock, opened cracks shall be properly treated so as to ensure the strength of the dam foundation. Foundation treatment, i.e. grouting shall be conducted in order to achieve the required design objectives.

3-3 Embankment materials (Fill type dam)

Soil materials shall be a suitable moisture content and grain size for the embankment. The following methods are recommended for adjustment of the moisture content.

(1) Humid materials:

i) A rake dozer or scarifier is employed to turn the soil for the purpose of drying.

ii) A stockyard is constructed, and utilized after moisture content has been lowered.

(2) Dry materials:

i) In order to increase the moisture content of dehydrated materials, water sprinkling, spraying are performed. In the case that the abundant water does not exist near the dam site, the following are recommended:

a) impervious zone composed of impervious material with proper moisture content is established at the center of the dam embankment. (Fig. 9)

b) Increase of compaction energy makes the maximum dry density increase and optimum moisture content decrease. Accordingly, whole of the embankment or highly embankment portion shall be compacted with 200 to 300 % compaction energy prescribed in ASTM, as well. (Fig. 10)

Fig. 9

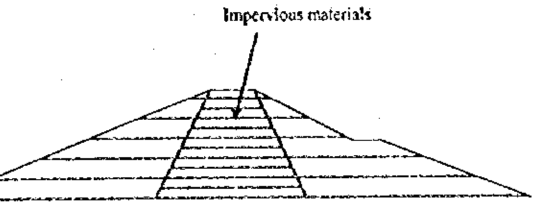
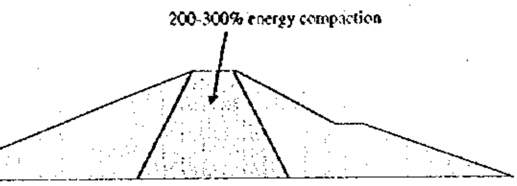


Fig. 10



(3) Grading adjustment:

Grading adjustment is performed at a stockyard to mix with fine materials and coarse materials. The thickness of the each layer shall be limited to the minimum possible thickness where the uniform laying out of fine grain materials can be implemented.

3-4 Embankment

(1) Fill type dam

In general, bulldozer are used for materials spreading. Tire rollers, wave rollers, tamping rollers, vibratory roll, in addition bulldozer and wheel-loader are sometimes used for compaction. It is difficult to standardize selection of compaction machinery that fully meets design values, the machinery is determined on the basis of embanking test at the field.

Prior to commencement of actual embankment, test embankment is performed to: 1) identify the most economical embankment, ii) determine criteria for construction management, and iii) determine site standards.

Application of Compaction Machinery

Type	Machinery	Materials or ground for which machinery is applicable	Spreading depth	Number	Remarks
Rolling compaction type	Tired-roller	Clayey material (dry)	15 - 25 cm	6 - 10	Multiple axis type, more than 10-30ton is preferable 3-6ton tractor operated type
	Sheep foot roller	Clayey material (wet)	15 - 25	6 - 10	22ton mobile type
	Tamping roller	Earth materials mixed with boulder, crushed rock	30 - 45	5 - 7	
Vibration type	Tired roller	Clayey materials (dry) Gravel materials	20 - 25 25 - 30	6 - 8 5 - 7	3-11ton
	Flat roller	Gravel	20 - 30	5 - 7	3-5ton (Compaction surface shall be raked)
	Compactor	Gravel material or abutment portion at natural ground	20 - 30	3 - 5	0.5-2.0ton
	Tamper	Abutment portion at natural ground, or narrow area	10 - 20	3 - 5	50-500kg tamping rammer or vibration rammer

(2) Gravity dam

Layout of the concrete plant is decided in due consideration of the entire work schedule, daily work volume, daily operation time and machine efficiency. Concrete is placed according to lift thickness which has been determined after considering the construction performance capability and temperature constraints The thickness of the lift generally standardized at 1.5 m to 3.0 m. It is difficult to reduce the placing interval to less than four days. When temperature rises, the temperature of the placing concrete also rises resulting in the increase of the maximum temperature of the placed concrete, and thus cracks are easily formed. Other problems such as cracks due to dry contraction, an increase in the slump loss due to water evaporation, deterioration of the workability, a shortened setting time and an earlier green cut time also occur. In case when the temperature of the placed concrete exceeds 25 degree, placing work is avoided or cooling water is employed for the concrete mixing.

D. Initial Ponding, Dam Inspection and Operation and Maintenance

1. General

Concerns about potential failure are increasingly important along with considerable loss life or property, but limited areas downstream of the dams. In general, delay action dams are built in areas remote from population centers. In this connection, special attention for the dam safety should be paid in the case that the populated areas are exists or developed at downstream of the dam sites.

Overtopping, leakage and piping through the dam embankment and foundation prominently cause dam failures. These failures result from a variety of causes: unpredictability of extreme floods, uncertainties of geologic setting, seepage through foundations and embankments, design and construction defects, etc. To secure dam safety, it is necessary to inspect the dam conditions in short and long-term aspects. Leakage, deformation, stability of the embankment slope be observed for several months after the dam completion, especially during initial ponding. On the other hand, observation of sedimentation slope stability of the reservoir area be required in addition to these observation.

Furthermore, inspection of leakage, cracks, land slips and scour of spillway be carried out immediately after the floods or earthquake occurs. Dam failure caused by leakage or deformation in general occurs gradually along with some abnormality in initial fault, which leads to further damage or even disaster. In this connection, it is proposed to conduct routine inspection to secure the dam safety.

Along with dam inspection, proper operation and maintenance (O&M) of the dam and reservoir is essential to secure dam safety, life of dam and to maintain recharge ability of the dam. Adequate seepage is expected through reservoir because of the high permeability of the reservoir foundation. However, the seepage through the reservoir foundation is gradually reduced along with siltation development in the reservoir. Accordingly, it is proposed to install outlet conduits to release the storaged water to the downstream of the dam embankment. The released water is percolated into the ground through infiltration ponds, as well.

With respects to this, a regulation on reservoir operation should be prepared with emphasis on valve control for water release, frequency of release water discharge, maximum depth of the drawdown of the storaged water in terms of the dam safety, as well as proper operation of the infiltration ponds. Various maintenance works are required to secure the dam safety, and to ensure the recharge ability for, i.e. outlet conduits, infiltration ponds, transmission lines, etc. Institutional organizations and regulations should be established to carry out proper inspection and O&M activities.

2. Governmental Agencies for Inspection and O&M

The Irrigation Department has ownership of the dam and is responsible for the inspection and O&M of the dam, reservoir and also the recharge devices, e.g. intake, outlet conduits, control valves, transmission lines and infiltration ponds.

The Irrigation Department undertakes regular and emergency inspection immediately after large floods or any unusual event such as earthquake occurs for every dams and reservoirs. The Irrigation Department is responsible for recommendation of necessary steps to be taken to maintain, improve or restore the dam safety. Routine inspection for devices, installations and equipment necessary for safe operation and behavior of the dam should be made at short intervals by the operating personnel.

3. Initial Ponding

A ponding progress shall be observed aiming at the confirmation of dam safety, function of the intake structures, as well. Particular items to be monitored are the leakage quantities, uplift, deformation. There are cases when the measured values for these items increase suddenly under the conditions of constant load, as well as cases when not only do the measured values increased, but the rate of increase becomes larger over the time for the same loading conditions. Such occurrences of unusual behavior requires the implementation of the emergency measures such as lowering the reservoir water level in order to maintain the dam safety.

4. Dam Safety Inspection

Visual inspection is important, for the engineer can draw up a list of his own observations such as cracks, leakage, deformation, scour, vegetation (sign of seepage), etc. In the case frequently little or no serious geological investigation has been performed on the foundation of the dam, in such cases, dam inspection with assistance of a geologist is indispensable. The geologist's work is not easy however, for there are no longer any visible excavation, surface rock is weathered. However, good geological data of a general nature may have become available since construction.

The following are typical disorders affected to the dam safety on concrete dams, earth dams, and their foundations:

(Concrete dams)
All disorders in concrete dams are practically due to concrete volume change. Concrete is a fragile materials, and generalized or localized volume change sets up tensile stresses which cause cracking. The end result is leakage and associated complications. Some concrete dams are damaged by deformation of their abutment, but this is a far less frequent occurrence than concrete swelling or shrinkage. Shrinkage can be due to creep under loading or shrinkage prolonged beyond what is

normal for the curing time.

(Earth dams)

Apart from the risk of scour of the dam embankment by overspill if spillway capacity is not sufficient, the main risk facing the embankment is that of retrogressive erosion which can lead to piping. Special attention should be given to the interfaces between fill and rigid members like culverts, or exposed rock surface on the dam abutments, for these interfaces are often the starting point of the piping. It is always possible to reinforce dam embankment by placing draining materials on the downstream side and, through more rarely, on the upstream side. Contact clay is also effective to prevent piping along the dam abutment.

(Foundations)

Instability of the foundation manifests itself in the form of slides or as piping. The solution is practically always to improve percolation flow, and generally involves clearing the existing drains or installation of another drains fitted with graded filter materials if necessary.

Suitable equipment should be installed before a reliable diagnosis can be given. The most important equipment includes:

1. flow meters,
2. piezometers in the dam and foundation, and
3. settlement gauges to examine the deformation of the embankment.

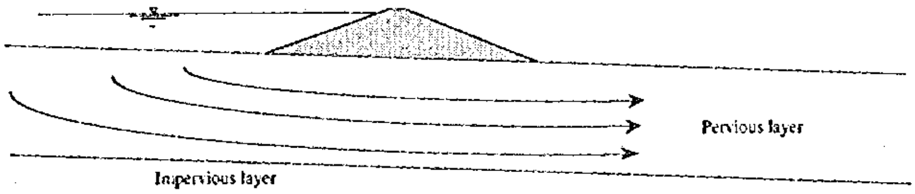
5. Operation and Maintenance

1) General

The structural performance of the dam should be examined. The groundwater recharge is achieved through dam and reservoir foundation (upstream recharge) and also through infiltration pond (downstream recharge). Artificial recharge flow routes along with delay action dams construction are broadly categorized into three types according to the geological conditions.

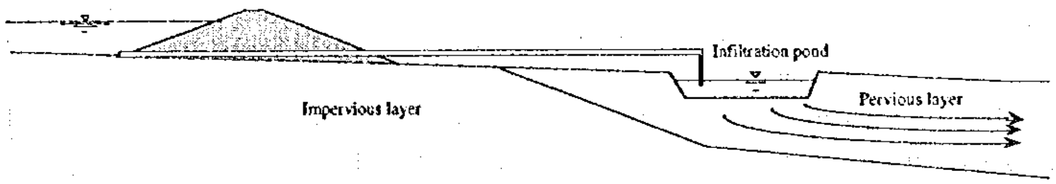
(a) Upstream recharge

Upstream recharge is quantitatively accelerated through dam and reservoir foundation with its high permeability and thick aquifer. However, recharge capacity is gradually reduced due to sediment accumulation composed of fine load materials.



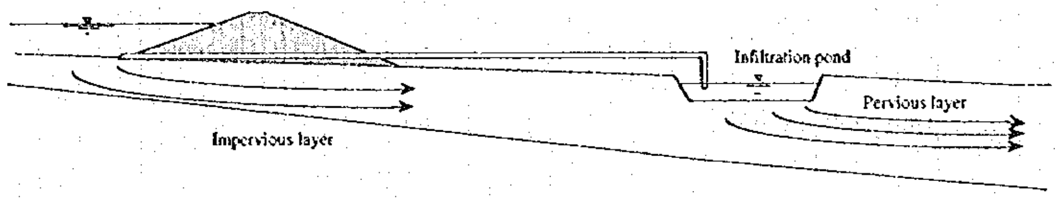
(b) Downstream recharge

Downstream recharge is realized through recharge devices located at where high permeable materials deposited. Seepage through dam and reservoir foundation is negligible due to impermeability of the bed rock.



(c) Conjunctive recharge

Recharge is expected both routes of upstream and downstream of the dam. The plan is proposed at where reservoir foundation is less permeable or its aquifer is not considerably deep. The plan is highly advantageous against reduction of recharge capacity incurred by siltation in the reservoir.



On the other hand, spillways and outlet structures should be free of any foreign materials and unauthorized installations which might reduce their discharge capacity or effect operational reliability. O&M works are discussed in following paragraph.

2) Dam and Appurtenant Structures

(a) Dam embankment and reservoir

Concerning to the earth dams, rapid drawdown of more than 30 cm a day should be avoided, and be controlled by outlet valves to prevent slope sliding toward reservoir side. Meanwhile, rapid and substantial change of the seepage flow through the dam embankment may offer evidence of embankment deformation. In this regard, it is recommended to install leakage monitoring system and deformation measuring system for the dams of which height is relatively high and its foundation is week such as clay and silt. Concrete pits are constructed at points where leakage water can be accumulated from the downstream portion of the embankment, and then the natural ground. After the installation of a V-notch weir, the turbidity of the leakage water is observed in conjunction with measurement of the leakage volume in order to monitor the dam safety. The dam embankment and foundation is deformed due to their own weight and the reservoir pressure during the construction as well as after the dam completion. It is therefore necessary to gauge the deformation and to utilize these measurements in the monitoring of the dam. The apparatus, e.g. displacement measuring mark is generally recommended for measuring the deformation of the dam and foundation.

Measurement of the vertical and horizontal displacement is extremely important in the case of weak foundation. *A number of (a minimum of 5) pipes of approximately 6 cm diameter should be set up* at least the maximum cross section face of the embankment so as to examine the seepage line position in the embankment. In the case of large embankment length, pipes should be provided at intervals of 100 m as required.

(b) Foundation and abutments

Monitoring of seepage through dam foundation and abutments should be carried out to secure the dam safety. Excessive settlement, misalignment of the dam or the offset of joints of the concrete structures may be an indication of foundation yielding. Boiling and piping phenomena should be examined for the dams of homogeneous type dams and zone type dams, respectively. Furthermore, *concentration of the seepage flow through highly porous layers should be restored for further failure* of the dam safety.

The abutments should be examined for appearance of springs, slides or surface cracks which may indicate the development of an instability in the slopes.

(c) Spillway

Spillway channel is susceptible to erosion by floods, accordingly be protected with concrete, gabion, masonry, etc. Initial scouring or structural faults should be maintained to prevent further serious damages of the spillway. Excessive seepage through spillway channel, which may be caused by poor construction manner, should be rehabilitated.

(d) Intake structures

Inlet type is structurally categorized in tower type, inclined type and drop inlet type. Inlet gates are installed in various elevations as required to release storage water from different water depth corresponding to the siltation development and forming turbid water layer in the reservoir, especially after inflow of flood.

Bottom outlets are restricted to install for large dams constructed on the weak foundation. Seepage flow is concentrated along the rigid materials, that cut-off walls should be provided to prevent leakage and piping through the bottom outlets. Excessive seepage with turbidity through the bottom outlets should be carefully examined.

Discharge control devices should be durable. Because a gate or valves is used for a long period, the gate guide supports and lifting device should be free from rusting and corrosion. In general, main valve and sub valve are installed aiming at the discharge control and maintenance of the main valve, receptively.

(e) Infiltration pond and transmission channel (link canal)

Surface layer of the infiltration ponds should be replaced with pervious materials with certain intervals to consecutively maintain recharge capacity of the ponds. Chemical reactions and bacterial, weed growth should be examined to secure permeability of the ponds. It is recommended to install stilling basins next to the infiltration ponds for easy desilting. It is simultaneously required to install maintenance concrete pits along the transmission channel for easy desilting.

(f) Access road for O&M

Accessibility to the dam sites and also the infiltration ponds should be attained for the smooth O&M activities. Rehabilitation work of the road surface as well as drainage facilities should be properly carried out in certain period.

(g) Water management

The following contribute to the smooth water management through the delay action dams:

i) Recording of storage water
Fluctuation of the water level (storage capacity) should be recorded to utilize for an estimate of ground water recharge through the dam and reservoir foundation, river run-off, as well as fundamental analysis for the dam safety.

ii) Recording of infiltration rate
Recharge rate through the infiltration pond should be observed to estimate ground water recharge capacity through the pond, and also further study of recharge devices and its O&M planning.

iii) Water quality
Salinity and turbidity should be examined aiming at scheduling of water release, appreciation for irrigation and domestic water use, etc.

iv) Desiltation

Groundwater recharge is accelerated by upstream recharge through dam foundation and downstream recharge through intake devices. Siltation accumulated near the dam embankment induces a remarkable reduction of the recharge ability through dam foundation, so that fine materials shall be removed to maintain recharge capacity of the dam, as required. In respect to the downstream recharge, removal of fine materials in the recharge trench pits, replacement of filter materials are required to maintain recharge capacity.

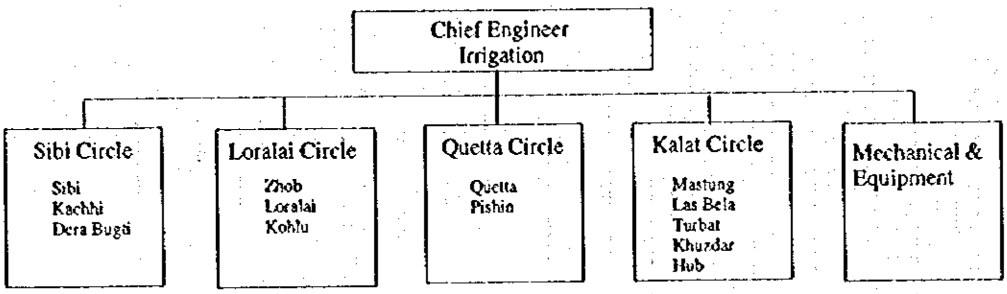
v) Observation of ground water level

Groundwater level should be observed in respective sub-basin. The observation contributes to ensure the effect of the delay action dams, and also shows crisis of the groundwater budget caused by excessive pumpage of the water. It is recommended to observe groundwater level in every month for short and long term analysis.

Delay action dams have been constructed to realize effective and efficient recharge of the ground water. However, it was difficult to quantitatively estimate their effectiveness for the groundwater recharge because of the insufficient observation data such as meteoro-hydrological observation, hydro-geological exploration, together with excessive water extraction by tube wells from the aquifers.

3) O&M staff

Provision of staff for the maintenance of dam, reservoir and recharge devices should properly made in view the O&M of these structures. The following O&M staff has been organized in each irrigation circles.



According to the O&M of the delay action dams, the following are achieved in due consideration of rapid fluctuation of the water level in the reservoir:

Outline for Monitoring of Fill Type Dam

Items	Initial ponding	Reservoir empty	Full water level
Leakage	once/day	once/month	once/half month
Deformation	once/week	once/month	once/month
Seepage line	once/week	once/month	once/month

Outline for Monitoring of Gravity Dam

Items	Initial ponding	Reservoir empty	Full water level
Leakage (Foundation)	once/day	once/month	once/half month
Deformation	once/week	once/month	once/month

E. Relative Structures with Delay Action Dams

Most of the river basins have been devastated due to severe erosion by precipitation. Accordingly, it is anticipated that huge amount of thick sediment in the river bed be flown down towards downstream by the floods, and consequently fully occupies the reservoir area of the delay action dams. In these river basins, washout of sediment is supposed to increase year by year. It is therefore necessary to take certain countermeasures to prevent washout of sediment from basins and to flow into reservoir area.

1. Erosion Control Plan

The purpose of constructing erosion control facilities are principally, i) to settle and storage sediment, ii) to control erosion by means of loosening riverbed slope, iii) to decrease sediment production from hillside due to raising riverbed elevation, iv) to prevent the movement of riverbed deposits, v) to reduce the peak discharge of debris flows.

Here, the rise of river bed level and water level will be come up by the result of sedimentation in upstream area of these schemes during floods. Then, the deliberate study should be made to prevent flood damages and functional disorder of existing intake facilities of cultivating lands or villages located close to these facilities.

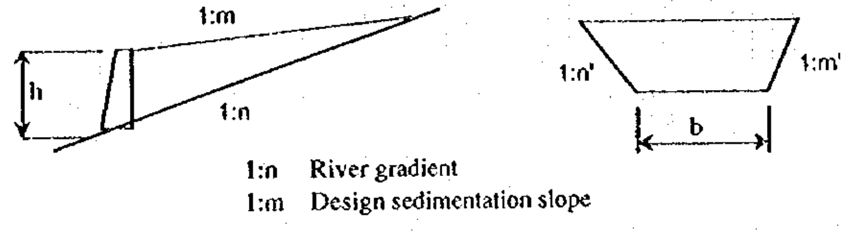
(1) Design sediment volume and design discharge

i) Design sediment volume
5 to 10 years sediment volume should be adopted as design sediment volume.

ii) Estimation of design sedimentation
It is possible to estimate design sediment volume by following equation.

$$\text{Sedimentation volume: } V = \frac{1}{2} \times \frac{m \times n}{m - n} \left(b + \frac{1}{3}(m' + n') \times h\right) \times h^2$$

Longitudinal section　　　Cross section



1:n River gradient
1:m Design sedimentation slope

Here, it is recommended that design sedimentation slope shall be 1/2 of present riverbed slope.

iii) Design discharge

It is recommendable to adopt 30 year probable discharge including sediment in flood as design discharge. And, it is estimated that involved sediment volume will be about 15 percent of flood discharge volume.

(2) Site selection

The site of erosion control facility should be determined under consideration of following items.

- It is economically desirable to select the site where width of valley is narrow, riverbed slope is gentle and large pocket for storage exists for the purpose of storage and control. However, it is also necessary to select wider section of the streams to disperse flow energy in the case that the abutment is not stable and foundation is susceptible to scouring.
- In case of having tributary, the downstream site from confluence should be selected. However, in case that devastation is proceeding in tributary worse than main river, it is important to take precedence tributary.
- If it is necessary to raise the river bed and prevent collapse of hillside, the site should be selected at downstream of collapse area.
- In case of preventing landslide, it should be necessary to select the downstream site from the lowest point of landslide area.
- Under condition of large erosion along river, it is effective to construct a series of dams like stairs.

(3) Type of facility

According to dam up height, it is recommended to select the type of facility as followings:

- up to 3 meters dam up height	Gabion detention bund
- over 3 meters dam up height	Cobble stone dam or gravity dam

(4) Facility planning

Standard dimensions of erosion control dam (cobble stone dam) and detention bund are shown in drawing (see Drawing). On designing, it is indispensable to check the stability of facility.

i) Erosion control dam (cobble stone dam, gravity dam)

It is necessary to be designed in accordance with delay action dam.

ii) Detention bund

It is recommend to adopt stair type slope at upstream slope to utilize the weight of sediment and make bund stable. And also, for scouring protection, it is desirable not only to install cut-off wall which height is 1 meters at least on both edges of bund, but also to set materials preventing draw-out under bund.

Reference

The following methods have been generally adopted and implemented as watershed treatment in Balochistan under the Integrated Area Development Program.

- Conservation contour trench

This trench are dug to intercept runoff water and store for infiltration to recharge ground water. Dimension of trench is about 3 m wide, 3~5 m long and .0.3~0.5 m deep. In trench, salt bush and indigenous species are planted. And grass tufts are also planted on the berms of the trench. This method is generally adopted in hilly area.

- Hill side ditch

Hill side ditch is 0.5~1.0 m wide and about 0.3 m deep at a spacing of 30 m. This ditch is dug along the contour for trapping runoff and conserving for plantation. Dug soil is piled on one side in the ditch to reduce velocity of water flow for preventing erosion. Salt bush and tree species are planted in ditches. This method is conducted on alluvial fans.

- Live sills

Live sills is adopted in small stream bed where river deposit is composed of silt and clay. This sill is useful for erosion control.

- Loose stone check dam

Check dam is set up by stacking boulder and cobble stone in small stream to decrease water flow velocity and store runoff. Generally this adopted for treatment of small stream for the purpose of erosion control. It is preferable several check dams are built at a proper interval. Check dam in small size is useful as gully plug.

2. Land Surface Protection

The yield of sediment, which is mainly depends on the scale of catchment area, topo-geological conditions, density of vegetation, hydrological feature and land use, is most important factor to establish sediment control plan, and also to make a appropriate structural design. Aiming at reduction of sedimentation in the reservoir and basin conservation, surface drainage ditch, bench cutting, slope protection by means of reforestation are proposed. Meanwhile, retaining wall composed of gabion and stone masonry are proposed to prevent large-scale land slide in the basin. Contour bund and small-scale check dam across a gully or small river are also recommended to eliminate surface erosion, furthermore to trap eroded soil materials for vegetation.

These works should be proceeded covering whole area of river basin, and it is important that implementation plan should be prepared on basis of the long-term strategy, especially on reforestation and vegetation planning.

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