# IFAS AGENCY for the GEF PROJECT

## ARAL SEA BASIN PROGRAM
## WATER & ENVIRONMENTAL MANAGEMENT PROJECT

## COMPONENT C:
## DAM SAFETY AND RESERVOIR MANAGEMENT

# KOPETDAG DAM

# SAFETY ASSESSMENT REPORT

MARCH 2000

GIBB
LAWGIBB Group Member

In association with

SMEC

# KOPETDAG DAM
# SAFETY ASSESSMENT REPORT

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## UNITS AND ABBREVIATIONS

| | |
|---|---|
| ASBP | Aral Sea Basin Program |
| CA | Central Asia |
| CMU | Component Management Unit |
| EA/EIA | Environmental Assessment/Environmental Impact Assessment |
| EC-IFAS | Executive Committee of IFAS |
| FSL | Full Storage Level |
| FSU | Former Soviet Union |
| FAO/CP | Food and Agriculture Organisation/World Bank Co-operative Programme |
| GDP | Gross Domestic Product |
| GEF | Global Environment Facility |
| ICB | International Competitive Bidding |
| ICOLD | International Commission on Large Dams |
| ICWC | Interstate Commission for Water Coordination |
| IDA | International Development Association of the World Bank |
| IFAS | International Fund to Save the Aral Sea |
| JSC | Joint Stock Company |
| LDL | Lowest Drawdown Level |
| M & E | Monitoring and Evaluation |
| NCB | National Competitive Bidding |
| NGO | Non-governmental Organisation |
| O & M | Operation and Maintenance |
| PIP | Project Implementation Plan |
| PIU | Project Implementation Unit |
| PMCU | Project Management and Coordination Unit |
| RE | Resident Engineer |
| TA | Technical Assistance |
| TOR | Terms of Reference |
| SIC | Scientific Information Centre (of the ICWC) |
| SU | Soviet Union |
| SW | Small Works |
| VAT | Value Added Tax |
| WARMAP | Water Resource Management and Agricultural Production in CA Republics |

| | |
|---|---|
| masl | metres above sea level |
| $Mm^3$ | million cubic metres |
| $km^3$ | cubic kilometres = 1000 $Mm^3$ |
| $m^3/s$ | cubic metres per second |
| ha | hectare |
| hr | hour |

# 1 INTRODUCTION

This report is one of ten reports prepared under Component C: Dam and Reservoir Management, of the Water and Environmental Management Project (WAEMP). The WAEMP is supported by a variety of donors, such as the Global Environment Facility (GEF) via the World Bank, the Dutch and Swedish Governments and the European Union, and is being implemented by the IFAS Agency for the GEF Project under the Aral Sea Basin Program.

## 1.1 Background to Project

In general, the WAEMP aims at addressing the root causes of overuse and degradation of the international waters of the Aral Sea Basin, and to start reducing water consumption, particularly in irrigation. The project also aims to pave the way for increased investment in the water sector by the public and private sectors as well as donors. The project addresses this aim in several components. Dam and Reservoir Management, the assignment with which this report is concerned, is one of them. The other components are: Water and Salt Management, the leading component, to prepare common policy, strategy and action programs; Public Awareness to educate the public to conserve water; Transboundary Water Monitoring to create the capacity to monitor transboundary water flows and quality; Wetlands Restoration to rehabilitate a wetland near the Amu Darya delta; and Project Management. The components have close links with each other.

The Dam and Reservoir Management Component focuses on four activities as follows:

a) Continuing an independent dam safety assessment in the region, improve dam safety, address sedimentation and prepare investment plans;
b) Upgrading of monitoring and warning systems at selected dam sites on a pilot basis;
c) Preparing detailed design studies for priority dam rehabilitation measures; and
d) Gathering priority data and preparation of a program for Lake Sarez.

The activities are grouped for work process purposes into two packages and will be executed simultaneously, according to an agreed schedule of works:

- Dam safety and reservoir management (including activities "a", "b" and "c");
- Lake Sarez safety assessment (covering activity "d").

The Dam Safety and Reservoir Management package covers the following areas: dam safety, natural obstructions, silting of reservoirs, control of river channels etc.

The activity covers the following 10 dams, two in each country:

Kazakhstan: Chardara and Bugun dams;
Kyrgyzstan: Uchkurgan and Toktogul dams;
Tajikistan: Kayrakkum and Nurek dams;
Turkmenistan: Kopetdag and Khauzkhan dams; and
Uzbekistan: Akhangaran and Chimkurgan dams.

Because of the need to safeguard human life, early priority is being given to safety reviews at each of the dams, which is the subject of this report.

## 1.2 Safety Assessment Procedures

The dam safety assessments are the first stage in the evaluation (including costing and economic justification) , analysis, design and implementation of measures aimed at ensuring safe operation of the selected dams. They have been prepared based on a brief reconnaissance visit to each dam, discussions with the operating staff and a perusal of such information and data as was found to be readily available. No attempt has been made at this stage to analyse any of the data. A data collection and cataloguing procedure was initiated before commencement of the assignment but this process (to be carried out by National Teams) is still at an early stage in implementation.

The field visits were made and the reports prepared by a team of international experts specialising in dam engineering and dam safety procedures. The team comprises experts from GIBB Ltd (United Kingdom) and its associate for this assignment, Snowy Mountains Engineering Corporation (SMEC) from Australia, together with members of a team of regional experts who have been contracted as individuals to work with the Consultants for this project. This team is referred to here as the International Consultants (IC). The International Consultants have been supported during the field visits by members of National Teams appointed for this project from each of the five Central Asian republics.

The principal members of the international team, who are the authors of this report, are the following: -

- Jim Halcro-Johnston (GIBB Ltd) – Team Leader
- Gennady Sergeyevich Tsurikov (Uzbekistan) – deputy Team Leader
- Edward Jackson (GIBB Ltd) – Dam Engineering Specialist
- Ljiljana Spasic-Gril (GIBB Ltd) – Geotechnical Engineer/Dam Structures Specialist
- Pavel Kozarovski (SMEC) – Hydrologist/Hydraulic Engineer
- E.V. Gysyn – Dams Specialist (Kazakhstan)
- E.A . Arapov – Hydraulic Structures Specialist (Turkmenistan)
- G.T . Kasymova – Energy Expert (Kyrgyz Republic)
- R. Kayumov – Hydrostructures Specialist (Tajikistan)
- R.G. Vafin – Hydrologist, specialising in reservoir silting (Uzbekistan)
- V.N. Pulyavin – Dam Instrumentation Specialist (Uzbekistan)
- N.A. Buslov – Dam Specialist (Turkmenistan)
- Y.P. Mityulov – Cost and Procurement Expert (Uzbekistan)
- N. Dubonosov – Mechanical Equipment Expert (Kyrgyz Republic)

Most of the above team members have contributed in the preparation of this report.

## 1.3 Scope of Safety Assessment

The safety assessments are made based on superficial evidence observed during the site visits, discussions with operating staff and subsequent discussions with members of the National Teams and an examination of supporting design and construction documents as has been made available to the IC for review. (A full list of the documents reviewed is included as Appendix A )

The safety evaluation of the dam has required an assessment of the following factors:

(1) The **characteristics of the reservoir and dam site**, which includes the flood regime
for the river, and the geological conditions at the site;
(2) The **characteristics of the dam,** covering its design and present condition;
(3) The expected **standards of operation and maintenance** of the dams, its performance, and the implications for safety;
(4) The **effects on the downstream** area resulting from a failure of the dam or an excessive release of water.

The structure of this report reflects the scope of safety assessment. Chapter 2 presents a general description of the dam, including location, purpose, principal dimensions and assessment of its hazard rating in relation to the impact that a safety incident would have on the adjacent community. Chapter 3 discusses the design factors that principally affect the safety of the dam.

Comments on the condition and performance of the dam are given in Chapter 4 and in Chapter 5 an assessment of its safety is given.

Chapter 6 gives recommendations for studies, works and supplies to be undertaken in the interests of ensuring the safety of the dam and the downstream community. Conclusions and recommendations are summarised in Chapter 7.

The recommendations for safety measures given in this report must be regarded as tentative as their precise scope will depend on the outcome of further studies which are outside the scope of the present assignment. No attempts has therefore been made at this stage to evaluate the cost of the required remedial works or to carry out an economic justification for the works proposed, which will be necessary to support an application for funding. This will be carried out when the necessary studies and detail designs have been completed.

# 2 PRINCIPAL FEATURES AND DIMENSIONS OF THE DAM

## 2.1 Location, Purpose, and date of Construction

Kopetdag channel type reservoir is located at Km 837 - 850 on the Karakum canal in Ashgabat viloyat of Turkmenistan, 6 km north-west of Geok-tepe village (see Figure1).

The dam can be accessed by asphalt road Ashgabat-Turkmenbashy. Dam construction was completed in 1994.

The project was elaborated by "Turkmengiprovodkhoz".

## 2.2 Description of the Dam

The dam complex include (see Figure 2):

- Inlet
- Headwater channel
- Dam
- Outlet

The inlet structure at Km 837 on the Karakum canal consists of a double-barrel pipe sluice-regulator combined with a chute, ended by a stilling pool with downstream spillway apron strengthened by mesh and loaded with stones. The regulator is equipped with two slide gates (3.5 x 3.0 m) with screw hoist 20EV with hand drive, two bulkheads and gantry crane.

The headwater channel is 9.5 km long with five concrete drop structures with 50 m difference in head between the outlet structure and top water level in the reservoir.

The dam , constructed of hydraulic fill, has a homogeneous profile with upstream slope 1:20 – 1:35 (see figure 3) and with gravel wave protection 80cm thick. It crosses the Karakum canal at Km 850. There is a concrete upstream facing 40 cm thick and 200 m long in the area of the outlet structure, with an upstream slope of 1:4. The downstream slope has inclined drainage.

The outlet structure is located within the embankment and is represented by a triple-barrel conduit with the tower extended on the upstream slope( see Figure 4). The conduit has a free-flow hydraulic regime. The conduit has seven sections each 12 m long and it ends in an energy dissipator discharging on a downstream flexible spillway apron which is strengthened with gabions. The outlet structure is equipped with six slide gates (5 x 5 m), 3 service gates and 3 emergency gates, operated by hydraulic hoist with 160 t capacity. In addition, there are three emergency gates (5 x 5 m), operated by gantry crane.

The principal dimensions of the reservoir and the various components of the dam are given in Table 2.1.

## 2.3 Hazard Assessment

In many countries a formal classification system is used to define the risk a dam represents, in terms of the potential for loss of life and/or damage to property which could result in the event of flooding caused by failure of the dam or an extensive release of water. The magnitude of the risk depends partly on the characteristics of the dam and reservoir and partly on the conditions downstream of the dam.

Risk factors based on the procedure set out in ICOLD Bulletin 72 (Reference 1) are shown in Tables B1 and B2 in Appendix B.

Based on the Tables in Appendix B, the total risk factor of 20 points (Table 2.2) puts the Kopetdag dam in Risk Class III, that is the second highest risk category.

**Table 2.2 Kopetdag Dam – Risk Factor**

| | | **Points** |
|---|---|---|
| Reservoir Capacity ($Mm^3$) | 550 | 6 |
| Dam Height (m) | 25 | 2 |
| Downstream Evacuation Requirements | 100 - 1000 | 8 |
| Potential Damage Downstream | Low | 4 |
| | **TOTAL** | 20 |

**Table 2.2 Kopetdag Dam – Principal Dimensions**

| | |
|---|---|
| **Water Reservoir** | |
| Total storage capacity at FSL | 550.0 $Mm^3$ |
| Active storage capacity at FSL | 525.0 $Mm^3$ |
| Dead storage capacity at DSL | 25.0 $Mm^3$ |
| FSL | 151.20 masl. |
| DSL | 134.17 masl. |
| Maximum design wave height | 2.8 m |
| Surface area at FSL | 47.5 $km^2$ |
| Height of draw-off shell | 15.6 m |
| Tail water level | 134.75 masl. |
| **Inlet** | |
| Type | Pipe regulator |
| Maximum discharge | 79 $m^3/s$ |
| Sill level | 185.71m. |
| Number of pipes | 2 ps. |
| Size of pipes | 3.5 x 3 m |
| Hoist | 20 ЭВ – 2 ps., gantry crane |
| Type of gates | Slide, welded – 4 ps. |
| Service 3,5x3 m | 2 ps. |
| Guard 3,5x3 m | 2 ps. |
| **Headwater Channel** | |
| Type | Earth |
| Inlet structures | Reinforced concrete- 5ps |
| Maximum discharge | 79 $m^3/s$ |
| **Embankment** | |
| Type | hydraulic fill |
| Crest level | 154,00 masl |
| Maximum dam height | 24 m |
| Crest length | 15,4 km |
| Crest width | 8 m |
| Road width | 6 m |
| Foundation width | 600 m |
| Freeboard at FSL | 2.8 m |
| Upstream slope | 1:20-1:35 |
| Downstream slope | 1:4 |
| **Outlet** | |
| Type | Pipe, pressure free |
| Maximum design outlet capacity | 148 $m^3/s$ |
| Maximum actual outlet capacity | 65 $m^3/s$ |
| Sill level | 131.50 masl. |
| Number of pipes | 3 ps. |
| Size of pipes | 5x5 m. |

| | |
|---|---|
| Hoist | ГП- 160t.,gantry crane |
| Type of gates | Slide botomm-9ps |
| Service, emergency, guard, | 3ps each. |

# 3 DESIGN CONSIDERATIONS

## 3.1 Hydrology

Filling of the water reservoir is carried out from the Karakum canal, which has an intake on the Amudariya with a head discharge of 500 $m^3/s$ and annual average runoff of 13,800 $Mm^3$. Regulation of the runoff is done with a cascade of four water reservoirs, including Kopetdag, with a volume of 1,720 $Mm^3$, that allows to cut the peak of the maximum intake discharge at the head of the canal from 741 $m^3/s$ to 610 $m^3/s$.

The maximum monthly mean design inflow discharge is 79 $m^3/s$ and the maximum discharge is 65 $m^3/s$. Annual average inflow volume to the water reservoir is 2.897 $x10^{6}$ $Mm^3$, outflow is 2.748 $x10^{6}$ $Mm^3$.

## 3.2 Geology and Seismicity

The piedmont plain underlying the water reservoir is formed by quaternary alluvium deposits 30 - 40 m thick, and represented by sandy, sandy silt - silt soils. Lithologic texture is represented by cohesive and semi-cohesive soils (see Figure 5).

Natural ground water flow is in the north western direction, towards the Karakum desert.

The seismic intensity of the site is IX.

## 3.3 Construction Materials and Properties

Local construction materials have been widely used during the construction of the dam (washed sand, gravel, crushed stone, rubble stone).

The supporting mass is hydraulically filled with sandy-silt and silt from downstream borrow areas.

Liquefaction of wet soils in the embankment occurs as a result of hydrodynamic processes as affected by seismic acceleration. This type of seismic deformation is observed in fine-grained loose materials, and depending on the intensity, may lead to partial or full loss of structural stability. Material used the for hydraulic filling has a uniform grading.

In 1997 Kopetdag dam experienced a 4-5 intensity earthquake. As a result of the earthquake longitudinal cracks 8 cm wide and 2 m deep were formed on the dam crest from PK 11+80 to PK 13+50. No settlements were observed. Downstream slope and the draw-off were not damaged. At that section some loosening of the fill material occurred .The initial densities were reduced by 10-15%, from 1.7 $t/m^3$ to 1.5-

1.45-1.38 $t/m^3$. According to the measurement, ground acceleration magnified 1.5-2 times throughout the embankment.

According to information received from the operating staff, the phreatic surface is lower than the design one.

## 3.4 Seepage Control Measures

On all hydrotechnical structures the sheet pile cut-off walls were installed.

## 3.5 Reservoir Draw-off Works

The filling and draw-off of water from the reservoir is carried out in accordance with a control schedule, which is linked with the schedule of water transfer through the whole Karakum canal system. The water reservoir filling and draw-off schedule is worked out in accordance with “Operating rules of Kopetdag water reservoir” requirements, which exclude the possibility of making conditions that threaten the stability of the structures.

The “Operating rules…” regulate the limit on admissible rate of draw-off and filling of the water reservoir to 10 cm/day.

The work of structures in an emergency situation forbids the filling of the water reservoir higher than FSL = 151.2 masl. Changes in the working regime stipulated by the ”Rules…” are possible only in accordance with the order of the person responsible for the water reservoir operation, with subsequent notification of higher organisation and local administration.

## 3.6 Performance Monitoring Instrumentation

The water reservoir instrumentation are the following:

- water level gauge – 4 ps
- piezometer – 54 ps
- current meter (GR-21) – 1 ps
- rod H-10 – 1 ps
- survey bench mark in foundation – 2 ps

## 3.7 Hydropower Facilities

Not provided.

# 4 DAM CONDITION AND PERFORMANCE

## 4.1 Comments Arising out of Inspection

The IC, in company with representatives from the Turkmen National Team and Engineers from the site visited the dam on 18 October 1999. Areas inspected included the whole of the embankment and the draw-off works. The reservoir level at the time was 143.6 masl, equivalent to 239.2 $Mm^3$.

During the inspection the following was established:

- The centre of the dam at the outlet structure does not have dependable, up-to-date communication with other parts of the dam (inlet and outlet structures), or with the central control department of Karakum canal.
- The reservoir bed, inlet and outlet structures, does not have instrumentation for measuring of water levels, discharges and inflow withdrawal.
- There is no lighting on the dam.
- The electric supply to the hydromechanical equipment is provided by a temporary line from the substation 110/35/6kW. The length of the line is 5 km.
- A stand-by power supply is available - diesel generator with power 35 kW, but it is placed on the outlet tower in the open air and its working capacity raises doubts.
- There are no necessary spare parts and materials for regular repairs.
- The equipment is under the control of untrained employees in questions of its operation, which can give rise to emergency situations.
- Out of 54 piezometers, 41 are in working order.

## 4.2 Assessment of Performance Monitoring Results

Assessment of the results of the monitoring that is carried out (observation for water levels, discharges of filling and draw-off volume, phreatic surface, condition of tail and head water) is carried out in accordance with “ Operation rules of Karakum canal system” , “Operation rules of Kopetdag water reservoir” and also with orders and protocols.

The monitoring records and their assessment are available, but there was no opportunity to study these.

## 4.3 Dam Safety Incidents

There were no emergency situations during the operation of the water reservoir.

## 4.4 Maintenance Procedures and Standards

"Operation rules of Kopetdag water reservoir" were elaborated on the basis of "Operation standards and rules of Karakum canal" (1983) and "Basis of Karakum canal technical operation in modern conditions" (1997) by the institute "Turkmengiprovodkhoz".

Implementation of the above mentioned documents is obligatory for operational organisations, independent of the department to which they belong.

## 4.5 Existing Early Warning & Emergency Procedures

The structure complex of the Kopetdag water reservoir has obsolete communications with the central control point of the Karakum canal, and communications around the site are non-existent. The actions of the maintenance personnel in an emergency situation are determined by their job descriptions as defined by the chief of the water resources department.

# 5 SAFETY ASSESSMENT

## 5.1 General

The safety assessment is based on the following general criteria:

(1) Structural safety
The dam, along with its foundations and abutments, shall have adequate stability to withstand extreme loads as well as normal design loads.

(2) Safety against floods
The reservoir level shall not rise above the critical level (maximum flood level) for the largest possible flood. Gate mechanisms and power units must remain fully operational and accessible at all times.

The dam should have adequate facility for rapid lowering of the reservoir level in case of emergency.

(3) Safety against earthquakes
The dam shall be capable of withstanding ground movements associated with the maximum design earthquake (MDE) without release of the reservoir. The selection of the appropriate value of MDE is based on an assessment of the consequences of dam failure (Section 2.3).

(4) Surveillance
Arrangements for inspection, surveillance and performance monitoring of the dam should ensure that a danger arising from damage, defect in structural safety or an external threat to safety is recognized as soon as possible, so that all necessary measures can be taken to control the danger.

Adequate emergency planning, early warning and communications facilities shall be in place to ensure the safety of the downstream population in case of emergency.

In the light of the review of the design and performance of the Kopetdag dam, the findings of the condition assessment, and the review of the hydrological and geological conditions, the following conclusions are drawn regarding the safety of the dam:

## 5.2 Structural Safety

### 5.2.1 Embankment

This hydraulic fill dam appears to have operated completely successfully since completion of the first stage in 1976, and the second stage in 1994.

Information provided by the operating staff indicates that the dam is well monitored and inspected regularly.

The phreatic surface within the downstream shoulder is measured by means of piezometers (41 out of a total of 54 of which are reported to be in working order) and is said to be within the design limits.

After some initial seepage problems and remedial works, seepage is now understood to be minimal, although not measured. It is not known whether settlement measurements are made.

It is important that sufficient instrumentation is installed and in working order to allow the performance of the embankment to be properly maintained. For a large hydraulic fill embankment this would comprise measurement of pore pressures, seepage and horizontal and vertical deformations. The instrumentation system should be reinstated to allow the necessary measurements to be made.

The embankment crest wave wall is as yet incomplete, which might increase the vulnerability of the embankment to damage by reservoir waves during high winds.

Both faces of the embankment are in satisfactory condition.

### 5.2.2 Draw-off Works

The draw-off works are of large capacity in comparison with the normal inflows to the reservoir, and so are likely to be capable of handling any unexpected circumstances. However, potential flood inflows from the local catchment are of unknown size, also the Karakum Canal itself is at a greater elevation than the reservoir so that there is a possibility of the canal emptying itself into the reservoir. In these circumstances, simultaneous failure to close the inlet and to open the outlet could result in overtopping of the embankment.

Superficial examination of the draw-off works indicated that they are in generally satisfactory condition; the operating staff did not report any major problems with the gates and other equipment. The equipment is currently operating from a temporary power supply and clearly there is a need to complete the electrical installation.

## 5.3 Safety against Floods

Kopetdag is an off-stream storage, located on the Karakum canal, with a local catchment of approximately 950 km$^2$ (Sekizab Creek). Maximum capacity of the inlet canal is 79 m$^3$/s. The outlet from the reservoir is controlled by three gates with a total capacity of 79 m$^3$/s.

Runoff from the local catchment has not been taken into account during the design of the dam. In a case of a PMF event it is likely that the runoff from the local catchment can fill the reservoir and even overtop the dam crest. It was revealed through the discussions with the chief engineer of the Karakum canal that, in a case of such an event they would most likely excavate an emergency spillway on the eastern side of the dam, discharging all water into the Kyzilkum dessert.

It can be concluded that the Kopetdag dam has a high hydrological risk. In case of a dambreak, the consequences would be an interrupted water supply for settlements along the canal and for irrigation. It is therefore recommended to undertake a hydrological study and define inflow hydrographs for various AEPs, including a PMF and provide an appropriate solution to reduce or even eliminate the hydrological risk.

## 5.4 Provision for Emergency Draw-down

Draw-down of the reservoir in case of emergency can be achieved by means of the draw-off sluices. The maximum draw-off rate when the reservoir is at full storage level is about 142$m^3$/s, giving a maximum draw-down rate of some 0.25 m /day. This is not a high rate but should be sufficient to relieve a substantial proportion of the load on the embankment in a few days in case of emergency.

## 5.5 Safety against Earthquakes

### 5.5.1 Seismic design criteria

In the original design seismic input parameters and stability analysis in seismic condition are assumed to have been carried out in accordance with procedure given in the Russian Seismic Standards (Reference 2). According to the Russian Seismic Standard, a seismic design coefficient ($K_g$) is derived for a site based on MSK earthquake intensity scale. The coefficients are derived based on 1:500 year earthquake. The required minimum factor of safety in seismic condition is always greater than unity.

However, the current practice based on the guidelines given in ICOLD Bulletin 72 (Reference 1) is to assess dam safety against two representative design earthquakes that are as follows:

OBE - Operating Basis Earthquake
MDE - Maximum Design Earthquake

Where:

- OBE, or “no damage earthquake” is the earthquake which is liable to occur on average not more than once during the expected life of the structure (of not less than 100 years). During an OBE, the dam and its ancillary works should remain functional but may need repair. The required minimum factor of safety for the OBE earthquake should be greater than unity.

- MDE or “no failure earthquake” is the earthquake that will produce the most severe level of ground motion under which the safety of the dam against catastrophic failure should be ensured. For dams which are classified to be Risk Class III a recommended return period of MDE is 10,000 years (Reference 3). For this earthquake displacements of the crest are assessed and compared with the allowable wave freeboard.

The dam safety has not been assessed for OBE and MDE earthquakes and it is recommended to carry out additional engineering studies (See Section 6.2.4) to evaluate dam performance in those conditions.

As a part of safety assessment a check should also be carried out to evaluate the height of seismic waves (seismic seiche) of the reservoir which may occur during a seismic event and which requires the additional height to be added to the standard “static” freeboard.

### 5.5.2 Liquefaction of fill and foundation materials

It is reported that an Intensity VII earthquake occurred in 1997 with epicentre about 40 km south of the dam, which caused longitudinal vertical cracks in the upstream face of the embankment. The cracks were above the water at this time, but below FSL, and are said to have been 2 m deep and up to 0.08 m wide at the top. The cracks were repaired by digging out the affected area in trench and backfilling with sand compacted in layers.

No further details are available of this incident but the cracking pattern is consistent with sliding failure, possibly associated with loss of strength of the saturated material below the water level due to liquefaction. If further information could be provided, including an assessment of the peak ground acceleration, it would provide valuable data for back analysis of the seismic stability of the embankment. The incident does, however, confirm that an embankment constructed of saturated, low density hydraulic fill is vulnerable to damage during seismic shaking.

It is recommended to carry out further in-situ testing to verify the properties of the embankment and foundation materials in order to assess soil strength reduction and displacements that could occur during strong earthquakes.

### 5.5.3 Ancillary Works

It is possible that the crane gantry would also be vulnerable to damage by an earthquake. Any damage which impaired the function of the crane in operating the draw-off gates would have important dam safety implications, and an assessment should be made of the likely impact of an earthquake on such items.

## 5.6 Other Safety Matters

A number of other matters will need further examination as part of more comprehensive safety assessment than has been possible during the present study, for instance:

### 5.6.1 Safety of access

The dam can be accessed from both sides and the chances that extreme events (e.g. floods, earthquake) would completely severe both are remote, unless the roads are cut due to washouts, collapsed culverts, etc.

### 5.6.2 Security of electricity supply

It is unlikely that 100% security of electricity supply for gate operation can be assured in all circumstances, and a standby generator to operate the crane gantry for operation of the draw-off gates in emergency is recommended.

## 5.7 Safety Assessment – Summary

### 5.7.1 Principal matters of concern

On the basis of a brief examination the IC find no serious safety problems with the Kopetdag dam. However, being of hydraulic fill, the embankment is vulnerable to instability due to loss of strength of the saturated low density fill during earthquake shaking.

There are some deficiencies in the performance monitoring installation in that some piezometers are no longer functioning, though sufficient appear to be in operation to provide evidence that the internal water level is satisfactory.

The inflow channel to the reservoir drops by some 50 m through five drop structures in a 10 km distance between the inlet control structure and the reservoir. There thus appears to be the possibility that the reservoir could be overfilled should the outlet gates fail to operate and the inflow continues to flow. The time taken for the reservoir to fill significantly above its normal level would be considerable, however, and the risk of the embankment actually being overtopped is remote, but cannot be discounted.

### 5.7.2 Safety Statement

Static stability has not been checked as soil strength parameters are not available, but slopes are conventional and consistent with the construction materials used.

Apart from the risk of earthquake damage (which requires further study to confirm or otherwise) the Kopetdag dam appears to meet acceptable safety criteria.

As the reservoir is filled from Karakum Canal and has only a small independent catchment the danger from floods is not great. It is remotely possible that malfunction of the draw-off works could result in overfilling of the reservoir which in extreme circumstances could lead to overtopping of the embankment.

# 6 RECOMMENDED STUDIES, WORKS AND SUPPLIES

## 6.1 General

The review of the design of the dam, information obtained during the site inspections, and discussions with the site manager has enabled the IC to arrive at certain conclusions regarding the safety of the dam, which are discussed in Section 5. These conclusions, along with considerations of requirements for emergency management have provided the basis for an assessment of the need for additional studies, investigations, construction works and supplies necessary to bring it to an acceptable and sustainable standard of safety. However, it must be recognized that the need for further work might still become evident as an outcome of this work, as the preliminary conclusions are refined.

A more detailed specification and methodology for the work described in this Section is presented in the accompanying report `Methodology for Detailed Design of Priority Rehabilitation Measures'.

## 6.2 Additional Surveys, Investigations, Inspections and Studies

### 6.2.1 General

To provide the basic data for designing the works described below and for refining the conclusions of the safety assessment, additional information is required which is outside the scope of the present study. This work is described under the following headings:

- ground surveys
- ground investigations and inspections
- engineering studies

### 6.2.2 Surveys

(1) Topographic Surveys

The following ground surveys are recommended:

- embankment longitudinal crest profile;
- typical cross sections of the embankment to verify the `as-constructed' profile;

### 6.2.3 Ground Investigations and Inspections

The following investigations and inspections are recommended:

(1) Reinstatement of the embankment piezometers will involve a considerable amount of drilling in the embankment. It is recommended that during the course of this work in-situ testing should be carried out to verify the properties of the embankment and foundation material, and samples taken for laboratory testing.

(2) Inspections

To provide information on which to base a detailed assessment of required repairs and equipment, it is recommended that a detailed inspection of the embankment and associated works should be carried out and an inventory of defects, materials and repairs required prepared, covering:

- repairs to embankment upstream face (inspect when reservoir is at a low level);
- improvements to embankment drainage (inspect for seepages when reservoir is at high level);
- repairs to embankment downstream face protection and surface water drainage works;
- interior of draw-off culvert, upstream and downstream of gates;
- electrical wiring etc., and lighting;
- gates and hydraulic operating equipment;
- steelwork (e.g. gate tower stairs and landings);

### 6.2.4 Additional Engineering Studies

The following additional engineering/hydrological studies are recommended:

1) Review Reservoir Management Procedures using updated flood estimates and reservoir sedimentation data, and freeboard allowance for wave run-up based on updated wind data.
2) Review the seismicity of the site, derive estimates of peak ground accelerations for Operating Basis Earthquake (OBE) and Maximum Design Earthquake (MDE).
3) Assess susceptibility of embankment material to liquefaction under seismic shaking. Review embankment static and seismic stability on the basis of measured properties of the in-situ materials, and determine deformations where factors of safety during seismic shaking are less than unity.
4) Hydrological studies of Sekiz-Yab catchment.

## 6.3 Construction Works

A preliminary assessment of the required construction works is made on the basis of the safety assessment and available data. Final details will depend on the outcome of the studies described above.

1) Embankment instrumentation

Although the embankment appears to be generally in good condition it is a major dam and it is essential that its performance is properly monitored. The performance monitoring installation should be reinstated where necessary. The following is proposed:

- install new standpipe piezometers where the existing tubes are blocked;

- install additional electrical (remote reading) piezometers at critical locations;
- install network of surface deformation measurement markers and fixed beacons, for precise measurement of horizontal and vertical displacements.
- Provide for measurement of seepage flows

2) Embankment Crest

   Complete the embankment crest wall.

3) Hydromechanical Equipment

   The safety of the dam relies heavily on the proper operation of the hydromechanical equipment. Any necessary repairs and renewals should be undertaken immediately, and adequate standby electricity generating plant provided. Although not directly related to safety, the electrical installation should be completed, principally the crest lighting.

4) Spillway

   If found to be necessary as a result of further hydrological studies, design and construct a new spillway.

5) Miscellaneous

   Other matters requiring attention discovered during the detailed inspections described above should be rectified.

## 6.4 Equipment and Supplies

A preliminary assessment of supplies needed, based on the Consultants' inspection and discussions with site managers, is as follows:

(1) Piezometers - at present all piezometers are standpipe type, but consideration should be given to installing a number of additional electrical (remote reading) type in critical locations.

(2) Surface movement measurement fixed beacons and targets, and deformation measuring equipment.

(3) Provide electrical installation, crest lighting, standby generator and associated housing and wiring.

(4) Provide vehicles for use of site staff to inspect and monitor new instrumentation.

(5) Provide communications system between inlet structure and dam outlet works, and other structures on the canal.

## 6.5 Emergency Planning Studies

The dam impounds a large reservoir and an emergency would result in the release of a large volume of stored water. The downstream area is very flat, however, and the consequences for the population in these areas may not be particularly serious. Nevertheless the economic consequences of such an event could be very serious and it is essential that plans for dealing with such a situation are well prepared, and supported by an efficient organization, communications and alarm system. Inundation and flood hazard maps showing dambreak wave arrival time and duration of inundation should be prepared, based on dambreak modelling and simulation of dambreak wave propagation in the downstream areas. Flood damage estimates and potential loss of life should be developed on the basis of the above results.

A detailed emergency plan and instruction document should be prepared setting out the procedures to be followed, and the responsibilities of the site managers, regional engineers and civil authorities

## 6.6 Safety Measures-Priorities

The safety measures identified above are listed in Table 6.1 and assigned to one of three priority levels (I, II, III).

The proposed Priority levels are:

I - high priority; work to be carried out immediately
II - intermediate; work to be carried out within three years
III - low priority; the need to be kept under review.

**Table 6.1 Kopetdag Dam - Dam Safety**
**Priorities for Studies, Works and Supplies**

| Item | Studies etc | Construction Works and Supplies | | |
|---|---|---|---|---|
| | | Priority I | Priority II | Priority III |
| 1. Surveys (6.2.2) | ☐ | | | |
| 2. Investigations and Inspections (6.2.3) | ☐ | | | |
| 3. Engineering Studies (6.2.4) | ☐ | | | |
| 4. Construction Works (6.3) | | | | |
| • Crest wall | | ☐ | | |
| • Instrumentation | | ☐ | | |
| • Hydromechanical equipment | | ☐ | | |
| • New spillway | | | ☐ | |
| • Miscellaneous Repairs | | | ☐ | |
| 5. Supplies (6.4) | | | | |
| • Piezometers and deformation monitoring equipment | | ☐ | | |
| • Standby Generator | | ☐ | | |
| • Early warning system and communication equipment | | ☐ | | |
| • Vehicles | | ☐ | | |
| 6. Emergency Planning Studies (6.5) | ☐ | | | |

# 7 CONCLUSIONS

The IC conclude that on the basis of the information received and a brief inspection the Kopetdag dam is in a generally satisfactory state. A number of requirements for rehabilitation have been identified, but the principal items to which high priority should be given are:

(a) reinstatement of piezometers and installation of a comprehensive deformation monitoring system, and thereafter regular monitoring or pore pressures, deformations and seepages;

(b) vehicles to allow the site operating staff to regularly inspect the dam and carry our routine monitoring of instruments

(c) establishment of a reliable early warning system for the downstream population in the event of an emergency, supported by an efficient organization and communications system.

(d) Provision of telecommunications between dam and intake, a permanent electrical installation and standby generation facilities.

# APPENDIX A

# KOPETDAG DAM

# LIST OF DATA EXAMINED

## Kopetdag Dam

## Appendix A – List of Data Examined

1. World Bank June Mission, 1997

# APPENDIX B

# HAZARD ASSESSMENT PROCEDURE

## APPENDIX B – HAZARD ASSESSMENT PROCEDURE

**Table B1 Classification Factors**

| | Classification Factor | | | |
|---|---|---|---|---|
| Capacity ($10^6 m^3$) | >120<br>(6) | 120-1<br>(4) | 1-0.1<br>(2) | <0.1<br>(0) |
| Height (m) | >45<br>(6) | 45-30<br>(4) | 30-15<br>(2) | <15<br>(0) |
| Evacuation requirements (No of persons) | >1000<br>(12) | 1000-100<br>(8) | 100-1<br>(4) | None<br>(0) |
| Potential downstream Damage | High<br>(12) | Moderate<br>(8) | Low<br>(4) | None<br>(0) |

**Table B2 Dam Category**

| Total Classification factor | Dam Category |
|---|---|
| (0-6) | I |
| (7-18) | II |
| (19-30) | III |
| (31-36) | IV |

**Ref: ICOLD Bulletin 72, (Reference 1)**

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# DRAWINGS