IFAS AGENCY for the GEF PROJECT

# ARAL SEA BASIN PROGRAM
# WATER & ENVIRONMENTAL MANAGEMENT PROJECT

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

# BUGUN DAM

# SAFETY ASSESSMENT REPORT

March 2000

GIBB
LAWGIBB Group Member

In association with

SMEC

# BUGUN DAM
# SAFETY ASSESSMENT REPORT

## CONTENTS

## 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 |
| PMF | Probable Maximum Flood |
| 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 (see Appendix A). 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. Chapter3 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

The dam is located on Bugun river, near Bugun village, in the South Kazakhstan Oblast of Republic of Kazakhstan (see Figure 1). The reservoir was formed by construction of two dams: one dam was located on Bugun river, the other sealed Karazhantak depression. The dam can be accessed all the year round by asphalt road Chimkent-Bugun village.

The dam was designed for redistribution of Bugun and Arys river flows with the help of Aryk main canal with the purpose of irrigation application on the area of 70,600 ha. The dam was designed by “Kazgiprovodkhoz” Institute in 1955. Dam construction was completed in 1963.

## 2.2 Description of the Dam

The following are the principal components of Bugun dam (see Figure 2):

- Bugun embankment
- Karazhantak dyke
- Draw-off works
- Division wall with head works of Turkestan Main Canal (TMC)
- Arys Main Canal (AMC).

Bugun dam was constructed of compacted silt material available locally (see Figure 3). The upstream slope is protected against the wave action with prefabricated reinforced concrete slabs 12 cm and 10cm thick down to 252.70 masl and 247.21 masl respectively .The slabs are placed on 35 cm thick sandy gravel layer. 12m x 12m concrete blocks were made from prefabricated slabs (36 or 48 slabs alongside the slope) with temperature joints and three-layer reverse filter on top of them. In the upper part of the dam, from the crest down to 252.70 masl, a second layer of monolithic reinforced concrete was placed in order to seal all joints of assembled concrete blocks. Separate strips made of monolithic reinforced concrete are placed at the abutments in order to seal vertical and horizontal joints. In addition to the above works, a parapet was constructed on the dam crest to enhance safety of the dam against the wave action. The downstream slope is reinforced with grass seeding. Drainage works comprise clay pipes (150 mm diameter) with three-layer reverse filter and are provided at the foundation of the downstream slope. The seepage water is drained from the pipes into 23 manholes that have 6 outlets into water diversion culverts.

Karazhantak dyke is constructed of silts (see Figure 3). The cross-section profile has a complex outline as the irrigation canal, which transfers water to the other side of the valley, crosses the downstream slope of the dyke. The upstream slope is protected (as Bugun dam) with reinforced concrete slabs of 10 cm thickness covered by rip-rap. A drainage clay pipe (150 mm diameter) with three-layer reverse filter is placed in the toe of the downstream slope. There are 10 manholes and 2 outlets.

Draw-off works comprise two reinforced concrete pipes that consist of five sections, each 13.5 m long and 2.5 x 2.5 m in cross section. The gate shaft is located between the second and third pipe section and it is almost fully located within the dam body. The tower finishes with a platform at the top of the dam crest where double hoists with 20 t lifting capacity are mounted. There are four roller gates in the shaft located in two sections, namely maintenance gates in the first, and working gates at the second section. The gates are operated with the double hoists that have a manual and an electric drive. The main power supply comes from a substation (100/10KW). Back up supply is provided by mobile diesel substation. A stilling basin which conjugates with water division wall is constructed at the end of the pipe.

The division wall consists of head works of the main canal (TMC) with a discharge capacity of 45 $m^3$/s and the outlet canal sluice with a discharge capacity 90 $m^3$/s. The head works of the main canal have two bays **(**5 m each) which are closed by radial gates. The length of fixed section behind the sill is 12 m, width - from 11 m to 12 m. The sluice of the outlet canal has two 6 m wide bays equipped with radial gates designed for 4 m of head. The length of sheeted section behind the sill is 15 m, width - from 13 m to 14 m. Both radial gates are equipped with cable hoists with lifting capacity - 10 t each.

Arys Main Canal (AMC) transfers free flow from Arys river to Bugun reservoir. The end part of AMC is very close to Bugun reservoir. Canal is 10 m wide at the bottom with 1 V:1.5 H side slope. The external dyke slope is 1:1.7 and protects the dyke from being washed out by water.

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 – B2 in Appendix B.

Based on the Tables in Appendix B, the total risk factor of 32 points (Table 2.2) puts the Bugun dam in Risk Class IV, that is the highest risk category.

**Table 2.2 Bugun Dam – Risk Factor**

| | | **Points** |
|---|---|---|
| Reservoir Capacity ($Mm^3$) | 370 | 6 |
| Dam Height (m) | 21 | 2 |
| Downstream Evacuation Requirements | >1000 | 12 |
| Potential Damage Downstream | High | 12 |
| | **TOTAL** | 32 |

**Table 2.1 Bugun Dam principal dimensions**

**Principal dimensions of reservoir**

| | | |
|---|---|---|
| Full storage capacity | | 370 Мм$^3$ |
| Active storage capacity | | 363 Мм$^3$ |
| Dead storage capacity | | 4.0 Мм$^3$ |
| Full storage level | (FSL) | 259.85 мasl |
| Maximum flood level | (MFL) | 261.38 мasl |
| Dead storage level | (DSL) | 248.5 мasl |
| Reservoir surface area at FSL | | 63.5 км$^2$ |

**Bugun embankment principal dimensions**

| | | |
|---|---|---|
| Crest length | | 5.2 km |
| Crest elevation | | 262.0 masl |
| Parapet elevation | | 262.9 masl |
| Maximum height of embankment | | 21.0 m |
| Crest width | | 8.0 m |
| Upstream and downstream slopes: | Above the berm | 1:2.5 to 1: 3.8 |
| | Below the berm | 1:2.0 to 1:3.0 |

**Karazhantak embankment principal dimensions**

| | |
|---|---|
| Crest length | 3.2 mm |
| Crest elevation | 262.0 masl |
| Parapet elevation | 262.9 masl. |
| Maximum height of embankment | 10.0 m. |
| Crest width | 8.0 m |
| Upstream slope | 1:2.5 |
| Lower side slope | 1:1.5 to 1:2.5m |

**Maximum discharge capacity during 0,01% flood**

| | |
|---|---|
| Outlet structure | 90m$^3$/sec |

# 3 DESIGN CONSIDERATIONS

## 3.1 Hydrology

River Bugun is formed from two rivers which run down from Karatau mountains, namely - Katta-Bugun and Bala-Bugun. The river is fed by snow melting. Catchment area is 2,040km$^2$. The river carries water almost only during floods which take place in February-March with a maximum discharge of 140 m$^3$/s.

The average annual flow of Bugun river in the section of reservoir (50% of available water supply) is 62 Mm$^3$. The floods make up 90% of the total annual flow.

Maximum design discharge at 1% is 184 m$^3$/s and at 0.1% is 344 m$^3$/s. During Spring 1959 floods Bugun river discharge at 1% was 277 m$^3$/s, which was higher than that assumed in the design. Therefore, it is necessary to review calculated Spring flood parameters. Arys river flow transferred by AMC to Bugun reservoir is 596 Mm$^3$. Arys river sediment run-off is characterised by a sediment load of 0.015 – 0.251 kg/m$^3$. The annual volume of sediment run-off into the reservoir is 125 000 m$^3$.

## 3.2 Geology and Seismicity

Bugun and Karazhantak embankment foundations comprise loess silt deposits, 18 m-22 m thick, underlain by sand and gravel.

## 3.3 Construction Materials and Properties

Bugun and Karazhantak embankments were constructed of compacted silts. According to the design a unit weight of compacted soil should have been:1.82 t/m$^3$ below elevation 254 masl and 1.74 t/m$^3$ above elevation 254 masl. However, no actual data on construction compactions were made available.

## 3.4 Seepage Control Measures

No special seepage control measures were installed Bugun and Karazhantak embankments except the drainage works which were described in Section 2.2.

## 3.5 Reservoir Draw-off Works

The calculated 75% of reservoir water inflow is 618 Mm$^3$ which includes Arys river flow of 596 Mm$^3$ and Bugun river flow of 22 Mm$^3$. 518 Mm$^3$ of water is needed for irrigation, which exceeds the reservoir storage capacity of 370 $Mm^3$. Thus, at the beginning of the irrigation season water from Arys river diverted via the reservoir is used. The reservoir water starts to be utilised in second half of May.

## 3.6 Performance Monitoring Instrumentation

The original design envisaged the following instruments to be installed (see Appendix C):

On Bugun embankment

- 11 piezometers
- 1 foundation bench points
- 12 surface settlement markers

On Karazhantak dyke

- 3 piezometers
- 1 foundation bench points
- 6 surface settlement markers

## 3.7 Hydropower Facilities

Hydropower facilities are not available.

# 4 DAM CONDITION AND PERFORMANCE

## 4.1 Comments Arising out of Inspection

Bugun dam was visited by GIBB specialists accompanied by regional and national experts on the 1st October 1999. At the time of inspection the reservoir water level was at the dead storage level.

During the inspection the following was found:

- The upstream slope of Bugun embankment is in unsatisfactory condition. There is significant erosion of the filter underneath the concrete slabs. The voids underneath the concrete blocks are from 1cm to 30 cm. At the left end of the dam the shores of the lake are severely eroded which has a negative effect on the performance of the whole facing during storms. In the discussions with exploitation personnel it was revealed that the personnel had results of TV survey of voids under the concrete facing carried out by the “Intermelioracia” from Moscow. However these results were not made available

- On the upstream slope of Karazhantak dyke a stone rip-rap of different thickness and sizes was placed in an area of the maximum wave impact. However, not everywhere the rip-rap is continuous and extends up to the parapet.

- One working gate is missing from the draw-off tower. The gate is now on the crest of the dam and is corroded and is not suitable for further use. Judging by the condition of this gate there is a fear that the other working gate is in the same condition.

- The electrical equipment controlling the gates is disconnected due to long-term exploitation.

- At the time of the visit the drainage was not operational. According to the exploitation service, phreatic surface daylights at the downstream slope when the water level in the reservoir is higher. This means that the drainage is not working. Drainage ditches are overgrown with cane, which obstructs outflow of water.

## 4.2 Assessment of Performance Monitoring Results

Over the last ten years monitoring on the dam has not been carried out. Previous monitoring results were not found (see Appendix C).

## 4.3 Dam Safety Incidents

Pre-emergency situation occurred three times: in 1969, 1980 and 1982. All emergencies took place as the result of wave action during storms.

In 1969, i.e. in the first years of exploitation, initially constructed concrete slabs combined into 12 m x 12m blocks of 10 cm-12 cm thickness were destroyed on certain section. The slope facing was restored by placing of additional concrete at joints.

The storm in 1980 caused overtopping over the parapet; the embankment crest and downstream slope were damaged. The parapet was replaced with a stronger one, the crest was resurfaced with asphalt, and the downstream slope restored.

Upstream facing at the left bank and a section of Karazhantak dyke were destroyed during 1982 storm. The upstream slope was subsequently restored with rip-rap.

## 4.4 Maintenance Procedures and Standards

An exploitation procedure for Bugun dam has been elaborated by Institute Kazgiprovodkhoz. “Standard exploitation procedures for reservoir with the capacity of 10 $Mm^3$ and more” (Ministry of Water Resources of USSR, 1987) together with design studies were used for establishment of exploitation procedure for Bugun dam. “The procedure…” determines principal exploitation rules which meet the requirements of main water users and guarantees safety of the dam structures. “The procedure…" is the guiding document for all organisations and departments which are related to the use of reservoir regardless of their departmental classification.

## 4.5 Existing Early Warning & Emergency Procedures

The early warning system is not in place. There is a public telephone that allows communication with all personnel working on the main canal, in oblast centre, etc. Emergency actions by maintenance personnel are determined by Director of the hydro system in emergency situation.

# 5 SAFETY ASSESSMENT

## 5.1 General

In the light of the review of the design and performance of the Bugun 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. No drawings of the dam were available for inspection, nor any inspection reports or results of any performance monitoring measurements.

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 mechanism 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 recognised 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.

## 5.2 Structural Safety

Bugun Embankment

There are many aspects of the embankment which raise concern about its integrity and safety. Generally the embankment is in a poor condition. The main areas of concern are:

(1) The dangerous state of the upstream face protection does not provide satisfactory protection against reservoir waves caused by high winds. It is reported that in 1969, the dam was overtopped by waves caused by very strong winds that are a constant feature of the reservoir area. On that occasion, the Civil Defence sent 40 buses to evacuate people. The generation of such high waves had not been anticipated in the design that foresaw a freeboard of 2 m. Wind velocity record in 1969 was 36 m/s, fetch can be estimated as 5.5 km. The wind blows continuously during winter and maintains its peak velocity over periods of 2 to 3 weeks. The upstream slope protection is initially made of concrete slabs that have been reinforced following dislocation caused by waves. The erosion of the underlying embankment is evident.

At the left end of the main dam from PK9 - PK22 (some 1,300 m in length) the shores of the lake are severely eroded by the action of waves. The upstream slope protection is completely dislocated and badly eroded all along the side dam. There is a danger that, as a consequence of the on going erosion processes, the reservoir can find its way into a nearby irrigation canal and throughout a nearby valley.

(2) There are serious deficiencies in the embankment performance monitoring works. Only two piezometers were said to be operational. However, no monitoring of the piezometer or seepage flow has been undertaken for the last ten years. This is unsatisfactory and regarded as unsafe since there is no indication where the phreatic surface is in the embankment but there are signs on the downstream slope that it might be very high.

(3) The downstream drainage system is in a bad condition; most of the drainage wells and collector drains are blocked and appear not to have been cleared for many years.

(4) The drainage system downstream of the embankment needs to be cleared. No drainage flow measurements are being carried out. Widespread seepage is reported to occur at high reservoir levels near to the toe of the dam, particularly in the area of the old river course. There is a 7 m deep well (open casing steel pipe), from which the water under pressure is observed to flow out. The well is located some 50 m from the toe of the embankment and the flow is said to be in the range of 5 to 10 l/s.

(5) Very serious erosion cavities were observed along the downstream slope. These are 5 m to 10 m wide and up to 2 m deep. Each year the cavities are further eroded by rainfall caused partly by malfunctional surface drainage works and partly due to the highly erodible and possibly dispersive nature of the embankment material.

Karazhantak Embankment

The flank embankment is a low structure and while being untidy appears to be in a reasonable condition structurally. The concrete slab wave protection to the upstream face has been reinforced with rip-rap, which although not continuous appears to be effective in preventing the same type of damage as has been sustained by the main dam.

## 5.3 Safety against Floods

### 5.3.1 Introduction

Bugun outlet structure was designed using 1% and checked against 0.1% annual exceedance probability (AEP) hydrograph. The maximum capacity of the outlet structure is 90 $m^3$/s. The 1% AEP design hydrograph based on the historical 1949 hydrograph resulted in the reservoir water level approaching the maximum reservoir level of 261.3 masl, or 100 mm below the maximum water level of 261.4 masl. If one of the two outlet gates is blocked then the resulting water level would approach a level of 261.58 masl.

The 0.01% AEP hydrograph based on historical 1969 hydrograph, with two gates opened, resulted in the water level of 262.4 masl, which is 400 mm higher than the dam crest.

### 5.3.2 Factors which reduce the dam safety during floods

There are several factors that affect the performance of the Bugun dam during large flood events. These are related to:

- The 1% AEP design hydrograph is not considered adequate for this dam. Larger floods such as 0.01% AEP flood might result in the dam being overtopped with possibly serious consequences. In other words Bugun Dam has a high hydrological risk.

- Uncertainty in definition of extreme flood hydrographs based on statistical analysis of relatively short historical records of annual peak discharges and flood volumes.

### 5.3.3 Conclusions and recommendations

It can be concluded in general that:

- The design discharge hydrograph has a relatively high AEP.

- It is recommended to determine a PMF, by taking into account an extreme snow melt combined with a probable maximum precipitation, and to re-assess the adequacy of the outlet structure.

## 5.4 Provision for Emergency Draw-down

The water discharge works consist of a bottom outlet controlled by roller gates with a maximum capacity of 90 $m^3$/s. The roller gates are out of service and regulation is presently carried out by the maintenance gates (these are vertical sliding gates not suitable for regulation). There is no electricity (disconnected due to unpaid bills) and operation is carried out manually (1 day required to open). The concrete is in bad condition, and it is reported that the invert slabs at the exit of the bottom outlet were dislocated 10 years ago and never repaired.

With a draw-off capacity of 90 $m^3/s$ and a reservoir area at FSL of 63 $km^2$ the maximum potential draw-down rate is only 0.13 m/day or 1 m in 8 days, assuming no inflow and not allowing for the long period presently needed to open the gates manually.

## 5.5 Safety against Earthquakes

### 5.5.1 Seismic design criteria

It is anticipated that in the original design seismic input parameters and stability analysis in seismic condition were 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 scale earthquake intensity. The coefficients are derived based on one in 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 IV a recommended return period of MDE is 30,000 years (Reference 3). For this earthquake displacements of the crest are assessed and compared with the allowable wave freeboard.

Since the dam safety has not been assessed for OBE and MDE earthquakes 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 shall 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 material

The risk that the material in the dam and its foundations might liquefy during a strong seismic event has to be assessed as a part of dam safety assessment for dams in areas with higher seismicity.

Bearing in mind that the embankment fill and its foundation comprise fine loess silts (see Reference 4) there is a risk of possible partial loss of strength in the silt material due to liquefaction during strong earthquakes. It is therefore recommended to carry out some in-situ testing (see Section 6.2.3) to verify properties of the embankment and foundation materials in order to assess risk.

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## 5.6 Other Safety Matters

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A number of other matters will need examination as part of a more comprehensive safety assessment than has been possible during the present study.

### 5.6.1 Security of access

A preliminary assessment suggests that the main access roads to the dam could be vulnerable to flooding. It is not known whether secure access is available from both ends.

### 5.6.2 Security of electric power

Although the outlet gates are intended to be electrically operated, it is reported that the electricity supply has been cut off for some time and that gate operation is by hand. A source of electric power is therefore not an essential requirement for dam safety.

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## 5.7 Safety Assessment Summary

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### 5.7.1 Principal matters of concern

The IC see the following as the principal matters of concern as regards the safety of the Bugun dam.

1) The upstream facing to the embankment does not provide satisfactory protection against reservoir waves caused by high winds, and is in a dangerous state.

2) There are serious deficiencies in the embankment performance monitoring works.

3) The downstream slope of the embankment is deteriorating due to erosion by rainfall caused partly by the disintegration of much of the surface drainage works, and partly by the naturally highly erodible (and possibly dispersive) nature of the embankment material.

4) The only outlet facilities to the reservoir are of inadequate size to pass a major flood, and are in a poor state of repair, with manually operated gates, so that there is a risk that a major flood will overtop the embankment.

5) An emergency situation could arise due to natural cause (e.g. floods), human error or unauthorised activity, which could endanger the downstream population. There is, however, no emergency plan or early warning system for dealing with such circumstances. Guidance is also needed to assist the supervisory staff to recognise when the monitoring process indicates that a dangerous situation is developing.

6) There appears to be no programme of formal inspections or reporting.

### 5.7.2 Safety Statement

From examination of the dam and the very limited data made available, and discussions with the engineers responsible for the dam, the IC conclude that the Bugun dam cannot be regarded as meeting all normal safety standards.

The principal dangers facing the dam are from:

(1) Danger from floods, because of the inadequate outlet facilities,

(2) Structural defects in that substantial areas of the upstream slope are at risk from serious damage due to reservoir waves,

(3) Structural instability
It is probable that the embankment is not at risk from structural instability, but the poor state of the present monitoring system does not allow its behaviour to be sufficiently closely monitored.

(3) Danger from earthquakes
The IC are not satisfied that the stability of the embankment under the effects of earthquake shaking is assured, due to the possibility of loss of strength due to liquefaction of the saturated silt material in the embankment and its foundations.

# 6 RECOMMENDED STUDIES, WORKS AND SUPPLIES

## 6.1 General

The review of the design of the dam, together with 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 the dam 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 report `Methodology for 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:

- surveys
- ground investigations and inspections
- engineering studies

In addition, it is recommended that a dossier of 'as constructed' drawings and other essential information relating to the design, construction and performance of the dam is assembled and regularly updated. Where original drawings have deteriorated they should be retraced or preferably redrawn using a computer system. The dossier would comprise the basic source of information to be referred to when carrying out inspections or undertaking modifications in the future.

### 6.2.2 Surveys

(1) Ground Surveys

In the absence of a coherent set of 'as constructed' drawings for the main dam and saddle dam it is recommended that a topographic survey of both structures be carried out to confirm dimensions and slopes, etc, comprising:

- cross sections at 100 m intervals from the reservoir to 50 m downstream of the embankment toe;
- longitudinal section along embankment crest;

- plan of the embankment showing actual locations of piezometers, drainage wells, drainage collector chambers, channels, drains and flow measuring points;

(2) Reservoir Sedimentation

The IC understands that no reservoir bed survey has been carried out since first impounding of the reservoir in 1963. To provide data for an updated review of reservoir sedimentation and its effect on reservoir management it is recommended that a reservoir bed (bathymetric) survey be carried out.

### 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 materials, and samples taken for laboratory testing, with the object of:

- verifying the shear strength of the embankment and foundation materials;
- verifying the in situ permeability of the embankment and foundation material;
- investigating the susceptibility of the saturated silt material in the embankment and foundations to liquefaction during earthquake movements
- establishing whether the embankment and foundation materials are dispersive, in which case special remedial works would be necessary to ensure the structure's continued safety.

(2) Inspections

In order to provide information on which to base a more detailed assessment of required repairs and equipment than is possible in the present report, and to allow a comparison of options where applicable, it is recommended that a detailed inspection of the whole of the dam be carried out and an inventory of defects, materials and repairs required prepared, as follows:

- Embankment upstream face

  When reservoir level is at its lowest level, inspect the condition of the upstream face protection and report:

  - location of concrete panels that are seriously damaged and need to be replaced;
  - location and size of areas that could be repaired by cutting out and replacing damaged concrete;
  - location and length of joints between slabs that have been undercut or damaged.

- Embankment downstream face

  When reservoir is at its highest level:

- carry out a detailed inspection of the downstream face and downstream toe of the embankment and report location of seepages with estimated or measured flows,
- record flows from downstream drainage wells,
- record piezometer levels,
- assess required repairs to downstream face erosion protection and surface water drainage works;

- interior of draw-off culvert, upstream and downstream of gates;
- electrical wiring and lighting installation;
- gates and operating equipment;
- steelwork (e.g. gate tower stairs etc).

### 6.2.4 Additional engineering studies

The following additional engineering/hydrological studies are recommended:

1) Review estimates of extreme flood inflows to the reservoir.

2) Review reservoir flood management procedures.

3) Review estimates for reservoir wave heights by using updated wind speed data.

4) Study options for repair/renewal of embankment upstream face wave protection, and select the most favourable:

   It was suggested in the 1997 World Bank Report that trial panels of various types of wave protection surfacing should be constructed and their performance monitored before reaching a conclusion as to the most favourable solution. However, it could be many years before the panels were subjected to a severe wave attack during which time the remainder of the existing surface, already in a dangerous state, would deteriorate still further. Design methods for surfaces to resist severe wave attack are well developed and the IC are of the opinion that the options should be studied using conservative estimates of design wind speed and direction, and the most favourable solution adopted for construction.

   In its present state, to repair the existing concrete facing would be a major undertaking, and large areas would need to be removed before a new facing was placed. Possible alternatives, all well tried and tested in severe conditions and which could be placed on top of the existing concrete, are:

   - rip-rap, on a suitable underlayer,
   - open stone asphalt.

5) Review the seismicity of the site and derive estimates of peak ground accelerations for Operating Base Earthquake (OBE) and Maximum Design Earthquake (MDE).

6) Review embankment static and seismic stability on the basis of measured properties of the in situ materials and their potential liquefaction, and determine deformations where factors of safety during seismic shaking are less than unity.

## 6.3 Construction Works

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

1) Embankment
    - Repair or renew upstream face wave protection;
    - Instrumentation
        - Install new standpipe piezometers where existing tubes are blocked;
        - Install flow measuring weirs at embankment downstream drainage outlets;
        - Install markers for measurement of vertical deformations (settlements);

2) Hydromechanical equipment

    The safety of the dam relies heavily on the proper operation of the hydromechanical equipment. All necessary repairs, electrical wiring renewals, etc, should be undertaken immediately, and adequate standby electricity generating plant provided.

    Works required are:

    - Immediate replacement or complete refurbishment of all gate leaves;

    - Eventual replacement of all the remaining components of the hydromechanical and electrical equipment.

3) New Spillway

    Depending on the outcome of the further flood studies, and options for flood management, it may be necessary to construct a new spillway. It is understood that a possible site for such a structure exists on the left flank of the main dam, with a channel that would discharge back into the Bugun river. The alternative option of raising the crest of the dam to provide additional flood storage capacity will probably not be attractive because of the length of the dam, and the consequent exposure of additional surface area to the damage that is being caused by wave action.

4) Miscellaneous

    Other matters which are discovered during the detailed investigations above should be rectified.

## 6.4 Equipment and Supplies

A preliminary assessment of supplies needed, based on the IC's inspection and discussions with the site manager and NTs, is as follows:

(1) Piezometers, standpipe type;

(2) Movement beacons for measurement of vertical displacement; and measuring equipment;

(3) Standby generator and associated housing and wiring;

(4) Early warning and communications equipment;

The list will be refined following a more detailed inspection.

## 6.5 Emergency Planning Studies

It is always possible that exceptional circumstances, human error or structural failure could give rise to an emergency situation. For this reason a comprehensive emergency plan supported by an efficient organisation and alarm system is essential. 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 precise emergency plan document should be prepared as soon as possible, giving detailed instructions to the site managers and regional engineers.

## 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 Bugun 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) | | | | |
| • Instrumentation | | ☐ | | |
| • Embankment wave protection | | ☐ | | |
| • Hydromechanical equipment | | | | |
| - Gates renewal | | ☐ | | |
| - Actuators | | ☐ | | |
| • New spillway structure | | | ☐ | |
| • Miscellaneous repairs | | | ☐ | |
| 5. Supplies (6.4) | | | | |
| • Piezometers and deformation monitoring equipment | | ☐ | | |
| • Standby generator(s) | | ☐ | | |
| • Early warning and communications equipment | | ☐ | | |
| 6. Emergency Planning Studies (6.5) | ☐ | | | |
| | | | | |

# 7 CONCLUSIONS

On the basis of the information received and a brief inspection of the dams the IC conclude that Bugun dam is in an unsatisfactory state and cannot be regarded as meeting normally accepted safety standards.

High priority should be given to the following activities;

(a) reinstatement of piezometers and installation of a comprehensive deformation and seepage monitoring system, and thereafter regular monitoring of pore pressures, deformations and seepages, with clear presentation of the results and interpretation and analysis by experienced dam engineers;

(b) repair of embankment upstream wave protection surfacing ;

(c) review of flood estimates and flood management procedures - depending on the results of this review, it may possibly be necessary to consider constructing a new spillway;

(d) replacement of gate equipment and provision of reliable standby electrical power generation facilities;

(e) instructing a formal programme of inspections and reporting on the performance and safety of the dam;

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

# REFERENCES


1. ICOLD Bulletin 72, 1989

2. SNIP 11-7-81, Russian standard for Seismic Design

3. 'An Engineering Guide to Seismic Risk to dams in the United Kingdom', Building Research Establishment (BRE) UK, 1991

4. L. Wang, 'Zonation on seismic Geotechnical hazards in loess areas of China', Manual for zonation on Seismic Geotechnical Hazards, 1999 Technical committee for earthquake Geotechnical Engineers, ISSMGE

# APPENDIX A

# BUGUN DAM

# LIST OF DATA EXAMINED

## Bugun Dam

## Appendix A – List of Data Examined

1. Summary of design,
2. World Bank June Mission, 1997.
3. Irrigation of Uzbekistan, Fon, Uzbek SSR, 1975

# APPENDIX B

# HAZARD ASSESSMENT PROCEDURE

# APPENDIX B – HAZARD ASSESSMENT PROCEDURE

| Table B.1 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) |

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

| Table B.2 Dam Category | |
|---|---|
| **Total Classification factor** | **Dam Category** |
| (0-6) | I |
| (7-18) | II |
| (19-30) | III |
| (31-36) | IV |

**Ref: ICOLD Bulletin 72, (Reference 2)**

# APPENDIX C

# BUGUN DAM INSTRUMENTATION

# REPORT BY SPECIALIST MR V. N.PULYAVIN

# OCTOBER 1999

# Inspection of instrumentation condition and dam structures observations

## Bugun embankment

Dam safety monitoring instruments stipulated in the design for Bugun dam are as follows:

**Embankment**

- Piezometers 11
- Surface movement markers 12
- Foundation bench marks 1
-

**Karajantak embankment**

- Piezometers 3
- Surface movement markers 6
- Foundation bench marks 1

No piezometers and geodetic marks were found during the inspection of the dam, except 4 piezometers near the outlet structure. There are no drawings showing the instrumentation of the dam.
There is no control of Bugun dam performance.

**Recommendations**

1. Install piezometers and geodetic marks on the dam.
2. Installation of filters in boreholes should be carried out with obligatory presence of Employer's representative. It is recommended to use as a filter the up-to-date synthetic materials (fabric, gauze). Equip the spillways on the drainage.
3. Full scale observations should be carried out in accordance with water reservoir operating rules and existent standard documents. There is no necessity in measurement of dam horizontal displacements in case of absence of local deformation.
4. Work out extremely admissible value of controlled parameters (phreatic surface, seepage discharge, dam settlement), characterizing dam safety conditions.
5. Get experts of scientific-research and planning organizations to take part in data analysis.

# DRAWINGS