IFAS AGENCY for the GEF PROJECT

ARAL SEA BASIN PROGRAM
WATER & ENVIRONMENTAL MANAGEMENT PROJECT

COMPONENT C:
DAM SAFETY AND RESERVOIR MANAGEMENT

TOKTOGUL DAM

SAFETY ASSESSMENT REPORT

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TOKTOGUL DAM
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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 Electricity 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

Toktogul dam with carry-over storage is situated in the central part of the Tian-Shan mountain system at the downstream part of the Naryn river (170 kms from the mouth of the Naryn river, also 5 kms from Kara-Kul town of Djalal_Abad oblast of the Republic of Kyrgyzstan (Figure 1). The access to the dam is available at any season of the year by means of an asphalt road which connects Kara-Kul town with the dam.

The purpose of the reservoir is:

- To produce cheap electric power;
- To guarantee available water supply to existing 800,000 ha irrigated area, and also to irrigate 480,000 ha new area.
- The long-term regulation of runoff, which influence is distributed to downstream dams and to Syrdarya river runoff.

Toktogul dam was designed in 1961 by Hydroprojekt institute named by S.Ya.Juk. Construction of the dam was started in 1962 and was finished in 1976. Term of commissioning of the first unit - 1974, and state acceptance - 24 June 1986. The reservoir went into operation in 1978.

2.2 Description of the Dam

The dam consists of a concrete structure, two sluices, emergency spillway, power station house with inlets and power conduits, and tunnel network for the reservoir service (Figure 2).

The main structure is a gravity dam, which consists of central and abutment sections. The central section has a trapezium view in plan. The abutment sections which are 18 m wide have contact with the bed rock and they are sloped in the upstream direction. The sections are divided with construction joints. Construction of a grout curtain and consolidation grouting was performed in dam foundation. The dam has two sluices of section 5 x 6 m which have 1,200 m^3/s capacity, and an overflow spillway (2 bays, each 10 m wide) of 1,160 m^3/s capacity (Figure 3).

There is an inlet in the central part, from which are laid four steel lined power conduits each of 7 m diameter in the body of the dam (Figure 4). There is a gantry crane at the crest of the dam for the hydropower station inlet and for operation of the spillway gates.

The hydropower station building (Figure 5) has a double row arrangement for the four units, and adjoins directly the dam on the upstream side. The units are Francis turbines having a runner diameter of 5.35 m with working capability from 110 - 180 m head and umbrella design generating units with air cooling each of 300 MW capacity. Each of the two spans of the turbine hall is equipped with a travelling gantry crane of 400/80 t capacity, each of which serves two hydro units. To lift the assembled 700 t hydro-unit, the opportunity of combined use of the cranes was provided. This is achieved by moving one of the cranes to the adjacent span by a special rotating platform.

There is the following equipment at the dam:

- Double-section bulkhead gates (for repair and maintenance) of two bay spillway, of dimensions 10 x 12 m
- Double-section sliding guard gates for the power conduits with dimensions 7x7m. Each of them is operated by the 150 t capacity gantry crane.
- The sliding emergency gates of the power conduits have dimensions 7 x 7m. Sliding emergency guard gates and radial gates of the sluices have dimensions 5 x 7 m. They are both operated by individual hydraulic cylinders.

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 36 points (Table 2.2.) puts the Toktogul dam in Risk Class IV, that is the highest risk category.

Table 2.2 Toktogul Dam – Risk Factor

		Points
Reservoir Capacity (Mm^3)	2,000	6
Dam Height (m)	215	6
Downstream Evacuation Requirements	>1000	12
Potential Damage Downstream	High	12
	TOTAL	36

Table 1.1 Toktogul Dam – Principal Dimensions

Reservoir	
Maximum Water Level (MWL)	904.2 masl
Full Storage Level (FSL)	900.0 masl
Lowest Drawdown Level (LDL)	837.0 masl
Reservoir Volume at FSL (after siltation)	19,500 Mm^3
Effective Volume	14,000 Mm^3
Dead Storage at LDL (after siltation)	5,500 Mm^3
Surface area at FSL	284.3 Km^2
Wave height at wind speed of 35 m/s	5.9 m

Dam	Concrete gravity
Crest Length	295 m
Crest Level	905.0 masl
Width at foundation	175
Height of Dam	215 m
Crest width	20m

Draw-Off Works	
Surface spillway (at MWL)	1,320 m^3/s
Deep spillway (at MWL)	2380 m^3/s
Turbines (at MWL)	760 m^3/s

3 DESIGN CONSIDERATIONS

3.1 Hydrology

The reservoir was constructed near the downstream end of the Naryn river in the Syrdarya river basin. The river basin is located among high mountain ranges, of which the northern group belongs to the Terskey-Alatau mountain system, and the southern group to the Kokshaltau mountain system. The height above sea level, either peripheral or internal, with small exception exceeds 4,000 m; some of the peaks are frequently above 4,500 m, the highest peak being 5,108 m. Despite the altitude, the large distribution of permanent snow and glaciation is not marked. Their small development is explained by the conditions of humidity of the territory and, most of all, by precipitation. The permanent snow line is at an altitude of 3,800 - 4,300 m. The total number of glaciers is 750; the total glaciation area is about 1,000 km^2.

The river is fed by glacier-snow .lacier alimentation.

At the Toktogul reservoir site (the gauge 0.9 kms downstream from the mouth of the Karasu left), the catchment area is 53,660 km^2, length 435 km. The normal stream flow at the site is 383 m^3/s, the runoff rate m = 7.34 l/s per km and the runoff depth 232 mm. A runoff of 50% available water supply at Cv = 0.16, Cs = 2 Cv is 379 m^3/s, or 1,1960 Mm^3. The runoff in the flood period (May - August) makes up to 70 % of the annual runoff.

Average date started of the high water -	March 21
Average date of passage of peak -	June 17
Average date finished of the high water -	October 4
Average duration of high water -	198 days
Total depth of runoff for high water -	182 mm
Observed maximum discharge is	2,990 m^3/s - May 21, 1966
Designed maximum discharges with the guaranteed correction are:	
0.01% of available water supply	5,570 m^3/s
0.1 % of available water supply	3,804 m^3/s
1 % of available water supply	2,940 m^3/s
5 % of available water supply	2,420 m^3/s
10 % of available water supply	2,180 m^3/s
Summer monthly mean minimal discharge is	335 m^3/s
winter	68 m^3/s
and daily minimum -	43 m^3/s
Mass runoff of sediments for a long-term period	15,840,000 t
at unit weight of 1.25 t/m^3	12,672,000 m^3
Possible estimated silting for the period of operation is	200 Mm^3

According to information from the chief of the enterprise of the Toktogul hydroelectric stations cascade, the maximal discharge of 0.1 % of available water supply is passed downstream with a discharge of 3,510 m^3/s, and for 0.01 % of available water supply is 4,550 m^3/s .

3.2 Geology and Seismicity

Toktogul dam is located in the Naryn river canyon between Chatkal and Fergana mountain ranges. Ketmen-Tubinskaya basin , 20 km upstream of the site, forms a bed of the reservoir.

Bed rock at the dam foundation and its abutments is highly non-uniform. The basic rock is represented by carboniferious marblezied limestone, which layers cross the valley almost sideways and dip in the upstream direction at an angle of 70-75°. The rocks of the site are broken by numerous tectonic fractures with width from 1 cm up to 15 cm.

Seismic Intensity of the site is IX.

3.3 Construction Materials and Properties

The dam is constructed from reinforced concrete that met necessary density and strength requirements.

3.4 Seepage Control Measures

To reduce seepage beneath the dam a grout curtain and consolidation grouting were constructed at the dam foundation.

In 1998 the operation personnel executed the works on inundation reducing in the galleries of the second stage with seepage water removing to downstream by drainage.

3.5 Reservoir Draw-off Works

The reservoir operating regime provides:

- The weir structures forming reservoir safety, and also safety of the population and facilities of surrounding zone of reservoir and downstream in the river valley;
- Water supply of the users, taken into the list of water economy balance of Syrdarya river.

Toktogul reservoir operating regime should correspond to the dispatching diagram, which is made in view of mode of operations Kayrakkum, Chardara, Charvak and Andizhan reservoirs.

3.6 Performance Monitoring Instrumentation

The established instrumentation allows to carry out the control of deformations of the dam and its foundation , seepage at the foundation of the dam and through the upstream slope, performance of the dam under static loadings, of the temperature regime, of reinforcement stress, of local deformations, and also the control of deformations of concrete – rock contact, precipitation and horizontal offsets of the hydropower station building and of the dam (Figure 6).

During exploitation period of Toktogul hydropower station many instruments have become out of operation, so for example piezometers - 40 % from design amount, geodetic instrumentation - 23 %, remote instrumentation - 28%. The total percentage of instrumentation that is out of order is 33 %.

3.7 Hydropower Facilities

Toktogul hydropower dam is the main dam (of Nigene-Narynsk) of Toktogul hydropower cascade, which includes Toktogul, Kurpsay, Tashkumir, Shamaldisay and Uch-Kurgan hydroelectric stations. The hydropower dam installed capacity is 1200 MW.

The basic parameters of the Toktogul hydropower station are the following:

Heads:	maximal -	183 m
	minimal -	110 m
	designed -	140 m
Discharge:	annual average of the river -	360 m^3/s
	maximal of hydropower station	960 m^3/s
	minimal of hydropower station	190 m^3/s
	designed of hydropower station	924 m^3/s

For power generation demands is allowed to perform daily water regulation in volume guaranteed monthly average power spill (80 m^3/s). Uninterrupted sanitary spill at a rate of 100 m^3/s downstream of Toktogul reservoir is guaranteed.

The distribution of the electric power is carried out at a voltage of 500 kV by four high-voltage cables of length 1200 m up to item of transition and further by two air transitions to distributive substation located at distance 3 kms in lateral canyon.

The electric power is transferred energy by two VL - 500 kV lines, departing in northern and southern directions.

4 DAM CONDITION AND PERFORMANCE

4.1 Comments Arising out of Inspection

The IC, in company with representatives from the Kyrgyz National Team and Engineers from the site visited the dam on 6 October 1999. Areas inspected included the crest of the dam and the downstream toe. The reservoir level at the time was 888.5 masl.

During the inspection of Toktogul dam there were found the following:

- The engineering-seismological observation was not carried out

- The condition of the instrumentation was unsatisfactory (33 % of devices failed, the cable communications became unfit for use, there was no communication cable to the central control consol, there were not many geodetic devices, in particular coordinatemeter, geodetic-distance meters and others).

- Devices for taking measurements by remote instrumentation (generator - frequencymeter ЦС -5м, vibrating wire readout ЧСД -4, portable periodmeter ПЦП -1) are worn out.

- Because of absence of computer facilities, the data processing of full-scale observation is out of date and not at a required level.

- In general the condition of the hydromechanical and electrotechnical equipment was satisfactory. In connection with high degree service life of the equipment, it is getting wear and tear, and that requires the presence at the station of a necessary complete set of spare parts and materials.

- It is disadvantage to have long time of lowering the emergency gates, which provide power conduits closing in the occasion of incident with power units. It is necessary to increase diameter of feeding oil pipeline of hydrocylinders from 40 mm up to 60 - 65 mm.

- The pump station allows to execute the given modernization.

- In extreme situations, for example in case of flood conditions it is necessary to have water draw down in the Toktogul hydroelectric station cascade. In such cases there is a fulfilled mechanism for prevention of a emergency. There are four Kyrgyzgidromet gauges, Uch-terk, Usta-say, Torkent and Chichkan, close to Toktogul Reservoir. Mutual relations between the managements of the joint-stock company Kyrgyzenergo and Kyrgyzgidromet, is carried out on the basis of long term contract on information delivering (inflow, precipitation, etc.). Personnel of Kyrgyzgidromet provide flood forecasts and on the basis of the forecasts is carrying out the operation regime of the reservoir.

- So, for example, according to a forecast extremely high water was expected in June-July 1994, and there was carried out pre-flood water draw down started from February. Thanks to the pre-flood draw down there was no extreme situation at the reservoir. There is hydraulic engineering service at Toktogul dams cascade, that is engaged on question of optimazation and forecasting of the flood phenomena, and which also supervises the maintenance regime of Toktogul reservoir and all over the cascade in extreme situations.

- Taking into account the present economic situation, the meteorological data is not supplied in full. The control and preliminary data processing is carried out by qualified personnel of the Labarotory of Full-Scale Observation of the Toktogul Dams cascade. On the basis of the data obtained it is drawn up report on results of full-scale observation of hydraulic structures.

- Also, once in every five years, the commission of the representatives of the specialized organisations performs a complete inspection of the condition of the hydraulic engineering structures of Toktogul reservoir and gives an assessment of its safety. The certificates of inspection are kept in Joint Stock Company Kyrgyzenergo and in the archive of Toktogul dams cascade in Kara-Kol town of Djalal-Abad oblast. According to the Order of joint-stock company Kyrgyzenergo, measures to increase the reliability of the hydraulic engineering structures are planned annually. There is a list of measures executed in 1998 (as applied).

4.2 Assessment of Performance Monitoring Results

General condition of the dam satisfies safety and operational criteria. The dam is in a satisfactory condition. Some increase in tensile stress that was registered on instruments is related to temperature change in concrete stress and it does not represent any risk to the structure. The grout curtain, contact grouting works and drainage works underneath the dam and the abutments provide effective reduction in hydrostatic pressure when the reservoir is full.

Settlements of the dam have stabilised and are generally lower than predicted. A slight increase in settlement due to weight of the dam itself relative to the predicted settlements, have been noticed when the reservoir is full. This is related to the changes in the bedrock at the upstream foundation; at the downstream part of the dam uplift of the foundation has been noticed. Horizontal deformation of the dam is towards downstream and is 0.01%. Open joints in the dam do not show any movements; movements of the joints have stopped after the grouting.

To increase control of Toktogul dam safety it is recommended to carry out the following:

- To develop and to establish at the dam an automated system of seismometric observation for accelerations, linear and angular velocity measurements at control points, and recording it in digital form to a computer.

- Update devices for taking measurements by remote instrumentation (generator - frequencymeter ЦС -5м, vibrating wire readout ЧСД -4, portable periodmeter ПЦП -1) as they are worn out.

- To equip full-scale observation group with deficit geodetic devices (co-ordinatemeter Prozision-mechanik, geodetic-distance meters БЛК 2, Hi-Fi levels and theodolites).

- To repair instrumentation cable networks, to establish communication cable to the central control consol of the instrumentation room.

- Modernize processing of full-scale observation data using computers.

4.3 Dam Safety Incidents

It was found out during conversation with the management of Toktogul hydroelectric station, that there have not been any failures at the dam for the period of its operation.

4.4 Maintenance Procedures and Standards

Maintenance Rules of Toktogul dam were prepared based on "Terms of Reference of the Ministry of Water Economy of the USSR" dated 18 February 1988 in accordance with "Typical Maintenance Rules of Reservoirs of Capacity 10 Mm^3 and More" РД 33-3.2.08.08-87, Moscow, USSR, and with "Rules on Water Resources Utilization of Reservoirs in the USSR" Publishing House Moscow, 1972, and on the basis of the "Specified Scheme of Complex Utilization and Protection of Water Resources of Syrdarya river basin", and also "Toktogul Hydroelectric Station Project Report", Publishing House of Tashkent, Uzbek SSR.

"Maintenance Rules of Toktogul Reservoir" were prepared by "Sredazgiprovodhlopok" in 1988, Publishing House of Tashkent Uzbek SSR.

4.5 Existing Early Warning & Emergency Procedures

An early warning system for early notification of an emergency to the population of the nearby area is present, but it does not comply with international norms and standards.

In extreme situations (at failure), there is searching loud speaker communication, automated telephone communication with the switchboard, and also channels of external communication, which help local power bodies warn the population about an emergency in the reservoir downstream area.

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 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.

The material made available for study in respect of the Toktogul dam has been very limited, but the following conclusions are drawn regarding its safety. It is understood that inspections are carried out and instrumentation results analysed but no reports were seen.

5.2 Structural Safety

The Toktogul dam is a high dam which ranks well up on the list of the world's highest dams, and its design would have involved many of the USSR's leading dam engineers and specialists. It is certain that a very large number of documents exist describing the studies carried out for the investigations and design of the dam but none has been seen by the IC, and in any case the time available for the present study would not have allowed anything but a very superficial examination of such documents. The dam has performed satisfactorily since it was commissioned in 1975 and has successfully withstood a nearby major earthquake. All instrument readings are reported to be within their design limits and the IC's brief examination of the dam did not show any obvious signs of structural deterioration.

The IC conclude that the Toktogul dam is structurally sound and can continue to be operated at reservoir levels up to the full storage level of 900.00 masl.

5.3 Safety against Floods

5.3.1 Discussion on the exceedance probability of design hydrographs

The aim of this Section is to discuss the conservatism involved during derivation of design hydrographs in accordance with SNIP and how do these hydrographs compare with PMF. No account is taken of the effect of other reservoirs upstream.

Toktogul outlet structures were designed using 0.1% exceedance probability hydrograph and checked against 0.01% hydrograph. The design flood hydrograph is routed through the dedicated 0.8 km^3 flood storage which is located between 900.0 masl and 904.2 masl.

The design hydrographs are determined by means of a statistical analysis of historical records. A theoretical curve, based on a 3-parameter gamma distribution, is fitted to maximum annual peak discharge values and design peak discharges for various exceedance probabilities are determined. The 0.01% discharge value is subject to a correction, which is approximately 20% higher than the original value. The correction brings the exceedance probability of the obtained value to approximately 0.005% or 1 in 20,000 years.

The volume of the hydrograph is also defined by means of a frequency analysis of the annual maxima series. The coincidence of all historical peaks and maximum flood volumes would result in the two variables (peak discharge and flood volume) to be totally dependent, with the exceedance probability of the combined hydrograph equal to the exceedance probability of the peak discharge value. However, the ranked historical peak discharge values do not necessarily coincide with the ranked maximum volumes. In other words these two variables are partially dependent, resulting in a hydrograph with exceedance probability lower than the exceedance probability of the peak discharge.

During the practical fitting of the theoretical frequency curve, a coefficient of asymmetry Cs is calculated from the recorded series of annual maxima. This coefficient is then used to fit an appropriate curve. The higher the coefficient, the more skewed is the theoretical curve, resulting in higher discharge values for low probabilities of exceedance. This practice introduced an additional conservatism into the derivation of the design discharge values, which results in some overestimation of the design discharge value.

The above three factors result in the design discharge hydrograph having an exceedance probability significantly lower than 0.01% (1 in 10,000 years). It is expected that the resulting exceedance probability of the design hydrograph would be in the range of 0.001% or 1 in 100,000 years. Further investigations into this matter are required to support this statement. If the results confirm the above statement it can be concluded that the conservatism introduced during the design calculations results in the outlet structures of the dams to have been designed for a 1 in 100,000 years event instead of 1 in 10,000 years event, which in general approaches the exceedance probability of a PMF event.

The Uzbekistan “Gidro-Met” (Bureau of Meteorology) provides forecasts of expected streamflows at the beginning of the wet season (early spring). The forecast is based on the snow deposits in the catchments of particular rivers. The Bureau of Meteorology of Uzbekistan is currently developing a methodology for estimation of snow extent and water equivalent using satellite images. Based on the forecast, the central authority, which regulates the dam operation, issues a request for the initial level in the reservoir prior to the beginning of the melting season. In the cases of extremely wet years the requested initial level can be lower than the FSL. This procedure might introduce an additional storage available for flood routing, increasing the dam safety during extreme floods.

5.3.2 Factors which reduce the dam safety during floods

There are several factors that affect the performance of the Toktogul dam during large flood events. The following factors have been identified during the assessment:

1. Estimates of extreme floods used for design of outlet structures are based on statistical available records. Analysis of longer records following the dam construction resulted in the 0.01% exceedance probability peak discharge with correction to change from 4,970 m^3/s to 5,570 m^3/s. In order to make meaningful extrapolation of events with exceedance probability of 0.1% the extrapolation would have to be based on regionalized parameters with records in excess of 100 years. As this is not the case, the extrapolation beyond 0.1% exceedance probability must be considered to be beyond the credible limit. In order to establish the exact relation between the 0.01% exceedance probability discharge hydrographs developed in accordance with SNIP and the extreme flood hydrographs based on PMF estimates a PMF study must be undertaken for this site.

2. The design of the dam is based on a release of water during extreme flood events through a combination of the low level sluices (2,380 m^3/s), emergency (gated) spillway (1,320 m^3/s) and turbines (570 m^3/s), totalling 4,270 m^3/s. The release through the turbines is based on an assumption that all turbines are operational, the power lines are capable of transferring the generated energy and that the demand centres are able to consume the generated power during the extreme flood event. In order to assess the safety of the dam during an extreme flood, it is normal to assume that the turbines will not be operational due to one of the factors mentioned above. In this case the maximum outlet capacity is thus 3,700 m^3/s, assuming that all radial gates on bottom and surface outlets are functional throughout the period of an extreme flood.

3. For the current situation, assuming that the 0.01% discharge hydrograph is representative of the PMF flood, the following reservoir levels would be achieved for different combinations of the outlet capacities:

Scenario Description	Max Reservoir Level, for initial reservoir level of 900 masl
Qbottom+Qsurface+Qturbine	900.5
Qb+Qs+Qt/2	900.9
Qb+Qs	901.4
Qb/2+Qs	908.9
Qb+Qs/2	904.3

It can be seen from the table that the only critical case is that where turbines are not operational and when only one radial gate on the bottom outlet is opened. In all other cases the water level is well below the maximum allowable level of 904.2 masl.

5.3.3 Conclusions and recommendations

It can be concluded in general that the adopted design procedure in accordance with SNIP provides a relatively conservative estimate of large floods. The exceedance probability of the design flood is lower than 0.01% and is expected to be nearer 0.001% or 1 in 100,000 years.

The assumption that the turbines will be operational during an extreme flood event is over-optimistic, so during a 0.01% flood event with turbines closed, the water level would still remain below the maximum allowable level. The most critical scenario with significant impact on the dam safety is when one of the bottom outlet gates is not operational. Otherwise, assuming that the 0.01% exceedance probability hydrograph is representative of a PMF event, the Toktogul dam can be considered as meeting normally accepted safety criteria for extreme floods.

It is recommended that:

- A PMF study be conducted, taking into account the combined effect of an extreme snow (glacier) melt and an extreme rainfall (PMP).
- The obtained PMF hydrograph be routed through the storage using the bottom outlet and the emergency spillway only, commencing at FSL. The maximum reservoir water levels should be identified and the dam stability for that level should be reviewed.
- Regular checks of the gates and the outlet tunnels must be conducted prior to the beginning of every wet season and if one of the bottom outlet gates is not operational then the reservoir level must be kept below 880.0 masl during spring and summer, until the radial gate is operational again.

5.4 Provision for Emergency Draw-down

Draw-down of the reservoir in case of emergency can be achieved using the spillway gates and/or the low level sluices.

The two 10 m wide spillway gates provide a discharge capacity of 900 m^3/s at full storage level, while the low level sluices if fully open would add a further 2300 m^3/s giving a total initial discharge potential of 3200 m^3/s. The reservoir area is 280 km^2 at full storage level, hence the maximum reservoir draw-down rate (excluding the use of the turbines) is initially 1 m/day, assuming no significant inflow to the reservoir.

The draw-down rate will remain sensibly constant at lower reservoir levels, hence in case of extreme emergency it would be possible to reduce the reservoir level by about 50 m to around 70% of its depth in about 2 months provided inflows are low, without the use of the turbines. This would reduce the load on the dam to 50% of its maximum which would normally be expected to be sufficient to avoid any structural catastrophe.

The effect of such emergency action on the valley downstream of the gorge would be serious, however, (particularly so in the area downstream of Uchkurgan dam) but could be mitigated if an effective emergency plan could be put into action rapidly.

It should be appreciated that a long period of rapid draw-down as well as being wasteful of water and damaging in other ways, could trigger landslips into the steep sides of the canyon, which could cause large waves on the reservoir.

5.5 Safety against Earthquakes

5.5.1 Dam Structure

The IC have not had opportunity to examine any documents related to the seismic design of the Toktogul dam. The method of analysis and materials parameters used and the resulting dynamic stresses are not known, but given that the dam is a massive structure in a narrow rock gorge the IC have no reason to question its overall stability under any loading condition.

It is reported that the structure withstood a large earthquake in 1992 with only minor cracking, but no information was available as to the actual magnitude of ground movements or whether accelerations were recorded by instruments mounted on the dam.

5.5.2 Ancillary Works

It is possible that the rather tall and massive crane gantry on the crest of the dam is more vulnerable to damage by earthquake shaking than the concrete structure itself. This could have important safety implications if the ability to operate the sluices or spillway gates was impaired.

5.6 Other Safety Matters

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

The low level access road to the dam is vulnerable to rockfalls due to rainfall, and possibly earthquakes. Measures are in hand to construct a rock trap below the principal area of instability immediately downstream and to the right of the dam which should assist in keeping the access road open.

Access to the crest of the dam is by way of a 3 km tunnel, and it was noted that a shelter had been constructed to protect the entrance from rockfalls or snow slides.

5.6.2 Security of electric power supply

The safety of the dam depends on the availability of the electric power to operate the crest gantry crane. Electricity is reported to be supplied by three independent power lines, although all of them traverse steep mountain terrain and appear to be vulnerable to damage. A standby generator at the dam is regarded as an essential safety precaution.

5.6.3 Crane Gantry

It is essential for the safety of the dam that the crane gantry should be available at all times to respond to the need to operate the various gates, and to be readily transferable between the two tracks on the dam crest. A detailed assessment of its condition or the availability of critical spare parts was not made, although it appears currently to be in good working order.

5.6.4 Stability of reservoir sides

The 1997 World Bank report raised the question of the possibility of large rock slides into the reservoir which might cause a wave sufficient to overtop the dam. The possibility is recognised by the site manager, but it is also recognised that to establish the risk would require a major study, although it would probably be impractical to carry out works to mitigate the risk if an unstable area was identified.

5.7 Safety Assessment - Summary

5.7.1 Principal matters of concern

The IC see following the principal matters of concern with regard to the safety of the Toktogul dam:

(1) Deterioration of the dam performance monitoring instrumentation, and the need for upgrading certain items, making provision for remote measurement where appropriate, and improving the speed and standard of presentation of the results. Absence of seizmographs on and around the dam.

The IC were informed that detailed proposals for upgrading the instrumentation system had been prepared, but these were not seen.

(2) Deteriorating condition of mechanical and electrical plant, and inadequate funds and shortage of skilled staff for maintenance.

(3) Absence of a coherent emergency plan and early warning system which could be put rapidly into operation in case of emergency as indicated by performance monitoring instrumentation or arising from natural causes (e.g. extreme floods), human error, equipment malfunction or unauthorised actions.

Guidance is also needed to assist the supervising staff in recognising when the monitoring process indicates that a dangerous situation is developing.

(4) Absence of reliable communications systems between individual senior staff, or with other installations on the cascade, independent of the public telephone system.

5.7.2 Safety statement

From examination of the dam and the data made available, and discussions with the engineers responsible for the dam the IC conclude that at present the Toktogul dam is in a safe condition and can continue to be operated at reservoir levels up the normal full storage level.

The principal dangers facing the dam as perceived by the IC are from:

(1) Floods

In the event of an extreme flood the situation can be controlled if the gates can be operated reliably, as appears to be the case at present. High discharges from the reservoir are minimised by regular flood forecasting and appropriate forward planning but it must be accepted that high discharges may be justified on rare occasions in the interests of dam safety. It is, however, essential that the reservoir management procedures give priority to ensuring the safety of the dam rather than to commercial considerations of maximising power generation.

The ability of the dam to control floods depends wholly on the hydromechanical plant and in particular the gantry crane. The present situation appears to be satisfactory but a high standard of future maintenance and availability of spare parts is essential if the ageing equipment is to be kept in 100% reliable order. Adequate standby power generation facilities are required.

(2) Deficiencies in performance monitoring capability

The ageing performance monitoring installation no longer allows the structural behaviour of the dam to be comprehensively monitored. This situation must be improved, but nevertheless, the IC regard the present risk of structural failure to be sufficiently low to be discounted.

6 RECOMMENDED STUDIES, WORKS AND SUPPLIES

6.1 General

The review of the design of the dam, along 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 and Inspections

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' record 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 carry out inspections or undertaking modifications in the future.

6.2.2 Surveys

(1) Topographic surveys – none recommended

(2) Reservoir bed (bathymetric) surveys

At some time in the not too distant future it will be advisable to carry out a reservoir bed survey to indicate the extent of sediment deposition.

6.2.3 Ground Investigations and Inspections

The following investigations and inspections are recommended:

(1) Investigations – none recommended

(2) Inspections

To provide information on which to base a more detailed assessment of requirements for repairs and equipment than is possible in the present report it is recommended that a detailed inspection of the dam and associated equipment be carried out. An inventory of defects, materials and repairs required should be prepared covering:

- concrete, steel and architectural works;
- hydromechanical equipment;
- crane gantry;
- electrical wiring and lighting;
- performance monitoring instrumentation and portable read-out equipment.

6.2.4 Engineering Studies

The following studies are recommended:

1) Review the estimates of extreme flood inflows to the reservoir, taking into account possible emergency situations or unauthorised actions at other major dams in the upstream catchment.

2) Review reservoir management procedures, giving first priority to ensuring the safety of the dam.

3) Review plans for future handling of reservoir sedimentation in the light of updated reservoir bed survey.

6.3 Construction Works

To ensure the continued safe operation of the dam the following works are recommended:

1) Reinstate and upgrade the dam performance monitoring instrumentation, and provide new portable read-out apparatus where applicable. Install seismographs in and around the dam. Upgrade means used for data storage, processing and analysis. More detailed recommendations of the instrumentation are given in Section 4.2 and Appendix C.
2) Carry out necessary repairs, electrical wiring renewals, etc., to the hydromechanical equipment (gates, crane, etc.) and provide adequate standby generating facilities.
3) Remedy any other significant defects identified during the inspection.

6.4 Equipment and Supplies

A preliminary assessment of equipment and supplies needed for the rehabilitation of the dam is as follows:

(1) Dam instrumentation (see Appendix C)

(2) Standby generator for crane gantry

(3) Early warning and communications equipment

6.5 Emergency Planning

Given the importance of the dam and the potentially damaging consequences for the downstream population of an emergency which results in the release of a large volume of stored water, it is essential that plans for dealing with such a situation are well prepared, and supported by an efficient organization, communications and alarm system.

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: Toktogul 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		☐		
• Hydromechanical equipment			☐	
• Miscellaneous repairs			☐	
5. Supplies (6.4)				
• Piezometers and deformation monitoring equipment		☐		
• Standby Generator		☐		
• 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 dam the IC conclude that the Toktogul dam is in a satisfactory state and, in terms of structural stability, may safely be impounded to the normal full storage level of 900.00 masl. However, it is essential to recognise that the reservoir impounded by the dam has immense strategic importance in terms of its command of the Naryn Cascade and the densely populated Fergana Valley, and that a component of provision for flood storage within the reservoir provides the security against flooding that these communities have become accustomed to, and have a right to expect. For this reason, reservoir management procedures must be formulated in a way that gives priority to control of flood releases, and not to other more commercial interests. It is suggested that, to avoid any possible conflict of interest, the power to authorise reservoir impoundment levels prior to the inflow of the annual flood should be vested in a flood safety commission, made up of technical experts, which is established independent of the management structure of the present operator of the dam. Such an arrangement would have the advantage of protecting the present operator from liability for maloperation of the dam in the event of releases generated by exceptional flood conditions.

Apart from the above, high priority should be given to the following activities:

- Inspecting and reinstating the performance monitoring system and upgrading the methods needed to process the data and present the results,
- Inspecting and carrying out such repairs as may be necessary on the hydromechanical plant, electric wiring and lighting, and crane gantry and providing a standby generator;
- Instituting a programme of formal inspections and reporting on the safety of the dam;
- Preparing a comprehensive emergency plan.

REFERENCES

1. ICOLD Bulletin 72, 1989

APPENDIX A

TOKTOGUL DAM

LIST OF DATA EXAMINED

Toktogul 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 (6)	120-1 (4)	1-0.1 (2)	<0.1 (0)
Height (m)	>45 (6)	45-30 (4)	30-15 (2)	<15 (0)
Evacuation requirements (No of persons)	>1000 (12)	1000-100 (8)	100-1 (4)	None (0)
Potential downstream Damage	High (12)	Moderate (8)	Low (4)	None (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

TOKTOGUL DAM INSTRUMENTATION

REPORT BY SPECIALIST MR V.N. PULYAVIN

October 1999

DRAWINGS

Inspection of instrumentation condition and dam structures observations
Toktogul water reservoir

Supervision for seepage regime of the dam, settlement and offset of the power station house and of the dam, also for reinforcement and concrete stresses and temperature regime, joints disclosing and cracks, strains at concrete-rock contact joints, are carried out at the process of Toktogul dam safety control.

Besides, for tasks solution that related with affect of seismicity loads to the structure,
the dam should be equipped with seismicity observation posts, head wall pressure sensors and dynamic tensometers, that work in waiting mode
Number of instrumentation, either it was provided by the design or for actual situation, is given below in the table.

Observations	Instrumentation	Designed number of instrumentation	Installed (no)	In operation (no)
The dam strains and its footing by geodetic methods	geodetic marks inverted plumb bob plumb bobs basemeters string control sections three mark unit at deformation joints	323 4 22 702 1 36	248 20 395 1 36	214 4 14 395 1 36
The dam offset observation	3-axis slotmeters at deformation joints	82	5	5
Seepage regime observation at the dam footing and the downstream slope	piezometers measuring weirs	220 10	216 10	179 10
Observation of the dam strains condition from static loads	wire longitudinal deformations transducer (ПЛДС-300,400)	184	184	136
temperature regime observation	Temperature vibrating wire (ПТС-60)	395	389	329
Joint disclosing observation	Wire longitudinal offset transducer (ПЛПС-3,6)	213	192	157
Reinforcement strain observation	wire reinforcement transducer of force (ПСАС-28,40)	16	8	4

Local deformations observation	vibrating wire (ПЛДС-2000, 5000)	127	118	60
Observation of impact pressure to the dam at a seismic activity	pressure measuring element (ДД-10)	40	41	_
Potentially unstable bodies observation	multipoint leveling system deformograph bench mark	20 8 _	20 8 31	20 _ 31
Seismic activity observation	engineering seismology points seismic station (of an extremely destroying earthquake) including: С5С ВБП ОСП АТП	28 9 27 18 84 9	9 1 15 _ _ _	1 _ 15 _ _ _
Upstream and downstream water levels, and trash fall observation	level measuring element (ДУ-10, ДУ-20, ДРП)	42	42	_

As it is shown from the table given, there were out of operation significant quantity of the instrumentation including (in % of the design/exissting):

- geodetic marks -34 / 14 %;
- 3-axis extensometers - 94 / 0 %
- piezometers - 19 / 17 %
- transducers to measure concrete deformations converted into tensions -26/0 %
- transducers for measurements of joints disclosing -26 /18 %
- transducers for local deformations measurement - 53 / 49 %
- water pressure sensors for measurements of pore pressures of seismic activity - 100/100 %
- seismoreceivers - 90%

By hydraulic engineering service of joint-stock company «Kirgizenergo» the instrumentation failure during the period of operation is characterized by the following parameters:

piezometers network - 40 %
geodetic instrumentation - 23 %
remote instrumentation - 28 %

To define whether it is enough working instrumentation for determining of the dam safety, is possible only after the analysis of an arrangement of wire transducers and other measuring elements, and installations, and designed stressed-deformed condition of the dam . In particular, it concerns with tensiometer installed to measure concrete deformations and then convert them to tensions.

While such assessment is not executed it is necessary to ascertain, that the working instrumentation does not allow to provide the dam safety control at required level.
It was submitted the1998 report on full-scale observation for acquaintance with the data on a condition of the dam, received during observation. There was no information on local deformations, no data on behaviour of unstable slopes and concrete stresses in the report given. Up to 1999 the observation were carried out once per one quarter, in 1999 - once per two months.

The assessment of condition of the dam at the object is carried out by comparison of limiting properties of controlled parameters with actual one, received during performance of full-scale observation.

The limiting properties were established for the following parameters:

1. Maximal vertical displacement of the footing of the dam (settlement) - 30 mm
2. Difference of settlements between the Hydroelectric station and the dam - 4mm
3. Horizontal displacement of a point at the 5m depth relatively to the same point (32m) - 3 mm
4. Maximal disclosure of deformation joints from right and left banks side - 15mm
5. Flexure of crest section relatively to the point in the foundation 32 m below the footing – 12 mm
6. Horizontal displacement of the footing relatively to the same point – 5 mm
7. Horizontal displacement of the dam and the footing - 9mm
8. Maximal seepage discharge at scope of underground contour of the right bank – 50 l/sec
9. Maximal seepage discharge at scope of the dam levels and at underground contour of the left bank –250 l/sec
10. Maximal seepage discharge at low elevations of central part of the dam - 1.25m3/c
11. Residual head behind grouting curtain (H- head at corresponded elevation) – 0,2H
12.

In 1998r the actual value of parameters controlled have not exceeded limiting parameters.

Data of previous years observation showed, that actual settlements of the dam were less than designed one, degree of inclination to downstream side at filling of the reservoir reached 0,01% and in future did not increase. Local deformations at zone near to footing (H=20 m), that caused by concrete weight impact, were down in the range $1.2*10^{-4}$. Maximal displacement of the dam footing in direction of tale head was 2.4 mm. Seepage discharge at highest reached upstream water level was about 300 l/sec. Grouting curtain rather effectively close zones of increased permeability. Seepage head effective reducing with gradients in the range from 1 to 4,5 took place behind downstream drainage. Intersection joints were disclosed, and maximal disclosing for the right bank sections it was 1,45 mm, and the same for the left bank sections was 0,55 mm. Grouting for this sections did not performed. Stresses at the dam footing under hydrostatic pressure and of its weight did not exceed designed values. And at the same time tensile stresses caused by temperature changes (from +1,3 down to +0,4 MPa) exceeded designed (from +1,3 down to –1,1 MPa)

To carry out safety control of Toktogul hydroelectric station it is recommended first of all, to execute following:

1.	Piezometers installation	40
2.	Drainage wells cleaning	
3.	Manometers purchasing	70

4. Installation of elevator of hight 8
5. Geodetic marks installation 31
6. Slotmeter marks installation 102
7. 3-axis slotmeters installation 82
8. Electric level meter purchasing 6
9. To develop and to establish on a dam the automated seismic observation system for measurements of acceleration, linear and angular speeds of control points with recording them in digital form into a computer. Cost of one station for 4 canal that made in USA would be $10 000. Cost of seismometric set for 50 seismic canals, that would be made in Uzbekistan, would be about 3-4 thousand of dollars (without computers)
10. To get secondary devices for performance of measurements by remote instrumentation (generator - frequencymeter ЦС-5м, vibrating wire readout ЧСД-4, portable periodmeter ПЦП-1). The specified devices were made in Moscow, cost of one device was about $250-300.
11. Cable communications of remote instrumentation should be repaired, it is necessary to install the cable from the remote instrumentation transducers to central concole at specially provided for this purpose house.
12. To equip full-scale observation group with deficit geodetic devices including coordinatemeter «Pzozisions-mechanik».
13. Purchase personal computer «Pentium-200», printer and other equipment.for data processing and storing full-scale observation data.

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