PN-ACB-706

FINAL

REPUBLIC OF GEORGIA

HYDROPOWER REHABILITATION STUDY

PREPARED UNDER THE DIRECTION OF

BURNS AND ROE ENTERPRISES

PREPARED FOR AND FUNDED BY

UNITED STATES AGENCY

FOR

INTERNATIONAL DEVELOPMENT

by

HARZA
Engineering Company

JUNE 1996

PN-ACB-706

BURNS AND ROE ENTERPRISES, INC.

FINAL

FEASIBILITY REPORT for DELIVERY ORDER No. 15
World Bank Loan to Georgia
Hydropower Plant Rehabilitation Program

GEORGIA

December 1996

Prepared by:	**HARZA**
Submitted to:	**U.S. Agency for International Development**
Contract No.:	**CCN-0002-Q-00-3154-00** **Energy Efficiency and Market Reform Project** **Delivery Order No. 15,** **Hydropower Plant Rehabilitation Program**

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December 24, 1996

Mr. Iqbal M. Chaudhry
U.S. Agency for International Development
320 21st Street N.W., Rm 4440 NS
Washington, D.C. 20523

Subject: **Georgia - Delivery Order #15**
World Bank Feasibility Report
Hydropower Rehabilitation Study

Dear Mr. Chaudhry:

This letter transmits the "Final" report for the rehabilitation of the Hydropower Rehabilitation. This report was prepared by Harza Engineering Company. Work began in March of 1995. The rehabilitation needed for the Lajanuri, Khrami II, Tkibuli and Vartskhe Hydroelectric Projects has been considered in detail. Two other hydropower stations were considered but dropped during the conceptual design phase of this work. A draft report was reviewed during the April 1996 World Bank mission to Georgia. The comments made at that time by the World Bank and Sakenergo have been addressed. This report addressed the technical, financial and environmental aspects of the hydropower rehabilitation. Since it was decided in August 1996, by Sakenergo, that all funds should be spent on rehabilitation of the Tbilisi Thermal Electric Power Station, no further review of this report has been made.

Delivery Order No. 15 is complete. The delivery order completion dated was August 30, 1996. If there are any questions, please call me at (202) 408-6831, x14.

Sincerely,

Douglas D. Tuckhorn

Douglas D. Tuckhorn
Project Director-Caucasus

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EXECUTIVE SUMMARY

Introduction

Over the past several years, the supply of electricity in the Republic of Georgia has substantially declined due to reductions of energy imports and available generating capacity. Civil unrest, lack of spare parts, equipment failures and design problems, and the age of most of the power generation facilities in the country have resulted in less than 20 percent availability of installed capacity. As a result, the consumption of electricity is entirely supply-constrained at present, and power rationing -- whereby power is discontinued in selected areas for several hours or more each day -- is a routine occurrence.

The rehabilitation, restoration, and maintenance of existing generating capacity have thus been established as key objectives of both short and long term strategies in the energy sector. Over 60 percent of this capacity -- almost 2,900 MW -- resides in 54 hydroelectric power stations owned and operated by SAKENERGO, the state electricity enterprise. Of these, four projects have been identified by the World Bank for potential rehabilitation. These projects were initially listed in a study of potential hydropower rehabilitation projects sponsored by the European Union's TACIS Programme (Technical Assistance to the Commonwealth of Independent States). The selected projects are:

The Lajanuri Hydroelectric Project - Lajanuri, located in western Georgia, was commissioned in 1960 and has an installed capacity of 111 MW and a maximum reservoir capacity of 25 million cubic meters. The station houses three 37 MW Francis units.

The Khrami II Hydroelectric Project - Khrami II, located in eastern Georgia, was commissioned in 1962 and has an installed capacity of 110 MW. The flows to Khrami II originate from Khrami I which has a total active storage capacity of 312 million cubic meters. The station houses two 55 MW Francis units.

The Tkibuli Hydroelectric Project - Tkibuli, located in western Georgia, was commissioned in 1956 and has an installed capacity of 80 MW and a total active storage capacity of 80 million cubic meters. The station houses four 20 MW Francis units.

The Vartsikhe Hydroelectric Project - Vartsikhe, located in western Georgia, consists of four identical power stations located on a common power canal. Vartsikhe I was commissioned in 1976; Vartsikhe II was commissioned in 1978; Vartsikhe III was commissioned in 1980; and Vartsikhe IV was commissioned in 1988. Each of the four stations have a total installed capacity of 46 MW. Each station houses two 23 MW Kaplan units. The storage reservoir upstream of Vartsikhe I has a total storage volume of 15 million cubic meters.

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Site visits were performed to assess the existing condition of these facilities, collect relevant information and data, and formulate short term and long term rehabilitation programs for each project. Short term rehabilitation programs were conceived to enable the generation and delivery of maximum energy to the power system at least cost for the immediate future, which was defined as the next 3-5 years. Only the most critical elements of equipment repair or replacement and civil rehabilitation were included in these alternatives. The primary objective in the formulation of long term rehabilitation programs was to extend the life of the plants and enable their reliable operation for another 10-25 years. Major equipment replacements and refurbishments are identified for the long term.

Detailed cost estimates were prepared for each of the rehabilitation programs formulated for the projects, and one of four methods of procurement -- international competitive bidding, international shopping, direct contracting, and local competitive bidding -- were indicated for each of the mechanical, electrical, and civil rehabilitation items identified.

Benefits were estimated in terms of average annual incremental energy production resulting from the rehabilitation program, as compared to continuing under current programs (the Base Case alternative). Energy production estimates were derived from available hydrological and project operation parameters, and the incremental energy resulting from rehabilitation was derived primarily from improvements in maximum allowable production capacity, average plant/unit availability, and average overall generating efficiency.

Economic analyses were performed for each of the rehabilitation programs, based on five-year benefit and cost streams for short term rehabilitation, and 25-year streams for long term rehabilitation. The economic parameters derived from the analyses -- Net Present Value, Benefit-Cost Ratio, and Economic Internal Rate of Return (EIRR) -- provide indications of the economic attractiveness of a given rehabilitation program. The EIRR was used to establish a project ranking index which, along with considerations of total rehabilitation costs, average annual incremental energy production, and risk reduction and safety, were used to establish investment priorities for total investment amounts varying from $10 to $34 million.

General Assessment of Projects

The projects, except for Vartsikhe, are relatively old and utilize the original equipment without any major rehabilitation. At all of the power stations, operations and maintenance staff are having to devote considerable attention to the service and maintenance of shaft seals, turbine guide bearings, wicket gates, hydraulic power units, generators (stator coil replacements), circuit breakers and switchgear, and motors (replacement of burnt out motors). The frequency of and necessity for maintenance is increased by a lack of lubricating oil. Equipment cleaning (stator windings) and inspections are lacking. The powerhouse interiors, with the exception of Lajanuri, present a drab,

unpainted, and uncared for appearance, and there is a need for significant improvement in house-keeping standards.

All of the stations have been subjected to long periods of operation at frequencies much different than the rated frequency of 50 hertz. The frequency range is approximately 37-53 hertz; however, most of the time the frequency of operation falls in the range of 43-47 hertz. There are periods of time when the frequency is greater than 50 hertz. Operation at reduced frequency results in the electrical equipment operating at above standard temperatures, causing failures of motors and stator coils.

Lajanuri Rehabilitation Plan

The Lajanuri Hydroelectric Project is generally in fair condition from an overall appearance and maintenance point of view. It was apparent from initial observations that the management of this plant had a strong commitment to maintenance in the past, and is making every effort to preserve this commitment in spite of the obvious lack of funding that would be required to support an ongoing maintenance program. The office building and power station were in fairly good condition considering the age of the plant. The plant was generally clean, painted and generally well lit.

From the perspective of the short term, the equipment is generally in fair condition with the exception of (1) Unit 2, which requires extensive generator repairs to bring the unit back on-line, and (2) certain key equipment items that are essentially at the end of their useful life or are in critical near term-condition. Mechanical rehabilitation related to the major equipment is primarily focused on upgrading the governors for the three units and providing a convenient method to maintain the lubricating oil systems to reduce wear of the rotating components. Electrical rehabilitation related to the major equipment is primarily focused on upgrades for Unit 2, regulators for all three units, and replacements of essential station support equipment. Also, for short term rehabilitation, there are a number of civil items to be addressed to ensure project safety, including monitoring of the arch dam, repair of the training wall at the diversion headworks, repair of the dam piers on the downstream side of the spillway, and inspection and repair of the gravity flow tunnel.

For long term rehabilitation, there is considerable need for mechanical and electrical rehabilitation and equipment replacements to extend the useful life of the project.

The estimated short term and long term rehabilitation costs for the Lajanuri Project are $4,500,000 and $11,690,000, respectively.

Khrami II Rehabilitation Plan

The Khrami II Hydroelectric Project is relatively old (the initial year of operation was 1962) and has long required excessive maintenance of major equipment components to keep it in operation. Additionally, the quality of the finish work both inside and outside the plant is poor.

Mechanical rehabilitation related to the major equipment in the short term is primarily focused on upgrading the turbine wicket gates and seals for the two units, and providing a convenient method of maintaining the lubricating oil systems to reduce wear of the rotating components. Short term electrical rehabilitation is primarily focused on upgrades for the generator circuit breakers and generator bearings, and replacements of essential station support equipment, including the station service switchgear and reactors. No major civil work is recommended for the short term.

For long term rehabilitation, there is considerable need for mechanical and electrical rehabilitation and equipment replacements to extend the useful life of the project.

The estimated short term and long term rehabilitation costs for the Khrami II Project are $4,980,000 and $10,580,000, respectively.

Tkibuli Rehabilitation Plan

The Tkibuli Hydroelectric Project is generally in fair condition from an appearances and civil works perspective, but it requires considerable mechanical and electrical rehabilitation to extend its useful life. Civil rehabilitation requirements are not extensive, comprised primarily in the short term of repairs to the powerhouse roof, repairs to the power tunnel lining, and the provision of 10.5 kV uninterruptable service directly from the powerhouse to the intake.

For all four units, problems with vibration are experienced at unit generating capacities greater than 15 MW due to excessive bearing clearances, variations in wicket gate openings, and bottom ring surfaces and runner inlet surfaces that are not flush. Adjustments to guide bearing clearances, wicket gate settings, and runner settings are currently carried out at three-month intervals to mitigate these problems. The original thrust bearing pads are also worn out.

Short term rehabilitation will focus on upgrading the turbines, including bearings, wicket gates, and wearing rings; rehabilitating the four governors, and providing a convenient method to maintain the lubricating oil systems to reduce wear of the rotating components. In terms of electrical equipment, the effort will focus on upgrades of the generator stators and exciters.

For long term rehabilitation, there is considerable need for mechanical and electrical rehabilitation and equipment replacements to extend the useful life of the project.

The estimated short term and long term rehabilitation costs for the Tkibuli Project are $2,650,000 and $12,000,000, respectively.

Vartsikhe Rehabilitation Plan

In addition to electromechanical rehabilitation, Vartsikhe, compared to the other projects, requires major civil rehabilitation. This is because during the construction of the project, there was a "five-year plan" in effect which rushed the plants into production. To be on-line according to schedule, there was a significant amount of civil work which was (1) simply bypassed, (2) started but not completed, or (3) constructed, but in deviation from the design and drawings. Consequently, the selection of this project for rehabilitation will entail significant rehabilitation of certain critical civil works -- the diversion intake training wall, power canals and embankments, and emergency overflow spillways, particularly -- to ensure project and public safety, in addition to increasing the quantity and reliability of power production.

Mechanical rehabilitation related to the major equipment is primarily focused on upgrading the station auxiliary equipment rather than the turbines, with the exception of new turbine blades for Unit 5 and the provision of a convenient method to maintain the lubricating oil systems to reduce wear of the rotating components. Electrical rehabilitation related to the major equipment is primarily focused on upgrades for the Unit 6 generator and spare parts for ongoing generator maintenance. Also, major civil work is required for the short term to improve the safety of this project and to reduce the probability of a catastrophic failure.

For long term rehabilitation, there is considerable need for mechanical and electrical rehabilitation and equipment replacements to extend the useful life of the project.

The estimated short term and long term rehabilitation costs for the Vartsikhe Project are $14,590,000 and $53,730,000, respectively.

Environmental Impact Statement

The rehabilitation work proposed at the four hydroelectric stations will have little or no impact on the environment. The rehabilitation work to be performed inside the stations primarily consists of replacing equipment components rather than reconstruction work. During the rehabilitation work, care will need to be taken to prevent spillage of oil, to ensure the proper handling of contaminated wastewater within the powerhouses to prevent discharges to the project waters, and to ensure the proper handling of all waste materials. The rehabilitation work to be performed outside the stations is generally minor at Lajanuri, Khrami II, and Tkibuli, and no environmental impact is anticipated during construction. At Khrami II and Tkibuli, care will need to be taken in the substation area during the replacement of the oil-filled transformers. Proper handling of this insulating oil at the site

and between the site and the disposal area is extremely important to prevent contamination. However, a significant environmental impact could occur at both Khrami II and Tkibuli if the existing transformers are not replaced. These transformers have reached the end of their useful lives and are susceptible to oil leakage from a tank rupture or possible explosion. This concern is heightened at Khrami II because these transformers are being operated in an overloaded condition on a regular basis. At Vartsikhe, care must be exercised during the civil rehabilitation work in the power canal and drainage canal. The rehabilitation work must be performed in a manner which will minimize the deposition of construction debris in the project waters and adjacent canals.

Economic Analysis and Project Prioritization

An economic analysis was performed to assess the general viability of the scenarios and prioritize their implementation. Viability was assessed in terms of Economic Internal Rate of Return (EIRR) and other economic parameters, computed on the basis of incremental energy production benefits and investment and operation and maintenance (O&M) costs over the periods of analysis.

The results of the economic analyses are provided in Table ES-1. The results were based on the provision by SAKENERGO of hydroelectric O&M costs of 0.2 ¢/kWh and an energy value of 3.4 ¢/kWh -- the least cost to produce electricity by thermal generation. A discount rate of 10 percent was employed to compute present value costs and benefits.

Table ES-1

ECONOMIC ANALYSES OF GEORGIA HYDRO REHAB. ALTERNATIVES

Project Name	Investment Cost ($ million)	Average Annual Incremen-tal Energy Production (GWh)	Risk Reduction Benefit (GWh)	Total Energy Production Benefit (GWh)	NPV ($ million)	Present Value Benefit/ Cost	EIRR	**Ranking Index**
Short Term Rehabilitation								
Lajanuri	4.50	61	-	61	2.9	1.6	33%	0.7
Khrami II	4.98	24	-	24	-2.1	0.6	-9%	-0.2
Tkibuli	2.65	13	-	13	-1.1	0.6	-8%	-0.2
Vartsikhe	14.59	111	153	264	17.5	2.1	50%	1.0
Long Term Rehabilitation								
Lajanuri	11.69	162	-	162	35.4	3.4	44%	1.0
Khrami II	10.58	116	-	116	23.1	2.8	35%	0.8
Tkibuli	12.00	61	-	61	5.8	1.4	16%	0.4
Vartsikhe	53.73	259	153	412	65.9	2.1	24%	0.5
Short Term with Delayed Long Term Rehabilitation								
Lajanuri	16.19	61 - 162	-	61 - 162	23.0	2.7	38%	1.0
Khrami II	15.56	24 - 116	-	24 - 116	10.9	1.8	21%	0.6
Tkibuli	14.65	13 - 61	-	13 - 61	1.9	1.2	13%	0.3
Vartsikhe	68.32	111 - 259	153	264 - 412	53.8	2.0	36%	0.9

On the basis of the economic analyses, along with considerations of total rehabilitation costs, incremental energy production, and risk reduction and safety (for Vartsikhe), priorities were established for total allocations of investment ranging from approximately $10 to $34 million, as shown in Table ES-2.

Table ES-2

INVESTMENT PRIORITIZATIONS
GEORGIA HYDRO REHABILITATION PROGRAM

Approximate Investment Allocation ($ million)	Project Name	Rehabilitation Program	Investment Cost Excluding Substations ($ million)	Investment Cost for Substations ($ million)	Total Investment Cost ($ million)	Average Annual Incremental Energy Production (GWh)	Total Investment	Notes
10	Investment Prioritization						$9,480,000	
	Khrami II	Short Term	1.26	3.72	4.98	24		
	Lajanuri	Short Term	3.77	0.73	4.50	61		
	TOTAL				9.48	85		
15	Investment Prioritization						$15,080,000	
	Khrami II	Long Term	6.86	3.72	10.58	116		
	Lajanuri	Short Term	3.77	0.73	4.50	61		
	TOTAL				15.08	177		
17	Investment Prioritization						$16,670,000	
	Lajanuri	Long Term	10.96	0.73	11.69	162		
	Khrami II	Short Term	1.26	3.72	4.98	24		
	TOTAL				16.67	186		
20	Investment Prioritization						$19,570,000	
	Vartsikhe	Short Term	13.14	1.45	14.59	111		
	Khrami II	Short Term	1.26	3.72	4.98	24		
	TOTAL				19.57	135		
22 - 27	Investment Prioritization, Option 1						$22,270,000	1
	Khrami II	Long Term	6.86	3.72	10.58	116		
	Lajanuri	Long Term	10.96	0.73	11.69	162		
	TOTAL				22.27	278		
	Investment Prioritization, Option 2						$24,070,000	2
	Vartsikhe	Short Term	13.14	1.45	14.59	111		
	Khrami II	Short Term	1.26	3.72	4.98	24		
	Lajanuri	Short Term	3.77	0.73	4.50	61		
	TOTAL				24.07	196		
	Investment Prioritization, Option 3						$25,170,000	3
	Vartsikhe	Short Term	13.14	1.45	14.59	111		
	Khrami II	Long Term	6.86	3.72	10.58	116		
	TOTAL				25.17	227		
	Investment Prioritization, Option 4						$26,730,000	4
	Vartsikhe	Short Term	13.14	1.45	14.59	111		
	Khrami II	Short Term	1.26	3.72	4.98	24		
	Lajanuri	Short Term	3.77	0.73	4.50	61		
	Tkibuli	Short Term	1.46	1.20	2.66	13		
	TOTAL				26.73	209		

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Table ES-2

INVESTMENT PRIORITIZATIONS
GEORGIA HYDRO REHABILITATION PROGRAM

Approximate Investment Allocation ($ million)	Project Name	Rehabilitation Program	Investment Cost Excluding Substations ($ million)	Investment Cost for Substations ($ million)	Total Investment Cost ($ million)	Average Annual Incremental Energy Production (GWh)	Total Investment	Notes
30	Investment Prioritization						$29,670,000	
	Vartsikhe	Short Term	13.14	1.45	14.59	111		
	Khrami II	Long Term	6.86	3.72	10.58	116		
	Lajanuri	Short Term	3.77	0.73	4.50	61		
	TOTAL				29.67	288		
32	Investment Prioritization, Option 1						$31,260,000	5
	Vartsikhe	Short Term	13.14	1.45	14.59	111		
	Lajanuri	Long Term	10.96	0.73	11.69	162		
	Khrami II	Short Term	1.26	3.72	4.98	24		
	TOTAL				31.26	297		
	Investment Prioritization, Option 2						$32,330,000	6
	Vartsikhe	Short Term	13.14	1.45	14.59	111		
	Khrami II	Long Term	6.86	3.72	10.58	116		
	Lajanuri	Short Term	3.77	0.73	4.50	61		
	Tkibuli	Short Term	1.46	1.20	2.66	13		
	TOTAL				32.33	301		
34	Investment Prioritization						$33,920,000	
	Vartsikhe	Short Term	13.14	1.45	14.59	111		
	Lajanuri	Long Term	10.96	0.73	11.69	162		
	Khrami II	Short Term	1.26	3.72	4.98	24		
	Tkibuli	Short Term	1.46	1.20	2.66	13		
	TOTAL				33.92	310		

Notes:

1. This option maximizes incremental energy.
2. This option provides an attractive return on investment for top three energy producing projects.
3. This option maximizes return at this level of investment.
4. This option includes all four projects.
5. This option maximizes return at this level of investment, and equals the incremental energy of Opt. 1.
6. This option includes all four projects, including the highest ranked long term rehabilitation program (Khrami II).

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For an investment amount of about $10 million, the Short Term Rehabilitation programs for Khrami II and Lajanuri comprise the best investment. At around $15 million, the Long Term Rehabilitation of Khrami II with the Short Term Rehabilitation of Lajanuri is most attractive, while for around $17 million, the Long Term Rehabilitation of Lajanuri with the Short Term Rehabilitation of Khrami II should be considered.

For investment allocations around $20 million, the program should include the Short Term Rehabilitation of Vartsikhe, with the possible exception of an option to implement Long Term Rehabilitation at both Khrami II and Lajanuri -- at approximately $22 million -- in order to maximize incremental energy production. Alternatively, the Short Term Rehabilitation programs for Vartsikhe, Khrami II, and Lajanuri could all be accomplished and yield an attractive return for an investment of approximately $24 million.

For approximately $25 million, the Short Term Rehabilitation of Vartsikhe combined with the Long Term Rehabilitation of Khrami II appears to maximize the return on this level of investment. The Short Term Rehabilitation of all four facilities could also be accomplished for approximately $27 million, but the additional investment in Tkibuli appears to be marginal.

For an investment allocation of approximately $30 million, both Long Term Rehabilitation of Khrami II and Short Term Rehabilitation of Lajanuri may be included with Short Term Rehabilitation of Vartsikhe.

Two options may be considered for approximately $32 million. The first option would be to implement the Long Term Rehabilitation program for Lajanuri in combination with Short Term Rehabilitation of Vartsikhe and Khrami II. The second option would be to implement the Long Term Rehabilitation program for Khrami II along with the Short Term programs for the other three facilities (including Tkibuli), thereby including all four facilities. Either alternative yields about 300 GWh of average annual incremental energy production.

Finally, for $34 million, the Long Term Rehabilitation of Lajanuri may be combined with Short Term programs at the other three facilities.

As the foregoing discussion implies, the actual program to be implemented will depend not only on total amount of investment available, but on the relative importance of the following objectives:

- Maximizing the anticipated return on investment,
- Maximizing incremental energy production,
- Assigning investment priority in accordance with the overall energy production capability of each project, or
- Including all four hydroelectric projects in the program.

For an anticipated investment allocation in the range of $22 to $27 million, the first and third objectives are recognized by the Short Term Rehabilitation of Vartsikhe, Khrami II, and Lajanuri (approximately $24.1 million). In addition to being economically attractive, this program involves rehabilitation of the top three energy producing facilities - Vartsikhe, Lajanuri, and Khrami II, in that order. For an additional $2.6 million, the fourth objective can be attained by the inclusion of Short Term Rehabilitation of Tkibuli. The anticipated return on investment would appear to be highest -- attaining to the first objective -- for the program involving Short Term Rehabilitation of Vartsikhe and Long Term Rehabilitation of Khrami II ($25 million).

On the other hand, if the second objective is considered to be of greatest importance, the Long Term Rehabilitation of Khrami II and Lajanuri should be implemented ($22.3 million), resulting in an average incremental energy production of 278 GWh annually. By comparison, the Short Term Rehabilitation of all four projects would result in approximately 210 GWh of additional energy per year.

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Republic of Georgia
Hydropower Rehabilitation Study

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Chapter 1

INTRODUCTION

1.1 Background

As a result of reduced energy imports, declining economic activity and a shortage of generating capacity, electric supply has declined to approximately 45% of the 1990 level in the Republic of Georgia. The power sub-sector in Georgia was previously under the Ministry of Fuel and Energy until 1993. In 1992, SAKENERGO, a state enterprise, was established for operation planning and development. At the operational level, the company is structured into five principle areas which are hydropower plants, thermal power plants, transmission and distribution networks, general system support and trusts.

The Georgian electrical power system consists of 24 main power stations with a total capacity of 4700 MW of which 1800 MW is produced by thermal power generation and 2900 MW is produced by hydroelectric power generation. In general, the hydroelectric plants are located in western Georgia and the thermal plants are located in eastern Georgia. The two generation centers are connected over an antiquated 500 kV transmission system. The large installed capacity in Georgia should satisfy all of their peak energy needs and even allow for some exporting of power. However, due to the sharp reduction of generating capacity resulting from civil unrest, severe shortages of spare parts, equipment design problems and the age of most of their plants, the effective capacity at the end of 1994 was less than 20% of the installed capacity. Approximately half of the energy produced is supplied to the most critical areas, such as, pumping stations, food processing plants, the media, hospitals and other similar type facilities. The remaining power is supplied to households, industry, public buildings, agriculture and commercial activities. Power is typically supplied in a rationing manner where power is routinely discontinued in selected areas for several hours or more each day due to the limited power supply and frequent equipment failures.

The hydroelectric capacity in Georgia is distributed over 103 stations and 214 generating units. SAKENERGO owns and operates 54 power stations with an installed capacity of about 2895 MW and the Ministry of Agriculture owns and operates 49 isolated power stations with a total installed capacity of about 5 MW. Under its TACIS program, the European Union has undertaken a study to select the hydropower stations which should be rehabilitated on a priority basis. This priority list was established on an engineering basis only without consideration of the financial aspects or economic benefits of the rehabilitation effort.

1.2 Rehabilitation Program

The World Bank participated in an assessment mission in December 1994 and have identified three areas where they intend to invest in a reconstruction program to rehabilitate the deteriorated infrastructure in Georgia. These areas include thermal power plants; hydroelectric power plants; and transmission and distribution systems including dispatch and communication.

The World Bank organized a preparatory mission in March 1995 for the purpose of investigating these three areas in more detail. Technical specialists in all three areas visited Georgia during this preparatory mission and worked with their counterparts at SAKENERGO in an effort to identify the major areas of concern and to prepare a detailed scope of work identifying the immediate and future rehabilitation needs of their deteriorated energy systems.

A program to accomplish this scope of work has been performed under the sponsorship of the USAID through their *NIS Energy Efficiency and Market Reform Project* . Under this Project, the following responsibilities were identified:

> Burns & Roe Enterprises, Inc. was chosen to serve as Project Manager for the rehabilitation effort identified by the World Bank and for the rehabilitation work associated with the thermal power plants.
>
> Harza Engineering Company is responsible for the rehabilitation work associated with the hydroelectric power plants, with the exception of the substation equipment.
>
> AEP Service Corporation is responsible for the rehabilitation work associated with the transmission and distribution systems including dispatch and communication, and the substation equipment at the hydroelectric power plants.

This report relates to the rehabilitation work associated with the hydroelectric power sector performed by Harza Engineering Company.

1.2.1 Selected Hydropower Projects

The World Bank mission identified four hydroelectric power stations from the TACIS report as potential rehabilitation projects. The selected projects are:

> **The Lajanuri Hydroelectric Project** - Lajanuri, located in western Georgia, was commissioned in 1960 and has an installed capacity of 111 MW and a maximum reservoir capacity of 25 million cubic meters. The station houses three 37 MW Francis units.

The Khrami II Hydroelectric Project - Khrami II, located in eastern Georgia, was commissioned in 1962 and has an installed capacity of 110 MW. The flows to Khrami II originate from Khrami I which has a total active storage capacity of 312 million cubic meters. The station houses two 55 MW Francis units.

The Tkibuli Hydroelectric Project - Tkibuli, located in western Georgia, was commissioned in 1956 and has an installed capacity of 80 MW and a total active storage capacity of 80 million cubic meters. The station houses four 20 MW Francis units.

The Vartsikhe Hydroelectric Project - Vartsikhe, located in western Georgia, consists of four identical power stations located on a common power canal. Vartsikhe I was commissioned in 1976; Vartsikhe II was commissioned in 1978; Vartsikhe III was commissioned in 1980; and Vartsikhe IV was commissioned in 1988. Each of the four stations have a total installed capacity of 46 MW. Each station houses two 23 MW Kaplan units. The storage reservoir upstream of Vartsikhe I has a total storage volume of 15 million cubic meters.

1.2.2 Scope of Services

The objective of this study is to identify a least cost rehabilitation program for the four identified projects; assess the cost effectiveness of the proposed projects; and to prioritize them for financing. The scope of work included the following tasks:

1. Prepare a work plan considering the Bank missions and visit the Sakenergo offices and the four projects.

2. Perform site investigations, collect data, and make recommendations for two life-extension scenarios.

3. Prepare detailed cost estimates for each of the two life-extension scenarios.

4. Document the results of the study in a feasibility report which is to include recommendations and a priority listing for each of the two scenarios.

The two life-extension scenarios reflect a short-term and long-term rehabilitation, as requested by the World Bank.

For the short term, the emphasis was placed on generating and delivering maximum energy to the power system at least cost for the immediate future which was defined as the next 3-5 years. Under this scenario, increased maintenance associated with aging equipment will be required. It was assumed that SAKENERGO will have this capability of providing the required maintenance and also

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the capability to install spare parts. Equipment replacement was only to be undertaken if the equipment was out of service or in critical near term condition and, considering both long term operation and the extent of the repair, it was deemed more economical to replace than to repair. Major costs for civil items were included in the short-term analysis when, in the opinion of the evaluation team, the structure might be in a state of incipient failure, when the item had failed and was required for operation of the station, and when an item had failed and failure to rehab created a potential for catastrophic failure. Aesthetic items not affecting power production, such as replacement of floor tiles or painting, were considered to be normal maintenance items and no separate provisions were made.

For the long term, assumed to be 10-25 years, emphasis was on life extension of the plants to ensure reliable operation. Due to the limited funds expected to be available, no attempt was made to improve or update the basic power station design other than to use modern equipment and practices. As an example, a modern control system for the plants would incorporate equipment for remote control from a distant point, such as the SAKENERGO dispatch center. Such equipment was discussed, but not recommended; because it is outside the scope of this study; however, turbine runner, generator winding, and transformer replacements will result in some efficiency improvements because of improved designs today compared with 30 years ago. Increased efficiency will also result in increased unit capacity.

The ranking of the stations was to consider the long term rehabilitation needs, short term rehabilitation needs, significance of the plant with respect to the overall power system, and the associated costs for the short term rehabilitation. The long term rehabilitation will be done sequentially, by station, according to the ranking to minimize power interruptions. The stations which are lower on the long term ranking will require increased short term rehabilitation as they await their turn for long term rehabilitation.

1.3 Site Visits

A team of technical specialists from Harza revisited Georgia in May and June, 1995 to perform detailed site inspections at the four selected projects. During these site visits the team worked closely with their SAKENERGO counterparts in a joint effort to establish a detailed list of major items for consideration in the rehabilitation program. The results of this effort established the basis for the cost estimates and the economic analyses presented hereinafter.

SAKENERGO personnel at the initial site visits included Revaz Sulaberidze, Chief Specialist of SAKENERGO; Konstantine (Kote) Khachidze, Chief Engineer of Operations and Maintenance Directions; Erveri Totadze-Plant Manager; Merab Mukvani-Plant Chief Engineer; Otar Chachkniani-Plant Mechanical Engineer; and other on-site specialists. Harza representatives included: Edul Bam, Mechanical Engineer; Glenn Meloy, Electrical Engineer and Jim Witnik, Civil Engineer.

A second visit was made in August, 1995 by Gary Hoornaert, Harza's Team Leader to further define the scope of work for each project and to gather additional key project related data for completion of this study.

A third trip was made by Jud Woods in November, 1995 to collect data and information to facilitate the evaluation of the rehabilitation program and the economic analyses of the projects.

1.4 General Observations

The power stations, except for Vartsikhe, are relatively old and utilize the original equipment without any major rehabilitation. All of the power stations require excessive maintenance of shaft seals, turbine guide bearings, wicket gates, hydraulic power units, generators (stator coil replacements), circuit breakers and switchgear, and motors (replacement of burnt out motors), to keep them running. The frequency of and necessity for maintenance is increased by a lack of lubricating oil. Equipment cleaning (stator windings) and inspection needs attention. The power-house interiors present a drab, unpainted and uncared for appearance and there should be a significant improvement in housekeeping standards.

All of the stations have been subjected to long periods of operation at frequencies much different than the rated frequency of 50 hertz. The frequency range is approximately 37-53 hertz; however, most of the time the frequency of operation falls in the range of 43-47 hertz. There are periods of time when the frequency is greater than 50 hertz. Operation at reduced frequency results in the electrical equipment operating at above standard temperatures causing failures of motors and stator coils.

1.5 Environmental Impact Statement

The rehabilitation work proposed at the four hydroelectric stations will have little or no impact on the environment. The rehabilitation work to be performed inside the stations primarily consists of replacing equipment components rather than reconstruction work. During the rehabilitation work, care will need to be taken to prevent spillage of oil, to ensure the proper handling of contaminated wastewater within the powerhouses to prevent discharges to the project waters, and to ensure the proper handling of all waste materials. The rehabilitation work to be performed outside the stations is generally minor at Lajanuri and Tkibuli, and no environmental impact is anticipated. At Khrami II, care will need to be taken in the substation area during the replacement of the oil-filled transformers. Proper handling of this insulating oil at the site and between the site and the disposal area is extremely important to prevent contamination. However, a significant environmental impact could occur at both Khrami II and Tkibuli if the existing transformers are not replaced. These transformers have reached the end of their useful lives and are susceptible to oil leakage from a tank rupture or possible explosion. This concern is heightened at Khrami II because these transformers

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are being operated in an overloaded condition on a regular basis. At Vartsikhe, care must be exercised during the civil rehabilitation work in the power canal and drainage canal. The rehabilitation work must be performed in a manner which will minimize the deposition of construction debris in the project waters and adjacent canals.

1.6 Content of the Report

The report is structured to include an Executive Summary, this Introduction, the Rehabilitation Program for each project, and the economic analysis and ranking and the conclusions and recommendations.

The rehabilitation program is presented by Project and consists of:

A description of the project,

A condition assessment,

The rehabilitation plan for the short term and the long term, and

An estimate of the cost.

The economic analysis includes the estimation of energy production without and with the short and long-term rehabilitation, an economic evaluation, and the prioritization of the rehabilitation effort.

1.6.1 The Rehabilitation Plan

The rehabilitation plan was based on the condition assessments and the repairs or improvements that were considered necessary by the Project Team to provide for continued operation over the short-term life extension. Wherever possible, SAKENERGO should work with local contractors in Tblisi or make use of their workshop and personnel for the fabrication of mechanical and electrical components for use in the rehabilitation effort.

1.6.2 Cost Estimating Procedure

The feasibility level cost estimates were prepared for mechanical, electrical, and civil work on an analytical basis utilizing feasibility level data obtained from Georgia, Armenia, Russia, and other countries of the former USSR, manufacturers data, historical data, and from information obtained through discussions with SAKENERGO personnel. For the analytical costing method, the construction of each individual project is planned, the quantity of labor and equipment is determined, the cost per unit of time is computed, and the time required to complete the specified quantity of

work is estimated. The estimates for both short term and long term rehabilitation are based on a January 1996 price level. The costs include both direct costs and indirect costs, contractors overhead and risk, and a contingency cost. Indirect costs include items, such as, contractors local staff; expatriate supervisory staff; temporary offices; storage and shops; temporary utilities; vehicles; insurance; security; and site maintenance. The overall costs are broken down into local and foreign costs.

1.6.3 Methods Of Procurement

Four methods of procurement are expected in the implementation of the projects. International competitive bidding (ICB) will typically apply to major equipment which can be procured most economically by allowing worldwide advertising where qualified bidders are invited to bid competitively. International shopping (IS) will typically apply to less expensive or more specialized equipment which can be procured at reasonable prices by selecting three or four equipment manufacturers directly without worldwide advertising. Direct contracting (DC) will typically apply to equipment which needs to be purchased directly from the original equipment manufacturers to assure compatibility of the component or equipment with the original installed equipment. Local competitive bidding (LCB) will apply to the civil related work as well as the installation of mechanical and electrical equipment. The method of procurement for each of the mechanical, electrical and civil rehabilitation items is indicated in the cost estimate summary tables at the end of each chapter.

1.6.4 Energy Production

The benefits of rehabilitation accrue as a result of an increase in annual energy production and/or a reduction of the risk of project loss. Estimates of average annual energy production for the Base Case (i.e., the continued operation of the existing project at current maintenance levels until the attrition or failure of project components render continued operation impracticable) and for the proposed rehabilitation alternatives were derived from available historical inflow data and other project operation parameters. The estimates were primarily derived from information available for the ten-year period 1984 through 1993.

Of the operation parameters employed in the estimates, the most significant were maximum allowable plant production capacity, average plant/unit availability, and average overall generating efficiency. Values of these parameters were established for the Base Case and rehabilitation scenarios on the bases of (1) actual knowledge of their values, (2) "calibrations" with historical generation data, and/or (3) reasonable expectations of the specific measures recommended for each facility.

1.6.5 Economic Analysis and Project Prioritization

Parameters and a general format were established for economic analyses of the rehabilitation scenarios. The format is essentially based on the calculation of annual incremental benefits and costs associated with the implementation of rehabilitation as compared to the Base Case alternative, and discounting the annual stream of benefits and costs to present value for an established term of analysis -- five years for short term rehabilitation, and 25 years for long term. In addition to the average annual incremental energy production associated with rehabilitation, other key parameters for the analyses are rehabilitation investment cost, hydroelectric operations and maintenance (O&M) costs and energy value (both in terms of $/MWh), and the discount rate.

The economic parameters derived from the analyses -- Present Value Benefits and Costs, Net Present Value, Benefit-Cost Ratio, and Economic Internal Rate of Return -- provide indications of the economic attractiveness of a given rehabilitation program. The EIRR was used to establish a project ranking index which, along with considerations of total rehabilitation costs, average annual incremental energy production, and risk reduction and safety, were used to establish priorities for total investment allocations varying from $10 to $34 million.

The establishment of the final Georgia Hydropower Rehabilitation Project will depend not only on the amount of investment available, but on the relative importance of the following objectives:

- Maximizing the anticipated return on investment,
- Maximizing incremental energy production,
- Assigning investment priority in accordance with the overall energy production capability of each project, or
- Including all four hydroelectric projects in the program.

Chapter 2

LAJANURI REHABILITATION PLAN

2.1 Description of Project

The Lajanuri Hydroelectric Project develops the head and the flow of the Lajanuri River, a tributary of the Rioni River, and the intra-diversion flow of the Tskhenis-Tskali River. The first of three units at this project was commissioned in 1960.

The intra-diversion headworks on the Tskhenis-Tskali River consists of a low, four bay gated, concrete spillway structure designed to pass 1,600 cubic meters per second (cms) and an intake with sediment sluices to divert 60 cms to the Lajanuri reservoir. Water from the intake is conveyed to the storage reservoir via a 934 meter long gated canal and a 5,524 meter long, 5.4 meter diameter gravity flow tunnel.

The Lajanuri reservoir is impounded by a 67 meter high arch dam with a crest length of 127 meters. Three spillway outlets, each 7 meters wide with a discharge capacity of 120 cms, are located below the dam roadway. The power intake, located at the right abutment of the arch dam, conveys water through a 2,549 meter long, 5.5 meter diameter gravity tunnel; a 99.4 meter long, 4.5 meter diameter vertical shaft; elbow section; and a horizonal manifold that distribute water to the penstocks for each of the plants three turbines. A surge shaft 12.5 meters in diameter is located at the end of the 5.5 meter tunnel. The underground powerstation houses three, vertical shaft Francis turbines and three-phase synchronous generators. The power station's capacity is 111.6 MW at a rated head of 131 meters. The average annual energy is 425 GWH.

Table 2-1 provides significant data for the Lajanuri Project including generator and turbine nameplate data, key elevations and physical dimensions for key structures.

Table 2-1

SIGNIFICANT DATA FOR THE LAJANURI PROJECT

Component	Description	Values
Generator Nameplate Data	Voltage Rated Speed Frequency Phases Capacity Power Factor Current Manufacturer Date of Manufacture	10,500 V ± 5% 257 rpm 50 Hz 3 46,600 kVA 0.8 2561 A Siemens-Schuckert 1956
Turbine Nameplate Data	Capacity Rated Speed Runaway Speed Rated Head Flow Manufacturer Date of Manufacture	38.6 MW 257 rpm 460 rpm 135 m 33.8 cms Voith 1955
Significant Elevations	Normal Headwater Normal Tailwater (1 unit) Normal Tailwater (3 units) Centerline of Runner Design Head	El. 491.00 m El. 357.27 m El. 359.12 m El. 358.07 m 128.3 m
Physical Dimensions	Arch Dam Arch Dam Spillway Powerhouse	67 m high 127 m crest length 3 bays at 7 m 54 m x 17 m x 14 m

2.2 Condition Assessment

The Lajanuri Hydroelectric Project is generally in fair condition from an overall appearance and maintenance point of view. It is apparent based upon initial observation that the management of this plant had a strong commitment to maintenance and is making every effort to maintain this plant in

spite of the obvious lack of funds required to support an ongoing maintenance program. The office building and powerstation were in fairly good condition considering the age of the plant. The plant was generally clean, painted and generally well lit.

For the short term scenario, the equipment overall is in fair condition with the exception of Unit 2 which requires extensive generator repairs to bring the unit back on-line and certain key equipment items that are essentially at the end of their useful life or are in critical near term-condition. Mechanical rehabilitation related to the major equipment is primarily focused on upgrading the governors for the three units and providing a convenient method of maintaining the lubricating oil systems to reduce wear of the rotating components. Electrical rehabilitation related to the major equipment is primarily focused on upgrades for Unit 2, regulators for all three units and replacement of essential station support equipment. Also, for the short term, there are a number of civil items which must be addressed during the rehabilitation effort, because they affect the continued operation of the project and safety issues. For the long term, there is considerable need for mechanical and electrical rehabilitation to extend the useful life of the project.

2.2.1 Mechanical Assessment

The inlet valve, turbine and governor have the following main features:

- Spherical inlet valve with dedicated hydraulic power unit.
- Cast, integral spiral case and stay ring partially embedded in concrete with a pressure relief bypass valve.
- Francis runner with cast stainless steel blades, 2750-mm runner diameter.
- Vertical, one piece, forged steel shaft.
- The turbine wicket gates (24) are controlled by a Voith governor located at the turbine floor, with separate actuator cabinet and sump tank. The oil pumps and motors, and distributing valve are mounted on the sump tank. A separate air-oil pressure tank is located near the sump tank. The gate servomotors are mounted on brackets attached to the spiral case.
- Journal-type turbine guide bearing, forced oil lubricated. An external oil tank with main and standby oil pumps provide oil under pressure for the generator upper and lower guide bearings and the turbine guide bearing. The thrust bearing has a separate oil system.
- Labyrinth type shaft seal with water thrower ring.

- The automatic greasing system no longer functions so a manual greasing system is being used.

- Two powerhouse cranes, each with a capacity of 120/20 tons. There is a lifting beam to connect the main hooks for generator rotor lifts.

At the time of the visit (2 Jun 95), two of the three units in this underground powerhouse were generating at approximately 30 MW each, and the third, Unit 2, was shut down and disassembled. It was reported that circa April 93, Unit 2 was disassembled for a capital overhaul, and various parts were sent to Tblisi for repair. They were lost, and due to a lack of funds to purchase replacements, the unit has been idle for two years.

The spherical valves leak, and although sufficient stainless steel seals to replace all the spherical valve seals are available (they are stored in the switchyard), severe power shortages make it impractical to take the power station out of service to replace the operational and maintenance seals of the spherical valves.

Condition of Turbines and Governors. After 39 years in operation, the turbines and governors are at the end of their useful life. Erosion and cavitation damage have taken their toll on the runner, wicket gates and discharge ring. The original governors used to be serviced by specialists from St. Petersburg or Moscow, Russia. It was reported that there are no specialists capable of servicing governors in Georgia.

2.2.2 Electrical Assessment

Generator Oil Circuit Breakers. Six of the eight breakers have recently been replaced. Two new breakers are needed. The following observations also are pertinent:

- The generator circuit breakers are of the oil type and are in a switchgear lineup in common with several station breakers, eight in total.

- The circuit breaker for Unit 2 (old type) was removed and installed at Khrami II and the circuit breaker for Unit 3 has not been updated and is at the end of its useful life.

- Spare parts are no longer available, and SAKENERGO desires to purchase a spare breaker.

Stator Coils. The generators are original equipment and have not been rehabilitated and stator winding repair is required because the windings have reached or exceeded their normal life expectancy. Unit 2 has been out of service for two years due to a major winding failure and lack of money to repair the unit. At least 257 half coils will be required to repair the unit. The units have 612 half coils installed in 306 slots. The following observations are made:

- SAKENERGO has indicated that they believe the generators should receive major rehabilitation.

- These units have their neutrals grounded.

- In previous discussions there was some concern about chronic coil failures in these machines.

- The coils for Unit 2 have been contracted for from a Russian firm who is a licensee of Siemens. The firm will also assist in the installation of the winding into the unit.

Generator Rotor Poles. At the time of the failure of Unit 2, its rotor contacted the stator resulting in damage to the rotor and three rotor pole windings require replacement.

Generator Exciters and Regulators. The exciters and regulators are original equipment and are currently working without undue problems except for the regulator for Unit 2 which has burned out. The exciters and regulators have reached the normal life expectancy for this type of equipment.

Power and Control Systems. The station is controlled locally from the station switchboard. The switches are old and require increased maintenance. Relays are functioning but are old and have reached their normal life expectancy. The meters are working but need replacing due to age and wear.

Wire and Cable. The wire and cable in the station is old and in need of replacement. The replacement of the station control boards will require disconnection of a high percentage of the terminations and most probably require additional conductors.

Station Batteries. The batteries show considerable corrosion at the connections and in the cells and several cells have been shorted out of the lineup. New station batteries are required.

Motors. The motors are generally original and many motors have failed over the years for various reasons. Lack of money has precluded replacement of many of the motors and the supply of spare motors at site has been exhausted.

Miscellaneous Spare Parts. Due to lack of funds and availability, spare parts are virtually non-existent. Spare parts are required to effectively perform required maintenance on most plant electrical equipment and should be made available.

250 kW Diesel for Connection to the System for Black Start. About seven years ago the line to Kutaisi was lost and never restored. This line provides power to Kutaisi but it also served as a reliable connection to the power system for a black start of the powerhouse. A 250 kW diesel would provide the black start capability more reliably. There is a strong desire by SAKENERGO to

reestablish this line which is about 70 kilometers long. Construction of the line is outside the scope of this study and not included in the cost estimates.

Other Equipment. No problems were reported with the station service reactors, the station service transformers, or the generator coolers.

2.2.3 Civil Assessment

The civil works are in fair condition. Work is required to repair the training wall, the dam piers on the downstream side of the spillway, and to fix the tunnel lining.

Training Wall. The diversion headworks consisting of training walls, spillway, power intake and canal is located in the adjacent valley from the arch dam, on the Tskhenis-Tskali River.

Pertinent facts regarding the training wall:

- The right side approach wall to the spillway has suffered from undermining of the toe.
- It was reported that the reason for the undermining was that the construction was not done according to the drawings. The toe plinth which was to be about 0.7 m wide x 2.0 m deep was never built.
- A 45 m long section of the wall is virtually destroyed, and temporary safety measures in place involve the placement of large concrete blocks. This is an important safety issue. If the dike is washed out, the village adjacent to this complex will be flooded.

Dam Piers. On the downstream side of the spillway, three intermediate piers of the four spillway bays which are at 14 m spacing, are suffering concrete degradation and reinforcing is exposed. These piers provide support for the bridge spanning the piers, and continued deterioration threatens this support. The piers were supposed to have been constructed with granite facing blocks as shown on the drawings. These blocks have been found to be very effective at resisting wear due to flowing and turbulent water. However, the downstream portion of the piers had this protective granite facing layer omitted during construction and the concrete in this area is now showing damage. Concrete has been spalled off to an extent where the damage is visible at the water line and reinforcing bars are also exposed due to this damage.

Tunnel Lining. The gravity flow tunnel section is over 5.5 km long and is lined in different portions with either of two different lining systems, based on the geologic conditions encountered. One type of section consists of reinforced concrete, and the other is a cast iron lining (bolted together) with a plain concrete lining on the inside water surface.

In 1985, during an inspection of the tunnel lining, there was a section of tunnel about 40 m long which was found to be squeezed out of its circular shape. The liner in that section was comprised of the plate type section. A repair was initiated, where the plate liner was taken down, the tunnel section enlarged to the design section and the liner reinstalled with a reinforced concrete layer on the inside face for strength. This reduced the net cross section to a 2.4 m radius, but is of no consequence since this is a gravity flow section.

An inspection in 1993 revealed another section of tunnel, about 30 m to 40 m long, with the same problem of squeezing cross-section as described above. This new section with damage is close to the previous damaged section. An attempt was made by the Project Team to inspect the tunnel, but it would have taken at least a day to obtain the permissions required to dewater the tunnel, so no inspection was done. This reach of tunnel also should be repaired.

Arch Dam and Intake Structure. The arch dam looked to be in good shape and no problems were reported. The intake structure located on the right hand side of the dam also looked to be in good condition, and well maintained. There were a number of large concrete blocks piled on the deck of the intake. It was reported that the blocks were only being stored there temporarily. There is a section of the road on the way to the powerhouse that is collapsing. These blocks will be used in the reconstruction of the road, as part of the retaining mechanism.

It was reported that the monitoring program for the arch dam, such as monitoring the deflection and settlements for example, had previously been done on a regular basis, but that the program was discontinued by SAKENERGO. The monitoring of the behavior of an arch dam is of extreme importance with regard to safety, and some monitoring program, even on a limited basis, should be done.

Transportation Considerations. The main route to the project from Kutaisi along the Rioni and Lajanuri rivers is the only practical route for any truck traffic with supplies or equipment. The other route along the Tskhenis-Tskali river is too steep and with too many switchbacks for large trucks or heavily loaded rigs, though it was noted that some smaller size bus traffic uses the road.

The route along the Rioni is by necessity a slow trip, due to the deteriorated sections of road which are encountered along many sections. The grades encountered are not too severe, and, overall would not deter heavy truck traffic. In summary, transportation would not be considered a problem, though it will enter into the cost considerations for bringing in materials and parts.

Access to the Power Station. The access tunnel is about 1/2 km long, into the underground power station cavern. The tunnel is only wide enough for one way vehicular traffic. The portal at the tunnel entrance was decorative, and maintained in good condition. Similarly, the tunnel itself was observed to be in good condition. It was a dry tunnel, and leakage was not evident.

Power Station Cavern. The entrance to the machine hall is from the access tunnel. A turnaround area for the car was not available due to the materials stored in the erection bay area due to the ongoing turbine maintenance. The layout of the main cavern was as follows; the erection bay was at the end near the entrance tunnel, adjacent were the three units and the control room was at the other end of the cavern. There were two cranes in the cavern, with each crane having a main hook of 100 tons and auxiliary hook of 20 tons.

The ceiling of the machine hall was of cross beam construction breaking the ceiling into seven sections along the length, and three sections along the width. The HVAC vents were placed between the beams resulting in a very neat and organized appearance. No problems were reported with the ceiling system.

The spherical valves are located in the same chamber of the main power chamber, accessible through removable steel hatches. The spherical valves were all exhibiting what would be characterized as a significant amount of leakage.

In the electrical hall above the spherical valve chamber, the cavern was observed to be dry and in good shape. It was reported that the contents of this cavern had been rebuilt about ten years ago because of destruction caused by an explosion. The temperature was somewhat elevated in the cavern, and it was also noted that the control room was very warm inside. There is an elevator in the powerhouse, but it was reported that it does not work.

Draft Tube Gate Chamber. The draft tube gates are housed in a separate chamber downstream of the main powerhouse cavern. The rock surface was left exposed and was in good condition. The rock was classified as "type 9", which is an indication of very high quality. The cavern itself was dry, and fairly well lit. There was a light duty crane in the cavern. The crane rails were supported on concrete anchor blocks which were reported to be anchored to the rock with rock anchors. The draft tube gates were painted and appeared to look well maintained. It was reported that the rubber seals were in good condition.

Emergency Exit Shaft. There is an emergency exit stairwell accessible off of the main access tunnel, just downstream of the main powerhouse cavern. This shaft was inspected, and it was found to be in good condition. The shaft itself was dry and no leakage was evident.

2.3 Recommended Rehabilitation Work

2.3.1 Short Term Rehabilitation

Mechanical Rehabilitation. The inlet valves, turbines, governors and auxiliary mechanical systems will require extensive rehabilitation in the immediate-term; however, for the short term rehabilitation

the emphasis will be on continued operation of the equipment at the least cost. The following commodity purchases and repairs are recommended as a minimum necessary to maintain operation.

(1) Purchase one oil purifier to be used for both the turbine oil systems and the governor systems.

(2) Purchase rubber seals for the gates.

(3) Purchase miscellaneous valves for use in the various water supply systems.

(4) Purchase gasket material for various applications in the mechanical systems.

(5) Rehabilitate the governors for the three units with service recommended by the original equipment manufacturer.

(6) Furnish two station drainage pumps of the deep well type.

Electrical Rehabilitation. For short term rehabilitation the emphasis will be on continued operation of the equipment at the least cost.

(1) Three rotor pole windings should be procured and installed.

(2) Purchase new regulators for all three generators.

(3) Purchase 400 meters of generator mainlead busbar for Unit 2.

(4) A minimal number of spare parts to be used during normal required maintenance should be procured to keep the plant operational for the next 3-5 years. This complement of spare parts should be the absolute minimum required to perform essential maintenance and keep the plant operational. Particular care should be exercised to minimize spare parts purchases for equipment which will be scheduled for replacement in the long term. It is emphasized that the spare parts procurement program for the short term must be particularly austere.

(5) A 250 kW diesel should be procured and installed to provide black start capability.

(6) The contract with the Russian firm for the generator stator coils should be expanded to include a complete winding with Class B insulation and 100 spares as well as assistance with the installation of the new winding. The contract should include assistance in testing and repairing damage to the stator iron.

(7) The station battery and battery charger should be replaced.

(8) A minimum number of the most critical motors should be procured.

Civil Rehabilitation. For short term rehabilitation the emphasis will be on safety related items and protection of equipment at the least cost.

(1) Reinstate a regularly scheduled monitoring program for the arch dam. The program does not need to be as exhaustive an endeavor of measurements such as when the dam was new, but needs to be comprehensive enough so as to be able to identify problems which may arise.

(2) The training wall at the diversion headworks needs to be repaired to ensure the safety of the village. A cost comparison will be performed to evaluate various possible measures of repair.

(3) Provide for inspection and repair of the gravity flow tunnel:

- Evaluate the extent of the new damage with more detail so that a proper estimate of construction materials and time requirements for repair can be made.

- Reinspect the previously repaired section to ascertain that the repairs are in fact holding up satisfactorily.

- Provide design details of the previously used repair procedure for incorporation in the contract documents and specifications.

2.3.2 Long Term Rehabilitation

Mechanical Rehabilitation. The original turbines, governors, and ancillary equipment, after 40 years in service, are at the end of their useful life. In order to improve the plant for 10 to 25 years of additional service, the following additional rehabilitation work is recommended. The units will be rehabilitated consecutively to minimize power generation interruptions.

(1) Provide new digital control governor including:

- hydraulic actuator system with pumps;
- speed signal generator;
- electronic restoring;
- accumulator tank with pressure and level control and gauges.

(2) Provide new gate servomotors to work with the higher governor oil pressure.

(3) Provide new, improved design, stainless steel Francis runner with replaceable labyrinth seals, at the runner crown and runner band. (The existing turbine shaft is serviceable; the runner connection will have to accommodate the runner flange of the existing shaft.)

(4) Provide new head cover, gate operating mechanism, and wicket gates. All bearings will be of the self-lubricating type. Provision will be made for containing and pumping/draining leakage onto the head cover. For the pumping arrangement two pumps under echelon control will be employed.

(5) Provide new and efficient proprietary shaft seal with filtered water supply. A wire wound filter with automatic back wash facility will also be provided.

(6) Provide new forced oil lubricated turbine guide bearing with external sump, main and standby motors, echelon controls and piping. This system will also supply the generator upper and lower guide bearings as at present.

(7) Provide new bottom ring, discharge ring, and partial draft tube immediately below discharge ring.

(8) The existing integral spiral case and stay ring are serviceable; they will be examined, sandblasted, and painted inside and out with an epoxy paint.

(9) Purchase a set of turbine spare parts.

(10) Overhaul of 3 spherical valves. (Spherical valve seals are available. Servomotor seals have to be purchased - details required.)

Electrical Rehabilitation. In order to improve the plant for 10 to 25 years of additional service, the following additional rehabilitation work is recommended.

(1) Procure and install three 10 kV generator oil circuit breakers. One of the new breakers is to be used for a spare.

(2) Generators 1 and 3 should have their windings replaced. The new windings should have Class B insulation.

(3) At the time of repair the stator cores should also be tested for hot spots and appropriate repair or replacement. It is anticipated that the core steel will not require replacement.

(4) Procure and install exciters for all three units.

(5) The station control boards should be replaced complete with switches, indicators, meters and relays.

(6) The wire and cable should be replaced in conjunction with the replacement of the station control boards.

(7) A substantial supply of spare motors should be procured and motors replaced under normal maintenance as they fail.

(8) A list of those spare parts required for reliable long term operation of the plants should be developed and those spare parts maintained in inventory.

(9) The reestablishment of the Kutaisi line should be studied by the USAID transmission study group.

Civil Rehabilitation. If it is decided to perform major rehabilitation of mechanical and electrical equipment and systems at this plant, detailed civil inspections will be required. On the basis of the cursory site inspections performed, no long term rehabilitation is recommended, except as follows:

- Repair the dam piers on the downstream side of the spillway. A repair method and procedure has already been designed for the piers, and some of the fabrication of the plates has already been done. This involves the fabrication of steel liner plates which will be bent and cut to shape to reflect the original pier shape. The pier will be chipped and cleaned to remove all damaged material. Anchors will be drilled and grouted into the pier. This liner will then be attached to the anchors. The space between the plate and the existing concrete will be filled in with concrete. Note that this work will need to be scheduled during the fall low water season. Quantities estimated are as follows: 37.8 tons of steel plate, 8 to 12 mm thickness; 0.8 tons of anchor steel; 0.75 tons of welding electrode and 20 cubic meters of concrete.

2.4 Cost Estimates

The estimated short term and long term rehabilitation costs for the Lajanuri Project is $4,500,000 and $11,690,000 respectively. Tables 2-2 and 2-3 provide a detailed breakdown for the civil, mechanical, and electrical items recommended both for the short term and long term rehabilitation. The distribution of foreign and local costs for the short term and long term rehabilitation programs is shown in Table 2-4.

GEORGIA HYDROPOWER REHABILITATION PROJECT
PROJECT: LAJANURI HYDROELECTRIC POWER GENERATING STATION
SHORT TERM REHABILITATION (3 TO 5 YEARS)

COMPONENT DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE	PROCUREMENT PROCEDURE
CIVIL ITEMS					
Mobilization & Demobilization	LS	1	58,000	58,000	LCB
Diversion Headworks Retaining Wall					
Cofferdam/Care of Water	LS	1	17,000	17,000	LCB
Concrete Demolition	CuM	500	78	39,000	LCB
New Reinforced Concrete	CuM	500	202	101,000	LCB
Power Tunnel Lining					
Concrete Demolition	CuM	200	189	37,800	LCB
New Concrete Lining	CuM	200	380	76,000	LCB
Arch Dam					
Monitoring Program	LS	1	20,000	20,000	LCB
		Subtotal		348,800	
MECHANICAL ITEMS					
Portable Lube Oil Purifier					
Unpacking & Familiarization	EA	1	200	200	LCB
Purchase	EA	1	35,000	35,000	DC
Spherical Valve Rehabilitation					
Dismantle	EA	3	300	900	LCB
Install	EA	3	300	900	LCB
Governor Rehabilitation					
Dismantle	EA	3	800	2,400	LCB
Repair	EA	3	10,000	30,000	DC
Reassemble & Adjust	EA	3	1,500	4,500	LCB
Rubber Seals for Gates					
Dismantle	SET	1	1,700	1,700	LCB
Purchase	SET	1	25,000	25,000	DC
Reassemble	SET	1	1,700	1,700	LCB
Miscellaneous Valves					
Dismantle	SET	1	1,000	1,000	LCB
Purchase	SET	1	9,000	9,000	DC
Install	SET	1	1,000	1,000	LCB
Gasket Material					
Purchase	SET	1	7,000	7,000	DC
Station Drainage Pumps					
Dismantle	EA	2	1,000	2,000	LCB
Purchase	EA	2	20,000	40,000	DC
Install	EA	2	1,300	2,600	LCB
		Subtotal		164,900	
ELECTRICAL ITEMS					
Stator Coils					
Half Coils > 602	LS	1	900,000	900,000	ICB
Spare Coils > 100	LS	1	76,000	76,000	ICB
Dismantle existing Coils	LS	1	3,000	3,000	LCB
Reassemble new Coils & Testing	LS	1	23,000	23,000	LCB
Remove rotor & reinstall	LS	1	1,000	1,000	LCB
Foreign Supervision	LS	1	40,000	40,000	ICB

GEORGIA HYDROPOWER REHABILITATION PROJECT
PROJECT: LAJANURI HYDROELECTRIC POWER GENERATING STATION
SHORT TERM REHABILITATION (3 TO 5 YEARS)

COMPONENT DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE	PROCUREMENT PROCEDURE
ELECTRICAL ITEMS (Cont'd)					
Rotor Poles					
Three rotor poles for Rotor # 2	LS	1	61,000	61,000	ICB
Remove existing Poles	LS	1	500	500	LCB
Install New Poles	LS	1	1,000	1,000	LCB
Foreign Supervision	LS	1	3,000	3,000	ICB
Generator Exciter & Regulator					
Regulator	EA	3	162,000	486,000	ICB
Remove	EA	3	1,000	3,000	LCB
Install	EA	3	3,300	9,900	LCB
Foreign Supervision	LS	1	20,000	20,000	ICB
Motors					
Regulator	LS	1	8,000	8,000	DC
Remove	LS	1	700	700	LCB
Install	LS	1	1,200	1,200	LCB
Spare Parts					
Generator	LS	1	30,000	30,000	ICB
Excitation	LS	1	25,000	25,000	ICB
13.8 kV Switch Gear	LS	1	18,000	18,000	DC
Low Voltage Switchgear	LS	1	10,000	10,000	DC
Protective Relay	LS	1	15,000	15,000	DC
Illumination	LS	1	10,000	10,000	DC
Standby Power					
Diesel Generator	LS	1	101,000	101,000	IS
Diesel Tank	LS	1	5,100	5,100	LCB
Installation & Piping	LS	1	3,700	3,700	LCB
Battery System					
Battery	EA	1	30,000	30,000	DC
Battery Charger	EA	1	9,000	9,000	LCB
Remove Existing Battery	EA	1	500	500	LCB
Install New Battery & Test	EA	1	700	700	LCB
Generator Mainleads					
3000A 3Phase, Segregated Phase Bus, 10.5 kV	M	400	1,500	600,000	ICB
Removal Existing Bus	M	400	70	28,000	LCB
Install New Bus	M	400	250	100,000	DC
		Subtotal		2,623,300	
				=========	
Subtotal				3,137,000	
Construction Contingency		20 % ±		628,000	
				=========	
Total Price @ Jan. 1996 Level				**3,765,000**	

Legend:

ICB = International Competitive Bidding
IS = International Shopping
DC = Direct Contracting
LCB = Local Competitive Bidding

GEORGIA REHABILITATION PROJECT
PROJECT: LAJANURI HYDROELECTRIC POWER GENERATING STATION
LONG TERM REHABILITATION (10 TO 25 YEARS)

COMPONENT DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE	PROCUREMENT PROCEDURE
CIVIL ITEMS					
Mobilization & Demobilization	LS	1	57,000	57,000	LCB
Spillway Piers					
Steel Plate & Accessories	TONS	40	25	1,000	LCB
Concrete	CuM	20	100	2,000	LCB
		Subtotal		60,000	
MECHANICAL ITEMS					
Refurbish Turbines					
Dismantle parts	EA	3	8,000	24,000	LCB
Purchase	EA	3	1,172,000	3,516,000	ICB
Install	EA	3	12,000	36,000	LCB
Foreign Supervision	LS	1	100,000	100,000	ICB
Governors					
Dismantle parts	EA	3	1,700	5,100	LCB
Purchase	EA	3	222,000	666,000	ICB
Install	EA	3	5,000	15,000	LCB
Foreign Supervision	LS	1	29,900	29,900	ICB
Refurbish Inlet Valves					
Dismantle Parts	EA	3	750	2,250	LCB
Purchase	EA	3	99,000	297,000	IS
Install	EA	3	1,250	3,750	LCB
		Subtotal		4,695,000	
ELECTRICAL ITEMS					
3000A, 12kV Generator Circuit Breaker					
Circuit Breaker	EA	2	74,000	148,000	IS
Spare Circuit Breaker	EA	1	74,000	74,000	IS
Removal	LS	1	700	700	LCB
Modifying, Installing, Connection And Testing	LS	1	4,000	4,000	LCB
Generator Winding	EA	2	1,080,000	2,160,000	ICB
Stator Core Test	LS	1	8,000	8,000	LCB
Exciter Equipment					
Exciter	EA	3	129,000	387,000	ICB
Removal	EA	3	1,000	3,000	LCB
Install, Connect, Test	EA	3	3,300	9,900	LCB
Foreign Supervision	LS	1	45,000	45,000	ICB
Control Switchboard					
Control, Metering, & Protection Eqpt.	EA	3	178,000	534,000	ICB
Remove Exisitng Cubicles, Disconnect	EA	3	1,000	3,000	LCB
Install New Cubicles, Connect	EA	3	1,600	4,800	LCB
Test	EA	3	1,600	4,800	LCB
Foreign Supervision	LS	1	45,000	45,000	ICB
Wire And Cable					
Wire And Cable	LS	3	119,000	357,000	IS
Removal Of Existing Cable	LS	3	3,300	9,900	LCB
Install New Cables And Design	LS	3	7,000	21,000	LCB
Conduits And Trays	LS	3	44,000	132,000	IS

GEORGIA REHABILITATION PROJECT
PROJECT: LAJANURI HYDROELECTRIC POWER GENERATING STATION
LONG TERM REHABILITATION (10 TO 25 YEARS)

COMPONENT DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE	PROCUREMENT PROCEDURE
ELECTRICAL ITEMS (Cont'd)					
Motors					
New Motors	LS	1	25,000	25,000	DC
Remove Existing	LS	1	3,900	3,900	LCB
Install New Motors	LS	1	5,000	5,000	LCB
Spare Parts					
Generator	LS	1	80,000	80,000	ICB
Excitation	LS	1	100,000	100,000	IS
MV Switch Gear	LS	1	50,000	50,000	DC
LV Switch Gear	LS	1	40,000	40,000	DC
Measurement Indicator & Protection	LS	1	100,000	100,000	IS
Illumination	LS	1	20,000	20,000	DC
		Subtotal		4,375,000	
				=========	
Subtotal			9,130,000	9,130,000	
Construction Contingency		20 % ±	1,825,000	1,825,000	
				=========	
Total Price @ Jan. 1996 Level			10,955,000	**10,955,000**	

Legend:

ICB = International Competitive Bidding
IS = International Shopping
DC = Direct Contracting
LCB = Local Competitive Bidding

GEORGIA HYDROPOWER REHABILITATION PROJECT
LAJANURI HYDROELECTRIC POWER GENERATING STATION
LOCAL AND FOREIGN COST COMPONENTS

DESCRIPTION	LOCAL	FOREIGN	TOTAL
SHORT TERM			
Manhour, Labor Cost	329,000	63,000	392,000
Equipment	187,000	2,223,000	2,410,000
Materials	283,000	52,000	335,000
	=========	=========	=========
Subtotal	799,000	2,338,000	3,137,000
Construction Contingency 20 % ±	160,000	468,000	628,000
	=========	=========	=========
Total Price	959,000	2,806,000	3,765,000
LONG TERM			
Manhour, Labor Cost	996,000	220,000	1,216,000
Equipment	216,000	7,527,000	7,744,000
Materials	117,000	52,000	170,000
	=========	=========	=========
Subtotal	1,329,000	7,799,000	9,130,000
Construction Contingency 20 % ±	265,000	1,560,000	1,825,000
	=========	=========	=========
Total Price	1,594,000	9,359,000	10,955,000

Chapter 3

KHRAMI II REHABILITATION PLAN

3.1 Description of Project

The Khrami II Hydroelectric Project is located downstream of the Khrami I power station and storage reservoir on the Khrami River, approximately 115 km west of Tbilisi. The discharge from the Khrami I powerhouse together with additional inflow from the Khrami River and its tributaries, Dashbasha, Kapabulakh and Chochiani, between the two projects, provide the flow for the Khrami II powerhouse. The Khrami II power station was commissioned in 1962.

The headworks for Khrami II consist of a non-overflow dam and spillway; a water intake; a silt ejector canal; a daily storage reservoir with chute spillway; water conveying structures consisting of a 13-km-long pressure tunnel, a double-chamber surge shaft, a butterfly valve chamber, a penstock, a rotary gate chamber, an underground power station, a tailrace tunnel, and 110/220 kV switchyard. The power station and the butterfly valve chambers are located underground, in rock excavated chambers.

The power station chamber houses two 56.5 MW, vertical shaft, Francis turbines operating at a rated head of 307 meters and a rated discharge of approximately 21 cms. The Francis turbines each drive 55 MVA generators. The total installed capacity of the station is 110 MW, and average annual energy production is 370 GWH.

Table 3-1 provides significant data for the Khrami II Project including generator and turbine nameplate data, key elevations, and physical dimensions for key structures.

Table 3-1

SIGNIFICANT DATA FOR THE KHRAMI II PROJECT

Component	Description	Values
Generator Nameplate Data	Voltage Rated Speed Runaway Speed Frequency Phases Temperature Rating Capacity Power Factor Current Manufacturer Date of Manufacture	10,500 V ± 5% 428.6 rpm 700 rpm 50 Hz 3 35 degrees C over 40 degrees C ambient 68,750 KVA 0.8 3785 A Electrosilica (Russian) 1961
Turbine Nameplate Data	Capacity Rated Speed Runaway Speed Rated Net Head Maximum Net Head Manufacturer Date of Manufacture	56.5 MW 428.6 rpm 700 rpm 307 m 324.3 m LMZ (Russian); Model #460 1961
Significant Elevations	Headwater Tailwater Centerline of Runner	El. 1090.8 m El. 760.65 m El. 757.45 m
Physical Dimensions	Access Tunnel Generator Hall Valve Chamber	480 m long 32.14 m long x 11.7 m wide x 19 m high 20.6 m long x 6.3 m wide x 11 m high
Water Conductors	Discharge tunnel to river is gravity flow Power Conduit Inclined Tunnel Penstock	1253 m long 4 m diameter 3.2 m diamater 1.7 m diameter

3.2 Condition Assessment

The Khrami II Hydroelectric Project is relatively old (the initial year of operation was 1962), utilizes original equipment, and has never had a rehabilitation program, though it has long required excessive maintenance of its major equipment to keep the plant in operation. Additionally, the quality of the finish work both inside and outside the plant is poor.

The power station operations and maintenance staff are having to expend a significant effort just to keep the units on-line and generating power, with the result that powerhouse lighting and interior appearances, regular equipment cleaning and inspections, adequate provision of replacement materials and spare parts, and other safety- and security-related concerns and practices are wanting.

Mechanical rehabilitation related to the major equipment is primarily focused on upgrading the turbine wicket gates and seals for the two units and providing a convenient method of maintaining the lubricating oil systems to reduce wear of the rotating components. Electrical rehabilitation related to the major equipment is primarily focused on upgrades for the generator circuit breakers and generator bearings, and replacement of essential station support equipment, including the station service switchgear and reactors. No major civil work is recommended for the short term.

For the long term, there is considerable need for mechanical and electrical rehabilitation to extend the useful life of the project.

3.2.1 Mechanical Assessment

The inlet valve, turbine and governor have the following main features:

- Spherical inlet valve with one hydraulic power unit for the spherical valves of both units.
- Cast, integral spiral case and stay ring, partially embedded in concrete, with a pressure relief bypass valve.
- Francis runner with cast stainless steel blades.
- One piece forged steel shaft.
- Turbine wicket gates controlled by an LMZ governor located at the turbine floor, with separate actuator cabinet and sump tank. The oil pump and motor and the distributing valve are mounted on the sump tank. A separate air-oil pressure tank is located near the sump tank. The gate servomotors are mounted on brackets attached to the spiral case.

- Journal-type turbine guide bearing, originally grease-lubricated, later converted to oil lubrication, and most recently converted to water lubrication (one unit converted so far).

- Labyrinth type shaft seal with thrower ring.

- Automatic greasing system, no longer functioning, and replaced by the manual greasing system currently in use.

The Francis turbine unit specifications for Khrami II were very conservatively selected, as evidenced by the specific speed, corresponding to a "k" value of 1,389 in metric units, which is well below what, even today, would be considered a conservative "k" value of 1,995 for the rated net head of 307 m, a full gate output of 56.5 MW, and a speed of 428.6 rpm. Furthermore, in view of the advances in Francis turbine technology since the early 1960's, the 307-m net head rating for the Khrami II units is well within the experience range for this turbine type.

The original shaft seal design relied mainly on labyrinth seals and a water thrower ring for sealing. The original turbine guide bearing was a grease-lubricated journal bearing. As the shaft seal was not very effective, it would wash away the grease, and cause accelerated wear of the turbine guide bearing. Increased guide bearing clearances would permit the turbine shaft to 'cone', causing wear of the labyrinth seals. It was reported that sand particles in the water also contributed to wear of the labyrinth seals. The original labyrinth seals had V-grooves cut into the rotating and stationary mating surfaces. Repairs made in SAKENERGO's work shops did not replicate these V-grooves, thus further reducing the effectiveness of the shaft seal arrangement. It was reported that an oil lubricated turbine guide bearing arrangement was installed in 1967, but the oil sump still flooded on occasions, and repairs to the turbine guide bearing were required at regular intervals. A water lubricated bearing is thought to be the solution of the twin problems of a shortage of lubricating oil, and of flooding and contamination of an oil lubricated bearing because of the ineffectual shaft seal. Recently, a water lubricated turbine guide bearing was fitted, and it was reported that the preliminary indications are that it will work. The bearing surface is made of graphite, using a proprietary process to form the journal surface. The water lubricated bearing was developed by a bearing maker for submarine propeller shafts.

Condition of Turbine and Governor. After 32 years in service the turbines are at the end of their useful life. Erosion due to sand, and cavitation, have caused significant deterioration of the runner, discharge ring and wicket gates.

Leakage past the piston rings of the gate servomotors renders the servomotors much less effective and starting difficult.

The location of the governors on the turbine floor has resulted in periodic flooding, and it was reported that the unit governors were being made to function on an oil/water emulsion. The distribution valves on both units are worn, and it was reported that there is a risk of runaway

occurring. Each governor oil pressure system has a main and standby oil pump, but they currently function on the main pump, as the second pump motor has burned out.

3.2.2 Electrical Assessment

Protective Relays and Switches. The station service switchgear is a double-ended lineup of oil circuit breakers fed from both ends through current-limiting reactors. This switchgear is considered very unreliable by plant personnel. At times, the switches are bypassed to keep the plant in service. Spare parts are no longer available.

Station Service Reactors. One of the two sets of the station service reactors has failed and has been removed. Failure of the second set of reactors would require bypassing the reactors to keep the plant in service. This scenario is unacceptable.

Generator Oil Circuit Breakers. The breakers are in a very deteriorated condition and have been operated with insufficient oil. They are at the end of their useful life. Spare parts are no longer available.

Stator Coils. The Unit 1 generator had its winding replaced in 1968 and it has not exhibited any winding problems since then. The Unit 2 generator has its original winding, though it experienced one coil failure in 1992. SAKENERGO identified at least four other coils that are suspect in Unit 2. The units do not have their neutrals grounded, nor do they have surge protection. The age and deteriorated condition of the windings are such that disturbing the rest of the winding by replacement of individual coils would increase the probability of failure of other coils in the winding. There does not, however, appear to be any evidence that chronic coil failures is a problem in these machines, as one failure in more than 27 years comprises a reasonable record.

Generator Exciters and Regulators. The exciters and regulators are original, and are currently working without undue problems, though they have reached the normal life expectancy for this type of equipment. The exciters are of the rotating type.

Power and Control Systems. The station is controlled locally from the station switchboard. Remote control is not installed. Switches are old, requiring increased maintenance. Relays are functioning, but they are old and have reached their normal life expectancy. Meters are also functioning, but in need of replacement due to age and wear.

Generator Thrust Bearing. The thrust bearings are original equipment, and for various reasons have failed to perform properly over the years. New thrust bearing segments for one unit, of a flouroplastic type, have been contracted for with a Russian firm and have already been manufactured. However, they have not yet been delivered due to lack of payment.

Motors. Many motor failures have occurred over the years for various reasons, but the lack of money has precluded replacement of all but the most critical motors.

Miscellaneous Spare Parts. Due to lack of funds and availability, spare parts are virtually non-existent. Spare parts of sufficient quantity are essential to the effective maintenance and reliable operation of plant electrical equipment.

3.2.3 Civil Assessment

Power Station Cavern. An actual inspection of the excavated rock face was not possible, due to the cavity walls and drip ceiling, but an inspection from access hatches in the wall from the lower level revealed no obvious problems, and the cavern itself was reported to be in good shape. The waffle slab drip ceiling showed no evidence of distress or leakage.

From a civil standpoint, the primary shortcomings are aesthetic in nature. Floor tiles on the floor of the generator hall are in need of cleaning, and missing tiles need replacement. The power station walls show evidence of paint blistering in some areas. This condition is apparently due to a previous flooding episode, after which, according to a previous report, steps were taken to insure that the condition does not occur again. Inspection revealed no evidence of water seeping behind these areas.

The corrugated plastic coverings of the cavern wall are in need of cleaning and repair. There is soot and fire damage evident on the panels of the downstream wall near Unit 1, from a fire which had occurred in the breakers.

In the lower levels of the powerhouse, the concrete appeared satisfactory, with minor spall areas and some small cracks evident, which are of no consequence. The area around the semi-embedded spiral case of Unit 2 is in good condition. Lack of lighting and related safety hazards do not allow adequate inspections of the lower level of Unit 1.

Spherical Valve Chamber. The spherical valve chamber itself is in adequate condition from a functional perspective, but, as is true for the power cavern as well, general maintenance and appearances are short of desirable. There is significant oil leakage evidenced on the floor in this chamber, originating from the spherical valve operators.

Access to the Powerhouse. The entrance tunnel portal concrete and the concrete lining of the tunnel are in good condition, with no visible evidence of repair required. The drainage system behind the lining is apparently functioning properly, as evidenced by the lack of seepage water through the tunnel lining. Only one small section of the 500-meter-long tunnel exhibits a minor presence of moisture.

Transportation Considerations. One of the considerations for the heavy construction typical of hydropower facilities is the physical condition and gradients of the access roads to the site. In general, the roads to the Khrami II project exhibit an obvious lack of maintenance, but they are passable. Large potholes exist in many stretches of the road. For large and heavy truck loads, appropriate measures would need to be taken to make the transit possible, such as the use of a grader to groom the road ahead of the truck and clear it of rock debris and other obstructions, or the placement of gravel fill in some areas.

Another possibility for bringing equipment and parts to the site would be to utilize the existing railroad from Tbilisi for a large part of the transit. According to discussions held with SAKENERGO personnel, this rail line gets to within 50 kilometers of the site, to the village of Tetri Tskaro, and from there trucks would need to be used. If, in fact, heavy loads will need to be transported to the Khrami II site, any bridges will need to be evaluated with respect to their capacity to withstand the expected loading.

3.3 Recommended Rehabilitation Work

3.3.1 Short Term Rehabilitation

Mechanical Rehabilitation. The turbines, governors and auxiliary mechanical systems require an extensive rehabilitation in the long-term; however, for the short term rehabilitation the emphasis will be on continued operation of the equipment at the least cost. The following commodity purchases and repairs are recommended as a minimum necessary to maintain operation:

(1) Purchase one oil purifier to be used for the both the turbine oil systems and the governor systems.

(2) Purchase labyrinth seals for both turbines. Two incomplete sets of labyrinth seals have been ordered, but have not been paid for due to lack of funds.

(3) Repairs to wicket gates are required for both units. Each set contains 24 wicket gates.

Electrical Rehabilitation. For short term rehabilitation the emphasis will be on continued operation of the equipment at the least cost, manifest in the following recommended measures:

(1) Replace the switches for station service switchgear to enhance both the short-term and long-term reliability of the plant. The new switches should be of the vacuum type, provided suitable ratings are available.

(2) Replace out-of-service reactors and the still-in-service second set of reactors at the same time, for purposes of economy.

(3) Replace the generator oil circuit breakers with modern breakers to enhance both the short- and long-term reliability of the plant. Consideration should be given to using other than oil breakers; however, station air is not presently available for air blast breakers. The cost estimates are based on replacing the breakers in kind.

(4) Procure the generator thrust bearing segments which have already been contracted for. The performance of the new bearing should be closely monitored to determine adequacy for long term use.

(5) Purchase a minimum number of the most critical motors.

(6) Purchase a minimal number of spare parts to be used during normal required maintenance to keep the plant operational for the next 3-5 years. This complement of spare parts should be the absolute minimum required to perform essential maintenance and keep the plant operational. Particular care should be exercised to minimize spare parts purchases for equipment which will be scheduled for replacement in the long term; the spare parts procurement program for the short term should be appropriately austere.

Civil Rehabilitation. For short term rehabilitation the emphasis is on safety related items and protection of equipment at the least cost. On the basis of the cursory site inspections performed, no short term rehabilitation is recommended.

3.3.2 Long Term Rehabilitation

Mechanical Rehabilitation. The original turbines, governors, and ancillary equipment are at the end of their useful life. In order to improve the plant to allow for 10 to 25 years of additional service, the following additional rehabilitation work is recommended. The units will be rehabilitated consecutively to minimize power generation interruptions.

(1) Provide new digital control governor including:

- hydraulic actuator system with pumps;
- speed signal generator;
- electronic restoring;
- accumulator tank with pressure and level control and gauges.

(2) Provide new gate servomotors to work with the higher governor oil pressure.

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(3) Provide new, improved design, stainless steel Francis runner with replaceable labyrinth seals, at the runner crown and runner band. (The existing turbine shaft is serviceable; the runner connection will need to accommodate the runner flange of the existing shaft.)

(4) Provide new head cover, gate operating mechanism, and wicket gates. All bearings will be of the self-lubricating type. Provision will be made for containing and pumping/draining leakage onto the head cover. For a pumping arrangement two pumps under echelon control will be employed.

(5) Provide new and efficient proprietary shaft seal with filtered water supply. A wire wound filter with automatic back-wash facility will also be provided.

(6) Provide new forced oil lubricated turbine guide bearing with external sump, main and standby motors and piping.

(7) Provide new bottom ring, and discharge ring.

(8) The existing integral spiral case and stay ring are serviceable; they will be examined, sandblasted, and painted inside and out with an epoxy paint.

(9) Purchase a set of turbine spare parts.

(10) Refurbish the inlet valves for both units.

Electrical Rehabilitation. In order to improve the plant for 10 to 25 years of additional service, the following additional rehabilitation work is recommended:

(1) A new winding should be procured for the Unit 2 generator complete with 12 spare coils. This winding should be insulated with not less than Class B insulation. At the same time, a similar number of spare coils should be procured for Unit 1.

(2) The exciters and regulators should be replaced with static equipment.

(3) The station control switchboards should be replaced complete with switches, indicators, meters and relays.

(4) New bearing segments should be procured. If the bearing procured in the short term has performed well, a second one should be procured for the other unit. If not, further study of a solution to the bearing problems will be required before a new procurement is undertaken.

(5) All of the motors, not replaced in the short term, should be replaced during normal maintenance.

(6) A list of those spare parts required for reliable long term operation of the plants should be developed and those spare parts maintained in inventory.

Civil Rehabilitation. If it is decided to perform major rehabilitation of mechanical and electrical equipment and systems at this plant, detailed civil inspections will be required. On the basis of the cursory site inspections performed, no long term rehabilitation is recommended.

3.4 Cost Estimates

The estimated short term and long term rehabilitation costs for the Khrami II Project is $4,980,000 and $10,580,000, respectively. Tables 3-2 and 3-3 provide a detailed breakdown for the civil, mechanical, and electrical items recommended both for the short term and long term rehabilitation. The distribution of foreign and local costs for the short term and long term rehabilitation programs is shown in Table 3-4.

GEORGIA HYDROPOWER REHABILITATION PROJECT
PROJECT: KHRAMI II HYDROELECTRIC POWER GENERATING STATION
SHORT TERM REHABILITATION (3 TO 5 YEARS)

COMPONENT DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE	PROCUREMENT PROCEDURE
GENERAL ITEMS					
Mobilization & Demobilization	LS	1	80,000	80,000	LCB
		Subtotal		80,000	
MECHANICAL ITEMS					
Portable Lube Oil Purifier					
Unpacking & Familiarization	EA	1	200	200	LCB
Purchase	EA	1	48,000	48,000	DC
Wicket Gates - 24 WG's/Turbine					
Dismantle	SETS	2	1,400	2,800	LCB
Repair	SETS	2	23,000	46,000	LCB
Reassemble	SETS	2	1,400	2,800	LCB
Labyrinth Seals					
Dismantle	EA	2	1,400	2,800	LCB
Purchase	EA	2	26,000	52,000	DC
Reassemble	EA	2	1,400	2,800	LCB
		Subtotal		157,400	
ELECTRICAL ITEMS					
380 V Station Service Switchgear					
Circuit Breakers - 20	LS	1	193,000	193,000	IS
Removal Of Existing Breaker	LS	1	5,000	5,000	LCB
Install New Breaker & Test	LS	1	9,000	9,000	LCB
Station Service Reactor					
Remove Existing	EA	2	1,100	2,200	LCB
Install New	EA	2	72,000	144,000	IS
General Circuit Breaker					
10.5kV, 56.5 MW					
Remove Existing	EA	2	900	1,800	LCB
Install New	EA	2	110,000	220,000	IS
Motors					
New Motors	LS	1	21,000	21,000	DC
Remove	LS	1	7,000	7,000	LCB
Install	LS	1	16,000	16,000	LCB
Spare Parts					
Generator	LS	1	41,000	41,000	DC
Excitation	LS	1	34,000	34,000	DC
MV Switch Gear	LS	1	25,000	25,000	DC
LV Switch Gear	LS	1	25,000	25,000	DC
Protective Relays	LS	1	14,000	14,000	DC
Illumination	LS	1	23,000	23,000	DC
Generator Thrust Bearing					
Dismantle	LS	1	500	500	LCB
Purchase	LS	1	27,600	27,600	DC
Reassemble	LS	1	500	500	LCB
		Subtotal		809,600	
				=========	
Subtotal				1,047,000	
Construction Contingency		20 % ±		209,000	
				=========	
Total Price @ January 1996 Level				**1,256,000**	

Legend:

ICB = International Competitive Bidding
IS = International Shopping
DC = Direct Contracting
LCB = Local Competitive Bidding

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GEORGIA HYDROPOWER REHABILITATION PROJECT
PROJECT: KHRAMI II HYDROELECTRIC POWER GENERATING STATION
LONG TERM REHABILITATION (10 TO 25 YEARS)

COMPONENT DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE	PROCUREMENT PROCEDURE
GENERAL ITEMS					
Mobilization & Demobilization	LS	1	57,000	57,000	LCB
		Subtotal		57,000	
MECHANICAL ITEMS					
Refurbish Turbines					
Dismantle parts	EA	2	8,000	16,000	LCB
Purchase	EA	2	1,190,000	2,380,000	ICB
Install	EA	2	12,000	24,000	LCB
Foreign Supervision	LS	1	70,000	70,000	ICB
Governors					
Dismantle parts	EA	2	1,750	3,500	LCB
Purchase	EA	2	222,000	444,000	ICB
Install	EA	2	5,000	10,000	LCB
Foreign Supervision	LS	1	40,000	40,000	ICB
Refurbish Inlet Valves					
Dismantle parts	EA	2	750	1,500	LCB
Purchase	EA	2	99,000	198,000	IS
Install	EA	2	1,500	3,000	LCB
		Subtotal		3,190,000	
ELECTRICAL ITEMS					
Generator Winding #2					
Complete Coils	LS	1	811,000	811,000	ICB
Spare Coils	LS	1	30,000	30,000	ICB
Dismantle Existing Coils	LS	1	11,000	11,000	LCB
Reassemble New Coils & Testing	LS	1	20,000	20,000	LCB
Remove Rotor & Reinstall	LS	1	1,000	1,000	LCB
Unit #1 - 24 Spare Coil	LS	1	30,000	30,000	ICB
Foreign Supervision	LS	1	75,000	75,000	ICB
Generator Exciter And Regulator					
Exciter	EA	2	129,000	258,000	ICB
Regulator	EA	2	158,000	316,000	ICB
Removal	EA	2	2,000	4,000	LCB
Install, Connect, Test	EA	2	7,000	14,000	LCB
Foreign Supervision	LS	1	70,000	70,000	ICB
Control Switchboard					
Control, Metering, & Protection Eqpt.	EA	2	178,000	356,000	ICB
Remove Exisitng Cubicles, Discon.	EA	2	1,000	2,000	LCB
Install New Cubicles, Connect	EA	2	1,500	3,000	LCB
Test	EA	2	1,000	2,000	LCB
Foreign Supervision	LS	1	30,000	30,000	ICB
Motors					
New Motors	LS	1	15,000	15,000	DC
Remove Existing	LS	1	2,500	2,500	LCB
Install New Motors And Testing	LS	1	5,000	5,000	LCB

GEORGIA HYDROPOWER REHABILITATION PROJECT
PROJECT: KHRAMI II HYDROELECTRIC POWER GENERATING STATION
LONG TERM REHABILITATION (10 TO 25 YEARS)

COMPONENT DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE	PROCUREMENT PROCEDURE
ELECTRICAL ITEMS (Cont'd)					
Generator Thrust Bearing					
Dismantle	LS	1	250	250	LCB
Purchase	LS	1	20,000	20,000	DC
Reassemble	LS	1	250	250	LCB
Spare Parts					
Generator	LS	1	80,000	80,000	ICB
Excitation	LS	1	100,000	100,000	ICB
MV Switch Gear	LS	1	50,000	50,000	DC
LV Switch Gear	LS	1	40,000	40,000	DC
Protective Relay	LS	1	100,000	100,000	ICB
Illumination	LS	1	20,000	20,000	DC
		Subtotal		2,466,000	
				=========	
Subtotal				5,713,000	
Construction Contingency		20 % ±		1,142,000	
				=========	
Total Price @ Jan. 1996 Level				6,855,000	

Legend:

ICB = International Competitive Bidding
IS = International Shopping
DC = Direct Contracting
LCB = Local Competitive Bidding

GEORGIA HYDROPOWER REHABILITATION PROJECT
KHRAMI II HYDROELECTRIC POWER GENERATING STATION
LOCAL AND FOREIGN COST COMPONENTS

DESCRIPTION	LOCAL	FOREIGN	TOTAL
SHORT TERM			
Manhour, Labor Cost	167,000	0	167,000
Equipment	104,000	635,000	739,000
Materials	50,000	91,000	141,000
	=========	=========	=========
Subtotal	321,000	726,000	1,047,000
Construction Contingency 20 % ±	64,000	145,000	209,000
	=========	=========	=========
Total Price	385,000	871,000	1,256,000
LONG TERM			
Manhour, Labor Cost	572,000	286,000	858,000
Equipment	175,000	4,544,000	4,719,000
Materials	85,000	51,000	136,000
	=========	=========	=========
Subtotal	832,000	4,881,000	5,713,000
Construction Contingency 20 % ±	166,000	976,000	1,142,000
	=========	=========	=========
Total Price	998,000	5,857,000	6,855,000

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Chapter 4

TKIBULI REHABILITATION PLAN

4.1 Description of Project

The Tkibuli Hydroelectric Project is the downstream plant of the interconnected Shaori-Tkibuli stations, located about a one-hour drive from Kutaisi. The project is a four-unit station with a total generating capacity of 80 MW, commissioned in 1956. The supply of water for the Tkibuli hydroelectric project is the turbine discharge from the Shaori hydroelectric project, which discharges into the Tkibuli river. The river formerly disappeared into a sink hole, but an earth dam constructed on the Tkibuli river prevents it from flowing into that sink hole and instead impounds the water in a reservoir with a 82,000,000 m^3 capacity.

The power intake is located near the right abutment of the dam, and it has two inlets with a total capacity of 34 cms. Flow from the intake into the power tunnel is controlled by a butterfly valve. Flow is conveyed to the powerhouse through a 32-meter long conduit, a 48-meter long inclined shaft, a 3,500-meter long low-head pressure tunnel and a 525-meter long penstock. A surge shaft is located at the end of the pressure tunnel. The low-head pressure tunnel is constructed of reinforced concrete. The penstock is located within an inclined excavated rock tunnel and supported on saddles. The penstock manifolds into four penstocks to serve each of the four units.

The turbine pit floor is connected to an emergency discharge tunnel which can divert the water from a draft tube rupture into the tailrace emptying into the Dzevrula River. A cone valve releases excess flow during plant operation into a trapezoidal 1,500 meter long spillway chute. The power station houses four vertical Francis hydraulic turbines each rated at 20 MW at a rated head of 310 meters. The Tkibuli project was commissioned in 1956. The plants average annual energy production is 165 GWH.

Table 4-1 provides significant data for the Tkibuli Project including generator and turbine nameplate data, key elevations an physical dimensions for key structures.

Table 4-1

SIGNIFICANT DATA FOR THE TKIBULI PROJECT

Component	Description	Values
Generator Nameplate Data (Units 1 and 3)	Type Voltage Current Capacity Rated Speed Runaway Speed Frequency Power Factor Manufacturer Date of Manufacture	SPEL 586/51 - 10 10,500 V 1375 A 25,000 KVA 600 rpm 1080 rpm 50 Hz 0.8 AEG 1954
Generator Nameplate Data (Units 2 and 4)	Type Voltage Current Capacity Rated Speed Runaway Speed Frequency Power Factor Manufacturer Date of Manufacture	SPEL 586/51 - 10 10,500 V 1375 A 25,000 KVA 600 rpm 1080 rpm 50 Hz 0.8 Siemens-Schuckert 1954
Turbine Nameplate Data	Capacity Rated Speed Runaway Speed Rated Head Flow Manufacturer Date of Manufacture	21 MW 600 rpm 1080 rpm 294 m 8.5 cms Voith 1955
Significant Elevations	Normal Headwater Tailwater (1 unit operating) Tailwater (4 units operating) Centerline of Runner Discharge Weir Crest	El. 522.5 m El. 211.65 m El. 212.55 m El. 212.20 m El. 211.0 m

Component	Description	Values
Physical Dimensions	Powerhouse Oil Purification Building	52 m long x 31.8 m wide x 32.7 m high (approximate) 14 m x 7 m
Water Conductors	Low Head Gravity Tunnel Inclined Tunnel Manifold	3.5 m diameter, 3.5 km long 3.5 to 2.5 m diameter, 534 m long 19 m upstream of unit center-line

4.2 Condition Assessment

The Tkibuli station is generally in fair condition from a physical standpoint, but it requires considerable mechanical and electrical rehabilitation to extend its useful life. Civil rehabilitation requirements are not extensive.

Rehabilitation will be primarily required for the major equipment. In the mechanical area, the effort will focus on upgrading the turbines, including bearings, wicket gates, and wearing rings; rehabilitating the four governors, and providing a convenient method of maintaining the lubricating oil systems to reduce wear of the rotating parts. In the electrical area, the effort will focus on upgrades of the generator stators and exciters.

The power station operations and maintenance staff are making a valiant effort to keep the units on line and generating power. However, regrettably, although understandably, good housekeeping practices have taken a back seat, and have suffered badly. Lighting is either inadequate or non-existent, and stairs and walkways are often covered in oil. Both conditions present safety hazards.

At the time of the assessment, all units were shut down as they were conserving water for the summer season. Two units were out of service for repairs; Unit 3 for scheduled unit overhaul, which occurs every four years for each unit, and Unit 4 due to lack of oil for the bearings and undue vibration. Spare parts have been depleted to the point where plant personnel now have to cannibalize less critical pieces of equipment to keep more critical pieces of equipment in service.

4.2.1 Mechanical Assessment

The inlet valve, turbine and governor have the following main features:

- An inlet valve is located upstream of the spiral case. The inlet valve is of the wedge gate type, with an integral water servomotor located directly above the valve. The servomotor is controlled by a water distribution valve actuated by an oil servomotor controlled by the governor. If the governor oil pressure should fail, the inlet valve closes under the action of penstock water pressure. A maintenance valve also of the wedge gate type with an integral water servomotor is situated immediately upstream of the inlet valve. Its servomotor is controlled by manually operated valves.

- The turbine has a cast, integral spiral case and stay ring, partially embedded in concrete with a pressure relief bypass valve, a Francis, stainless steel runner, 1,690-mm diameter with a runner height 475 mm, and a vertical, one-piece, forged steel shaft.

- The turbine wicket gates are controlled by a gate shaft governor located at the turbine floor. There are 20 wicket gates.

- The guide bearings are Journal-type with forced-oil lubrication. There is an anti-vibration bearing located below the turbine guide bearing.

- A gear wheel, clamped to the shaft, drives the following equipment:

  - an oil pump for the turbine guide bearing;
  - an oil pump for the generator upper and lower guide bearings;
  - a permanent magnet generator to provide the speed signal for the speed governor; and
  - an overspeed relay.

- A labyrinth type shaft seal.

- The automatic greasing system no longer functions and a manual greasing system is being used.

At the time of the visit (30, 31 May 95), all four of the units at this power station were shut down, two for maintenance, and the other two because, it was reported that the reservoir level was too low. The first two units, 1 and 2, were commissioned during May to July 1956, and units 3 and 4 two months later.

Adjacent to the powerhouse there is an oil purification building containing a leased oil centrifuge. A portable oil purifier which can be used to used to purify governor and bearing oil, while the turbine is operating, is considered a necessary accessory.

Synchronous condenser operation was discontinued 15-20 years ago due to mechanical operating problems and insufficient funds to properly correct these problems. SAKENERGO did not express a desire to continue synchronous condenser operation so this issue was not pursued further.

Vibration Problems. It was reported that each unit can operate up to 17-18 MW without undue vibration. Operation between 3 to 10 MW is very rough and the operations manual recommends passing through this range as quickly as possible. Provision for air injection below the runner, when operating at partial loads, was not made. Three causes of the vibration problem were identified:

- Excessive bearing clearances;
- Variation in wicket gate openings, in diametrically opposite locations;
- When the unit is operating under load, the bottom ring surface and the runner inlet surface are not flush. The resultant step between the bottom ring and runner inlet surfaces under load causes eddies, unstable flow conditions and vibration.

The following settings have to be maintained to minimize vibrations:

- Guide bearing clearances:

  0.17 mm normal, 0.25 maximum turbine guide bearing;
  0.30 mm normal, 0.40 maximum upper guide bearing; and
  0.30 mm normal, 0.40 maximum lower guide bearing.

- Wicket gates are adjusted to be 65 mm when open. However, adjusting the wicket gates in the open position results in an excessive gap of 0.1 to 0.5 mm when closed. The resulting leakage across the wicket gates and the pressure difference across the inlet valve makes for difficult opening of the inlet valve especially with worn seals on the inlet valve servomotors.
- With the turbine stopped, the lower edge of the runner must be 0.20 mm above the bottom ring so that when the unit is operating under load the runner is flush with the bottom ring.

In order to maintain these settings, 'planned' maintenance is carried out at 3-month intervals. This very high frequency of maintenance is required as the wicket gate settings have a tendency to slip.

The original thrust bearing pads are worn out. In 1989, a set of 12 fluoroplastic thrust bearing pads were installed in Unit 2. Four sets (48 pads) were ordered in 1992 from the Cheboksar experimental plant, "Energozapchast". Owing to a lack of funds to pay for them, they were not delivered. These pads and wearing rings must be replaced and the bearings must be repaired.

4.2.2 Electrical Assessment

Protective Relays and Switches (Station Service Switchgear-Oil Circuit Breakers). There are six station oil breakers, which include the generator oil circuit breakers, all rated at 10.5 kV and 3000 amperes. The circuit breakers are currently functional; however, they have attained their normal life expectancy and spare parts are no longer available.

Station Service Transformers. The original transformers have been upgraded with 1,000 kVA units; however, these transformers are overloaded. When replaced, the transformers should have a rating of 2.000 kVA.

Generator Oil Circuit Breakers. The generator breakers are included as part of the station service lineup. It is desirable to install a tie disconnect switch between the two generator buses for operational flexibility. This switch would be installed between for Units 3 and 4 and would require some additional aluminum bus.

Stator Coils. The windings, which consist of 303 slots with 606 half-coil bars have reached or exceeded their normal life expectancy. There have been coil failures on all units over the years and additional coils are now needed to keep the units in service. The repair of Unit 2 will require 184 half-coil bars.

Generator Exciters and Regulators. The exciters, which are of the rotating type, and regulators are original equipment and have reached the normal life expectancy for this type of equipment. New static exciters and regulators have been purchased and are on site and installation expertise is available in Tblisi.

Power and Control Systems. The station is controlled from the local switchboard and no provision for remote control exists. The station control system is functional; however, the meters, relays and switches are over 40 years old and are nearing the end of their useful life.

Wire and Cable. The wire and cable in the station has been exposed to the elements (water and oil) for many years and appears dried out and in need of replacement. The replacement of the station control boards will require disconnection of a high percentage of the terminations and most probably will require additional conductors.

Motors. The motors are in general the same age as the station and thus have reached their normal life expectancy. There are some motors which are not functioning now and have not been replaced because there are no spare parts and no money to purchase any new equipment.

Miscellaneous Spare Parts. Due to lack of funds and availability, spare parts are virtually non-existent. Spare parts are required to effectively perform required maintenance on most plant electrical equipment and should be provided.

No problems were reported with the station service reactors, the generator coolers, and the station battery.

4.2.3 Civil Assessment

Transportation Considerations. In general, the roads from Kutaisi to the project are in reasonably good shape. These roads are fairly flat or gently inclined, so the gradient of the road as it would concern heavily loaded trucks is not considered to be a problem. Isolated areas of deteriorated pavement exist, but these are relatively few in number. Overall, transportation is not a problem.

Powerhouse Exterior. In general the plastering, glazing and roofing of the powerhouse should be repaired. The plaster coat over the stone masonry units was in need of patching in some areas. Where the block was not coated with plaster, the 1' x 2' stone blocks were observed to be in good shape. A significant number of glass window panes were broken or missing (estimated to be about 100) and need to be repaired. On the upstream side of the building, there is significant cracking evident in the concrete wall, up above the level of the switchyard. See comment below. The roof of the powerhouse needs repair, as evidenced by the water damage visible inside. The original roof was sheet metal, which was subsequently overlaid with corrugated asbestos panels.

Oil Building. An oil centrifuge, which is used to purify oil, is located in a building, about 14 m x 7 m in size, located to the right of the powerhouse. There is no piping from there to the powerhouse, so cleaned oil is carried manually. This building's exterior is in a state of disrepair and it has also suffered damage from rock slides.

Two rehabilitation options were considered; 1) Abandon the old building and construct a new one on the opposite side of the powerhouse, up above the yard level, on the existing upstream bench, adjacent to the switchyard and 2) purchase of portable lube-oil purifier. The second option is recommended.

Water Conductors. The water to the powerhouse is supplied from a reservoir filled from the discharges from the Shaori hydroelectric project. There are no sediment problems reported with this reservoir, because the reservoir for the upstream Shaori project traps most of the silt. The powerhouse intake structure was reported to be functioning properly, with no known problems related to the structure or its operation.

The low head (gravity) tunnel is a 3.5 m diameter reinforced concrete lined tunnel, with total length of 3.5 km. It is reported that this tunnel is in need of repair, with an estimated 400 m of longitudinal cracks on the order of 2 cm to 3 cm width. An inspection of this tunnel on the date of the visit was not possible, because the tunnel was not dewatered. A reinforced concrete surge shaft is located at the end of the low head (gravity) tunnel and there are no problems reported. The steel penstock is contained within an inclined tunnel, supported on saddles. The diameter varies from 3.5 m to 2.5 m

along a length of 525 meters, leading to the manifold. It was reported that the only work needed on the penstock was painting.

The power supply to the butterfly valve operator at the intake is taken from regular power lines, and not a dedicated power supply. It previously had a dedicated power supply, but the transmission towers for this supply have since collapsed. This leaves the control of the gate suspect, due to the normal power interruptions which occur in the system. In the event of a rupture in the power tunnel penstock, dependable operation of the butterfly valve is critical for plant safety. It is recommended that this problem be corrected.

Switchyard. The switchyard is located on an elevated concrete slab upstream of the powerhouse, which appears to be functioning satisfactorily. The foundations for the structures on top of the slab are in good shape, but could use some patching and the steel structures in the switchyard need to be painted. The upstream retaining wall appears adequate and no problems were reported.

Yard Area. The yard area was fairly open and neat in general appearance. A new transformer is sitting on rails next to the powerhouse adjacent to the existing transformers. There are also new crated spherical valves sitting out in the yard area. There was evidence of protective coverings on these parts, which are now in disrepair. These coverings need to be repaired to protect the parts until they are installed.

Powerhouse Interior. The ceiling of the powerhouse and walls shows evidence of leakage and there is also water damage evident on the walls. There were no civil problems reported or observed regarding the machine hall floor or the turbine floor level. Inspection of the next lower level was not possible due to water inundation. It was reported that there is a small amount of civil work necessary for the reconstruction of the concrete ring which anchors the draft tube liner.

Miscellaneous Items. An issue was raised by SAKENERGO regarding a new office building for the project. This issue is not related to the production of energy, and therefore the issue is not considered here. The construction of a water supply pipeline and related pumps to supply a nearby village and the power complex with drinking water wa also raised. Again it was stated that this construction is not related to energy, and the issue was not considered here.

4.3 Recommended Rehabilitation Work

4.3.1 Short Term Rehabilitation

Mechanical Rehabilitation. As the inlet valves, turbines, governors and auxiliary mechanical systems require an extensive rehabilitation in the intermediate term, for the short term rehabilitation

the emphasis will be on continued operation of the equipment at the least cost. The following commodity purchases and repairs are recommended as a minimum necessary to maintain operation.

(1) Purchase one oil purifier to be used for both the turbine oil systems and the governor systems.

(2) Purchase four sets of fluoroplastic thrust bearing pads which have been ordered, but not delivered due to lack of funds.

(3) Replace wicket gates for the four units. Each set includes 20 wicket gates.

(4) Purchase four anti-vibration bearings similar to the original design. The modified rubber design did not function properly.

(5) Repair the turbine guide bearings for each of the four units.

(6) Rehabilitate the rotating oil sump for each of the four units.

(7) Purchase four sets of turbine runner wearing rings.

(8) Rehabilitate the four sets (2 pumps per set) of governor oil pumps.

(9) Purchase leather seals for the four turbine inlet valves.

(10) Purchase new spindles for the bypass valves on the inlet maintenance valves upstream of the turbine inlet valves.

(11) Repair the bronze rings for the oil-water valves on the four inlet operating valves.

(12) Replace one station drainage pump.

Electrical Rehabilitation. For short term rehabilitation the emphasis will be on continued operation of the equipment at the least cost.

(1) Purchase 100 new stator coils for maintenance of all units.

(2) The new exciters which have been purchased should be installed. A contract should be negotiated with a Tblisi firm which has expertise for this type of work.

(3) A minimum number of the most critical motors should be procured.

(4) A minimal number of spare parts to be used during normal required maintenance should be procured to keep the plant operational for the next 3-5 years. This complement of spare parts should be the absolute minimum required to perform essential maintenance and keep the plant operational. Particular care should be exercised to minimize spare parts purchases for equipment which will be scheduled for replacement in the long term. It is emphasized that the spare parts procurement for the short term must be particularly austere.

Civil Rehabilitation. For short term rehabilitation, the following is recommended:

(1) The plastering, glazing and roofing of the powerhouse should be included in the short term rehabilitation. These repairs are necessary to slow the physical deterioration of the plant. The repairs will also protect the investment in the plant with regard to the electromechanical equipment by aiding in preventing damage from rain water and the deleterious effects of the weather exposure.

(2) Erect transmission poles or light duty transmission towers and install conductors to supply the intake with 10.5 kv uninterruptable service directly from the powerhouse. Five such structures are required to replace the collapsed towers. This should be done as soon as possible to ensure the safety and reliability of the plant.

(3) After the mechanical rehabilitation previously discussed has been accomplished allowing the lower level to be dewatered, perform a thorough inspection to identify any problems that might exist. From discussions, no major problems are anticipated.

(4) The concrete demolition and repair for the draft tube liner is well within the capability of SAKENERGO, as the work has already been done on three of the four units.

(5) Repair and repaint the ceiling of the powerhouse after remedial measures previously described are implemented.

4.3.2 Long Term Rehabilitation

Mechanical Rehabilitation. The original turbines, governors, and ancillary equipment, after 39 years in service, are at the end of their useful life. In order to improve the plant for 10 to 25 years of additional service, the following additional rehabilitation work is recommended. The units will be rehabilitated consecutively to minimize power generation interruptions.

(1) Replace turbine rotating parts:

(a) Provide new, improved design, stainless steel Francis runner with replaceable labyrinth seals, at the runner crown and runner band.

(b) Use existing shaft with new stainless steel sleeved journal, and forced oil-lubricated turbine guide bearing and reliable, mechanical type shaft seal. Shaft seal will be provided with clean filtered water.

(2) Provide new head cover, operating ring and wicket gates;

(3) Provide new gate servomotors and connecting rods;

(4) Provide new bottom ring, discharge ring, and exposed vertical portion of draft tube below discharge ring;

(5) Refurbish stay vanes and spiral case, including painting.

(6) Provide new digital control governor including:

- hydraulic actuator system with pumps;
- speed signal generator;
- electronic restoring;
- accumulator tank with pressure and level control and gauges.

(7) Purchase a set of turbine spare parts.

(8) Install two spherical valves already purchased.

(9) Purchase and install 2 hydraulic power units for spherical valves.

(10) Purchase and install two additional spherical valves with dedicated hydraulic power units.

Electrical Rehabilitation. In order to improve the plant for 10 to 25 years of additional service, the following additional rehabilitation work is recommended.

(1) Purchase and install seven new station service switchgear-oil circuit breakers (including one spare) in the existing station lineup to replace the present breakers.

(2) Replace reactors as they fail as part of regular maintenance.

(3) Replace the station service transformers with units of not less than 2000 kVA rating as part of a general station rehabilitation.

(4) Purchase one 10.5 kV generator disconnect switch with about 100 meters of aluminum bus for installation by SAKENERGO.

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(5) Replace all windings with new stator windings having not less than Class B insulation.

(6) Replace the station control boards complete with switches, indicators, meters and relays.

(7) Replace the wire and cable in conjunction with the replacement of the station control boards.

(8) Procure a substantial supply of spare motors to permit replacement under normal maintenance as they fail. An inventory of recommended spare motors should be developed and purchased as spare parts.

(9) A list of those spare parts required for reliable long term operation of the plants should be developed and those spare parts purchased and maintained in inventory.

Civil Rehabilitation. If it is decided to perform major rehabilitation of mechanical and electrical equipment and systems at this plant, detailed civil inspections will be required. On the basis of the cursory site inspections performed, the following actions are recommended:

(1) Repair the power tunnel liner during a scheduled plant outage, which will allow sufficient time to make the repairs and also allow for the required cure time. This item, important, but not critical to operation or safety should be included under the long term rehabilitation plans to help improve power production.

(2) Paint the penstock.

(3) Relocate the existing oil tanks on the existing upstream bench adjacent to the switchyard. Construct appropriate pads and containment for the vessels. Pipe the oil supply directly down to the powerhouse.

4.4 Cost Estimates

The estimated short term and long term rehabilitation costs for the Tkibuli Project is $2,650,000 and $12,000,000 respectively. Tables 4-2 and 4-3 provide a detailed breakdown for the civil, mechanical, and electrical items recommended both for the short term and long term rehabilitation. The distribution of foreign and local costs for the short term and long term rehabilitation programs is shown in Table 4-4.

GEORGIA HYDROPOWER REHABILITATION PROJECT
PROJECT: TKIBULI HYDROELECTRIC POWER GENERATING STATION
SHORT TERM REHABILITATION (3 TO 5 YEARS)

COMPONENT DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE	PROCUREMENT PROCEDURE
CIVIL ITEMS					
Mobilization & Demobilization	LS	1	68,000	68,000	LCB
Repairs to Powerhouse					
Roof	SqM	1,100	16	17,600	LCB
Glass Panes	EA	100	31	3,100	LCB
Reinforced Concrete Pads	LS	1	3,500	3,500	LCB
Power Supply to Intake Structure					
Steel Power Poles	EA	5	4,000	20,000	LCB
10 kV Line Including					
Transformer and Accessories	M	2,000	89	178,000	IS
		Subtotal		290,200	
MECHANICAL ITEMS					
Turbine Guide Bearing					
Dismantle	EA	4	1,200	4,800	LCB
Repair	EA	4	9,000	36,000	DC
Reassemble	EA	4	1,200	4,800	LCB
Anti Vibration Bearings					
Dismantle	EA	4	1,200	4,800	LCB
Purchase	EA	4	9,000	36,000	DC
Install	EA	4	1,200	4,800	LCB
Thurst Bearing Pads -Fluoroplastic					
Dismantle	EA	4	1,200	4,800	LCB
Purchase	EA	4	9,000	36,000	DC
Reassemble	EA	4	1,200	4,800	LCB
Wicket Gates - 20 WG's/Turbine					
Dismantle	EA	80	100	8,000	LCB
Purchase	EA	80	3,200	256,000	DC
Reassemble	EA	80	100	8,000	LCB
Portable Lube Oil Purifier					
Unpacking & Familiarization	EA	1	200	200	LCB
Purchase	EA	1	41,000	41,000	DC
Drainage Pump					
Dismantle & Remove	EA	1	200	200	LCB
Purchase	EA	1	18,000	18,000	DC
Install New Pump	EA	1	400	400	LCB
Rotating Oil Sump					
Dismantle	EA	4	800	3,200	LCB
Repair	EA	4	4,000	16,000	LCB
Install	EA	4	800	3,200	LCB
Turbine Runner Wear Rings					
Dismantle	SETS	4	600	2,400	LCB
Purchase	SETS	4	8,000	32,000	LCB
Install	SETS	4	600	2,400	LCB

GEORGIA HYDROPOWER REHABILITATION PROJECT
PROJECT: TKIBULI HYDROELECTRIC POWER GENERATING STATION
SHORT TERM REHABILITATION (3 TO 5 YEARS)

COMPONENT DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE	PROCUREMENT PROCEDURE
MECHANICAL ITEMS (Cont'd)					
Overhaul Governor Oil Pumps					
Dismantle	EA	4	250	1,000	LCB
Repair	EA	4	12,000	48,000	LCB
Install	EA	4	200	800	LCB
Leather Seals For Inlet Valves					
Dismantle	SET	1	1,600	1,600	LCB
Purchase	SET	1	12,000	12,000	DC
Install	SET	1	1,600	1,600	LCB
New Spindles For Bypass Valve (Inlet Maint. Valve)					
Dismantle	EA	4	500	2,000	LCB
Repair	EA	4	7,000	28,000	DC
Install	EA	4	500	2,000	LCB
Repair Bronze Rings (Inlet Oper. Valve)					
Dismantle	EA	4	225	900	LCB
Repair	EA	4	3,300	13,200	DC
Install	EA	4	225	900	LCB
		Subtotal		639,800	
ELECTRICAL ITEMS					
General Stator Coils					
Spare Coils 100 With Insulating And Packing Materials	LS	1	177,000	177,000	DC
Exciter (Already Purchased)					
Dismantle Parts	EA	4	800	3,200	LCB
Install	EA	4	1,200	4,800	LCB
Motors					
New Motors	LS	1	9,000	9,000	DC
Remove	LS	1	1,000	1,000	LCB
Install	LS	1	3,000	3,000	LCB
Spare Parts					
MV Switch Gear	LS	1	24,000	24,000	DC
LV Switch Gear	LS	1	18,000	18,000	DC
Protective Relays	LS	1	29,000	29,000	DC
Illumination	LS	1	6,000	6,000	DC
		Subtotal		275,000	
				=========	
Subtotal				1,205,000	
Construction Contingency		20 % ±		240,000	
				=========	
Total Price @ January 1996 Level				**1,445,000**	

Legend:

ICB = International Competitive Bidding
IS = International Shopping
DC = Direct Contracting
LCB = Local Competitive Bidding

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GEORGIA HYDROPOWER REHABILITATION PROJECT
PROJECT: TKIBULI HYDROELECTRIC POWER GENERATING STATION
LONG TERM REHABILITATION (10 TO 25 YEARS)

COMPONENT DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE	PROCUREMENT PROCEDURE
CIVIL ITEMS					
Mobilization & Demobilization	LS	1	57,000	57,000	LCB
Power Tunnel Lining					
Repair Concrete Lining	M	400	130	52,000	LCB
Relocate Oil Tanks	EA	2	16,000	32,000	LCB
		Subtotal		141,000	
MECHANICAL ITEMS					
Refurbish Turbines					
Dismantle parts	EA	4	5,000	20,000	LCB
Purchase	EA	4	685,000	2,740,000	ICB
Install	EA	4	10,000	40,000	LCB
Foreign Supervision	LS	1	100,000	100,000	ICB
Governors					
Dismantle parts	EA	4	1,650	6,600	LCB
Purchase	EA	4	222,000	888,000	ICB
Install	EA	4	5,000	20,000	LCB
Foreign Supervision	LS	1	60,000	60,000	ICB
Install Spherical Valves (Already Purchased)					
Dismantle parts	EA	2	700	1,400	LCB
Install	EA	2	1,000	2,000	LCB
Hydraulic Power Units For Spherical Valves					
Dismantle parts	EA	2	800	1,600	LCB
Purchase	EA	2	23,000	46,000	IS
Install	EA	2	1,600	3,200	LCB
Spherical Valves and Hydraulic Power Units					
Dismantle parts	EA	2	1,500	3,000	LCB
Purchase	EA	2	42,000	84,000	IS
Install	EA	2	2,600	5,200	LCB
		Subtotal		4,021,000	
ELECTRICAL ITEMS					
10.5kV Circuit Breaker					
Generator Circuit BKR	LS	1	297,000	297,000	ICB
Feeder Circuit BKR	LS	1	89,000	89,000	ICB
Spare BKR	LS	1	40,000	40,000	ICB
Removal Of Existing Swgr	LS	1	1,600	1,600	LCB
Modifying, Installing, Connection And Testing	LS	1	7,000	7,000	LCB
Station Service Transformer					
2000 kVa Transformer	EA	2	30,000	60,000	ICB
Remove Existing	EA	2	1,600	3,200	LCB
Install New	EA	2	3,300	6,600	LCB
10.5kV Disconnect Switch					
Aluminum Bus And Support, 100 M	LS	1	7,000	7,000	DC
Modifying, Installing, Connection And Testing	LS	1	28,000	28,000	LCB

GEORGIA HYDROPOWER REHABILITATION PROJECT
PROJECT: TKIBULI HYDROELECTRIC POWER GENERATING STATION
LONG TERM REHABILITATION (10 TO 25 YEARS)

COMPONENT DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE	PROCUREMENT PROCEDURE
ELECTRICAL ITEMS (Cont'd)					
Generator Stator Winding					
Stator Coils	EA	4	544,000	2,176,000	ICB
Dismantle Existing Coils	EA	4	3,300	13,200	LCB
Reassemble New Coils & Testing	EA	4	20,000	80,000	LCB
Remove Rotor & Reinstall	EA	4	1,000	4,000	LCB
Foreign Supervision	LS	1	320,000	320,000	ICB
Control Switchboard					
Control, Metering, & Protection Eqpt.	EA	4	178,000	712,000	ICB
Remove Exist. Cubicles, Disconnect	EA	4	1,000	4,000	LCB
Install New Cubicles, Connect	EA	4	1,600	6,400	LCB
Test	EA	4	1,600	6,400	LCB
Foreign Supervision	LS	1	60,000	60,000	ICB
Wire And Cable					
Wire And Cable	EA	4	119,000	476,000	IS
Removal Of Existing Cable	EA	4	3,300	13,200	LCB
Install New Cables And Design	EA	4	7,000	28,000	LCB
Conduits And Trays	EA	4	44,000	176,000	IS
Motors					
New Motors	LS	1	15,000	15,000	DC
Remove Existing	LS	1	2,400	2,400	LCB
Install New Motors And Testing	LS	1	6,000	6,000	LCB
Spare Parts					
Generator	LS	1	30,000	30,000	ICB
Excitation	LS	1	40,000	40,000	DC
MV Switch Gear	LS	1	15,000	15,000	DC
LV Switch Gear	LS	1	10,000	10,000	DC
Protective Relay	LS	1	30,000	30,000	ICB
Illumination	LS	1	6,000	6,000	DC
Reactors	LS	1	70,000	70,000	DC
		Subtotal		4,839,000	
				=========	
Subtotal				9,001,000	
Construction Contingency		20 % ±		1,800,000	
				=========	
Total Price @ January 1996 Level				**10,801,000**	

Legend:

ICB = International Competitive Bidding
IS = International Shopping
DC = Direct Contracting
LCB = Local Competitive Bidding

GEORGIA HYDROPOWER REHABILITATION PROJECT
TKIBULI HYDROELECTRIC POWER GENERATING STATION
LOCAL AND FOREIGN COST COMPONENTS

DESCRIPTION	LOCAL	FOREIGN	TOTAL
SHORT TERM			
Manhour, Labor Cost	153,000	0	153,000
Equipment	117,000	736,000	853,000
Materials	182,000	17,000	199,000
	=========	=========	=========
Subtotal	452,000	753,000	1,205,000
Construction Contingency 20 % ±	90,000	150,000	240,000
	=========	=========	=========
Total Price	542,000	903,000	1,445,000
LONG TERM			
Manhour, Labor Cost	1,048,000	541,000	1,589,000
Equipment	256,000	6,992,000	7,248,000
Materials	106,000	58,000	164,000
	=========	=========	=========
Subtotal	1,410,000	7,591,000	9,001,000
Construction Contingency 20 % ±	282,000	1,518,000	1,800,000
	=========	=========	=========
Total Price	1,692,000	9,109,000	10,801,000

Chapter 5

VARTSIKHE REHABILITATION PLAN

5.1 Description of Project

The Vartsikhe Hydroelectric Project is comprised of four power stations, each housing two units. The powerhouses are essentially identical in features and layout, containing two Kaplan turbine/generating units, each rated at 23 MW at a rated head of 15 meters and a rated discharge of 175 cms. Vartsikhe I was commissioned in 1976, Vartsikhe II in 1978, Vartsikhe III in 1980, and Vartsikhe IV in 1988. The total capacity of the Vartsikhe Project is 184 MW, and the average annual energy production is 1,000 GWH.

A diversion dam and spillway constructed across the Rioni River diverts a rated flow of 350 cms from the river into a 27-km-long canal that serves all four of the powerhouses. The powerhouses are spaced along the length of the canal, and develop the available head along this stretch of the Rioni River through a combination of canal sections dictated by the topography. The head works at the upstream end of the canal consist of a low sill gated spillway dam, an earth embankment, a water intake for the canal, and a sediment basin.

Table 5-1 provides significant data for the Vartsikhe Project, including generator and turbine nameplate data, key elevations, and physical dimensions for key structures.

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Table 5-1

SIGNIFICANT DATA FOR THE VARTSIKHE PROJECT

Component	Description	Values
Generator Nameplate Data	Voltage Rated Speed Frequency Phases Capacity Power Factor Current Manufacturer	10,500 V 115.4 rpm 50 Hz 3 28,750 KVA 0.8 1580 A Kharkov (Ukraine)
Turbine Nameplate Data	Capacity Rated Speed Runaway Speed Rated Head Flow (water rated discharge) Manufacturer	23.8 MW 115.4 rpm 235 rpm 14.92 m 175 cms Kharkov (Ukraine)
Significant Elevations	Intake Normal Headwater Intake Normal Minimum Headwater Tailwater at Powerhouse #4	El. 87.0 m El. 78.0 m El. 23.09 m
Power Canal Lengths	Canal #1 Canal #2 Canal #3 Canal #4	664 m 4436 m 5484 m 12,116 m
Outlet Canal	From Powerhouse #4 to Rioni River	4434 m

5.2 Condition Assessment

Though the plants are of fairly recent construction, the inability to meet technical operation standards over the last several years has manifest itself in a run-down appearance beyond their ages. The power station operations and maintenance staff are having to expend a significant effort just to keep

the units on-line and generating power, with the result that powerhouse lighting and interior appearances, regular equipment cleaning and inspections, adequate provision of replacement materials and spare parts, and other safety- and security-related concerns and practices are wanting.

In addition to the electromechanical concerns in the powerhouses, this project, compared to the others, requires major civil rehabilitation. This is because during the construction of the project, there was a "five-year plan" in effect which rushed the plants into production. To be on-line according to schedule, there was a significant amount of civil work which was (1) simply bypassed, (2) started but not completed, or (3) constructed, but in deviation from the design and drawings. Consequently, the selection of this project for rehabilitation will entail significant rehabilitation of certain critical civil works to ensure project and public safety, in addition to increasing the quantity and reliability of power production.

Mechanical rehabilitation related to the major equipment is primarily focused on upgrading the station auxiliary equipment rather than the turbines, with the exception of new turbine blades for Unit 5 and the provision of a convenient method of maintaining the lubricating oil systems to reduce wear of the rotating parts. Electrical rehabilitation related to the major equipment is primarily focused on upgrades for the Unit 6 generator and spare parts for ongoing generator maintenance. Also, major civil work is required for the short term to improve the safety of this project and to reduce the probability of a catastrophic failure. For the long term, there is considerable need for mechanical and electrical rehabilitation to extend the useful life of the project.

5.2.1 Mechanical Assessment

Each of the turbines and governors has the following main features:

- Semi-spiral case formed in concrete.
- Kaplan runner with four stainless steel blades; 5.0-m runner diameter.
- Vertical, one-piece, forged steel shaft.
- Turbine wicket gates operated by an LMZ governor and hydraulic power unit, located on the generator floor. The governor has no ballhead or speed control element, and therefore does not control the unit speed; the governor controls power.
- Skirt-type shaft journal, oil lubricated, turbine guide bearing.
- Shaft seal comprised of two annular rubber pads hydraulically pressed against two polished rotating disks fixed to the shaft. The hydraulic pressure is provided by water from a tap off the intake. The mechanical seal arrangement is only partially successful.

- Manual greasing system (an automatic greasing system no longer functions).

- Powerhouse I has a 150/32 ton electric overhead travelling crane with a mono-rail hoist attached to one of the crane girders. Powerhouses II, III, and IV have 125/20 ton cranes, and no mono-rail hoist.

The Vartsikhe Hydroelectric Project is comprised of four powerhouses numbered I to IV in a cascade layout, each containing two identical Kaplan units, numbered 1 to 8. At the time of the inspections of the Project (28 and 29 May 95), all the units were in operation except Unit 6, which was off-line because of damaged stator coils. Most of the units were generating at less than their full capacity because of shaft seal problems. Depending on the condition of the individual shaft seal and the temporary head cover drainage pumps, each unit was generating at an established safe maximum output without flooding the head cover. It was concluded from visual inspections and discussions with operating personnel that replacement of the shaft seals alone without performing extensive repairs to correct shaft alignment problems, worn turbine guide bearings, and other expensive repairs was not cost effective. Therefore, only replacement of the head cover sump pumps related to this problem is recommended under the short term rehabilitation scenario. Any excess water is discharged through the bypasses at each station.

It was reported that when a line trips and power fails, it takes two to three minutes to flood the head cover and the turbine guide bearing. When the line trips, the unit comes to a standstill, but the shaft seal leaks sufficiently to require continued functioning of the head cover sump pumps. Lacking a reliable station service (or emergency power supply), the head cover sump pumps stop functioning.

The shaft of Unit 5 visibly 'coning' (i.e. running out of true) due to a worn turbine guide bearing. It was reported that its clearance was 1 mm, compared to a correct clearance of 0.15 mm.

One of the Kaplan runner blades was laid out on the unloading/erection bay in Powerhouse I. It had a large crack about 100 to 150 mm in length near the hub of the blade. It was reported that the water contains magnesium which contributes to corrosion and thinning of the blades. Cavitation pitting and erosion due to sand and silt in the water also contribute to blade thinning.

The units are designed for synchronous condenser operation, and each powerhouse has a bank of air receivers for the air depression system. However, it was reported that synchronous condenser operation has never been practiced.

Various replacement motors for governor oil pumps, air compressor, station drainage, cooling water, and dewatering systems are needed.

Intake and draft tube gantry crane motors and cables were removed from the site and need to be replaced. Various rubber seals for gates need replacement.

Condition of Turbines and Governors. Although the turbine and governor units at the powerhouses are of a more recent vintage than the other powerhouses inspected for this report, they also require considerable rehabilitation. The governors need to be upgraded, and both speed and power control functions should be provided.

5.2.2 Electrical Assessment

Station Service Switchgear - Oil Circuit Breakers. Several of the breakers have failed in the past, particularly at Vartsikhe Powerhouse Number IV. Some have been replaced with other types of breakers to keep the plant running. Spare parts have been exhausted.

Station Service Reactor. One reactor recently failed and was replaced. There are no spares currently in stock.

Generator Oil Circuit Breakers. The generator circuit breakers are of the oil type. Except for the Unit 6 breaker, which has failed and is out of service, the other breakers are functioning. The Unit 7 breaker was replaced recently due to an explosion. Spare parts have been exhausted.

Generator Voltage Bus. An isolated phase bus is used from the generator circuit breakers to the low voltage terminals of the transformer. The other generator voltage bus is of the flat bar type constructed on insulators at site and enclosed in a fabricated enclosure. All of the buses appeared in generally good condition, and no problems have been reported. The flat bar bus would generally be easy to modify to terminate on new equipment which may have different termination layouts.

Stator Coils. The generators are original equipment at this plant, and stator winding repair is increasingly required. Winding insulation is Class A. Each generator has 432 coils or 864 half coils (stems). Unit 6 stator has substantially failed and is out of service. It is estimated to require at least 200 half coils to repair. Unit 2 operated out of synchronism in January 1995 which resulted in sheared stator foundation bolts. It is currently being operated without foundation bolts. The rotor rim is also loose on the rotor spider. Unit 1 has one of 52 rotor pole windings bypassed.

Chronic Generator Coil Failures. Generator coils have been replaced on a fairly regular basis in all units since the early 1980's. For example, Unit 1 has had 32 half coils replaced and Unit 2 has had a total of 15 replaced. These units do not have their neutrals grounded. The protective circuit uses a circuit on the main bus which is tuned to the generator winding capacitance to detect grounds on the winding coils and limit ground fault currents. The generator windings do have surge protection.

During scheduled unit overhaul every four years, stator windings are tested with a.c. voltage of 1.7 times rated voltage. Winding insulation is Class A.

Generators are frequently operated at higher than rated temperature for extended periods of time due to air cooler limitations, and operation for extended periods of time at frequencies considerably lower than rated frequency.

Coil failures are generally at the top of the stator core steel. SAKENERGO has analyzed the failures and believes that the failures are the result of the adverse operating conditions, i.e. high operating temperatures, low frequency operation contributing to double frequency oscillation of the coil in the slot and age of the insulation.

Rotor Windings. Rotor pole windings have been shorted out on a total of ten poles at the four powerhouses. Each generator rotor has 52 poles. Spare rotor pole windings are not available at the stations.

Generator Coolers. The air coolers are prone to plug with silt, resulting in increased operating temperatures of the generator windings. For various reasons, cleaning of the coolers is not always accomplished as needed or required, contributing to the operation of the generators at elevated temperatures for extended periods of time.

Generator Exciters and Regulators. The exciters and regulators are original equipment, but are currently operating without undue problems. The exciters are of the rotating type. A complete spare exciter is stored at Vartsikhe III.

Power and Control Systems. The station is controlled locally from the station switchboard. Remote control is not installed. Load is controlled according to a schedule. Although the equipment appears to be much older than it actually is, no problems were reported with its operation. Spare parts such as relays, control switches and meters are not available at the site.

Station Battery. The batteries show considerable corrosion at the connections and in the cells, and are nearing the end of their normal life expectancy. Several cells have been shorted out of the lineup at all four stations. The battery cells are a Russian type CK5, 2.28 volts/cell and 180 ampere-hour. There are 108 cells in each battery.

Motors. The motors are generally original equipment and many motors have failed over the years for various reasons, but the lack of money has precluded replacement of many of the motors, and the supply of spare motors at the site has been exhausted.

Miscellaneous Spare Parts. Due to lack of funds and availability, spare parts are virtually non-existent. Spare parts of sufficient quantity are essential to the effective maintenance and reliable operation of plant electrical equipment.

Other Equipment. No problems were reported with the station service transformers, generator thrust bearing, and wire and cable.

5.2.3 Civil Assessment

In addition to electrical and mechanical items, there are several fairly extensive civil works deficiencies that need to be addressed at this project. The major items include the following:

- There is a failure or collapse of a downstream section of the right training wall, located on the downstream side of the diversion dam and spillway.

- Emergency overflow spillway structures are missing at three locations on the power canal, leaving the dike with no protection against canal overtopping in the event of operator error or a loss of power and control to the existing bypass gates.

- Drainage provisions are inadequate in various areas adjacent to the canal to protect against flooding of adjacent property and homes. Drainage is necessary because the elevated power canal dikes in certain reaches of the project have blocked the natural preproject drainage. In some areas the drainage ditch is undersized, and in some areas it was never constructed as originally envisioned.

- There are silt build-ups in the reservoir and the power canals that need to be removed to restore power canals to their design hydraulic profile. It has been reported that this silt reduces the total power output of the four projects by 15 to 16 MW.

These and other issues are discussed more fully in the item-by-item discussions which follow.

Reservoir. The reservoir, initially designed to contain 14,000,000 m^3 of water, has been reduced to a capacity of 2,000,000 m^3, due to sedimentation. Silt islands are visible in the reservoir during periods of low water. Essentially, the project operates as a run of river project.

In discussions at the main dam with SAKENERGO concerning the problem of silt, it was reported that there is a great need to flush out the silt, which had been done previously once a year. With the urgent need for power, however, they cannot afford to shut down the plants to perform this silt-flushing operation, and they haven't done it "for years". The need to recoup energy reserves in the form of water storage (and also, flood control storage) is an important operational problem.

Main Dam Spillway. The four spillway bays are generally reported to be in good condition. There is some surface concrete repair work required on the far right hand side bay, the other bays having already been repaired by SAKENERGO.

Training Wall. There is a portion of the downstream right training wall which has collapsed into the river channel. The collapse was attributed to a faulty design. The left wall, which is reported to be performing satisfactorily, was previously repaired.

There is an urgent need for repair of this training wall, so as not to jeopardize the power canal dike which this wall retains. There has already been a redesign of this wall performed by the Hydraulic Design Institute (HDI), the original project designer. The alignment of this wall is slightly different from the existing alignment, so as not to compromise the integrity of the dike during construction.

Power Canal 1. Along Power Canal I, which is the initial section of fully lined canal between the intake and Powerhouse I, the canal lining, which is constructed of asphaltic concrete, is showing areas of deterioration. Above the water line there are sections missing, large cracks, and surface spalling evident. It was also reported that silt needs to be cleaned out of the canal.

Power Canals 2, 3 and 4. The power canal lining between Powerhouses I and IV is showing signs of deterioration in various areas, consisting of cracking and spalling. There is foliage growing in the construction joints of the lining, and erosion is evident in the unlined portions of the canal immediately downstream of the powerhouses. It was reported that the eroded areas have stabilized, and have not increased in size since they were more or less initially formed.

It was reported that the hydraulic capacity of the canal is being compromised by the presence of silt sedimentation, and that segments of the canal were never excavated and completed as designed.

There is also a need for the incorporation of emergency overflow spillways into the canal structure upstream of each of Powerhouses II, III, and IV. The spillways would serve to divert excess headwater in the canal into the river, in the event of an accident or loss of control of the water in the canals.

There is a need for a 3-km length of parapet wall to be constructed on the crest along Canal IV in combination with the construction of the overflow spillway there. The Canal IV dikes have no filters or drainage canals for protecting the dike and villages from flooding.

The construction of the overflow spillways is considered essential from a project safety standpoint, as discussed with HDI and SAKENERGO. These structures are needed to protect the canal dike from overtopping in the event of loss of control of the existing bypass gates. The current bypass system is not reliable, and in the event of an accident, the dike structure can be compromised, and the potential for catastrophic failure of the dike exists. It is acknowledged that there are temporary parapet sections in place to try and alleviate the potential for further damage if an event would reoccur, but this is not a permanent solution. The only permanent solution is the emergency spillways and the parapet construction.

The ramification of not having emergency spillway capability is already apparent in the existing damage present on the outer face of the dike of Canal IV. In this reach of the canal, due to overflow accidents, some of the dike cross-section is eroded so severely that it currently constitutes a safety problem. It should also be noted that the construction of the spillway has already been started in Canal IV. The spillway orifice section and parts of the training walls are in place. Similarly, the

parapet wall construction is already started. It was reported that financial shortcomings curtailed the completion of these works.

Dike Between River and Power Canal. There is a dike already constructed in the area between the power canal and the river. This low dike is intended to protect the toe of the canal embankment from the effects of the river, especially during flood stages. This dike is in need of reinforcement. There are some areas of the dike that have not been built to full cross section due to interference with the dike road alignment, and there is also a lack of toe drain provisions in the original construction that should be remedied.

According to reports from HDI, this dike needs reinforcement, as it was not constructed according to the design drawings up to the standards of permanent works. The repair is designed as a slurry wall method of construction, with reinforcing plates as anchors. This work is reported to be necessary between Powerhouses 3 and 4.

Drainage Canal Rehabilitation and Improvements. The drainage provisions involve ditches which run adjacent to the outboard side of the access road located at the toe of the right hand side power canal dike. There are some existing sections of the drainage canal which are concrete lined ditch cross sections, and some which are just excavated grassed ditches; some of these segments have been found to be inadequate for the actual drainage. Other segments have been designed but are not yet constructed.

Between Powerhouses III and IV, the start of construction of bridge piers is evident that allows for crossing over a planned connection of the existing Kutaisi canal with the power canal. The design of the connection has been completed, but construction of the bridge crossing has stopped.

After Powerhouse IV, an unlined section of the canal approaches the intersection with the river. This area is experiencing severe erosion problems, and compromises the safety of a transmission tower's foundation..

As a result of construction of new concrete ditches, and expansion of existing ditches, it is necessary to consider providing crossings over these ditches for people and livestock. Bridges have been discussed, and detailed design is provided.

Powerhouses. The superstructure exteriors are in need of repair to the stone cladding. This is a safety-related issue due to the danger posed by falling debris. Some patching is already evident.

There is also glazing repair required. This is essential to protect the interior of the powerhouse from damage due to the elements. It was reported that the roofs of Powerhouses I and IV need repair, as also evidenced by missing flashing and interior signs of leakage.

The general appearance of the machine hall floors is satisfactory, with no apparent problems reported or noted, except for Powerhouse III, where the only major civil work apparent is the completion of construction of the upstream face cavity wall precast panels. Approximately 344 panels, 1.4 m x 0.5 m x .08 m, need to be fabricated and installed to complete the work.

On the generator floor, there are no apparent civil problems noted other than the need for general maintenance improvements.

For the turbine floors, there are minor seeps noted in the upstream wall which are of no consequence. A general clean-up of the gutters to remove the sediment and debris would help the drainage water to flow to the sump, and would likely help reduce maintenance problems with the pumps.

Other minor items needed include patching of the plaster coat on the downstream face of the retaining walls, patching or replacement of chipped stair treads for safety, and minor patching of substation equipment foundations.

Design of Deflectors to Protect the Railroad. As regards the dam embankment at the railroad, there is a concern about the undermining of the dam protective concrete face near the railroad bridge located to the right of the power intake. It is reported that high velocity flows in this area indicate the need for concrete hydraulic deflectors to protect the abutment.

Transportation Considerations. In general, the roads from Kutaisi to the project are in reasonably good condition. The roads are fairly flat or gently inclined, so the gradient of the road as it would concern heavily loaded trucks is not considered to be a problem. Isolated areas of deteriorated pavement exist, but these are relatively few in number. The access road between the power stations is in generally good condition, but it is fairly well deteriorated between Powerhouses III and IV. Overall, transportation of equipment would not pose a problem.

5.3 Recommended Rehabilitation Work

5.3.1 Short Term Rehabilitation

Mechanical Rehabilitation. As the turbines, governors, and auxiliary mechanical systems require an extensive rehabilitation for the long term, the emphasis of short term rehabilitation will be on continued operation of the equipment at the least cost. The following commodity purchases are recommended as a minimum necessary to maintain operation.

(1) Purchase one oil purifier to be used for both the turbine oil systems and the governor systems.

(2) One set of turbine blades (4 blades) for Unit 5.

(3) Purchase rubber seals for the draft tube and intake gates.

(4) Purchase miscellaneous valves for use in the various water supply systems.

(5) Purchase four governor air compressors.

(6) Purchase centrifugal type head cover drainage pumps. Eighteen pumps are recommended; two for each of the eight units and two spare pumps.

(7) Furnish four station drainage pumps of the deep well type.

Electrical Rehabilitation. For short term rehabilitation the emphasis will be on continued operation of the equipment at the least cost.

(1) Purchase and install one new oil circuit breaker in Unit 6.

(2) A new stator winding with Class B insulation should be procured and installed in Unit 6. Considering its age and the magnitude of the repair it would be more prudent to replace the complete winding with a new one rather than repair the old one.

(3) The Unit 2 stator should have new stator foundation bolts installed. The rotor poles should be rewedged to the rotor rim.

(4) Test voltage for stator maintenance for these older machines should be no more than 1.5 times rated voltage.

(5) One hundred upper half coils and fifty lower half coils should be purchased as spares.

(6) The surge protection equipment should be tested to insure that it is functioning properly.

(7) Coolers should be cleaned more frequently to prevent generator windings from operating beyond their rated temperature.

(8) The generator winding maintenance test voltage should be reduced to no more than 1.5 times rated voltage.

(9) Ten rotor pole windings should be procured to replace those currently shorted out. In addition, four additional pole windings should be purchased for spares.

(10) Purchase and install one complete new battery for powerhouse Number 1 plus 17 spare cells for station No. 2, and purchase one new battery charger.

(11) Purchase a minimum number of the most critical motors.

(12) Purchase a minimal number of spare parts to be used during normal required maintenance to keep the plant operational for the next 3-5 years. This complement of spare parts should be the absolute minimum required to perform essential maintenance and keep the plant operational. Particular care should be exercised to minimize spare parts purchases for equipment which will be scheduled for replacement in the long term; the spare parts procurement program for the short term should be appropriately austere.

Civil Rehabilitation. For short term rehabilitation the emphasis will be on safety related items and protection of equipment at the least cost.

Reservoir:

(1) It is recommended that the operation of flushing silt out of the reservoir should be resumed by SAKENERGO on a regular basis, or as often as possible.

(2) It is reported that there exists a plan, with an hour by hour schedule of an operation scenario, which coordinates the simultaneous releases of the upstream projects for this activity. This program should be implemented by SAKENERGO if possible.

(3) The silt-flushing operation should be scheduled so as to cause minimal disruption of power supply, and should, of course, be coordinated with other rehabilitation activities to the maximum extent possible.

Training Wall:

(1) The concrete repair should be implemented as soon as possible.

(2) The repair work involves demolition of the existing wall, preparation of the foundation and construction of a new redesigned wall.

(3) The construction involves cast-in-place concrete, precast concrete and a significant amount of earthwork.

Canal I:

(1) The canal should be dewatered to ascertain the extent of lining deterioration, and also the volume of silt sedimentation.

(2) The lining area deteriorated below the water line cannot be determined without dewatering the canal, so a provisional amount of 10% of the side wall surface area will be included in the estimate.

(3) The lining repair should be implemented, based on the results of the detailed inspection.

(4) Since this is a relatively short section of canal, the silt clean out should be scheduled and performed at the same time as the lining repair.

(5) Dewatering this canal results in taking the entire project off-line. This must be considered in the scheduling of these inspection and repairs, so as to minimize adverse effects due to the power disruption.

(6) Once repaired, the continued monitoring and maintenance of the liner is necessary.

Canal Nos. II, III, and IV:

(1) The lining repair should be implemented after a detailed inspection of the lining is performed.

(2) The presence of foliage growth in the joints between panels can become a serious problem when the roots grow and force the concrete to crack from below. Routine maintenance of the canal should include the elimination of this type of growth.

(3) Areas downstream of the lining, in the scour area, should be reinforced with concrete blocks to prevent any further deterioration. This has already been done to some extent, and additional blocks would be beneficial in preventing any further deterioration. This is a major item.

(4) The construction of the overflow spillways should be considered as a mandatory measure, essential to protect the dike, protect the adjacent population and also the project water supply and guarantee of normal plant functioning.

(5) Completion of construction of the parapet walls on both sides of Canal IV near Powerhouse IV also needs to be done for optimal power output.

(6) Flatten the earth dike downstream slope and implement graded filters and drainage canals.

Powerhouses:

(1) A general architectural provisional amount shall be established for the items such as roofing repair, glazing, exterior facing repair and other minor miscellaneous items.

Dike Between River and Power Canal:

(1) The need for this reinforcement and its final design will need to evaluated further, in the next phase of the work.

(2) The quantities for this work will be included in the feasibility cost estimate for planning purposes, but may be deleted from the final work package based on further review.

(3) The toe drainage provisions and build up of section are minor in scope, and should be incorporated in the work as incidental items.

5.3.2 Long Term Rehabilitation

Mechanical Rehabilitation. The original turbines, governors, and ancillary equipment are in need of a major rehabilitation even though this equipment is generally less than 20 years old. In order to improve the plant to allow for 10 to 25 years of additional service, the following additional rehabilitation work is recommended. The units will be rehabilitated consecutively to minimize power generation interruptions.

(1) Provide new digital control governor including:

- hydraulic actuator system with pumps;
- speed signal generator;
- electronic restoring;
- accumulator tank with pressure and level control and gauges.

(2) Replace the following turbine rotating parts:

- new Kaplan runner of improved design with stainless steel runner blades;

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- use existing shaft with new stainless steel sleeved journal, and forced oil-lubricated turbine guide bearing and reliable, mechanical type shaft seal. Shaft seal will be provided with clean filtered water. A wire-wound filter with automatic back-wash facility will also be provided.

(3) Replace complete head cover, bottom ring, operating ring and wicket gates;

(4) Replace gate servomotors and connecting rods;

(5) Replace runner chamber;

(6) Repair throat ring (liner between runner chamber and draft tube), and draft tube;

(7) Refurbish stay vanes, including painting, and spiral case.

(8) Purchase a set of turbine spare parts.

Electrical Rehabilitation. In order to improve the plant for 10 to 25 years of additional service, the following additional rehabilitation work is recommended.

(1) Purchase four replacement station service switchgear-oil circuit breakers.

(2) Purchase one reactor to be used as a spare.

(3) All generators should have new windings with Class B insulation procured and installed.

(4) A list of those spare parts required for reliable long term operation of the plants should be developed and those spare parts maintained in inventory.

(5) The other three station's batteries should be replaced, and new battery chargers should be procured at the same time as the new batteries.

(6) A substantial supply of spare motors should be procured and motors replaced under normal maintenance as they fail.

Civil Rehabilitation. As major rehabilitation is implemented for mechanical and electrical equipment and systems at this plant, detailed civil inspection will be required. On the basis of the cursory site inspections performed, the following long term rehabilitation is recommended:

Reservoir:

(1) It is necessary for SAKENERGO to continue the reservoir silt-flushing program to maintain to the greatest possible extent, the storage capacity of the reservoir.

Power Canal I:

(1) Operational procedures to reduce the level of silt sedimentation in the canal should be developed and implemented by SAKENERGO.

(2) The cleanout of the canal should be done to increase its capacity. Methods of excavation of the silt without the need to shut down the stations would be preferred. Hydrographic surveys to assess the amount of silt removal should be performed. It is recommended that HDI investigate this problem.

Power Canals II, III, and IV:

(1) Dredging of the power canals should be initiated to remove the large amounts of silt which have accumulated since the silt flushing operations were discontinued.

Powerhouses:

(1) Completion of the construction of the precast panel wall.

Drainage Canal:

(1) Observation and discussion in the field lead to the conclusion that the canal is adequate in capacity and design for the most part up to Powerhouse No. 2. These sections consist partly of cut ditches, which are not lined, and in need of cleaning and some reshaping. This is an ongoing maintenance item.

(2) Subsequent discussion with SAKENERGO and HDI reveals that design computations indicate the need for concrete lined ditches from Sta. 39+10 to Sta. 77+57, a distance of 3.847 km. The discharge from this section is into the power canal. The quantities for this construction will be included in the cost estimate.

(3) Along power canal 4, Sta. 150+72 to Sta. 189+00, a distance of 3.828 km, a concrete ditch of varying cross section is necessary according to design computations done by HDI.

(4) Along power canal 4, Sta. 189+00 to Sta. 227+47, a distance of 3.847 km, expansion of the existing concrete lined ditch to varying cross sections is necessary according to design computations. This will involve partial demolition and reconstruction.

(5) At Sta. 226+25, the construction to link the existing outlet canal to the power canal should be implemented. Related work to allow diversion of most of the Kutaisi canal drainage to the existing outlet canal should also be done.

(6) Bridges and culverts necessary for public crossing should be studied further and implemented as required. As a minimum, current available public access and crossings should be maintained.

(7) Construction of concrete retaining walls at the outflow, downstream of Sta. 225+84, which are currently unlined, should also be done to protect against further erosion. This is especially critical since the upgraded canal will have even larger capacity and flow than the current arrangement.

5.4 Cost Estimates

The estimated short term and long term rehabilitation costs for the Vartsikhe Project are $14,590,000 and $53,730,000 respectively. Tables 5-2 and 5-3 provide detailed breakdowns for the civil, mechanical, and electrical items recommended for the short term and long term rehabilitation programs. The distribution of foreign and local costs for the short term and long term rehabilitation programs is shown in Table 5-4.

GEORGIA HYDROPOWER REHABILITATION PROJECT
PROJECT: VARTSIKHE HYDROELECTRIC POWER GENERATING STATION
SHORT TERM REHABILITATION (3 TO 5 YEARS)

COMPONENT DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE	PROCUREMENT PROCEDURE
CIVIL ITEMS					
Mobilization & Demobilization	EA	4	55,000	220,000	LCB
Right Downstream Training Wall					
Excavation, Wet	M3	21,900	6	131,400	LCB
Earthwork (Fill)	M3	10,250	2	20,500	LCB
Concrete	M3	4,420	87	384,540	LCB
Precast Concrete	M3	100	131	13,100	LCB
Rebar	MT	47	390	18,330	LCB
Concrete Demolition	M3	150	160	24,000	LCB
Cofferdam/Care Of Water	LS	1	80,000	80,000	LCB
Power Canal 1					
Canal Wall Repair	M2	1,000	19	19,000	LCB
Power Canals 2, 3, & 4					
Excavation	M3	96,000	4	384,000	LCB
Earthwork (Fill)	M3	27,000	2	54,000	LCB
Concrete	M3	28,000	87	2,436,000	LCB
Rebar	MT	232	390	90,480	LCB
Concrete Demolition	M3	1,340	157	210,380	LCB
Dike Reinforcement					
Excavation	M3	4,615	4	18,460	LCB
Concrete	M3	32,700	87	2,844,900	LCB
Precast Concrete	M3	10,000	130	1,300,000	LCB
Rebar	MT	149	390	58,110	LCB
Architectural Provisional Sum					
Roof	PH'S	2	16,000	32,000	LCB
Glass	PH'S	4	3,000	12,000	LCB
Concrete Equipment Pads	PH'S	4	2,700	10,800	LCB
Stone Cladding	PH'S	4	70,000	280,000	LCB
Hydraulic Block Deflectors					
(Precast Concrete @ RR Bridge)	EA	60	1,000	60,000	LCB
		Subtotal		8,702,000	
MECHANICAL ITEMS					
Portable Lube Oil Purifier					
Unpacking & Familiarization	EA	1	160	160	LCB
Purchase	EA	1	33,000	33,000	DC
Rubber Seals For Draft Tube & Intake Gate					
Dismantle	SET	1	4,000	4,000	LCB
Purchase	SET	1	36,000	36,000	DC
Reassemble	SET	1	4,000	4,000	LCB
Governor Air Compressor					
Dismantle	EA	4	600	2,400	LCB
Repair	EA	4	7,000	28,000	LCB
Reassemble & Adjust	EA	4	900	3,600	LCB
Centrifugal Pumps For Head Cover Drainage					
Dismantle	EA	18	160	2,880	LCB
Purchase	EA	18	1,900	34,200	DC
Reassemble	EA	18	160	2,880	LCB

GEORGIA HYDROPOWER REHABILITATION PROJECT
PROJECT: VARTSIKHE HYDROELECTRIC POWER GENERATING STATION
SHORT TERM REHABILITATION (3 TO 5 YEARS)

COMPONENT DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE	PROCUREMENT PROCEDURE
MECHANICAL ITEMS (Cont'd)					
Station Drainage Pumps - Deep Well Type					
Dismantle	EA	4	900	3,600	LCB
Purchase	EA	4	19,000	76,000	DC
Install	EA	4	1,200	4,800	LCB
Turbine Blades - Unit 5 (2 T Each)					
Dismantle	SET	1	900	900	LCB
Purchase	SET	1	189,000	189,000	DC
Install	SET	1	900	900	LCB
Valves For Raw Water System - 200-mm Dia					
Dismantle	EA	2	80	160	LCB
Purchase	EA	2	1,300	2,600	DC
Install	EA	2	80	160	LCB
Valves For Raw Water System - 250-mm Dia.					
Dismantle	EA	6	80	480	LCB
Purchase	EA	6	2,300	13,800	DC
Install	EA	6	80	480	LCB
		Subtotal		444,000	
ELECTRICAL ITEMS					
10.5 Kv 2000A Oil Circuit BKR					
For Generator	EA	1	71,000	71,000	DC
Removal of Existing BKR	EA	1	300	300	LCB
Install, Connect, Test, Modify	EA	1	4,000	4,000	LCB
Generator Winding #6					
Stator Coils	EA	1	1,040,000	1,040,000	IS
Dismantle Existing Coils	EA	1	10,000	10,000	LCB
Reassemble New Coils & Testing	EA	1	129,000	129,000	LCB
Remove Rotor & Reinstall	EA	1	900	900	LCB
Generator #2					
Stator Foundation Bolts	EA	1	9,000	9,000	LCB
Rewedged Two Poles	EA	1	1,700	1,700	LCB
Remove Foundation Bolts	EA	1	4,000	4,000	LCB
Install New Foundation Bolts	EA	1	7,000	7,000	LCB
Stator Coil Spares					
Lower Coils - 100	LS	1	63,000	63,000	IS
Upper Coils - 50	LS	1	32,000	32,000	IS
Rotor					
Rotor Poles 10	LS	1	100,000	100,000	IS
Rotor Poles Spare 4	LS	1	40,000	40,000	LCB
Remove Existing Pole	LS	1	3,100	3,100	LCB
Install, Connect, Test	LS	1	12,000	12,000	LCB
Battery					
New Battery, 240VDC, 330AH	LS	1	28,000	28,000	DC
Battery Charger	LS	1	9,000	9,000	DC
Spare Cells 17	LS	1	3,000	3,000	DC
Remove Existing Battery	LS	1	2,000	2,000	LCB
Install New Battery & Test	LS	1	2,000	2,000	LCB

GEORGIA HYDROPOWER REHABILITATION PROJECT
PROJECT: VARTSIKHE HYDROELECTRIC POWER GENERATING STATION
SHORT TERM REHABILITATION (3 TO 5 YEARS)

COMPONENT DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE	PROCUREMENT PROCEDURE
ELECTRICAL ITEMS (Cont'd)					
Motors					
New Motors	LS	1	32,000	32,000	DC
Remove	LS	1	4,000	4,000	LCB
Install	LS	1	5,000	5,000	LCB
Spare Parts					
Generator	LS	1	40,000	40,000	IS
Excitation	LS	1	50,000	50,000	DC
MV Switch Gear	LS	1	25,000	25,000	DC
LV Switch Gear	LS	1	20,000	20,000	DC
Measurement Indicator & Protection	LS	1	50,000	50,000	DC
Illumination	LS	1	10,000	10,000	LCB
		Subtotal		1,807,000	
				==========	
Subtotal				10,953,000	
Construction Contingency		20 % ±		2,191,000	
				==========	
Total Price @ January 1996 Level				**13,144,000**	

Legend:

ICB = International Competitive Bidding
IS = International Shopping
DC = Direct Contracting
LCB = Local Competitive Bidding

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GEORGIA HYDROPOWER REHABILITATION PROJECT
PROJECT: VARTSIKHE HYDROELECTRIC POWER GENERATING STATION
LONG TERM REHABILITATION (10 TO 25 YEARS)

COMPONENT DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE	PROCUREMENT PROCEDURE
CIVIL ITEMS					
Mobilization & Demobilization	EA	4	57,000	228,000	LCB
Precast Wall Panels	PANELS	344	10	3,440	LCB
Dredging Power Canals 2, 3, 4	M3	98,000	10	980,000	LCB
Drainage Canal Rehab. - Concrete	M3	12,160	91	1,106,560	LCB
Drainage Canal Rehab. - Excavation	M3	197,000	4	788,000	LCB
		Subtotal		3,106,000	
MECHANICAL ITEMS					
Refurbish Turbines					
Dismantle parts	EA	8	8,000	64,000	LCB
Purchase	EA	8	3,524,000	28,192,000	ICB
Install	EA	8	15,000	120,000	LCB
Foreign Supervision	LS	1	300,000	300,000	ICB
Governors					
Dismantle parts	EA	8	1,625	13,000	LCB
Purchase	EA	8	222,000	1,776,000	ICB
Install	EA	8	5,000	40,000	LCB
Foreign Supervision	LS	1	80,000	80,000	ICB
		Subtotal		30,585,000	
ELECTRICAL ITEMS					
Station Service Switchgear					
380 V Circuit Breaker	EA	4	4,000	16,000	DC
Station Service Reactor 10kV, 630A	EA	1	79,000	79,000	DC
Generator Winding					
Stator Coils	EA	7	1,090,000	7,630,000	ICB
Dismantle Existing Coils	EA	7	11,000	77,000	LCB
Reassemble New Coils & Testing	EA	7	26,000	182,000	LCB
Remove Rotor & Reinstall	EA	7	1,000	7,000	LCB
Foreign Supervision	LS	1	700,000	700,000	ICB
Battery					
New Battery, 240VDC, 330AM	EA	3	30,000	90,000	DC
Battery Charger	EA	3	9,000	27,000	DC
Remove Existing Battery	EA	3	500	1,500	LCB
Install New Battery & Test	EA	3	500	1,500	LCB
Motors					
New Motors	LS	1	67,000	67,000	DC
Remove	LS	1	8,000	8,000	LCB
Install	LS	1	11,000	11,000	LCB
Spare Parts					
Generator	LS	1	200,000	200,000	ICB
Excitation	LS	1	250,000	250,000	DC
MV Switch Gear	LS	1	125,000	125,000	DC
LV Switch Gear	LS	1	100,000	100,000	DC
Measurement Indicator & Protection	LS	1	250,000	250,000	DC
Illumination	LS	1	50,000	50,000	LCB
		Subtotal		9,872,000	
				==========	
Subtotal				43,563,000	
Construction Contingency		20 % ±		8,713,000	
				==========	
Total Price @ January 1996 Level				**52,276,000**	

Legend:

ICB = International Competitive Bidding
IS = International Shopping
DC = Direct Contracting
LCB = Local Competitive Bidding

GEORGIA HYDROPOWER REHABILITATION PROJECT
VARTSIKHE HYDROELECTRIC POWER GENERATING STATION
LOCAL AND FOREIGN COST COMPONENTS

DESCRIPTION	LOCAL	FOREIGN	TOTAL
SHORT TERM			
Manhour, Labor Cost	884,000	0	884,000
Equipment	2,162,000	3,297,000	5,459,000
Materials	4,563,000	47,000	4,610,000
	=========	=========	=========
Subtotal	7,609,000	3,344,000	10,953,000
Construction Contingency 20 % ±	1,522,000	669,000	2,191,000
	=========	=========	=========
Total Price	9,131,000	4,013,000	13,144,000
LONG TERM			
Manhour, Labor Cost	1,052,000	1,078,000	2,130,000
Equipment	3,908,000	35,951,000	39,859,000
Materials	1,446,000	128,000	1,574,000
	=========	=========	=========
Subtotal	6,406,000	37,157,000	43,563,000
Construction Contingency 20 % ±	1,281,000	7,432,000	8,713,000
	=========	=========	=========
Total Price	7,687,000	44,589,000	52,276,000

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Chapter 6

ECONOMIC ANALYSIS AND PROJECT PRIORITIZATION

An economic analysis was performed for the short- and long-term rehabilitation scenarios formulated for each of the four hydroelectric projects. The objectives of the analysis were to assess the general viability of the scenarios and prioritize their implementation.

Viability was assessed in terms of Economic Internal Rate of Return (EIRR) and other economic parameters, computed on the basis of incremental energy production benefits and investment and operation and maintenance (O&M) costs over the periods of analysis. The EIRR was used to derive a project "ranking index", and prioritizations were established for various investment amounts according to the index, total rehabilitation costs, incremental energy production benefits, and considerations of risk reduction and safety.

6.1 Energy Generation Estimates

The benefits of rehabilitation accrue as a result of an increase in annual energy production and/or a reduction of the risk of project loss; and, for long-term rehabilitation, the extension of useful life. The benefits are measured as an increment over a Base Case which represents the continued operation of the existing project at current maintenance levels, until the attrition or failure of project components render continued operation impracticable.

Estimates of average annual energy production for the proposed rehabilitation alternatives and the Base Case were determined from available historical inflow data and other project operation characteristics.

6.1.1 Project Inflow Data

Various data were obtained from SAKENERGO from which ten years of historical monthly average project inflows were developed for each of the four projects. This information was, with some exceptions, available for the period of 1984 through 1993.[1]

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[1] Monthly flow data for periods prior to 1984 were unavailable, and daily inflow data were either unavailable, or unobtainable in a timely or cost-effective manner.

Lajanuri Hydroelectric Project. The inflow to the Lajanuri Hydroelectric Project is comprised of a transbasin diversion of up to 60 cms from the Tskhenis-Tskali River combined with the flow of the Lajanuri River (a tributary of the Rioni River).

Monthly average streamflows at the point of diversion of the Tskhenis-Tskali River and for the Lajanuri River were provided for the period 1984 through 1993. These flows are tabulated in Tables 6-1 and 6-2, respectively.

Table 6-1

STREAMFLOWS AT POINT OF DIVERSION FOR TSKHENIS-TKALI RIVER, CMS

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	29.1	14.9	17.9	22.1	24.0	25.5	27.6	24.2	31.9	32.0
February	24.6	17.3	22.9	27.6	23.0	20.4	26.5	22.1	30.2	32.6
March	37.7	23.5	36.1	31.7	27.4	71.9	60.8	42.5	55.9	62.9
April	103.0	103.0	99.1	101.0	108.0	162.0	101.0	81.1	79.0	110.0
May	138.0	147.0	119.0	314.0	133.0	139.0	118.0	108.0	116.0	151.0
June	160.0	113.0	160.0	321.0	189.0	177.0	112.0	113.0	132.0	152.0
July	127.0	67.3	128.0	230.0	141.0	141.0	85.9	105.0	114.0	120.0
August	60.5	41.8	65.1	163.0	121.0	90.9	49.2	69.5	87.6	84.1
Septembe r	32.8	41.8	45.0	45.5	57.4	54.3	41.8	49.6	62.7	66.2
October	18.8	64.5	38.3	29.9	47.0	96.4	40.5	40.8	90.0	43.1
November	17.1	40.4	34.5	30.4	66.7	44.2	51.0	40.3	82.2	35.6
December	15.8	29.2	21.1	30.0	50.6	29.9	36.0	40.9	48.1	28.3

Table 6-2

INFLOWS FROM LAJANURI RIVER, CMS

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	2.9	2.0	5.3	8.2	4.4	6.7	14.1	1.7	1.5	2.6
February	2.7	5.8	8.2	8.9	2.6	6.3	18.9	3.1	1.2	1.8
March	5.2	9.6	13.0	14.2	6.5	12.9	22.1	8.0	5.7	8.2
April	19.7	35.3	18.5	37.7	12.2	19.4	18.5	18.7	29.3	24.3
May	15.9	25.1	29.8	95.0	18.6	13.1	13.9	10.9	40.1	29.2
June	13.5	10.0	11.5	43.5	23.2	15.7	12.2	7.7	27.0	26.1
July	7.1	6.8	7.5	18.6	19.7	13.7	4.6	7.0	30.0	10.9
August	9.4	2.1	2.7	13.4	18.7	12.0	6.1	5.1	18.9	8.8
Septembe r	6.7	2.8	3.4	4.4	13.6	8.5	6.4	2.5	16.1	8.0
October	2.8	11.2	8.1	4.5	13.5	8.9	6.0	2.3	10.0	3.0
November	2.8	4.1	5.7	10.9	12.3	13.6	7.4	2.6	4.1	3.0
December	2.6	3.6	4.4	10.7	9.1	16.7	4.6	2.2	3.5	2.9

Average monthly irrigation requirements cited for the Tskhenis-Tskali River are shown in Table 6-3. There is also a year-round minimum instream flow requirement of 2.0 cms.

Table 6-3

IRRIGATION REQUIREMENTS OF TSKHENIS-TSKALI RIVER, CMS

January	2.1
February	2.6
March	3.6
April	5.1
May	10.1
June	13.4
July	15.6
August	16.1
September	13.6
October	10.1
November	3.6
December	3.6

After subtracting the irrigation requirement and instream flow requirement from the streamflows of Tskhenis-Tskali, the remaining flow up to a maximum of 60 cms (the maximum conveyance capacity of the gravity flow diversion tunnel) was combined with the inflows of Lajanuri to derive monthly average available inflows to the Lajanuri Hydroelectric Project for the period 1984 through 1993, as shown in Table 6-4.

Table 6-4

INFLOWS TO LAJANURI HYDROELECTRIC PROJECT, CMS

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	27.9	12.8	19.1	26.2	24.3	28.1	37.6	21.8	29.3	30.5
February	22.7	18.5	26.5	31.9	21.0	22.1	40.8	20.6	26.8	29.8
March	37.3	27.5	43.5	40.3	28.3	72.9	77.3	44.9	56.0	65.5
April	79.7	95.3	78.5	97.7	72.2	79.4	78.5	78.7	89.3	84.3
May	75.9	85.1	89.8	155.0	78.6	73.1	73.9	70.9	100.1	89.2
June	73.5	70.0	71.5	103.5	83.2	75.7	72.2	67.7	87.0	86.1
July	67.1	56.5	67.5	78.6	79.7	73.7	64.6	67.0	90.0	70.9
August	51.8	25.8	49.7	73.4	78.7	72.0	37.2	56.5	78.9	68.8
Septembe r	23.9	29.0	32.8	34.3	55.4	47.2	32.6	36.5	63.2	58.6
October	9.5	63.6	34.3	22.3	48.4	68.9	34.4	31.0	70.0	34.0
November	14.3	38.9	34.6	35.7	72.3	52.2	52.8	37.3	64.1	33.0
December	12.8	27.2	19.9	35.1	54.1	41.0	35.0	37.5	46.0	25.6

Khrami II Hydroelectric Project. The inflow to the Khrami II Hydroelectric Project is comprised of the discharge from the upstream Khrami I Hydropower Station combined with inflows from three small intervening tributaries: the Dashbasha, Kapabulakh, and Chochiani Rivers.

In lieu of historical monthly average inflows from the Dashbasha tributary, which were not available, the monthly average inflows exceeded 50 percent of the time were provided (period basis unknown), as shown in Table 6-5. For Kapabulakh, historical monthly average inflows were provided for the period 1984 through 1992, and for Chochiani, the inflows were provided for the period 1976 through 1985. These flows are tabulated in Tables 6-6 and 6-7, respectively.

Table 6-5

50% MONTHLY EXCEEDANCE FLOWS - DASHBASHA TRIBUTARY, CMS

January	4.2
February	4.2
March	4.4
April	5.0
May	5.0
June	5.0
July	4.4
August	4.2
September	4.3
October	4.3
November	4.3
December	4.2

Table 6-6

INFLOWS FROM KAPABULAKH, CMS

	1984	1985	1986	1987	1988	1989	1990	1991	1992
January	2.9	2.9	2.8	2.9	2.9	2.9	2.9	3.0	2.9
February	2.9	2.9	2.9	3.0	2.9	2.9	2.9	3.1	2.9
March	8.0	3.2	3.9	3.2	6.1	3.2	3.8	8.3	3.9
April	10.0	4.3	5.0	5.4	9.8	4.3	5.0	9.0	6.3
May	8.6	5.1	11.3	5.3	7.8	3.2	8.8	5.3	7.9
June	5.0	4.9	9.8	9.0	12.1	4.2	4.6	6.8	12.5
July	3.1	3.8	3.4	3.0	8.9	4.0	3.3	3.4	5.6
August	3.0	2.9	3.0	3.1	5.0	3.0	3.3	3.1	3.0
September	3.1	2.8	2.9	2.9	3.1	2.9	9.1	2.9	3.0
October	2.9	3.3	2.8	2.9	4.7	3.0	2.9	2.9	3.1
November	3.0	3.0	2.9	3.2	4.0	4.1	4.2	3.1	2.9
December	2.9	2.9	2.9	2.9	3.0	3.6	3.3	3.1	2.9

Table 6-7

INFLOWS FROM CHOCHIANI, CMS

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
January	0.4	0.3	0.4	1.0	1.0	0.1	0.2	0.2	0.2	0.3
February	0.3	0.8	0.8	1.0	1.3	0.1	0.2	0.1	0.2	0.3
March	1.3	1.4	4.5	0.9	2.0	0.3	0.3	0.3	1.4	0.5
April	4.4	1.8	6.2	1.5	2.2	0.4	1.8	0.6	3.7	1.2
May	7.9	3.1	3.8	1.4	3.7	0.8	2.7	2.3	2.3	1.6
June	6.0	5.7	1.7	2.7	2.0	0.9	1.1	2.6	1.4	1.8
July	2.7	1.5	0.7	2.7	0.8	1.1	0.4	1.1	0.5	0.6
August	0.8	0.4	0.5	0.6	0.8	1.3	0.4	0.5	0.4	0.3
Septembe r	1.4	0.7	0.4	0.4	0.4	0.8	0.2	0.7	0.3	0.3
October	1.3	0.9	0.6	0.6	0.8	0.4	0.2	1.7	0.3	0.5
November	0.9	0.6	0.6	1.3	0.4	0.3	0.2	1.3	0.3	0.3
December	0.6	0.5	0.7	1.5	0.5	0.3	0.2	0.3	0.3	0.4

For Kapabulakh and Chochiani, the mean inflows of the available periods of record were assumed for the years of missing data within the period 1984 through 1993, and the combination of these with the monthly 50 percent exceedance flows of Dashbasha comprised the ten-year monthly average inflow contributions of the three tributaries to Khrami II. Together, these inflows, on average, account for just over half of the total inflow to Khrami II, with the remainder coming from the upstream project.

Historical monthly average discharges from Khrami I were computed from monthly energy generation data provided for the Khrami I Project for the period 1985 through 1994. The energy generation data were multiplied by an average "transfer factor" of plant discharge to energy production (cms/kWh), resulting in estimates of monthly average discharge, as shown in Table 6-8. The mean discharges of the period of record were assumed for the year 1984.

Table 6-8

DISCHARGES FROM KHRAMI I HYDROPOWER STATION, CMS

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
January	17.2	9.6	12.6	19.8	16.7	15.7	21.1	28.0	19.9	21.1
February	13.8	17.3	5.3	21.6	20.0	12.0	18.8	7.9	14.0	2.6
March	3.7	14.5	7.4	5.9	10.4	5.6	3.6	3.5	4.6	5.6
April	0.6	0.8	2.8	4.9	5.9	2.7	1.6	3.5	5.7	9.2
May	1.2	4.7	2.7	4.5	6.7	0.8	2.4	3.7	4.4	4.8
June	3.0	4.1	14.6	10.1	3.7	1.5	0.8	2.7	4.6	5.4
July	4.9	5.7	12.4	14.7	4.9	7.3	5.6	7.3	7.6	9.1
August	5.6	6.4	9.1	5.7	5.1	5.3	4.8	5.0	7.9	7.1
Septembe r	2.1	3.6	9.8	7.1	4.5	4.4	2.4	3.9	7.1	4.6
October	1.0	7.9	9.6	7.1	4.9	6.4	3.5	6.1	4.7	8.5
November	5.1	11.0	11.4	13.9	9.0	10.4	12.5	12.4	22.1	11.7
December	10.8	16.1	15.0	13.9	13.5	16.4	22.4	23.8	22.9	10.4

The inflows from the three tributaries and the discharges of the Khrami I Project were then combined to generate the monthly average available inflows to the Khrami II Hydroelectric Project for the period 1984 through 1993, as shown in Table 6-9.

Table 6-9

INFLOWS TO KHRAMI II HYDROELECTRIC PROJECT, CMS

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	25.5	24.6	17.0	20.1	27.3	24.2	23.2	28.7	35.5	27.4
February	20.6	21.2	24.9	13.0	29.3	27.6	19.6	26.6	15.5	21.6
March	20.3	11.8	24.1	16.3	17.7	19.3	15.0	17.5	13.1	15.1
April	22.5	11.1	13.1	15.5	22.1	17.5	15.1	18.0	17.1	19.6
May	19.5	12.9	24.0	16.0	20.3	17.9	17.5	15.6	19.5	19.4
June	16.4	14.7	21.5	31.2	29.8	15.5	13.7	15.2	22.7	19.8
July	15.9	13.7	14.7	21.0	29.2	14.6	16.2	14.6	18.5	17.5
August	13.8	13.0	14.2	17.0	15.5	12.9	13.4	12.7	12.8	16.0
Septembe r	12.6	9.5	11.3	17.6	15.1	12.2	18.4	10.1	11.8	15.6
October	13.5	9.1	15.7	17.5	16.9	13.0	14.3	11.5	14.2	12.9
November	19.5	12.7	18.8	19.5	22.8	18.1	19.5	20.5	20.2	30.4
December	23.9	18.3	23.7	22.6	21.6	21.8	24.4	30.2	31.5	30.7

Tkibuli Hydroelectric Project. The inflow to the Tkibuli Hydroelectric Project is comprised of the discharge from the upstream Shaori Hydropower Station combined with inflow from the Tkibula tributary.

Historical monthly average discharges from Shaori were computed from monthly energy generation data provided for that project for the period 1985 through 1994. The energy generation data were multiplied by an average "transfer factor" of plant discharge to energy production (cubic meters to kilowatt-hours), resulting in estimates of monthly average discharges, as shown in Table 6-10. The mean discharges of the period of record were assumed for the year 1984.

Table 6-10

DISCHARGES FROM SHAORI HYDROPOWER STATION, CMS

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
January	2.1	4.8	2.9	3.8	4.9	4.8	4.1	1.7	5.2	4.4
February	3.4	5.0	3.3	5.1	6.0	4.9	4.7	0.4	5.6	4.8
March	1.6	5.0	4.8	4.8	4.4	4.7	4.7	0.6	5.5	4.3
April	0.4	3.0	3.3	1.9	6.1	4.7	4.7	1.8	5.6	3.4
May	0.3	2.8	5.1	3.4	6.3	5.1	2.4	4.7	5.5	2.4
June	0.2	1.2	5.1	4.3	5.8	5.1	0.8	4.1	5.1	2.4
July	0.3	0.8	3.0	4.1	2.9	3.8	1.0	2.9	1.8	2.5
August	0.3	1.0	2.2	2.1	2.1	1.6	0.9	2.2	2.8	1.7
Septembe r	0.2	0.9	2.7	3.3	2.3	1.7	0.9	2.7	2.7	1.1
October	0.4	1.5	3.1	3.2	2.8	2.8	1.2	2.7	2.2	0.5
November	2.5	2.9	3.5	5.3	3.4	3.3	3.3	3.5	4.3	1.4
December	4.2	3.6	3.4	5.6	4.2	3.9	3.1	5.0	4.4	2.2

The discharges from Shaori were then combined with historical monthly average inflows from the Tkibula tributary, which were provided for the period 1984 through 1993, as shown in Table 6-11, to generate the monthly average available inflows to the Tkibuli Hydroelectric Project for the period 1984 through 1993, as shown in Table 6-12.

Table 6-11

INFLOWS FROM TKIBULA TRIBUTARY, CMS

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	7.9	3.2	5.5	7.8	6.6	6.6	6.7	6.8	4.2	8.8
February	7.4	5.8	7.1	7.3	8.6	8.9	7.7	9.0	2.7	9.9
March	9.2	5.1	7.1	8.4	9.9	16.1	9.7	10.1	8.7	15.9
April	10.7	4.0	4.3	9.1	5.7	11.2	10.5	9.2	10.8	19.2
May	10.5	2.9	4.4	7.6	7.1	9.1	9.7	9.1	11.7	12.0
June	8.2	2.6	3.4	7.6	9.7	8.6	8.2	3.3	10.9	13.8
July	8.6	2.9	2.2	5.9	6.9	6.3	6.2	4.1	9.5	3.3
August	7.9	2.0	2.2	4.7	3.5	8.1	3.5	3.6	9.3	4.0
Septembe r	3.3	4.5	1.8	6.6	6.2	7.1	5.0	3.1	9.0	3.3
October	2.6	5.5	2.8	5.0	6.2	6.7	7.1	3.1	9.2	3.3
November	4.6	1.6	4.8	7.2	9.4	8.2	6.0	4.4	7.9	11.8
December	2.1	1.5	5.7	6.8	10.0	9.3	7.5	7.5	10.7	12.4

Table 6-12

INFLOWS TO TKIBULI HYDROELECTRIC PROJECT, CMS

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	11.8	5.3	10.3	10.7	10.4	11.5	11.5	10.9	5.9	14.0
February	11.7	9.2	12.1	10.6	13.7	14.9	12.6	13.7	3.1	15.5
March	13.2	6.7	12.1	13.2	14.7	20.5	14.4	14.8	9.3	21.4
April	14.2	4.4	7.3	12.4	7.6	17.3	15.2	13.9	12.6	24.8
May	14.3	3.2	7.2	12.7	10.5	15.4	14.8	11.5	16.4	17.5
June	11.6	2.8	4.6	12.7	14.0	14.4	13.3	4.1	15.0	18.9
July	10.9	3.2	3.0	8.9	11.0	9.2	10.0	5.1	12.4	5.1
August	9.6	2.3	3.2	6.9	5.6	10.2	5.1	4.5	11.5	6.8
Septembe r	5.2	4.7	2.7	9.3	9.5	9.4	6.7	4.0	11.7	6.0
October	4.6	5.9	4.3	8.1	9.4	9.5	9.9	4.3	11.9	5.5
November	7.9	4.1	7.7	10.7	14.7	11.6	9.3	7.7	11.4	16.1
December	6.1	5.7	9.3	10.2	15.6	13.5	11.4	10.6	15.7	16.8

Vartsikhe Hydroelectric Project. The inflow available for diversion to the Vartsikhe Hydroelectric Project is comprised of runoff from three sources: the Rioni, Khanistaskali, and Kvirila Rivers. These flows are tabulated in Tables 6-13, 6-14, and 6-15, respectively.

Table 6-13

INFLOWS FROM RIONI, CMS

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	65.0	36.8	49.1	119.0	59.6	69.3	82.7	48.2	42.9	86.3
February	43.2	64.6	75.2	166.0	66.8	43.9	84.8	69.0	51.2	77.3
March	91.6	74.7	108.0	133.0	127.0	266.0	170.0	133.0	128.0	159.0
April	250.0	255.0	232.0	303.0	292.0	333.0	290.0	237.0	231.0	341.0
May	265.0	285.0	222.0	582.0	316.0	285.0	392.0	299.0	302.0	325.0
June	289.0	225.0	266.0	482.0	354.0	301.0	307.0	267.0	318.0	311.0
July	229.0	152.0	198.0	276.0	299.0	241.0	248.0	226.0	262.0	223.0
August	185.0	122.0	115.0	196.0	235.0	184.0	169.0	168.0	187.0	160.0
Septembe r	98.0	107.0	73.5	76.0	172.0	122.0	126.0	96.7	154.0	142.0
October	57.1	167.0	64.7	56.8	153.0	216.0	120.0	73.6	220.0	77.3
November	61.8	123.0	63.0	90.7	204.0	179.0	170.0	76.6	189.0	81.6
December	37.5	84.5	49.2	120.0	181.0	156.0	108.0	74.2	118.0	62.5

Table 6-14

INFLOWS FROM KHANISTASKALI, CMS

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	15.6	11.1	10.8	17.4	10.4	11.1	9.2	6.4	5.1	7.7
February	9.4	17.5	15.7	13.1	15.5	14.8	12.4	10.9	5.6	8.9
March	22.3	27.9	17.1	10.2	29.8	58.7	26.3	27.5	23.9	26.5
April	29.4	48.2	32.3	34.2	48.2	63.3	39.3	24.0	46.0	52.0
May	32.1	35.8	34.0	38.8	38.9	21.2	34.9	16.5	37.1	33.4
June	17.8	19.0	20.5	36.8	31.9	19.2	14.4	11.5	20.0	19.7
July	18.0	10.7	8.1	17.1	20.3	14.2	8.3	6.5	8.6	6.9
August	13.7	6.8	6.7	2.3	16.3	10.3	2.9	5.4	6.5	8.3
Septembe r	7.6	6.7	6.6	8.0	8.0	7.9	5.7	4.1	7.7	6.2
October	5.9	12.4	7.8	7.0	8.9	9.4	8.0	3.6	10.3	5.2
November	9.4	10.6	7.6	8.9	16.2	16.0	10.3	3.8	9.8	11.1
December	7.0	16.8	9.0	10.4	16.4	18.3	7.4	4.4	7.1	9.3

Table 6-15

INFLOWS FROM KVIRILA, CMS

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	85.2	25.8	24.3	68.1	45.6	50.6	37.8	31.6	25.9	72.4
February	48.0	68.5	51.9	99.3	62.2	54.5	66.0	47.6	26.7	85.5
March	96.7	113.0	58.8	70.6	139.0	281.0	116.0	110.0	147.0	153.0
April	139.0	127.0	70.5	184.0	164.0	187.0	141.0	74.8	178.0	209.0
May	70.5	72.6	83.6	146.0	93.1	64.1	122.0	68.9	114.0	109.0
June	43.0	31.8	66.2	80.1	76.0	64.1	35.9	40.5	77.7	80.0
July	46.9	30.9	22.2	34.1	63.4	29.6	23.4	25.7	63.2	60.0
August	41.2	15.0	13.0	28.2	50.5	30.0	19.5	16.9	58.4	58.0
Septembe r	20.7	17.0	11.2	24.8	37.0	24.0	21.3	14.9	61.7	57.7
October	14.0	50.5	11.8	20.6	42.6	30.0	31.0	11.8	78.5	54.2
November	22.1	37.7	14.4	45.7	73.9	81.9	50.2	13.7	89.0	89.0
December	13.5	68.1	19.8	61.8	86.4	71.1	40.4	27.4	82.4	76.0

With the subtraction of an instream flow requirement of 15 cms from the sum of the three inflow sources, the resulting monthly average available inflows to the Vartsikhe Hydroelectric Project for the period 1984 through 1993 are shown in Table 6-16.

Table 6-16

INFLOWS TO VARTSIKHE HYDROELECTRIC PROJECT, CMS

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	150.8	58.7	69.2	189.5	100.6	116.0	114.7	71.2	58.9	151.4
February	85.6	135.6	127.8	263.4	129.5	98.2	148.2	112.5	68.5	156.7
March	195.6	200.6	168.9	198.8	280.8	590.7	297.3	255.5	283.9	323.5
April	403.4	415.2	319.8	506.2	489.2	568.3	455.3	320.8	440.0	587.0
May	352.6	378.4	324.6	751.8	433.0	355.3	533.9	369.4	438.1	452.4
June	334.8	260.8	337.7	583.9	446.9	369.3	342.3	304.0	400.7	395.7
July	278.9	178.6	213.3	312.2	367.7	269.8	264.7	243.2	318.8	274.9
August	224.9	128.8	119.7	211.5	286.8	209.3	176.4	175.3	236.9	211.3
Septembe r	111.3	115.7	76.3	93.8	202.0	138.9	138.0	100.7	208.4	190.9
October	62.0	214.9	69.3	69.4	189.5	240.4	144.0	74.0	293.8	121.7
November	78.3	156.3	70.0	130.3	279.1	261.9	215.5	79.1	272.8	166.7
December	43.0	154.4	63.0	177.2	268.8	230.4	140.8	91.0	192.5	132.8

6.1.2 Project Operation Parameters

Project operation parameters relevant to the estimation of average annual energy production were determined for each of the four projects. Base-load and peak-load generation distinctions (or alternatively, on- and off-peak generation) were not considered in this study for the following reasons:

- The monthly hydrological and generation data available for this study do not allow for daily and hourly-based production estimates.

- The projects are operated primarily as base-load generation facilities. Lajanuri and Vartsikhe are essentially run-of-river projects, and Khrami II and Tkibuli regulate the outflows of large upstream storage projects (Khrami I and Shaori, respectively), leveling out daily fluctuations and generating, for the most part, at a constant output.

- The available generation capacity and supply of electricity to the system falls short of demand, resulting in unserved energy, in all periods. Period-based distinctions in the value of energy are insignificant in these circumstances, where the present study is concerned.

Operation parameters employed to estimate energy production include normal headwater elevation, tailwater at maximum and minimum plant discharge, a headloss coefficient used to derive total conveyance headlosses, plant hydraulic capacity, installed and maximum plant production capacities, and average plant/unit availability and overall generating efficiency. Of these, availability and efficiency, and in some cases, maximum plant production capacity, are the most significant parameters for the estimation of incremental benefits associated with project rehabilitation versus the Base Case ("do-nothing") scenarios.

The available data were insufficient to discern any significant seasonal headwater variations at any of the projects, and, at any rate, they are insignificant in relation to both net head and the estimation of annual energy production.

Headloss coefficients were approximated by the use of Manning's equation, assuming a uniform Manning's 'n' value of 0.013, and an additional ten percent to account for form losses.

The values of the operation parameters employed in the annual energy production estimates, except availabilities and efficiencies which will be dealt with in subsequent sections, are tabulated in Table 6-17.

Table 6-17

PROJECT OPERATION PARAMETERS EMPLOYED IN ENERGY ESTIMATES

PARAMETERS	LAJANURI	KHRAMI II	TKIBULI	VARTSIKHE
Normal Headwater Elevation, m	491.0	1090.0	522.5	[~15 m of net head at each plant]
Tailwater Elevations at Maximum and Minimum Plant Discharge	359.1 357.3	760.7 760.7	212.6 211.7	"
Headloss coefficient, f	0.000487	0.013011	0.009420	"
Plant Hydraulic Capacity, cms	100	41.4	34	350 (each plant)
Installed Plant Capacity, MW	111.6	110	80	46 (each plant)
Current Maximum Plant Production Capacity, MW	64	90	45	46 (Plants I, II, IV), 23 (III)

6.1.3 Annual Energy Generation Estimates

Annual energy generation estimates were computed using the derived monthly average project inflows for the ten-year period 1984 to 1993 and the project operation parameters discussed in the previous section. The methodology for each plant is demonstrated on Exhibit 1, which shows the "Calibration" Case, discussed below.

"Calibration" Case. For each project, the suitability of the estimation parameters and the assumed values of availability and efficiency was supported through calibrations. These calibrations were necessary because the verification and, in some cases, the original sources and derivation of the input data provided by SAKENERGO were uncertain. Also, some information, like unit efficiency data, does not exist, and reasonable assumptions needed to be made.

Availability. Limited unit availability and outage data were provided by SAKENERGO for each of the projects. This information is partial and could not be verified; however, it provided some indication of the parameter values to assume in the estimates of average annual energy production. Within the period of the last ten years, 1985 through 1994, availability and outage data were provided in terms of hours in operation and reserve (or, alternatively, in a synchronous condensing mode of operation), and in terms of hours out of service for minor (termed "current"), major, and "emergency" repairs, with the distinctions between them not always apparent or uniformly designated. These data were tabulated and combined into either hours in service or out of service,

with the resulting historical annual plant availability factors, where data were available, shown in Table 6-18.

Table 6-18

PLANT AVAILABILITIES

Year	Lajanuri	Khrami II	Tkibuli	Vartsikhe			
				I	II	III	IV
1985	82.1%	94.0%	no data	91.7%	96.7%	88.7%	-
1986	no data	no data	no data	no data	no data	no data	-
1987	no data	no data	no data	no data	no data	no data	-
1988	no data	69.6%	70.3%	99.3%	78.7%	91.3%	-
1989	64.4%	no data	84.2%	83.2%	88.7%	98.8%	100.0%
1990	no data	76.8%	89.9%	88.2%	98.2%	77.6%	98.8%
1991	96.1%	65.9%	73.2%	no data	no data	no data	no data
1992	87.1%	82.8%	65.3%	no data	no data	no data	no data
1993	75.8%	87.1%	64.6%	no data	no data	no data	no data
1994	65.5%	27.2%	58.2%	47.4%	83.8%	97.5%	97.5%
Avg.	78.5%	71.9%	72.2%	82.0%	89.2%	90.8%	98.8%

For the calibrations, the following average annual availability factors in 1984 through 1993 were assumed for the projects:

- 75 percent average annual availability for Lajanuri, Khrami II, and Tkibuli;
- 85 percent for Vartsikhe I, II, and III; and
- 90 percent for Vartsikhe IV.

Plant Efficiency. Lacking any measurements of unit operating efficiencies, assumptions of average overall generating efficiencies were estimated based on age and type of units and their reasonableness as supported by the calibrations. Lajanuri, Khrami II, and Tkibuli were all commissioned with vertical Francis units that were installed between 1956 and 1962. A corresponding value of 80 percent is not an unreasonable assumption of average overall generating efficiency over the past ten years, and could be assumed based on an average combined turbine-generator and transformer efficiency of 85 percent at the time of commissioning, degraded by approximately five percent. The vertical Kaplan units in the Vartsikhe powerstations are less than 20 years old, on the other hand; accordingly, the past ten-year-average generating efficiency was assumed to be slightly higher, at 82.5 percent.

Calibration Results Compared to Historical Average Annual Production, 1984 - 1993. The results of the calibrations for each project are shown on Exhibit 1. The installed plant production capacities and the assumed values of availability and efficiency are tabulated in Table 6-19 with the resulting, estimated average annual energy production and the historical production, for the period 1984 through 1993. The production estimates compared to historical production for the ten-year period support the values of the parameters assumed for the calibrations. To provide an additional comparison, a longer term historical production average, for the period 1970 through 1994, is also shown in Table 6-19.

Table 6-19

HISTORICAL VERSUS CALIBRATION PRODUCTION RESULTS, 1984 - 1993

	LAJANURI	KHRAMI II	TKIBULI	VARTSIKHE
Installed Plant Capacity, MW	111.6	110	80	184
Assumed Plant Availability	75%	75%	75%	85-90%
Assumed Overall Average Generating Efficiency	80%	80%	80%	82.5%
"Calibration" Estimated Average Annual Energy Production , GWh	357.5	310.9	162.4	799.6
Historical Average Annual Energy Production, GWh	360.3	314.9	156.8	814.9
Historical Average Annual Energy Production, Gwh: 1970-1994	365.9	306.8	141.1	na

Average Annual Energy Production for Project Base Case and Rehabilitation Scenarios. Project operation parameters were estimated for the Base Case and Rehabilitation Scenarios on the bases of the detailed site inspections and above calibrations; and of reasonable expectations for improvement in availabilities and/or efficiencies associated with the recommended rehabilitation measures.

Base Case Scenarios. The Base Case Scenario for each project represents the continued operation of the project in its current condition, subject only to routine limited maintenance, until the attrition or failure of project components.

For the purpose of estimating Base Case energy production, average plant/unit availability factors and overall generating efficiencies were established for each project. In addition, all four projects are constrained by maximum production capacities that are currently less than the plants' installed capacities.

At Lajanuri, Unit 2 is no longer in service, and Units 1 and 3 are constrained by maximum production capacities of 32 MW each, dictated by increasing vibration levels that occur at outputs greater than 32 MW up to installed capacity (37.2 MW).

At Khrami II, both units, though in service, are constrained by maximum production capacities of 45 MW each -- 10 MW short of installed capacity -- due to vibration problems related to excessive bearing wear.

At Tkibuli, Unit 4 is no longer in service, and Units 1 through 3 are constrained by maximum production capacities of 15 MW each, again dictated by undue vibration that occurs at outputs greater than 15 MW up to installed capacity (20 MW).

At Vartsikhe, Unit 6 is no longer in service, and the other seven units are constrained to operate at less than their full capacity because of shaft seal problems. The safe maximum production capacities established for the units, which vary depending on the condition of the individual shaft seals and the temporary head cover drainage pumps, are as follows:

Vartsikhe I, Unit 1:	19 MW
Vartsikhe I, Unit 2:	19 MW
Vartsikhe II, Unit 3:	17 MW
Vartsikhe II, Unit 4:	17 MW
Vartsikhe III, Unit 5:	15 MW
Vartsikhe III, Unit 6:	out-of-service
Vartsikhe IV, Unit 7:	12 MW
Vartsikhe IV, Unit 8:	12 MW

In addition, though the four plants and appurtent facilities that comprise the Vartsikhe Hydroelectric Project range from only about eight to twenty years old, the energy production for the Base Case was estimated with an availability factor that not only encompasses electromechanical equipment items, but also critical civil components that need to be addressed.

Short Term Rehabilitation Scenarios. The short term rehabilitation scenarios have not been conceived to extend the useful life of the projects, as such, but to enable the projects to generate and deliver increased energy to the power system until long term rehabilitation can be performed; and additionally for Vartsikhe, to reduce the risk of catastrophic failure and improve safety conditions associated with the civil works. Short term rehabilitation also entails repairs and/or replacements necessary to bring all units back on-line which are currenly not in service, including (1) Lajanuri - Unit 2, at 32.0 MW (bringing it up to installed capacity would be part of the long term rehabilitation scenario), (2) Tkibuli - Unit 4, at 20 MW, and (3) Vartsikhe - Unit 6, at 16 MW.

A five-year period of analysis was assumed for the Short Term Rehabilitation Scenarios, with average availabilities and efficiencies established for each scenario that are reflective of the improvements proposed.

Long Term Rehabilitation Scenarios. The long term rehabilitation scenarios are essentially comprised of the installation of modern equipment and practices at the projects designed to extend the life of the plants, improve reliability, improve efficiency, and increase energy production.

Availability and efficiency values established for the long term rehabilitation scenarios were identical for all four projects. Maximum production capacities were increased above nameplate by approximately two percent. A 25-year period of analysis was assumed.

Average Annual Energy Production Estimates. For each of the projects and scenarios considered in the analysis, the values of maximum production capacity, availability, and efficiency are shown in Table 6-20. Also shown in Table 6-20 are the corresponding estimates of average annual production based on the available ten-year period of historical monthly flow data (1984 through 1993).

Table 6-20

AVERAGE ANNUAL PRODUCTION PARAMETERS AND ESTIMATES

Plant	Parameters Affecting Average Annual Production			Average Annual Production (GWh) based on 1984-1993
	Maximum Production (MW)	Availability	Efficiency	
LAJANURI				
Historical				360.3
Calibration	111.6	75.0%	80.0%	357.5
Base Case	64.0 (U2 out)	75.0%	75.0%	306.4
S.T. Rehab.	96.0	80.0%	77.0%	367.0
L.T. Rehab.	114.0	92.5%	85.0%	468.4
KHRAMI II				
Historical				314.9
Calibration	110.0	75.0%	80.0%	310.9
Base Case	90.0	75.0%	75.0%	291.5
S.T. Rehab.	100.0	80.0%	76.0%	315.1
L.T. Rehab.	112.0	92.5%	85.0%	407.4
TKIBULI				
Historical				156.8
Calibration	80.0	75.0%	80.0%	162.4
Base Case	45.0 (U4 out)	75.0%	75.0%	151.4
S.T. Rehab.	80.0	80.0%	76.0%	164.5
L.T. Rehab.	82.0	92.5%	85.0%	212.8
VARTSIKHE (TOTAL)				
Historical				814.9
Calibration	184.0	86.3%	82.5%	799.6
Base Case	111.0 (U6 out)	65.0%	80.0%	460.0
S.T. Rehab.	136.0	89.0%	80.0%	724.2
L.T. Rehab.	188.0	92.5%	85.0%	872.0

Lajanuri, Khrami II, Tkibuli - As will be noted from Table 6-20, the availability assumed for the Base Case for these projects was equal to 75 percent, the calibrated availability over the last ten years. The average overall generating efficiency, however, was suspected to be less than the previous ten years' efficiency derived in the calibrations, and a value of 75 percent was assumed.

The short term rehabilitation measures would be expected to improve availabilities (75 to 80 percent), and, to a lesser degree, efficiencies (from one to two percent above Base Case, depending on the specific measures implemented at each project, as discussed in previous sections of this report).
For the long-term rehabilitation measures, which to a large extent involve the installation of new, modern equipment, the availability and efficiency are expected to be 92.5 percent and 85 percent, respectively.

Vartsikhe - As a newer project, and as borne out to some extent by historical availability and outage data, as well, the expected average availability of the units still in service for the Base Case works out to approximately 86.3 percent (the average of 85 percent at Plants I, II, and III (Unit 5 only), and 90 percent at Plant IV). Current overall average generating efficiencies were expected to be on the order of 80 percent (less than the calibrated value of 82.5 percent).

For the Base Case, in addition to electromechanical availability, the risk of long-term outages and loss of capacity due to a failure of key civil components of the project is much greater than for the other projects, to the extent that it needs to be accounted for. This was accommodated through the incorporation of a "risk factor" in the availability factor. A 25 percent risk factor was applied to the electromechanical availability, reducing the availability from 86.3 to approximately 65 percent.

For the Short Term Rehabilitation Scenario, average plant availability works out to approximately 88.8 percent (the average of 88 percent for Plants I, II, and III, with Unit 6 now restored to service, and 91 percent for Plant IV). The short term rehabilitation measures address the critical near term civil components that necessitate the application of the risk factor in the Base Case. There are no measures proposed for the short term that would improve efficiencies above those of the Base Case, however.

For the Long Term Rehabilitation Scenario, the availability and efficiency are the same as those established for Lajanuri, Khrami II, and Tkibuli.

6.2 Economic Analysis

6.2.1 Parameters and Format of Economic Analyses

The parameters and general format were established for economic analyses of the rehabilitation scenarios. The format for the analysis of the Short Term Rehabilitation Scenario for Lajanuri -- indicative of the analysis performed for the other three projects -- is shown on Exhibit 2. In the top box on the exhibit, the rehabilitation scenario investment cost, hydroelectric O&M costs and energy value (in terms of $/MWh), the discount rate, and the derived economic parameters -- Present Value Benefits and Costs (PVB and PVC, respectively), the resulting Net Present Value (NPV), PVB/PVC

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ratio, and Economic Internal Rate of Return (EIRR) -- are shown. The middle box on the exhibit provides the maximum plant production capacity, average plant availability, average overall generating efficiency, and average annual energy production for the rehabilitation scenario and the Base Case ("do-nothing" alternative) to which it is compared; the average annual incremental production is the difference between rehabilitation scenario and Base Case production. The analysis for the Short Term Rehabilitation Scenario runs out five years.

In the analysis shown on Exhibit 2, the hydroelectric O&M cost (in this example, $2.00/MWh) is applied to the average annual incremental energy production to derive O&M Costs as a component of Incremental Costs. The Investment Cost is shown under Incremental Costs, as well, taking place before Year 1. Under Incremental Benefits, the energy value (in this example, $34.00/MWh) is applied to incremental energy production, as well.

The streams of Total Incremental Costs and Benefits (Energy Value) are both discounted to present value and cumulated over the five-year period of analysis. The economic parameters are determined as a result (with EIRR equal to the discount rate resulting in zero NPV).

For both Short Term and Long Term Rehabilitation Scenarios, the format of analysis is the same, with the difference that for the Long Term Rehabilitation Scenarios, the period of analysis is 25 years, as demonstrated on Exhibit 3.

To better compare the short term rehabilitation program with the long term program, an analysis was performed of Short Term Rehabilitation combined with Long Term Rehabilitation delayed until Year 5. This analysis is demonstrated on Exhibit 4, which is identical to the Short Term Rehabilitation analysis from the point of initial investment through Year 4, but showing the Long Term Rehabilitation Investment Cost in Year 5, with commensurate incremental energy production benefits from Years 6 through 25.

Establishment of Parameter Values. In addition to incremental energy production and rehabilitation investment costs, values were established for key parameters of the analyses, including hydroelectric O&M cost, energy value, and discount rate.

SAKENERGO cited an average hydroelectric production cost (operation and maintenance) of approximately 0.2 ¢/kWh, and an average thermal production cost, including fuel (based on mazout) and operation and maintenance, of between 3.4 to 4.0 ¢/kWh (mazout itself, comprising about 85 percent of the total cost, is approximately 2.9 ¢/kWh). Consequently, the various rehabilitation scenarios for the projects were evaluated on the basis of hydroelectric production costs of 0.2 ¢/kWh and energy value/thermal production costs of 3.4 ¢/kWh. Alternatively, hydro and thermal production costs currently assumed for Georgia by a multilateral lending source are 0.7 ¢/kWh and 3.96 ¢/kWh, respectively; however, the results of the analyses using these values are not significantly different.

The value of energy might also be assumed to be equivalent to the cost of unserved energy. There is considerable unfilled demand for electricity in the country, and consumption is entirely supply-constrained for the present and near future. The value of this unserved energy is determined as the loss of Gross Domestic Product due to lack of electricity, and may range anywhere from 80 ¢/kWh ($800/MWh) to $2/kWh, yielding extremely favorable results. However, for comparisons of the projects in relation to each other, the conclusions reached from analyses involving the high energy value do not differ from those involving the low energy value, and the analyses will consequently be confined to the assumption of 0.2 ¢/kWh of hydroelectric O&M costs and 3.4 ¢/kWh of energy value (thermal generation costs, including fuel, operation and maintenance).

A discount rate of 10% was selected for the analyses, as per the direction of the International Bank for Reconstruction and Development (IBRD).

6.2.2 Results of Economic Analyses

The results of the economic analyses for the rehabilitation scenarios are shown in Table 6-21 below.

Table 6-21

ECONOMIC ANALYSES

Based on Energy Production Parameters and

Hydroelectric O&M Costs	0.2	¢/kWh
Energy Value / Thermal Alternative	3.4	¢/kWh
Discount Rate	10.0	%

Project Name	Investment Cost ($ million)	Average Annual Incremental Energy Production (GWh)	Risk Reduction Benefit (GWh)	Total Energy Production Benefit (GWh)	NPV ($ million)	Present Value Benefit/ Cost	EIRR	**Ranking Index**
Short Term Rehabilitation								
Lajanuri	4.50	61	-	61	2.9	1.6	33%	0.7
Khrami II	4.98	24	-	24	-2.1	0.6	-9%	-0.2
Tkibuli	2.65	13	-	13	-1.1	0.6	-8%	-0.2
Vartsikhe	14.59	111	153	264	17.5	2.1	50%	1.0
Long Term Rehabilitation								
Lajanuri	11.69	162	-	162	35.4	3.4	44%	1.0
Khrami II	10.58	116	-	116	23.1	2.8	35%	0.8
Tkibuli	12.00	61	-	61	5.8	1.4	16%	0.4
Vartsikhe	53.73	259	153	412	65.9	2.1	24%	0.5
Short Term with Delayed Long Term Rehabilitation								
Lajanuri	16.19	61 - 162	-	61 - 162	23.0	2.7	38%	1.0
Khrami II	15.56	24 - 116	-	24 - 116	10.9	1.8	21%	0.6
Tkibuli	14.65	13 - 61	-	13 - 61	1.9	1.2	13%	0.3
Vartsikhe	68.32	111 - 259	153	264 - 412	53.8	2.0	36%	0.9

In these analyses, the EIRR and the other economic parameters were used to assess the general viability of the projects and scenarios. These economic parameters may only be considered as representative because of the limited data and the assumptions made for the analyses. A "ranking index" has been computed, based on the EIRR, to indicate the relative attractiveness of the projects.

For the Short Term Rehabilitation scenarios, the economic parameters suggest that the investment required to keep the Lajanuri and Vartsikhe Hydroelectric Projects operating until a more substantial investment can be made is viable. These two projects are all closely ranked. In the same time frame, an investment in Khrami II and Tkibuli cannot be economically justified. However, the Short Term Rehabilitation can be justified from a safety and reliability standpoint. The transformers at both of these stations have reached the end of their useful lives and are considered very susceptible to failure and possible explosion.

The analysis of the Long Term Rehabilitation scenarios was performed to evaluate the possibility of bypassing the short term investment in favor of immediate investment for the long term. It is apparent that Lajanuri and Khrami II both would be suitable projects for an immediate long term investment if the funds were available. Tkibuli and Vartsikhe are marginal but probably acceptable.

The analysis of Short Term Rehabilitation with a delayed Long Term Rehabilitation was performed to determine if the initial short term investment in any way precluded the long term investment. This appears not to be the case; in fact, the attractiveness of Vartsikhe seems to improve substantially as compared to immediate Long Term Rehabilitation.

[Paragraph deleted here]

6.3 Project Prioritization

On the basis of the foregoing studies, along with considerations of total rehabilitation costs, incremental energy production, and risk reduction and safety, priorities have been established for total allocations of investment ranging from approximately $10 to $34 million, as shown in Table 6-22. In Table 6-22, the investment costs for substations have been broken out separately. These costs have been provided by American Electric Power (AEP) Energy Services, Inc. For additional information related to these costs, please refer to AEP's report entitled "Republic of Georgia Study - Rehabilitation of the Communications, Control, and Dispatch Systems and Maintenance of Four Hydro Plant Substations."

The Harza costs differentiate between short term and long term rehabilitation. For mechanical and electrical costs, the short term and long term costs are mutually exclusive. For civil costs, the rehabilitation work for short term and long term are additive. AEP costs do not differentiate between short and long term and in Table 6-22, the same values are used regardless of whether the short term or long term rehabilitation program is being considered.

For an investment amount of about $10 million, the Short Term Rehabilitation programs for Khrami II and Lajanuri should be considered. At around $15 million, the Long Term Rehabilitation of Khrami II with the Short Term Rehabilitation of Lajanuri is most attractive, while for around $17 million, the Long Term Rehabilitation of Lajanuri with the Short Term Rehabilitation of Khrami II should be considered.

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For investment allocations around $20 million, the program should include the Short Term Rehabilitation of Vartsikhe, with the possible exception of an option to implement Long Term Rehabilitation at both Khrami II and Lajanuri -- at approximately $22 million -- in order to maximize incremental energy production. Alternatively, the Short Term Rehabilitation programs for Vartsikhe, Khrami II, and Lajanuri could all be accomplished for an investment of approximately $24 million.

For approximately $25 million, the Short Term Rehabilitation of Vartsikhe combined with the Long Term Rehabilitation of Khrami II appears to maximize the return on this level of investment. The Short Term Rehabilitation of all four facilities could also be accomplished for approximately $27 million. *[partial sentence deletion here]*

For an investment allocation of approximately $30 million, both Long Term Rehabilitation of Khrami II and Short Term Rehabilitation of Lajanuri may be included with Short Term Rehabilitation of Vartsikhe.

Two options may be considered for approximately $32 million. The first option would be to implement the Long Term Rehabilitation program for Khrami II along with the Short Term programs for the other three facilities (including Tkibuli), thereby including all four facilities. The second option would be to implement the Long Term Rehabilitation program for Lajanuri in combination with Short Term Rehabilitation of Vartsikhe and Khrami II. Either alternative yields about 300 GWh of average annual incremental energy production.

Finally, for $34 million, the Long Term Rehabilitation of Lajanuri may be combined with Short Term programs at the other three facilities.

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Table 6-22

INVESTMENT PRIORITIZATIONS
GEORGIA HYDRO REHABILITATION PROGRAM

Approximate Investment Allocation ($ million)	Project Name	Rehabilitation Program	Investment Cost Excluding Substations ($ million)	Investment Cost for Substations ($ million)	Total Investment Cost ($ million)	Average Annual Incremental Energy Production (GWh)	Total Investment	Notes
10	Investment Prioritization						$9,480,000	
	Khrami II	Short Term	1.26	3.72	4.98	24		
	Lajanuri	Short Term	3.77	0.73	4.50	61		
	TOTAL				9.48	85		
15	Investment Prioritization						$15,080,000	
	Khrami II	Long Term	6.86	3.72	10.58	116		
	Lajanuri	Short Term	3.77	0.73	4.50	61		
	TOTAL				15.08	177		
17	Investment Prioritization						$16,670,000	
	Lajanuri	Long Term	10.96	0.73	11.69	162		
	Khrami II	Short Term	1.26	3.72	4.98	24		
	TOTAL				16.67	186		
20	Investment Prioritization						$19,570,000	
	Vartsikhe	Short Term	13.14	1.45	14.59	111		
	Khrami II	Short Term	1.26	3.72	4.98	24		
	TOTAL				19.57	135		
22 - 27	Investment Prioritization, Option 1						$22,270,000	1
	Khrami II	Long Term	6.86	3.72	10.58	116		
	Lajanuri	Long Term	10.96	0.73	11.69	162		
	TOTAL				22.27	278		
	Investment Prioritization, Option 2						$24,070,000	2
	Vartsikhe	Short Term	13.14	1.45	14.59	111		
	Khrami II	Short Term	1.26	3.72	4.98	24		
	Lajanuri	Short Term	3.77	0.73	4.50	61		
	TOTAL				24.07	196		
	Investment Prioritization, Option 3						$25,170,000	3
	Vartsikhe	Short Term	13.14	1.45	14.59	111		
	Khrami II	Long Term	6.86	3.72	10.58	116		
	TOTAL				25.17	227		
	Investment Prioritization, Option 4						$26,730,000	4
	Vartsikhe	Short Term	13.14	1.45	14.59	111		
	Khrami II	Short Term	1.26	3.72	4.98	24		
	Lajanuri	Short Term	3.77	0.73	4.50	61		
	Tkibuli	Short Term	1.46	1.20	2.66	13		
	TOTAL				26.73	209		

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Table 6-22

INVESTMENT PRIORITIZATIONS
GEORGIA HYDRO REHABILITATION PROGRAM

Approximate Investment Allocation ($ million)	Project Name	Rehabilitation Program	Investment Cost Excluding Substations ($ million)	Investment Cost for Substations ($ million)	Total Investment Cost ($ million)	Average Annual Incremental Energy Production (GWh)	Total Investment	Notes
30	Investment Prioritization						$29,670,000	
	Vartsikhe	Short Term	13.14	1.45	14.59	111		
	Khrami II	Long Term	6.86	3.72	10.58	116		
	Lajanuri	Short Term	3.77	0.73	4.50	61		
	TOTAL				29.67	288		
32	Investment Prioritization, Option 1						$31,260,000	5
	Vartsikhe	Short Term	13.14	1.45	14.59	111		
	Lajanuri	Long Term	10.96	0.73	11.69	162		
	Khrami II	Short Term	1.26	3.72	4.98	24		
	TOTAL				31.26	297		
	Investment Prioritization, Option 2						$32,330,000	6
	Vartsikhe	Short Term	13.14	1.45	14.59	111		
	Khrami II	Long Term	6.86	3.72	10.58	116		
	Lajanuri	Short Term	3.77	0.73	4.50	61		
	Tkibuli	Short Term	1.46	1.20	2.66	13		
	TOTAL				32.33	301		
34	Investment Prioritization						$33,920,000	
	Vartsikhe	Short Term	13.14	1.45	14.59	111		
	Lajanuri	Long Term	10.96	0.73	11.69	162		
	Khrami II	Short Term	1.26	3.72	4.98	24		
	Tkibuli	Short Term	1.46	1.20	2.66	13		
	TOTAL				33.92	310		

Notes:

1. This option maximizes incremental energy.
2. This option provides an attractive return on investment for top three energy producing projects.
3. This option maximizes return at this level of investment.
4. This option includes all four projects.
5. This option maximizes return at this level of investment, and equals the incremental energy of Opt. 1.
6. This option includes all four projects, including the highest ranked long term rehabilitation program (Khrami II).

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6.4 Conclusions

The actual program to be implemented for the Georgia Hydropower Rehabilitation Project will depend not only on the total amount of investment available, but on the relative importance of the following objectives:

- Maximizing the anticipated return on investment,
- Maximizing incremental energy production,
- Assigning investment priority in accordance with the overall energy production capability of each project, *[delete 'or']*
- Safety and reliability, or
- Including all four hydroelectric projects in the program.

For an anticipated investment allocation in the range of $22 to $27 million, the first, third, and fourth objectives are recognized by the Short Term Rehabilitation of Vartsikhe, Khrami II, and Lajanuri (approximately $24.1 million). In addition to being economically attractive, this program involves rehabilitation of the top three energy producing facilities - Vartsikhe, Lajanuri, and Khrami II, in that order. For an additional $2.6 million, the fifth objective can be attained by the inclusion of Short Term Rehabilitation of Tkibuli. The anticipated return on investment would appear to be highest -- attaining to the first objective -- for the program involving Short Term Rehabilitation of Vartsikhe and Long Term Rehabilitation of Khrami II ($25 million).

On the other hand, if the second objective is considered to be of greatest importance, the Long Term Rehabilitation of Khrami II and Lajanuri should be implemented ($22.3 million), resulting in an average incremental energy production of 278 GWh annually. By comparison, the Short Term Rehabilitation of all four projects would result in approximately 210 GWh of additional energy per year.

Lajanuri Energy Computations

Exhibit 1
Sheet 1 of 7

Qp,max	100.0	MW,max	111.6
Qp,min	10.0	MW,min	10.0
HW	491.0	Availability	75.0%
TW,max	359.1	e, overall	80.0%
TW,min	357.3	Energy	357.5
f (hd-loss)	0.000487	Historical	360.3

Monthly Average Project Inflow, cms

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	27.9	12.8	19.1	26.2	24.3	28.1	37.6	21.8	29.3	30.5
February	22.7	18.5	26.5	31.9	21.0	22.1	40.8	20.6	26.8	29.8
March	37.3	27.5	43.5	40.3	28.3	72.9	77.3	44.9	56.0	65.5
April	79.7	95.3	78.5	97.7	72.2	79.4	78.5	78.7	89.3	84.3
May	75.9	85.1	89.8	155.0	78.6	73.1	73.9	70.9	100.1	89.2
June	73.5	70.0	71.5	103.5	83.2	75.7	72.2	67.7	87.0	86.1
July	67.1	56.5	67.5	78.6	79.7	73.7	64.6	67.0	90.0	70.9
August	51.8	25.8	49.7	73.4	78.7	72.0	37.2	56.5	78.9	68.8
September	23.9	29.0	32.8	34.3	55.4	47.2	32.6	36.5	63.2	58.6
October	9.5	63.6	34.3	22.3	48.4	68.9	34.4	31.0	70.0	34.0
November	14.3	38.9	34.6	35.7	72.3	52.2	52.8	37.3	64.1	33.0
December	12.8	27.2	19.9	35.1	54.1	41.0	35.0	37.5	46.0	25.6

Monthly Average Plant Discharge, cms

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	27.9	12.8	19.1	26.2	24.3	28.1	37.6	21.8	29.3	30.5
February	22.7	18.5	26.5	31.9	21.0	22.1	40.8	20.6	26.8	29.8
March	37.3	27.5	43.5	40.3	28.3	72.9	77.3	44.9	56.0	65.5
April	79.7	95.3	78.5	97.7	72.2	79.4	78.5	78.7	89.3	84.3
May	75.9	85.1	89.8	100.0	78.6	73.1	73.9	70.9	100.0	89.2
June	73.5	70.0	71.5	100.0	83.2	75.7	72.2	67.7	87.0	86.1
July	67.1	56.5	67.5	78.6	79.7	73.7	64.6	67.0	90.0	70.9
August	51.8	25.8	49.7	73.4	78.7	72.0	37.2	56.5	78.9	68.8
September	23.9	29.0	32.8	34.3	55.4	47.2	32.6	36.5	63.2	58.6
October	0.0	63.6	34.3	22.3	48.4	68.9	34.4	31.0	70.0	34.0
November	14.3	38.9	34.6	35.7	72.3	52.2	52.8	37.3	64.1	33.0
December	12.8	27.2	19.9	35.1	54.1	41.0	35.0	37.5	46.0	25.6

Monthly Average Production Capacity, MW

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	
January	29.1	13.4	20.0	27.4	25.4	29.3	39.1	22.8	30.6	31.8	31
February	23.7	19.4	27.7	33.2	22.0	23.1	42.4	21.5	28.0	31.1	28
March	38.8	28.7	45.1	41.8	29.5	74.3	78.5	46.5	57.7	67.1	31
April	80.8	95.4	79.7	97.6	73.6	80.5	79.7	79.9	89.9	85.2	30
May	77.2	85.9	90.3	99.7	79.8	74.5	75.3	72.4	99.7	89.8	31
June	74.9	71.5	72.9	99.7	84.1	77.0	73.6	69.2	87.7	86.9	30
July	68.7	58.2	69.0	79.8	80.8	75.1	66.2	68.6	90.5	72.4	31
August	53.5	26.9	51.4	74.8	79.9	73.4	38.7	58.2	80.1	70.3	31
September	25.0	30.2	34.2	35.7	57.1	48.8	34.0	38.0	64.8	60.3	30
October	0.0	65.2	35.7	23.3	50.1	70.4	35.8	32.3	71.5	35.4	31
November	15.0	40.4	36.0	37.1	73.7	53.9	54.5	38.8	65.7	34.4	30
December	13.4	28.4	20.8	36.5	55.8	42.6	36.4	39.0	47.6	26.7	31

Monthly Energy Production, GWh

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Average	Adjusted for Availability
January	21.7	10.0	14.9	20.4	18.9	21.8	29.1	17.0	22.7	23.7	20.0	15.0
February	15.9	13.0	18.6	22.3	14.8	15.5	28.5	14.5	18.8	20.9	18.3	13.7
March	28.9	21.4	33.6	31.1	22.0	55.3	58.4	34.6	42.9	49.9	37.8	28.3
April	58.2	68.7	57.4	70.3	53.0	58.0	57.4	57.5	64.7	61.3	60.6	45.5
May	57.4	63.9	67.2	74.2	59.3	55.4	56.0	53.8	74.2	66.8	62.8	47.1
June	53.9	51.5	52.5	71.8	60.6	55.4	53.0	49.9	63.2	62.5	57.4	43.1
July	51.1	43.3	51.4	59.3	60.1	55.8	49.3	51.0	67.3	53.8	54.2	40.7
August	39.8	20.0	38.2	55.6	59.4	54.6	28.8	43.3	59.6	52.3	45.2	33.9
September	18.0	21.8	24.6	25.7	41.1	35.2	24.5	27.3	46.7	43.4	30.8	23.1
October	0.0	48.5	26.6	17.3	37.2	52.4	26.6	24.0	53.2	26.3	31.2	23.4
November	10.8	29.1	25.9	26.7	53.1	38.8	39.2	27.9	47.3	24.7	32.4	24.3
December	10.0	21.1	15.5	27.2	41.5	31.7	27.1	29.0	35.4	19.9	25.8	19.4
TOTAL	365.6	412.3	426.3	502.0	521.0	529.9	477.8	429.8	596.0	505.6	476.6	357.5
TOTAL, adjusted for Availability...												
	274.2	309.2	319.7	376.5	390.8	397.5	358.3	322.4	447.0	379.2	357.5	
Compared to Historical...												
	326.0	345.3	333.0	396.9	411.2	373.4	357.1	336.9	389.9	333.7	360.3	

TOTAL, adjusted for actual (reported) availability...

82.1%	64.4%	96.1%	87.1%	75.8%		
338.5	341.3	413.1	519.1	383.3		

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Khrami II Energy Computations

Exhibit 1
Sheet 2 of 7

Qp,max	41.4	MW,max	110.0
Qp,min	6.2	MW,min	16.5
HW	1090.0	Availability	75.0%
TW,max	760.7	e, overall	80.0%
TW,min	760.7	Energy	310.9
f (hd-loss)	0.013011	Historical	314.9

Monthly Average Project Inflow, cms

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	25.5	24.6	17.0	20.1	27.3	24.2	23.2	28.7	35.5	27.4
February	20.6	21.2	24.9	13.0	29.3	27.6	19.6	26.6	15.5	21.6
March	20.3	11.8	24.1	16.3	17.7	19.3	15.0	17.5	13.1	15.1
April	22.5	11.1	13.1	15.5	22.1	17.5	15.1	18.0	17.1	19.6
May	19.5	12.9	24.0	16.0	20.3	17.9	17.5	15.6	19.5	19.4
June	16.4	14.7	21.5	31.2	29.8	15.5	13.7	15.2	22.7	19.8
July	15.9	13.7	14.7	21.0	29.2	14.6	16.2	14.6	18.5	17.5
August	13.8	13.0	14.2	17.0	15.5	12.9	13.4	12.7	12.8	16.0
September	12.6	9.5	11.3	17.6	15.1	12.2	18.4	10.1	11.8	15.6
October	13.5	9.1	15.7	17.5	16.9	13.0	14.3	11.5	14.2	12.9
November	19.5	12.7	18.8	19.5	22.8	18.1	19.5	20.5	20.2	30.4
December	23.9	18.3	23.7	22.6	21.6	21.8	24.4	30.2	31.5	30.7

Monthly Average Plant Discharge, cms

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	25.5	24.6	17.0	20.1	27.3	24.2	23.2	28.7	35.5	27.4
February	20.6	21.2	24.9	13.0	29.3	27.6	19.6	26.6	15.5	21.6
March	20.3	11.8	24.1	16.3	17.7	19.3	15.0	17.5	13.1	15.1
April	22.5	11.1	13.1	15.5	22.1	17.5	15.1	18.0	17.1	19.6
May	19.5	12.9	24.0	16.0	20.3	17.9	17.5	15.6	19.5	19.4
June	16.4	14.7	21.5	31.2	29.8	15.5	13.7	15.2	22.7	19.8
July	15.9	13.7	14.7	21.0	29.2	14.6	16.2	14.6	18.5	17.5
August	13.8	13.0	14.2	17.0	15.5	12.9	13.4	12.7	12.8	16.0
September	12.6	9.5	11.3	17.6	15.1	12.2	18.4	10.1	11.8	15.6
October	13.5	9.1	15.7	17.5	16.9	13.0	14.3	11.5	14.2	12.9
November	19.5	12.7	18.8	19.5	22.8	18.1	19.5	20.5	20.2	30.4
December	23.9	18.3	23.7	22.6	21.6	21.8	24.4	30.2	31.5	30.7

Monthly Average Production Capacity, MW

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	
January	64.1	61.9	43.4	51.0	68.4	61.2	58.8	71.7	87.1	68.8	31
February	52.4	53.9	62.9	33.5	73.0	69.2	50.0	66.8	39.6	54.8	28
March	51.5	30.4	60.7	41.7	45.1	49.2	38.5	44.8	33.5	38.8	31
April	56.9	28.5	33.7	39.8	56.0	44.8	38.6	46.0	43.8	49.9	30
May	49.6	33.2	60.5	40.9	51.6	45.6	44.7	40.0	49.7	49.4	31
June	42.1	37.6	54.6	77.6	74.3	39.6	35.1	38.9	57.6	50.5	30
July	40.8	35.1	37.6	53.4	72.9	37.3	41.4	37.5	47.2	44.7	31
August	35.3	33.3	36.3	43.4	39.6	33.2	34.3	32.6	32.8	40.8	31
September	32.5	24.6	29.1	44.9	38.6	31.4	46.9	26.1	30.2	39.9	30
October	34.5	23.3	40.1	44.7	43.1	33.3	36.6	29.4	36.4	33.1	31
November	49.8	32.6	47.8	49.7	57.6	46.1	49.6	52.1	51.4	75.7	30
December	60.4	46.6	60.0	57.2	54.9	55.4	61.7	75.3	78.1	76.4	31

Monthly Energy Production, GWh

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Average	Adjusted for Availability
January	47.7	46.1	32.3	38.0	50.9	45.5	43.7	53.3	64.8	51.2	47.3	35.5
February	35.2	36.2	42.2	22.5	49.1	46.5	33.6	44.9	26.6	36.8	37.4	28.0
March	38.3	22.6	45.2	31.0	33.6	36.6	28.7	33.3	24.9	28.8	32.3	24.2
April	41.0	20.5	24.3	28.6	40.3	32.2	27.8	33.1	31.5	35.9	31.5	23.6
May	36.9	24.7	45.0	30.5	38.4	33.9	33.3	29.8	37.0	36.8	34.6	26.0
June	30.3	27.1	39.3	55.9	53.5	28.5	25.3	28.0	41.4	36.4	36.6	27.4
July	30.4	26.1	27.9	39.7	54.3	27.7	30.8	27.9	35.1	33.3	33.3	25.0
August	26.3	24.8	27.0	32.3	29.5	24.7	25.5	24.2	24.4	30.4	26.9	20.2
September	23.4	17.7	21.0	32.3	27.8	22.6	33.7	18.8	21.7	28.7	24.8	18.6
October	25.7	17.3	29.9	33.2	32.1	24.8	27.3	21.9	27.0	24.6	26.4	19.8
November	35.8	23.5	34.4	35.8	41.5	33.2	35.7	37.5	37.0	54.5	36.9	27.7
December	44.9	34.6	44.6	42.6	40.8	41.2	45.9	56.0	58.1	56.8	46.6	34.9
TOTAL	415.9	321.3	413.2	422.2	491.7	397.5	391.2	408.8	429.7	454.3	414.6	310.9
TOTAL, adjusted for Availability...												
	311.9	241.0	309.9	316.7	368.8	298.2	293.4	306.6	322.3	340.7	310.9	
Compared to Historical...												
	327.0	247.3	323.1	317.9	323.2	338.5	285.3	318.2	339.1	329.2	314.9	

TOTAL, adjusted for actual (reported) availability...

94.0%	69.6%	76.8%	65.9%	82.8%	87.1%	
302.0	342.2	300.4	269.4	355.8	395.7	

Tkibuli Energy Computations

Exhibit 1
Sheet 3 of 7

Qp,max	34.0	MW,max	80.0
Qp,min	2.6	MW,min	6.0
HW	522.5	Availability	75.0%
TW,max	212.6	e, overall	80.0%
TW,min	211.7	Energy	162.4
f (hd-loss)	0.009420	Historical	156.8

Monthly Average Project Inflow, cms

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	11.8	5.3	10.3	10.7	10.4	11.5	11.5	10.9	5.9	14.0
February	11.7	9.2	12.1	10.6	13.7	14.9	12.6	13.7	3.1	15.5
March	13.2	6.7	12.1	13.2	14.7	20.5	14.4	14.8	9.3	21.4
April	14.2	4.4	7.3	12.4	7.6	17.3	15.2	13.9	12.6	24.8
May	14.3	3.2	7.2	12.7	10.5	15.4	14.8	11.5	16.4	17.5
June	11.6	2.8	4.6	12.7	14.0	14.4	13.3	4.1	15.0	18.9
July	10.9	3.2	3.0	8.9	11.0	9.2	10.0	5.1	12.4	5.1
August	9.6	2.3	3.2	6.9	5.6	10.2	5.1	4.5	11.5	6.8
September	5.2	4.7	2.7	9.3	9.5	9.4	6.7	4.0	11.7	6.0
October	4.6	5.9	4.3	8.1	9.4	9.5	9.9	4.3	11.9	5.5
November	7.9	4.1	7.7	10.7	14.7	11.6	9.3	7.7	11.4	16.1
December	6.1	5.7	9.3	10.2	15.6	13.5	11.4	10.6	15.7	16.8

Monthly Average Plant Discharge, cms

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	11.8	5.3	10.3	10.7	10.4	11.5	11.5	10.9	5.9	14.0
February	11.7	9.2	12.1	10.6	13.7	14.9	12.6	13.7	3.1	15.5
March	13.2	6.7	12.1	13.2	14.7	20.5	14.4	14.8	9.3	21.4
April	14.2	4.4	7.3	12.4	7.6	17.3	15.2	13.9	12.6	24.8
May	14.3	3.2	7.2	12.7	10.5	15.4	14.8	11.5	16.4	17.5
June	11.6	2.8	4.6	12.7	14.0	14.4	13.3	4.1	15.0	18.9
July	10.9	3.2	3.0	8.9	11.0	9.2	10.0	5.1	12.4	5.1
August	9.6	0.0	3.2	6.9	5.6	10.2	5.1	4.5	11.5	6.8
September	5.2	4.7	2.7	9.3	9.5	9.4	6.7	4.0	11.7	6.0
October	4.6	5.9	4.3	8.1	9.4	9.5	9.9	4.3	11.9	5.5
November	7.9	4.1	7.7	10.7	14.7	11.6	9.3	7.7	11.4	16.1
December	6.1	5.7	9.3	10.2	15.6	13.5	11.4	10.6	15.7	16.8

Monthly Average Production Capacity, MW

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	
January	28.5	12.8	25.0	26.0	25.2	27.9	27.9	26.5	14.4	33.8	31
February	28.4	22.4	29.2	25.7	33.3	35.9	30.5	33.2	7.5	37.5	28
March	32.1	16.2	29.4	32.0	35.7	49.3	34.8	35.8	22.6	51.5	31
April	34.3	10.6	17.8	30.0	18.4	41.7	36.7	33.6	30.6	59.2	30
May	34.6	7.7	17.4	30.9	25.6	37.2	35.9	27.9	39.6	42.2	31
June	28.2	6.9	11.1	30.9	34.0	34.8	32.2	10.0	36.3	45.4	30
July	26.5	7.7	7.4	21.5	26.6	22.5	24.2	12.4	30.2	12.4	31
August	23.3	0.0	7.7	16.7	13.7	24.8	12.5	11.1	28.0	16.7	31
September	12.6	11.4	6.6	22.6	23.0	22.9	16.3	9.8	28.4	14.7	30
October	11.3	14.3	10.5	19.7	22.9	23.1	24.0	10.5	28.8	13.4	31
November	19.3	9.9	18.6	26.0	35.6	28.1	22.5	18.8	27.6	39.0	30
December	14.8	14.0	22.5	24.9	37.7	32.6	27.6	25.8	37.9	40.6	31

Monthly Energy Production, GWh

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Average	Adjusted for Availability
January	21.2	9.6	18.6	19.3	18.8	20.7	20.8	19.7	10.7	25.2	18.5	13.8
February	19.1	15.1	19.6	17.3	22.4	24.2	20.5	22.3	5.0	25.2	19.1	14.3
March	23.9	12.1	21.9	23.8	26.5	36.6	25.9	26.6	16.8	38.3	25.3	18.9
April	24.7	7.6	12.8	21.6	13.2	30.0	26.5	24.2	22.0	42.6	22.5	16.9
May	25.8	5.7	13.0	23.0	19.0	27.7	26.7	20.8	29.4	31.4	22.2	16.7
June	20.3	5.0	8.0	22.2	24.5	25.1	23.2	7.2	26.2	32.7	19.4	14.6
July	19.7	5.8	5.5	16.0	19.8	16.7	18.0	9.2	22.4	9.2	14.2	10.7
August	17.4	0.0	5.8	12.4	10.2	18.5	9.3	8.2	20.8	12.4	11.5	8.6
September	9.0	8.2	4.7	16.3	16.6	16.5	11.7	7.0	20.5	10.6	12.1	9.1
October	8.4	10.7	7.8	14.6	17.0	17.2	17.8	7.8	21.4	10.0	13.3	10.0
November	13.9	7.1	13.4	18.7	25.6	20.2	16.2	13.6	19.9	28.1	17.7	13.3
December	11.0	10.4	16.8	18.5	28.1	24.3	20.6	19.2	28.2	30.2	20.7	15.5
TOTAL	214.3	97.1	147.9	223.8	241.7	277.7	237.1	185.9	243.5	295.9	216.5	162.4
TOTAL, adjusted for Availability...												
	160.7	72.9	110.9	167.9	181.3	208.3	177.8	139.4	182.6	221.9	162.4	
Compared to Historical...												
	128.0	66.6	116.7	171.4	184.0	223.1	165.8	113.6	174.1	224.8	156.8	

TOTAL, adjusted for actual (reported) availability...

70.3%	84.2%	89.9%	73.2%	65.3%	64.6%	
169.9	233.8	213.2	136.0	159.0	191.1	

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Vartsikhe I Energy Computations

Exhibit 1
Sheet 4 of 7

Qp,max	350.0	MW,max	46.0
Qp,min	52.5	MW,min	7.0
HW	86.8	Availability	85.0%
TW,max	71.8	e, overall	82.5%
TW,min	71.8	Energy	194.5
f (hd-loss)	0.000001	Historical	217.1

Monthly Average Project Inflow, cms

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	150.8	58.7	69.2	189.5	100.6	116.0	114.7	71.2	58.9	151.4
February	85.6	135.6	127.8	263.4	129.5	98.2	148.2	112.5	68.5	156.7
March	195.6	200.6	168.9	198.8	280.8	590.7	297.3	255.5	283.9	323.5
April	403.4	415.2	319.8	506.2	489.2	568.3	455.3	320.8	440.0	587.0
May	352.6	378.4	324.6	751.8	433.0	355.3	533.9	369.4	438.1	452.4
June	334.8	260.8	337.7	583.9	446.9	369.3	342.3	304.0	400.7	395.7
July	278.9	178.6	213.3	312.2	367.7	269.8	264.7	243.2	318.8	274.9
August	224.9	128.8	119.7	211.5	286.8	209.3	176.4	175.3	236.9	211.3
September	111.3	115.7	76.3	93.8	202.0	138.9	138.0	100.7	208.4	190.9
October	62.0	214.9	69.3	69.4	189.5	240.4	144.0	74.0	293.8	121.7
November	78.3	156.3	70.0	130.3	279.1	261.9	215.5	79.1	272.8	166.7
December	43.0	154.4	63.0	177.2	268.8	230.4	140.8	91.0	192.5	132.8

Monthly Average Plant Discharge, cms

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	150.8	58.7	69.2	189.5	100.6	116.0	114.7	71.2	58.9	151.4
February	85.6	135.6	127.8	263.4	129.5	98.2	148.2	112.5	68.5	156.7
March	195.6	200.6	168.9	198.8	280.8	350.0	297.3	255.5	283.9	323.5
April	350.0	350.0	319.8	350.0	350.0	350.0	350.0	320.8	350.0	350.0
May	350.0	350.0	324.6	350.0	350.0	350.0	350.0	350.0	350.0	350.0
June	334.8	260.8	337.7	350.0	350.0	350.0	342.3	304.0	350.0	350.0
July	278.9	178.6	213.3	312.2	350.0	269.8	264.7	243.2	318.8	274.9
August	224.9	128.8	119.7	211.5	286.8	209.3	176.4	175.3	236.9	211.3
September	111.3	115.7	76.3	93.8	202.0	138.9	138.0	100.7	208.4	190.9
October	62.0	214.9	69.3	69.4	189.5	240.4	144.0	74.0	293.8	121.7
November	78.3	156.3	70.0	130.3	279.1	261.9	215.5	79.1	272.8	166.7
December	0.0	154.4	63.0	177.2	268.8	230.4	140.8	91.0	192.5	132.8

Monthly Average Production Capacity, MW

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	
January	18.3	7.1	8.4	22.9	12.2	14.1	13.9	8.6	7.1	18.4	31
February	10.4	16.4	15.5	31.8	15.7	11.9	18.0	13.6	8.3	19.0	28
March	23.7	24.3	20.5	24.1	33.9	42.1	35.9	30.9	34.3	39.0	31
April	42.1	42.1	38.6	42.1	42.1	42.1	42.1	38.7	42.1	42.1	30
May	42.1	42.1	39.1	42.1	42.1	42.1	42.1	42.1	42.1	42.1	31
June	40.3	31.5	40.7	42.1	42.1	42.1	41.2	36.7	42.1	42.1	30
July	33.7	21.6	25.8	37.7	42.1	32.6	32.0	29.4	38.4	33.2	31
August	27.2	15.6	14.5	25.6	34.6	25.3	21.4	21.2	28.7	25.6	31
September	13.5	14.0	9.3	11.4	24.5	16.8	16.7	12.2	25.2	23.1	30
October	7.5	26.0	8.4	8.4	22.9	29.1	17.5	9.0	35.5	14.8	31
November	9.5	18.9	8.5	15.8	33.7	31.6	26.1	9.6	33.0	20.2	30
December	0.0	18.7	7.6	21.5	32.5	27.9	17.1	11.0	23.3	16.1	31

Monthly Energy Production, GWh

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Average	Adjusted for Availability
January	13.6	5.3	6.2	17.1	9.1	10.5	10.4	6.4	5.3	13.7	9.8	8.3
February	7.0	11.0	10.4	21.4	10.6	8.0	12.1	9.2	5.6	12.8	10.8	9.2
March	17.6	18.1	15.2	17.9	25.2	31.4	26.7	23.0	25.5	29.0	23.0	19.5
April	30.3	30.3	27.8	30.3	30.3	30.3	30.3	27.8	30.3	30.3	29.8	25.4
May	31.4	31.4	29.1	31.4	31.4	31.4	31.4	31.4	31.4	31.4	31.1	26.5
June	29.0	22.7	29.3	30.3	30.3	30.3	29.7	26.4	30.3	30.3	28.9	24.6
July	25.1	16.1	19.2	28.0	31.4	24.3	23.8	21.9	28.6	24.7	24.3	20.7
August	20.2	11.6	10.8	19.0	25.8	18.8	15.9	15.8	21.3	19.0	17.8	15.2
September	9.7	10.1	6.7	8.2	17.6	12.1	12.0	8.8	18.2	16.6	12.0	10.2
October	5.6	19.4	6.3	6.3	17.1	21.6	13.0	6.7	26.4	11.0	13.3	11.3
November	6.8	13.6	6.1	11.4	24.3	22.8	18.8	6.9	23.7	14.5	14.9	12.7
December	0.0	13.9	5.7	16.0	24.2	20.7	12.7	8.2	17.3	12.0	13.1	11.1
TOTAL	196.4	203.5	172.8	237.3	277.1	262.2	236.7	192.5	264.0	245.4	228.8	194.5
TOTAL, adjusted for Availability...												
	166.9	173.0	146.9	201.7	235.6	222.9	201.2	163.6	224.4	208.6	194.5	
Compared to Historical...												
	193.0	187.0	190.1	224.0	237.9	242.3	234.6	199.0	243.5	219.1	217.1	

TOTAL, adjusted for actual (reported) availability...

	91.7%	99.3%	83.2%	88.2%
	186.6	275.2	218.2	208.8

Vartsikhe II Energy Computations

Exhibit 1
Sheet 5 of 7

Qp,max	350.0	MW,max	46.0
Qp,min	52.5	MW,min	7.0
HW	71.0	Availability	85.0%
TW,max	56.0	e, overall	82.5%
TW,min	56.0	Energy	194.5
f (hd-loss)	0.000001	Historical	197.0

Monthly Average Project Inflow, cms

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	150.8	58.7	69.2	189.5	100.6	116.0	114.7	71.2	58.9	151.4
February	85.6	135.6	127.8	263.4	129.5	98.2	148.2	112.5	68.5	156.7
March	195.6	200.6	168.9	198.8	280.8	590.7	297.3	255.5	283.9	323.5
April	403.4	415.2	319.8	506.2	489.2	568.3	455.3	320.8	440.0	587.0
May	352.6	378.4	324.6	751.8	433.0	355.3	533.9	369.4	438.1	452.4
June	334.8	260.8	337.7	583.9	446.9	369.3	342.3	304.0	400.7	395.7
July	278.9	178.6	213.3	312.2	367.7	269.8	264.7	243.2	318.8	274.9
August	224.9	128.8	119.7	211.5	286.8	209.3	176.4	175.3	236.9	211.3
September	111.3	115.7	76.3	93.8	202.0	138.9	138.0	100.7	208.4	190.9
October	62.0	214.9	69.3	69.4	189.5	240.4	144.0	74.0	293.8	121.7
November	78.3	156.3	70.0	130.3	279.1	261.9	215.5	79.1	272.8	166.7
December	43.0	154.4	63.0	177.2	268.8	230.4	140.8	91.0	192.5	132.8

Monthly Average Plant Discharge, cms

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	150.8	58.7	69.2	189.5	100.6	116.0	114.7	71.2	58.9	151.4
February	85.6	135.6	127.8	263.4	129.5	98.2	148.2	112.5	68.5	156.7
March	195.6	200.6	168.9	198.8	280.8	350.0	297.3	255.5	283.9	323.5
April	350.0	350.0	319.8	350.0	350.0	350.0	350.0	320.8	350.0	350.0
May	350.0	350.0	324.6	350.0	350.0	350.0	350.0	350.0	350.0	350.0
June	334.8	260.8	337.7	350.0	350.0	350.0	342.3	304.0	350.0	350.0
July	278.9	178.6	213.3	312.2	350.0	269.8	264.7	243.2	318.8	274.9
August	224.9	128.8	119.7	211.5	286.8	209.3	176.4	175.3	236.9	211.3
September	111.3	115.7	76.3	93.8	202.0	138.9	138.0	100.7	208.4	190.9
October	62.0	214.9	69.3	69.4	189.5	240.4	144.0	74.0	293.8	121.7
November	78.3	156.3	70.0	130.3	279.1	261.9	215.5	79.1	272.8	166.7
December	0.0	154.4	63.0	177.2	268.8	230.4	140.8	91.0	192.5	132.8

Monthly Average Production Capacity, MW

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	
January	18.3	7.1	8.4	22.9	12.2	14.1	13.9	8.6	7.1	18.4	31
February	10.4	16.4	15.5	31.8	15.7	11.9	18.0	13.6	8.3	19.0	28
March	23.7	24.3	20.5	24.1	33.9	42.1	35.9	30.9	34.3	39.0	31
April	42.1	42.1	38.6	42.1	42.1	42.1	42.1	38.7	42.1	42.1	30
May	42.1	42.1	39.1	42.1	42.1	42.1	42.1	42.1	42.1	42.1	31
June	40.3	31.5	40.7	42.1	42.1	42.1	41.2	36.7	42.1	42.1	30
July	33.7	21.6	25.8	37.7	42.1	32.6	32.0	29.4	38.4	33.2	31
August	27.2	15.6	14.5	25.6	34.6	25.3	21.4	21.2	28.7	25.6	31
September	13.5	14.0	9.3	11.4	24.5	16.8	16.7	12.2	25.2	23.1	30
October	7.5	26.0	8.4	8.4	22.9	29.1	17.5	9.0	35.5	14.8	31
November	9.5	18.9	8.5	15.8	33.7	31.6	26.1	9.6	33.0	20.2	30
December	0.0	18.7	7.6	21.5	32.5	27.9	17.1	11.0	23.3	16.1	31

Monthly Energy Production, GWh

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Average	Adjusted for Availability
January	13.6	5.3	6.2	17.1	9.1	10.5	10.4	6.4	5.3	13.7	9.8	8.3
February	7.0	11.0	10.4	21.4	10.6	8.0	12.1	9.2	5.6	12.8	10.8	9.2
March	17.6	18.1	15.2	17.9	25.2	31.4	26.7	23.0	25.5	29.0	23.0	19.5
April	30.3	30.3	27.8	30.3	30.3	30.3	30.3	27.8	30.3	30.3	29.8	25.4
May	31.4	31.4	29.1	31.4	31.4	31.4	31.4	31.4	31.4	31.4	31.1	26.5
June	29.0	22.7	29.3	30.3	30.3	30.3	29.7	26.4	30.3	30.3	28.9	24.6
July	25.1	16.1	19.2	28.0	31.4	24.3	23.8	21.9	28.6	24.7	24.3	20.7
August	20.2	11.6	10.8	19.0	25.8	18.8	15.9	15.8	21.3	19.0	17.8	15.2
September	9.7	10.1	6.7	8.2	17.6	12.1	12.0	8.8	18.2	16.6	12.0	10.2
October	5.6	19.4	6.3	6.3	17.1	21.6	13.0	6.7	26.4	11.0	13.3	11.3
November	6.8	13.6	6.1	11.4	24.3	22.8	18.8	6.9	23.7	14.5	14.9	12.7
December	0.0	13.9	5.7	16.0	24.2	20.7	12.7	8.2	17.3	12.0	13.1	11.1
TOTAL	196.4	203.5	172.8	237.3	277.1	262.2	236.7	192.5	264.0	245.4	228.8	194.5
TOTAL, adjusted for Availability...												
	166.9	173.0	146.9	201.7	235.6	222.9	201.2	163.6	224.4	208.6	194.5	
Compared to Historical...												
	184.0	187.0	178.1	217.3	202.7	237.2	200.3	149.1	221.2	192.6	197.0	

TOTAL, adjusted for actual (reported) availability...

	96.7%	78.7%	88.7%	98.2%	
	196.8	218.1	232.6	232.4	

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Vartsikhe III Energy Computations

Exhibit 1
Sheet 6 of 7

Qp,max	350.0	MW,max	46.0
Qp,min	52.5	MW,min	7.0
HW	55.1	Availability	85.0%
TW,max	40.1	e, overall	82.5%
TW,min	40.1	Energy	194.5
f (hd-loss)	0.000001	Historical	187.2

Monthly Average Project Inflow, cms

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	150.8	58.7	69.2	189.5	100.6	116.0	114.7	71.2	58.9	151.4
February	85.6	135.6	127.8	263.4	129.5	98.2	148.2	112.5	68.5	156.7
March	195.6	200.6	168.9	198.8	280.8	590.7	297.3	255.5	283.9	323.5
April	403.4	415.2	319.8	506.2	489.2	568.3	455.3	320.8	440.0	587.0
May	352.6	378.4	324.6	751.8	433.0	355.3	533.9	369.4	438.1	452.4
June	334.8	260.8	337.7	583.9	446.9	369.3	342.3	304.0	400.7	395.7
July	278.9	178.6	213.3	312.2	367.7	269.8	264.7	243.2	318.8	274.9
August	224.9	128.8	119.7	211.5	286.8	209.3	176.4	175.3	236.9	211.3
September	111.3	115.7	76.3	93.8	202.0	138.9	138.0	100.7	208.4	190.9
October	62.0	214.9	69.3	69.4	189.5	240.4	144.0	74.0	293.8	121.7
November	78.3	156.3	70.0	130.3	279.1	261.9	215.5	79.1	272.8	166.7
December	43.0	154.4	63.0	177.2	268.8	230.4	140.8	91.0	192.5	132.8

Monthly Average Plant Discharge, cms

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	150.8	58.7	69.2	189.5	100.6	116.0	114.7	71.2	58.9	151.4
February	85.6	135.6	127.8	263.4	129.5	98.2	148.2	112.5	68.5	156.7
March	195.6	200.6	168.9	198.8	280.8	350.0	297.3	255.5	283.9	323.5
April	350.0	350.0	319.8	350.0	350.0	350.0	350.0	320.8	350.0	350.0
May	350.0	350.0	324.6	350.0	350.0	350.0	350.0	350.0	350.0	350.0
June	334.8	260.8	337.7	350.0	350.0	350.0	342.3	304.0	350.0	350.0
July	278.9	178.6	213.3	312.2	350.0	269.8	264.7	243.2	318.8	274.9
August	224.9	128.8	119.7	211.5	286.8	209.3	176.4	175.3	236.9	211.3
September	111.3	115.7	76.3	93.8	202.0	138.9	138.0	100.7	208.4	190.9
October	62.0	214.9	69.3	69.4	189.5	240.4	144.0	74.0	293.8	121.7
November	78.3	156.3	70.0	130.3	279.1	261.9	215.5	79.1	272.8	166.7
December	0.0	154.4	63.0	177.2	268.8	230.4	140.8	91.0	192.5	132.8

Monthly Average Production Capacity, MW

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	
January	18.3	7.1	8.4	22.9	12.2	14.1	13.9	8.6	7.1	18.4	31
February	10.4	16.4	15.5	31.8	15.7	11.9	18.0	13.6	8.3	19.0	28
March	23.7	24.3	20.5	24.1	33.9	42.1	35.9	30.9	34.3	39.0	31
April	42.1	42.1	38.6	42.1	42.1	42.1	42.1	38.7	42.1	42.1	30
May	42.1	42.1	39.1	42.1	42.1	42.1	42.1	42.1	42.1	42.1	31
June	40.3	31.5	40.7	42.1	42.1	42.1	41.2	36.7	42.1	42.1	30
July	33.7	21.6	25.8	37.7	42.1	32.6	32.0	29.4	38.4	33.2	31
August	27.2	15.6	14.5	25.6	34.6	25.3	21.4	21.2	28.7	25.6	31
September	13.5	14.0	9.3	11.4	24.5	16.8	16.7	12.2	25.2	23.1	30
October	7.5	26.0	8.4	8.4	22.9	29.1	17.5	9.0	35.5	14.8	31
November	9.5	18.9	8.5	15.8	33.7	31.6	26.1	9.6	33.0	20.2	30
December	0.0	18.7	7.6	21.5	32.5	27.9	17.1	11.0	23.3	16.1	31

Monthly Energy Production, GWh

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Average	Adjusted for Availability
January	13.6	5.3	6.2	17.1	9.1	10.5	10.4	6.4	5.3	13.7	9.8	8.3
February	7.0	11.0	10.4	21.4	10.6	8.0	12.1	9.2	5.6	12.8	10.8	9.2
March	17.6	18.1	15.2	17.9	25.2	31.4	26.7	23.0	25.5	29.0	23.0	19.5
April	30.3	30.3	27.8	30.3	30.3	30.3	30.3	27.8	30.3	30.3	29.8	25.4
May	31.4	31.4	29.1	31.4	31.4	31.4	31.4	31.4	31.4	31.4	31.1	26.5
June	29.0	22.7	29.3	30.3	30.3	30.3	29.7	26.4	30.3	30.3	28.9	24.6
July	25.1	16.1	19.2	28.0	31.4	24.3	23.8	21.9	28.6	24.7	24.3	20.7
August	20.2	11.6	10.8	19.0	25.8	18.8	15.9	15.8	21.3	19.0	17.8	15.2
September	9.7	10.1	6.7	8.2	17.6	12.1	12.0	8.8	18.2	16.6	12.0	10.2
October	5.6	19.4	6.3	6.3	17.1	21.6	13.0	6.7	26.4	11.0	13.3	11.3
November	6.8	13.6	6.1	11.4	24.3	22.8	18.8	6.9	23.7	14.5	14.9	12.7
December	0.0	13.9	5.7	16.0	24.2	20.7	12.7	8.2	17.3	12.0	13.1	11.1
TOTAL	196.4	203.5	172.8	237.3	277.1	262.2	236.7	192.5	264.0	245.4	228.8	194.5
TOTAL, adjusted for Availability...												
	166.9	173.0	146.9	201.7	235.6	222.9	201.2	163.6	224.4	208.6	194.5	
Compared to Historical...												
	166.0	172.4	173.4	179.4	211.1	230.7	184.0	168.2	204.1	182.8	187.2	

TOTAL, adjusted for actual (reported) availability...

	88.7%	91.3%	98.8%	77.6%
	180.5	253.0	259.1	183.7

Vartsikhe IV Energy Computations

Exhibit 1
Sheet 7 of 7

Qp,max	350.0	MW,max	46.0
Qp,min	52.5	MW,min	7.0
HW	38.1	Availability	90.0%
TW,max	23.1	e, overall	82.5%
TW,min	23.1	Energy	216.1
f (hd-loss)	0.000001	Historical	213.6

Monthly Average Project Inflow, cms

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	150.8	58.7	69.2	189.5	100.6	116.0	114.7	71.2	58.9	151.4
February	85.6	135.6	127.8	263.4	129.5	98.2	148.2	112.5	68.5	156.7
March	195.6	200.6	168.9	198.8	280.8	590.7	297.3	255.5	283.9	323.5
April	403.4	415.2	319.8	506.2	489.2	568.3	455.3	320.8	440.0	587.0
May	352.6	378.4	324.6	751.8	433.0	355.3	533.9	369.4	438.1	452.4
June	334.8	260.8	337.7	583.9	446.9	369.3	342.3	304.0	400.7	395.7
July	278.9	178.6	213.3	312.2	367.7	269.8	264.7	243.2	318.8	274.9
August	224.9	128.8	119.7	211.5	286.8	209.3	176.4	175.3	236.9	211.3
September	111.3	115.7	76.3	93.8	202.0	138.9	138.0	100.7	208.4	190.9
October	62.0	214.9	69.3	69.4	189.5	240.4	144.0	74.0	293.8	121.7
November	78.3	156.3	70.0	130.3	279.1	261.9	215.5	79.1	272.8	166.7
December	43.0	154.4	63.0	177.2	268.8	230.4	140.8	91.0	192.5	132.8

Monthly Average Plant Discharge, cms

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	150.8	58.7	69.2	189.5	100.6	116.0	114.7	71.2	58.9	151.4
February	85.6	135.6	127.8	263.4	129.5	98.2	148.2	112.5	68.5	156.7
March	195.6	200.6	168.9	198.8	280.8	350.0	297.3	255.5	283.9	323.5
April	350.0	350.0	319.8	350.0	350.0	350.0	350.0	320.8	350.0	350.0
May	350.0	350.0	324.6	350.0	350.0	350.0	350.0	350.0	350.0	350.0
June	334.8	260.8	337.7	350.0	350.0	350.0	342.3	304.0	350.0	350.0
July	278.9	178.6	213.3	312.2	350.0	269.8	264.7	243.2	318.8	274.9
August	224.9	128.8	119.7	211.5	286.8	209.3	176.4	175.3	236.9	211.3
September	111.3	115.7	76.3	93.8	202.0	138.9	138.0	100.7	208.4	190.9
October	62.0	214.9	69.3	69.4	189.5	240.4	144.0	74.0	293.8	121.7
November	78.3	156.3	70.0	130.3	279.1	261.9	215.5	79.1	272.8	166.7
December	0.0	154.4	63.0	177.2	268.8	230.4	140.8	91.0	192.5	132.8

Monthly Average Production Capacity, MW

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	
January	18.3	7.1	8.4	22.9	12.2	14.1	13.9	8.6	7.1	18.4	31
February	10.4	16.4	15.5	31.8	15.7	11.9	18.0	13.6	8.3	19.0	28
March	23.7	24.3	20.5	24.1	33.9	42.1	35.9	30.9	34.3	39.0	31
April	42.1	42.1	38.6	42.1	42.1	42.1	42.1	38.7	42.1	42.1	30
May	42.1	42.1	39.1	42.1	42.1	42.1	42.1	42.1	42.1	42.1	31
June	40.3	31.5	40.7	42.1	42.1	42.1	41.2	36.7	42.1	42.1	30
July	33.7	21.6	25.8	37.7	42.1	32.6	32.0	29.4	38.4	33.2	31
August	27.2	15.6	14.5	25.6	34.6	25.3	21.4	21.2	28.7	25.6	31
September	13.5	14.0	9.3	11.4	24.5	16.8	16.7	12.2	25.2	23.1	30
October	7.5	26.0	8.4	8.4	22.9	29.1	17.5	9.0	35.5	14.8	31
November	9.5	18.9	8.5	15.8	33.7	31.6	26.1	9.6	33.0	20.2	30
December	0.0	18.7	7.6	21.5	32.5	27.9	17.1	11.0	23.3	16.1	31

Monthly Energy Production, GWh

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Average	Adjusted for Availability
January	13.6	5.3	6.2	17.1	9.1	10.5	10.4	6.4	5.3	13.7	9.8	8.8
February	7.0	11.0	10.4	21.4	10.6	8.0	12.1	9.2	5.6	12.8	10.8	9.7
March	17.6	18.1	15.2	17.9	25.2	31.4	26.7	23.0	25.5	29.0	23.0	20.7
April	30.3	30.3	27.8	30.3	30.3	30.3	30.3	27.8	30.3	30.3	29.8	26.9
May	31.4	31.4	29.1	31.4	31.4	31.4	31.4	31.4	31.4	31.4	31.1	28.0
June	29.0	22.7	29.3	30.3	30.3	30.3	29.7	26.4	30.3	30.3	28.9	26.0
July	25.1	16.1	19.2	28.0	31.4	24.3	23.8	21.9	28.6	24.7	24.3	21.9
August	20.2	11.6	10.8	19.0	25.8	18.8	15.9	15.8	21.3	19.0	17.8	16.1
September	9.7	10.1	6.7	8.2	17.6	12.1	12.0	8.8	18.2	16.6	12.0	10.8
October	5.6	19.4	6.3	6.3	17.1	21.6	13.0	6.7	26.4	11.0	13.3	12.0
November	6.8	13.6	6.1	11.4	24.3	22.8	18.8	6.9	23.7	14.5	14.9	13.4
December	0.0	13.9	5.7	16.0	24.2	20.7	12.7	8.2	17.3	12.0	13.1	11.8
TOTAL	196.4	203.5	172.8	237.3	277.1	262.2	236.7	192.5	264.0	245.4	228.8	205.9
TOTAL, adjusted for Availability...	176.8	183.2	155.5	213.6	249.4	236.0	213.0	173.2	237.6	220.8	216.1	
Compared to Historical...						228.8	232.2	191.1	216.1	200.0	213.6	

TOTAL, adjusted for actual (reported) availability...

100.0%	98.8%
262.2	233.9

Exhibit 2

ECONOMIC ANALYSIS - SHORT TERM REHABILITATION SCENARIO
Lajanuri Hydroelectric Project

Economic Parameters	
Hydro Rehab. Investment Cost ($ x 1,000):	4,500
Hydro O&M Costs ($/MWh):	2.00
Energy Value ($/MWh):	34.00
Discount Rate:	10.0%
Present Value Benefits ($ million):	$7.8
Present Value Costs ($ million):	$5.0
Net Present Value, NPV ($ million):	$2.9
PVB/PVC Ratio:	1.6
Economic Internal Rate of Return, EIRR:	32.6%

LAJANURI HYDROELECTRIC PROJECT	Base Case Scenario; Do-Nothing	Rehab. Short Term
Maximum Plant Production Capacity (MW):	64.0	96.0
Average Plant Availability:	75.0%	80.0%
Average Overall Generating Efficiency:	75.0%	77.0%
Average Annual Energy Production (GWh):	306.4	367.0
Average Annual Incremental Production (GWh):		60.6

	INCREMENTAL COSTS					INCREMENTAL BENEFITS		
Year	Investment Cost ($ x 1,000)	O & M Cost ($ x 1,000)	Total Cost ($ x 1,000)	Present Value ($ x 1,000)	Cumulative Present Value ($ x 1,000)	Energy Value ($ x 1,000)	Present Value ($ x 1,000)	Cumulative Present Value ($ x 1,000)
	4,500		4,500	4,500	4,500			
1		121	121	110	4,610	2,060	1,873	1,873
2		121	121	100	4,710	2,060	1,703	3,576
3		121	121	91	4,801	2,060	1,548	5,124
4		121	121	83	4,884	2,060	1,407	6,531
5		121	121	75	4,959	2,060	1,279	7,811

Exhibit 3

ECONOMIC ANALYSIS - LONG TERM REHABILITATION SCENARIO
Lajanuri Hydroelectric Project

Economic Parameters	
Hydro Rehab. Investment Cost ($ x 1,000):	11,690
Hydro O&M Costs ($/MWh):	2.00
Energy Value ($/MWh):	34.00
Discount Rate:	10.0%
Present Value Benefits ($ million):	$50.0
Present Value Costs ($ million):	$14.6
Net Present Value, NPV ($ million):	$35.4
PVB/PVC Ratio:	3.4
Economic Internal Rate of Return, EIRR:	44.3%

LAJANURI HYDROELECTRIC PROJECT	Base Case Scenario; Do-Nothing	Rehab. Long Term
Maximum Plant Production Capacity (MW):	64.0	114.0
Year 1 Plant Availability:	75.0%	92.5%
Year 1 Overall Generating Efficiency:	75.0%	85.0%
Average Annual Energy Production (GWh): - based on Year 1 conditions	306.4	468.4
Average Annual Incremental Production (GWh):		162.0

	INCREMENTAL COSTS					INCREMENTAL BENEFITS		
Year	Investment Cost ($ x 1,000)	O & M Cost ($ x 1,000)	Total Cost ($ x 1,000)	Present Value ($ x 1,000)	Cumulative Present Value ($ x 1,000)	Energy Value ($ x 1,000)	Present Value ($ x 1,000)	Cumulative Present Value ($ x 1,000)
	11,690		11,690	11,690	11,690			
1		324	324	295	11,985	5,508	5,007	5,007
2		324	324	268	12,252	5,508	4,552	9,559
3		324	324	243	12,496	5,508	4,138	13,698
4		324	324	221	12,717	5,508	3,762	17,460
5		324	324	201	12,918	5,508	3,420	20,880
6		324	324	183	13,101	5,508	3,109	23,989
7		324	324	166	13,267	5,508	2,826	26,815
8		324	324	151	13,419	5,508	2,570	29,385
9		324	324	137	13,556	5,508	2,336	31,721
10		324	324	125	13,681	5,508	2,124	33,844
11		324	324	114	13,794	5,508	1,931	35,775
12		324	324	103	13,898	5,508	1,755	37,530
13		324	324	94	13,991	5,508	1,595	39,125
14		324	324	85	14,077	5,508	1,450	40,576
15		324	324	78	14,154	5,508	1,319	41,894
16		324	324	71	14,225	5,508	1,199	43,093
17		324	324	64	14,289	5,508	1,090	44,183
18		324	324	58	14,347	5,508	991	45,173
19		324	324	53	14,400	5,508	901	46,074
20		324	324	48	14,448	5,508	819	46,893
21		324	324	44	14,492	5,508	744	47,637
22		324	324	40	14,532	5,508	677	48,314
23		324	324	36	14,568	5,508	615	48,929
24		324	324	33	14,601	5,508	559	49,488
25		324	324	30	14,631	5,508	508	49,996

Exhibit 4

ECONOMIC ANALYSIS - SHORT TERM w/DELAYED LONG TERM REHAB.
Lajanuri Hydroelectric Project

Economic Parameters		
Hydro Rehab. ST & LT Costs ($ x 1,0	4,500	11,690
Hydro O&M Costs ($/MWh):		2.00
Energy Value ($/MWh):		34.00
Discount Rate:		10.0%
Present Value Benefits ($ million):		$36.9
Present Value Costs ($ million):		$13.9
Net Present Value, NPV ($ million):		$23.0
PVB/PVC Ratio:		2.7
Economic Internal Rate of Return, EIRR:		37.8%

LAJANURI HYDROELECTRIC PROJECT	Base Case Scenario; Do-Nothing	Rehab. Short Term	Rehab. Long Term
Maximum Plant Production Capacity (MW):	64.0	96.0	114.0
Year 1 Plant Availability:	75.0%	80.0%	92.5%
Year 1 Overall Generating Efficiency:	75.0%	77.0%	85.0%
Average Annual Energy Production (GWh): - based on Year 1 conditions	306.4	367.0	468.4
Average Annual Incremental Production (GWh):		60.6	162.0

	INCREMENTAL COSTS					INCREMENTAL BENEFITS		
Year	Investment Cost ($ x 1,000)	O & M Cost ($ x 1,000)	Total Cost ($ x 1,000)	Present Value ($ x 1,000)	Cumulative Present Value ($ x 1,000)	Energy Value ($ x 1,000)	Present Value ($ x 1,000)	Cumulative Present Value ($ x 1,000)
	4,500		4,500	4,500	4,500			
1		121	121	110	4,610	2,060	1,873	1,873
2		121	121	100	4,710	2,060	1,703	3,576
3		121	121	91	4,801	2,060	1,548	5,124
4		121	121	83	4,884	2,060	1,407	6,531
5	11,690	121	11,811	7,334	12,218	2,060	1,279	7,811
6		324	324	183	12,401	5,508	3,109	10,920
7		324	324	166	12,567	5,508	2,826	13,746
8		324	324	151	12,718	5,508	2,570	16,316
9		324	324	137	12,856	5,508	2,336	18,652
10		324	324	125	12,981	5,508	2,124	20,775
11		324	324	114	13,094	5,508	1,931	22,706
12		324	324	103	13,197	5,508	1,755	24,461
13		324	324	94	13,291	5,508	1,595	26,056
14		324	324	85	13,377	5,508	1,450	27,507
15		324	324	78	13,454	5,508	1,319	28,825
16		324	324	71	13,525	5,508	1,199	30,024
17		324	324	64	13,589	5,508	1,090	31,114
18		324	324	58	13,647	5,508	991	32,104
19		324	324	53	13,700	5,508	901	33,005
20		324	324	48	13,748	5,508	819	33,824
21		324	324	44	13,792	5,508	744	34,568
22		324	324	40	13,832	5,508	677	35,245
23		324	324	36	13,868	5,508	615	35,860
24		324	324	33	13,901	5,508	559	36,419
25		324	324	30	13,931	5,508	508	36,927