

COMMISSION INTERNATIONALE
DES GRANDS BARRAGES

VINGT ET UNIÈME CONGRÈS
DES GRANDS BARRAGES
Montréal, 2003

**COST-BENEFIT ANALYSIS OF THE REHABILITATION
OF KRASNODAR DAM IN RUSSIA ^(*)**

Patrice DROZ
Technical Director

Anne-Marie ACS
Economist

Stucky Consulting Engineers Ltd

SWITZERLAND

1. INTRODUCTION

Before the construction of the Krasnodar reservoir ($3 \cdot 10^9 \text{ m}^3$) in 1975, the lower basin of the Kuban river located close to the Azov Sea experienced important flooding events. Those which happened in the 1930's and 40's had dramatic consequences.

The construction of a dam (21 m high, 11.4 km long, partly in compacted loams and light clays and partly hydraulically filled with sandy materials) close to the city of Krasnodar was not only intended for flood protection of an area of 600 000 ha and 300 000 inhabitants, but also for regulation purposes. The presence of the dam and its regulatory role enabled the development of the lower basin of the Kuban river. Agriculture has since been developed over a surface of 270 000 ha, 248 000 ha being devoted to rice production. Presently, the Krasnodar territory contributes, for up to 80% to the total rice production of Russia.

^(*) *Analyse coût-bénéfice de la réhabilitation du barrage de Krasnodar en Russie.*

During the last decade, severe cuts in the maintenance budget of the whole system (reservoir, dam and dykes along the Lower Kuban River) drove to a certain degradation of its various components. Preliminary studies have been performed by the local consulting engineer, Kuban Vodprojekt, and a grant was allocated by the Swiss Government for a Feasibility Study of the works necessary for the rehabilitation of the scheme. The feasibility study of the restoration of Krasnodar water storage reservoir covered the following main points: seismic stability assessment of the dam, rehabilitation of the upstream facing and the drainage system, as well as rehabilitation of the Lower Kuban dykes.

Following the methodological principles of the concept of profitability in the rehabilitation of Krasnodar water reservoir, the analysis is based on the cost-benefit evaluation approach presented hereafter.

2. GENERAL DESCRIPTION

The Krasnodar dam is 11.4 km long. It is in average 14-16 m high above the flood plain and 21 m high in the former Kuban River bed. Starting from the left abutment, the structure of the dam body is made of 4.3 km of compacted loams and light clays, then 0,7 km partly filled with coherent materials and partly hydraulically filled with sandy materials, while the last 6.4 km were hydraulically filled with fine and medium-grained sand.

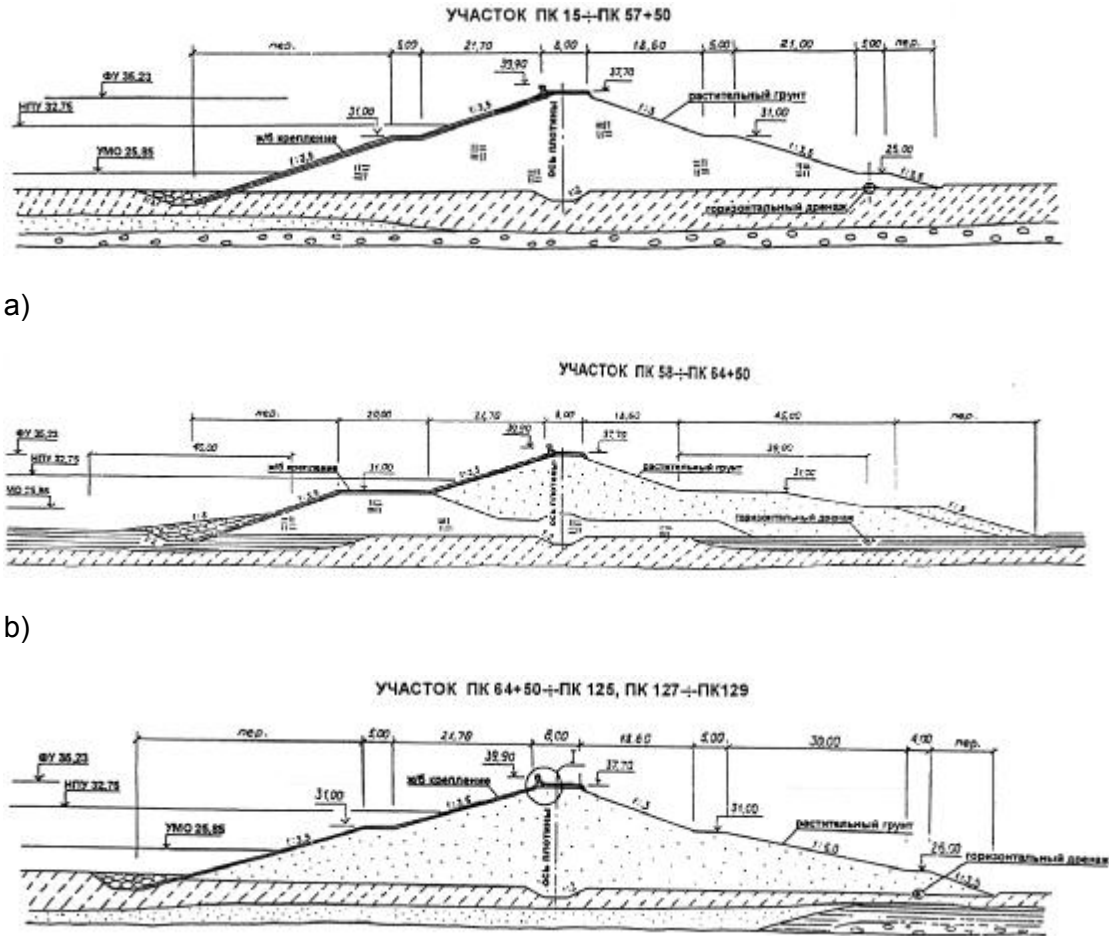
The width of the dam at the crest is 8 m. A wave wall in reinforced concrete was built on the lake side edge of the dam crest. The design level of the dam crest is 37.70 m asl.

The upstream face of the dam (1:3 - 1:3,5) has a berm 5 m wide (31.0 m asl) and is protected by reinforced concrete slabs of variable thickness (0,25 m to 0,4 m). The downstream face of the dam (1:3 - 1:3,5), has 2 intermediate berms 4 m wide (25.0, 26.0 and 31.0 m asl). It is protected by perennial grass all along the dam.

The downstream toe of the dam is drained by a horizontal drainage system and by two vertical drainage systems (208 wells; 15-35 m deep and 90 wells equipped with pumps; 22-37 m deep). The water collected by the drainage system flows by gravity towards two pumping stations.

The spillway consists of four independent gates separated by the mechanical fishlift, which acts as the fifth gate. The design discharge capacity of the spillway is 1 600 and 1 780 m³/s at NWL (initial normal water level) and EWL (emergency water level) respectively.

The length of the shiplock chamber is 135 m, with a width of 15 m, and a depth on the threshold of 2.0 m. The design carrying capacity of ships is 1000 tons with a draught of 1.6 m.



a)

b)

c)

Fig. 1
Typical cross sections of Krasnodar dam
Coupes types du barrage de Krasnodar

- | | |
|--|-------------------------------------|
| a) Typical cross section (compacted material) | a) Coupe type (matériaux compactés) |
| b) Typical cross section (transition) | b) Coupe type (zone de transition) |
| c) Typical cross section (hydraulic fill material) | c) Coupe type (remblai hydraulique) |

The Lower Kuban dykes must also be integrated in the flood protection scheme. 130 km before flowing into the Azov sea, the Kuban river splits into two channels: Kuban and Protoka rivers. In order to prevent meanderings and inundations, both rivers were dyked between the Krasnodar dam and the Azov sea. These dykes were calibrated for the design discharge 1 500 m³/s. About 650 km of dykes were constructed.

3. MAIN PROBLEMS

The feasibility study particularly concerned the following points:

- 1) the dam (dam safety, seismic stability and liquefaction assessment, concrete upstream facing degradation, drainage system deficiency, obsolete monitoring)
- 2) the spillway (check of the extremal flood using PMP-PMF method, flood routing capacity, hydromechanical equipment condition, scouring)
- 3) the reservoir and basin water management outline
- 4) the navigation lock (internal erosion, scouring, hydromechanical equipment condition)
- 5) the outlet near left abutment (civil works and hydromechanical equipment condition)
- 6) the left bank of the reservoir (environmental impacts of the reservoir on tributaries and agricultural land, erosion, sedimentation, water logging)
- 7) the fisheries (requirements for discharge, fish lift efficiency, fisheries development)
- 8) the irrigation area (requirements for irrigation water, drainage, flood control and capacity of the Lower Kuban river)
- 9) the water supply (quality and quantity for industrial and domestic usage)
- 10) the review of the existing emergency plan (flooded area, rescue and mitigation measures)
- 11) the outline design and cost estimate and economical cost benefit analysis
- 12) the terms of reference for detailed design and complementary studies.

4. MAIN ASPECTS OF THE REHABILITATION

The main points addressing the safety of the Krasnodar dam that can be driven from the analysis are summarised hereafter:

- the seismic risk to which Krasnodar dam is exposed has to be assessed by a detailed seismic risk analysis
- the analysis of the results of the recent site investigations shows that a moderate risk of liquefaction exists in the core of the hydraulic filled part and a high potential of liquefaction in the foundation of the dam. In case of an earthquake with a peak ground acceleration of 0.3 g, the dam would experience strong disorders due to settlements, but probably not a complete failure

- improving the safety of the Krasnodar dam with respect to the risk of liquefaction consecutive to an earthquake is extremely problematic since the major risk does not come from the dam itself but from its foundation. Few solutions can be considered among which, jet-grouting from the upstream toe of the dam or from the upstream berm has been selected, as well as the improvement of drainage by repairing the vertical drainage system along the downstream toe of the dam and extending it between the spillway and the shiplock as well as between the shiplock and the right bank
- the concrete facing has to be repaired using an appropriate rubber-elastomer bitumen
- the vertical drainage system has to be reconstructed as well as the main drainage collector
- the monitoring system has to be restored (piezometric network)
- the PMP-PMF approach confirmed the statistical analysis of extreme floods in terms of peak discharge. Nevertheless, the main parameter is the volume of the flood and the spillway has sufficient capacity to discharge extreme floods if flood occurrence is anticipated by lowering the lake in advance
- the hydromechanical equipment of the spillway and the fish lift needs improvement
- the internal erosion process near the shiplock must be stopped by the construction of drains in the lock chamber and by the extension of the sheet pile cut-off
- the hydromechanical equipment of the shiplock needs improvement
- the Lower Kuban dykes are in poor conditions and cannot discharge extreme floods. The erosion of the dykes must be stopped and prevented.

The estimated investment costs for the rehabilitation, operation and maintenance of the objects connected to flood protection were estimated. They are summarised in the table below.

	Rehabilitation costs (round off) (US\$)	Operation and maintenance costs (US\$)	Design studies and works duration
Dam and reservoir restoration	85 700 000	2 000 000	3 years
Reservoir and banks	300 000	850 000	1 year
Kuban and Protoka dykes	61 000 000	3 000 000	7 years
Lower Kuban left bank reservoirs rehabilitation	20 000 000	800 000	
Tikhovsky achievement	25 000 000	1 350 000	7 years
Total (round off)	192 000 000	8 000 000	7 years

Tab. 1

Summary of Investment and Operation and Maintenance costs
Résumé des coûts d'investissement, d'exploitation et de maintenance

5 DAMAGE COST ESTIMATE

According to the inundation mapping, in case of dam break, up to 11 raïons (administrative division) would be affected by the inundation. Among these raïons, nine belong to the Krasnodar Kraï and two to the Republic of Adigey (member of the Federation of Russia). In order to appraise to what extent these raïons would be affected, it is necessary to introduce two factors K_1 and K_2 :

- K_1 represents the percentage of the raïon's area that would be flooded
- K_2 represents the percentage of the fixed assets that would be ruined by the inundation, taking into account the average and maximum height of water in the flooded area.

Exposed Areas	Area exposed	Water height (m)		Rate of destruction due to flood
	K_1 (%)	average	maximum	K_2 (%)
Abinskyi raïon	30,5	2,0	5,0	30
Kalininskyi raïon	14,4	0,5	1,0	10
Krasnoarmeïskyi raïon	83,5	1,5	3,0	20
Primorsko-Akhtarsky raïon	12,1	0,0	1,0	0
Ceversky raïon	8,4	3,0	5,0	60
Timrioukskyi raïon	30,7	0,0	1,0	10
Krasnodar city	9,5	3,0	5,0	60
Krimsk raïon	32,2	2,0	3,0	30
Slabiansk na Kuban raïon	86,0	0,5	2,0	30
Teychesjkyi raïon	9,0	4,0	5,0	100
Takhtamukaïskyi raïon	75,0	4,0	5,0	100

Tab. 2
Rates of damage due to dam break flood
Taux de destruction en cas de rupture du barrage

The value of the fixed assets which is used here takes into account any existing goods or infrastructures with an economical life longer than one year. The estimation of the overall cost of the damages is based on the calculation of the Net Economic Losses on fixed assets increased by the Marginal Replacement Value (MRV).

The calculation of the Net Economic Losses on fixed assets are weighted by the factors K_1 and K_2 , taking into account both the area exposed to floods and the percentage of the fixed assets that would be damaged.

Exposed Areas	Total value of Fixed assets (10⁶ Rbls 1999)	Economic loss (calculated on fixed assets) (10⁶ Rbls 1999)
Abinskyi raion	3 023	277
Kalininskyi raion	3 424	49
Krasnoarmeïskyi raion	7 192	1 802
Primorsko-Akhtarsky	2 639	32
Ceverskyi raion	3 744	190
Timrioukskyi raion	5 903	181
Krasnodar city	77 735	4 442
Krimsk raion	6 434	621
Slabiansk na Kuban	8 287	1 426
Total without Adigey		9 019

Tab. 3

Net economic losses on fixed assets

Perte économique nette sur les biens immobiliers et de production

The Marginal Replacement Value (MRV) estimates the re-equipment and reconstruction costs of the fixed assets damaged by the inundation. Its calculation is based on an additional value corresponding to the depreciation rate of the fixed assets.

Assuming that the structure of the fixed assets in Krasnodar Krai consists equally of production equipment and buildings/infrastructures with an amortization quota of 60% for production equipment and 80% for buildings and infrastructures, the final economic cost of the damages on fixed assets is evaluated in the following table:

	Net economic losses (10⁶ Rbls 1999.)	Amortization quota	MRV (10⁶ Rbls 1999)	Final economic cost (net MRV) (10⁶ Rbls 1999)
Production equipment	4 509	60%	6 763	11 272
Building and Infrastructures	4 509	80%	18 036	22 545
Total without Adigey	9 019	-	24 799	33 817

Tab. 4

Final economic losses on fixed assets

Perte économique finale sur les biens immobiliers et de production

Data concerning the Republic of Adigey were not available

Financial losses on productions are appraised considering the following hypothesis:

- Agriculture: 1,5 years of production are lost
- Industrial production: 9 months of production are lost
- Construction works and trade: 2 months of production/turnover are lost

These losses can then be calculated for each raïon, taking into account the K_1 coefficient. Here again, no data was available for Adigey Republic.

Exposed Areas	Net Economic losses			
	Agriculture	Industry	Construction works	Trade turnover
Abinskyi raïon	179.6	55.2	17.0	12.4
Kalininskyi raïon	161.8	23.3	20.1	4.8
Krasnoarmeïskyi raïon	1 352.9	266.4	90.7	64.6
Primorsko-Akhtarsky	84.5	34.2	6.6	3.5
Ceverskyi raïon	42.1	33.2	229.3	3.9
Timrioukskyi raïon	447.1	190.6	42.1	24.6
Krasnodar city	120.3	1 137.1	2 186.4	246.3
Krimsk raïon	333.4	160.2	125.7	24.4
Slabiansk na Kuban	1 117.3	412.0	225.0	119.6
Total without Adigey	3 839	2 312	93	504

Tab. 5

Losses on agricultural, industrial, construction and trade production
Perte économique en terme de production agricole et industrielle touchant les secteurs de la construction et des échanges

An overall estimation of the losses on production requires to focus on the cumulated result of an initial decrease in the economic capabilities of the damaged areas. The measurement of the recession cycle that would durably affect the economic development of the flooded regions is estimated on the lost share of the regional income, balanced by the Marginal Propensity to Consume.

Share of the regional income of the flooded territory (8.1%), in 10^6 Rbls 1999.	6 748
National propensity to consume (based on the Russian Federation Statistics)	0.80
Value of the economic recession cycle due to the losses in production, in 10^6 Rbls 1999	33 740
Recession cycle on regional GDP (net value)	26 992

Tab. 6

Recession cycle on regional GDP
Cycle de récession sur le PNB régional

The following table summarizes the details of the calculation of the total cost :

	Inundation cost based on data of 1999 (10⁶ Rbls)
Fixed assets	9 019
Marginal replacement value	24 799
Industrial production	2 312
Construction works	93
Agricultural production	3 839
Trade turnover	504
Other productions and taxes	1 683
Recession cycle on regional GDP (net value)	26 992
Total (10⁶ Rbls 1999)	69 163

Tab. 7
Inundation cost in Krasnodar Kraï
Coût des inondations dans le Kraï de Krasnodar

The item "Other productions and taxes" represents 8.1 % (i.e. the percentage of the territory of the Krasnodar Kraï exposed to inundations) of the average value for the whole region from 1995 to 1999. The detailed values for each raïon were not available. This hypothesis is conservative since the flooded area could be considered more productive than other parts of the region.

As only few macro-economical data were available for the Republic of Adigey, the inundation cost was obtained by extrapolating the cost calculated for the Krasnodar Kraï. Because of the location of the territories of the Republic of Adigey, just below the dam, they would be completely flooded.

We can consider that the economical situation of the Republic of Adigey is similar to the Krasnodar Kraï's. The total exposed area cover 289,5 km² (5 866 km² in the Krasnodar Kraï). The average estimated destruction level in the exposed part of the Krasnodar Kraï reaches 24 %, i.e. 4 times less than expected in the Republic of Adigey. Therefore, the inundation cost in Republic of Adigey can be estimated as follows: 13 650 10⁶ Rbls 1999.

The total estimated cost of the inundation induced by a dam break reaches 82 816 10⁶ Rbls of 1999, i.e. 2.96 billion US\$:

Area	Inundation cost (US\$)
Krasnodar Kraï	2 470 000 000
Republic of Adigey	490 000 000
Total inundated area	2 960 000 000

Tab. 8
Total estimated cost of dam break
Coût total des inondations en cas de rupture du barrage

6 COST BENEFIT ANALYSIS

The Krasnodar hydraulic scheme aims at two main goals: flood protection and agricultural development. The approach which is proposed hereafter considers the whole scheme in terms of flood protection infrastructure. Therefore, according to the methodological principles of the concept of profitability in the restoration of Krasnodar water reservoir, the analysis will be focused on a cost-benefit approach. Unlike an Economical Internal Rate of Return analysis, shaped to estimate the profitability of a loan measured at the rate of the capital market, CBA requires a measuring factor focusing, in this case, on Risk Management assumptions and accordingly, on the project internal cost evaluation.

In the present study case, CBA will translate in monetary terms the implications of a decision making procedure comprising two options: the carrying out or not of the Krasnodar reservoir restoration project. The rate of risk for both options will be expressed in monetary value by an actuary formula comprising monetary and statistical variables. The theoretical risk premium formula, obtained in this way, will then be applied to the specific parameters of both options and finally included to the CBA evaluation.

The CBA was performed on a 25 years period, starting from the beginning of the implementation of the repair works. The financial impact of the two following scenarios has been assessed as follows:

First scenario, continuation of the present situation: the dam and the dykes are not repaired. The maintenance and operation budgets remain very low and the risk of failure increases. The safety of the dam and dykes was designed, after the construction, for floods with a return time period of 1 000 years. This initial figure has decreased to 100 years from 1975 to 2000 and it will, most probably, continue to decrease from 100 to 10 during the next 25 years. The main parameters of this scenario are:

Item	Selected values	Unit
GDP progression rate	5.0	%
Discount rate	7.0	%
Residual value of the infrastructures	395	10 ⁶ US \$
Dam break inundation cost	3.0	10 ⁹ US\$
Repair works duration	none	
Repair works cost	none	
Present accident probability	1	%
Accident probability after 25 years	10	%
Operation and maintenance costs	1.0	10 ⁶ US \$

Tab. 9

Main economical parameters for the first scenario
Paramètres économiques principaux pour le premier scénario

Second scenario, implementation of repair works: the dam and the dykes are repaired. The repair works last 7 years. The maintenance and operation budgets are increased to the required values. The probability for a dam break decreases to 0.01 % during the achievement of the works. In the course of the 18 following years, the probability of a dam break slightly increases up to 0.1%, because of the ageing of the structures. The main parameters of this scenario are:

Item	Used values	Unit
GDP growth rate	5.0	%
Discount rate	7.0	%
Residual value of the infrastructures	395	10 ⁶ US \$
Dam break inundation cost	3.0	10 ⁹ US\$
Repair works duration	7	years
Repair works cost	192	10 ⁶ US \$
Present accident probability	1	%
Accident probability after repair works	0.01	%
Accident probability after 25 years	0.1	%
Operation and maintenance costs	8.0	10 ⁶ US \$
Depreciation rates, according to Russian standards:		
the dam and its structures	1.60	%
engineering protections	1.70	%
Kuban and Protoka dykes	2.60	%

Tab. 10

Main economical parameters for the second scenario
Paramètres économiques principaux pour le deuxième scénario

For each scenarios and for each given year, the estimated value of risk of a dam break is calculated in reference to the probability of accident (strongly depending on the condition of the Krasnodar dam and of the lower Kuban dykes), multiplied by the economic cost inherent to the inundation. Accordingly, the formulation of CBA requires the following information for each scenario and for each year:

- The statistical risk of a dam break and the corresponding cost;
- The operation and maintenance costs;
- Depreciation rates and costs;
- The cost of repair works.

The cost benefit ratio (CBA ratio) is defined as the ratio between the two calculated costs. The results of the CBA are presented in the following table.

The following comments can be made:

- the CBA analysis clearly shows that the achievement of the repair works is extremely valuable, since the CBA ratio is much higher than 1.

- the table shows out the fact that the estimated value of risk is the determining factor, and the only way to decrease it level is to reduce the dam break probability by performing all necessary repair works.

Economic costs (US\$)	First scenario: continuation of the present situation	Second scenario: repair works implementation	Cost-Benefit ratio
Cost of the risk	2 268 188 000	47 192 000	
Operation and maintenance costs	12 469 000	99 755 000	
Depreciation costs	90 615 000	116 905 000	
Cost of repair works.	0	192 000 000	
Total cost	2 371 272 000	468 645 000	5.06

Tab. 11
 Cost-benefit analysis result
Résultats de l'analyse coût-bénéfice

It is interesting to check the sensitivity of the CBA ratio by changing the parameters selected above. Only variations with a negative impact on the CBA are taken into account.

- GDP growth rate: instead of assuming that the Russian GDP will pursue its growth for the next years at its current rate of $\pm 5\%$, we will assume a stagnation of its value and a growth rate of 0% for the next 25 years (which is unlikely).
- Discount rate: instead of the average value of 7% , we will assume a conservative value of 10% .
- Residual value of the infrastructures: an underestimation of 25% was assumed, with a residual value increased from 395 to $500 \cdot 10^6$ US\$.
- Dam break inundation cost: we assume that the exact figure is not $3.0 \cdot 10^9$ but $2.5 \cdot 10^9$ US\$.
- Repair works duration: instead of lasting 7 years, the repair works will last 10 years.
- Accident probability if repair works are not performed: we will assume that the probability of a dam break will be kept at its present value (1%) during the next 25 years, even if no peculiar repair works are performed (extremely unlikely).
- Accident probability after completion of the repair works: for any reason, the repair works allow to reduce the dam break probability from 1% to 0.1% (instead of 0.01%). Moreover, we will assume that this probability falls down to 1% after 25 years.
- Operation and maintenance costs: operation and maintenance costs are increased by 50% (12 instead of 8 millions US\$)

These changes, taken separately, lead to the following results:

Item	Unit	Selected value	Modified value	CBA ratio
CBA result without changes				5.06
GDP progression rate	%	5.0	0.0	2.67
Discount rate	%	7.0	10.0	3.81
Residual value of the infrastructures	10 ⁶ US \$	395	500	4.87
Dam break inundation cost	10 ⁹ US\$	3.0	2.5	3.57
Repair works duration	years	7	10	4.94
Accident probability after 25 years without repair works	%	10	1	1.51
Accident probability after completion of the repair works	%	0.01	0.1	3.97
Operation and maintenance costs	10 ⁶ US \$	8	12	4.57

Tab. 12

Cost-benefit analysis sensitivity result
Sensibilité de l'analyse coût-bénéfice

Here again, these results clearly show that the determining parameters are those linked to the value of risk, depending on the probability of a dam break: because of the economic value of the area exposed to a dam break, the present probability of accident is unacceptable. In any case, the final value of the CBA ratio is still higher than 1.

It is interesting to check what would be the CBA ratio, in case of a combination of the five most unfavorable parameters:

Item	Unit	Selected value	Modified value	CBA ratio
CBA result without changes				5.06
GDP progression rate	%	5.0	0.0	1.28
Discount rate	%	7.0	10.0	
Dam break inundation cost	10 ⁹ US\$	3.0	2.5	
Accident probability after 25 years without repair works	%	10	1	
Accident probability after completion of the repair works	%	0.01	0.1	

Tab. 13

Cost-benefit analysis for the worst case scenario
Analyse coût-bénéfice dans le cas du scénario le plus défavorable

Even, in this case, which is extremely unlikely, the CBA ratio is still higher than 1: this final sensitivity study leaves no doubt about the necessity to carry out the repair works.

The CBA has the additional advantage to lead to a reliable estimation of the financial amount of works that would lead to a critical CBA ratio equal to 1. If we consider the worst case scenario, we find out that the CBA ratio would

decrease to 1.0 if the total cost of the repair works was equal to $319 \cdot 10^6$ US\$, i.e. 1.6 times more than what was estimated.

7. CONCLUSION

The rehabilitation of the Krasnodar dam and of the lower Kuban infrastructures (rivers dykes, smaller reservoir) is fully justified from the economic point of view. The estimated cost of the repair works, even if important, is very low compared to the present risk of failure.

Only taking into account the flood protection aspect, the solution consisting in putting the dam out of use and raising up the Kuban and Protoka rivers dykes is not acceptable from the economical point of view. The assessment of the economical impact of this solution on the irrigated area could only confirm this result.

The cost benefit analysis of the rehabilitation of the Krasnodar dam was perfectly adapted to the problem since the main purpose of the dam is related to flood protection. In the present case, the evaluation of “the return on investment” (taken in its broader sense), should be addressed by an approach taking into account the difficulty to assess the financial parameters of a risk prevention program.

SUMMARY

Before the construction of the Krasnodar reservoir ($3 \cdot 10^9 \text{ m}^3$) in 1975, the lower basin of the Kuban river experienced important flooding events. Those which happened in the 1930's and 40's had dramatic consequences.

The construction of a dam (21 m high, 11 km long, partly in compacted loams and light clays and partly hydraulically filled with sandy materials) close to the city of Krasnodar was not only intended for flood protection of an area of 600 000 ha and 300 000 inhabitants but also for regulation purposes. The presence of the dam and its regulatory role enabled the development of the lower basin of the Kuban river basin. Agriculture has been developed over a surface of 270 000 ha, 248 000 ha being devoted to rice production. Presently, the Krasnodar territory contributes up to 80% to the total rice production of Russia.

During the last decade, severe cuts in the maintenance budget of the whole system (reservoir, dam and dykes along the Lower Kuban River) drove to a certain degradation of its various components. The feasibility study of the

restoration of Krasnodar water storage reservoir covered the following main points: seismic stability assessment of the dam, rehabilitation of the upstream facing and the drainage system as well as rehabilitation of the Lower Kuban dykes.

According to the methodological evaluation of the concept of profitability in the rehabilitation of Krasnodar water reservoir, the analysis has been focused on a cost-benefit approach. Unlike an economical internal rate of return analysis (EIRR), shaped to estimate the profitability of a loan measured at the rate of the capital market, CBA requires a measuring factor focused in the present case on Risk Management assumptions and accordingly, on the project internal cost evaluation.

In the present study case, CBA will translate in monetary terms the implications of a decision making procedure comprising two options: the carrying out or not of the Krasnodar reservoir restoration project. The rate of risk for both options has been expressed in monetary value by an actuary formula comprising monetary and statistical variables. The theoretical risk premium formula, obtained in this way, will then be included into the CBA calculation and applied to both options. The damages due to a dambreak flood have been estimated on the basis of calculations of damages to the fixed assets and losses on production.

The cost-benefit analysis clearly shows that the rehabilitation of the Krasnodar dam and of the lower Kuban infrastructures is fully justified on the economic point of view. The estimated cost of the repair works, even if important, is very low compared to the present risk of failure.

RÉSUMÉ

Avant la construction du barrage de Krasnodar et la création de son réservoir de 3 Mm³ en 1975, le bassin de la Kuban était soumis à des épisodes de crues intenses. Les événements qui survinrent dans les années 1930 et 40 ont eu des conséquences dramatiques.

La construction du barrage (21 m de haut, 11.4 km de long, partiellement en remblai limono-argileux compacté, partiellement en remblai hydraulique sableux) à proximité de la ville de Krasnodar n'avait pas pour but unique la protection contre les crues de 600 000 ha de terre et la protection de quelque 300 000 personnes mais aussi la régularisation du fleuve. La présence du barrage et son rôle régulateur ont permis le développement du bassin inférieur de la Kuban. En particulier, l'agriculture a été développée sur une surface de 270 000 ha, 248 000 ha étant consacrés à la culture du riz. A l'heure actuelle, la région de Krasnodar produit 80% du riz cultivé en Russie.

Durant la dernière décennie, de sévères restrictions dans le budget affectant la maintenance du système ont engendré une certaine dégradation de ses différents composants (réservoir, barrage, digue de protection à l'aval). L'étude de faisabilité de la réhabilitation du barrage de Krasnodar portait notamment les différents domaines suivants: évaluation de la stabilité des ouvrages face aux séismes, réparation du parement amont, du système de drainage et des digues de la basse Kuban.

En suivant une méthode d'évaluation basée sur un concept de rentabilité de la réhabilitation du barrage et des digues aval, l'analyse s'est focalisée sur une approche coût-bénéfice. Contrairement à une analyse du taux de rentabilité interne basé sur l'estimation la rentabilité d'un investissement par rapport aux taux du marché, l'analyse coût-bénéfice se base sur un facteur mesurant le risque et son évaluation.

En tant que méthode orientée vers la gestion du risque, la méthode transcrit en termes monétaires les conséquences d'un choix entre deux options: ne rien faire ou réhabiliter le barrage et ses structures, en recourant aux formules actuarielles. Les formules de prime sont introduites dans le calcul du coût bénéfice. Les dommages consécutifs à la rupture du barrage ont été estimés en considérant les atteintes aux biens immobiliers et aux pertes de production.

L'analyse coût-bénéfice montre clairement que la réhabilitation du barrage de Krasnodar et des digues de la basse Kuban est pleinement justifiée du point de vue économique. Les coûts de réhabilitation, bien qu'importants, sont bas en comparaison au risque lié à la rupture de l'ouvrage.