Developing Climate Resilient Flood and Flash Flood Management Practices to Protect Vulnerable Communities in Georgia

Final Report
Study of Dam Safety Practices - Rioni Basin Dams

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by

Hans M. Ewoldsen, Ph.D., P.E.
International Expert

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1. Executive Summary

In mid-2013, a project was commissioned by UNDP for study of means of developing climate resilient flood and flash flood management measures for the Rioni River Basin in northwestern Georgia. The Rioni is one of the major rivers in Georgia, and has experienced damaging floods over the past centuries. As the population of the region has increased, infrastructure and agricultural use has also increased in the region. Thus, floods have had greater impacts, including a flood in 2005, that did damage estimated at a value of 600 million dollars. The project had numerous tasks, including a review of the 6 hydroelectric dams in the Rioni Basin for safety and flood control capacity. This final report summarizes the results of the six tasks undertaken in the Dam Safety Subtask of the overall Project. The six tasks are:

1. Review of the Laws, Regulations and Guidelines applying to Dam Safety in Georgia
2. Summarization of Best International Practices in Dam Safety
3. Completion of a High Level Assessment of the Current Safety of Rioni Basin Dams
4. Assessment of Adverse Maintenance Practices at Rioni Basin Dams (subtask)
5. Development of a Robust Dam Safety Program for the Republic of Georgia
6. Identification of Measures for Mitigation of Flood Damage in New Construction (Task 6. assigned from another major flood assessment task)

Brief conclusions from the task studies are:

Review of the Laws, Regulations and Guidelines

The review of the laws, regulations, and guidelines, and the organizations responsible for their formulation, implementation and enforcement, indicated that:

- The dam safety requirements were usually not specifically called out, wording was vague rather than specific
- Current dam safety practice in Georgia is primarily legislation adapted from the Russian Federation, this legislation is recognized as out of date and requiring updating
- A multitude of Ministries, Departments and Agencies are involved in various facets of dam safety. This can result in confusion in authority and responsibility

Best International Practices in Dam Safety

A review of best international practices in dam safety, and comparison to the current status of programs and practices in Georgia, indicated that:

- The current practices in Georgia are less stringent than those of best practice countries, such as Sweden, New Zealand, Canada and the United States
- Best practice programs are available from a number of sources, and could be readily adapted to the conditions in Georgia

High Level Assessment of Safety of Rioni Basin Dams

An assessment of the current state of safety of the Rioni Basin dams was completed during a week field visit to the basin. Time constraints limited the assessment to a visual inspection of key components of the dams. The assessment results indicate that:

- There is no imminent danger of partial or complete failure of any of the six dams
- There is indication of an eroded fissure or foundation – rock interface at Gumati Dam, on the left abutment, at stilling pool lever. This is evidenced by a "boil of water" at the surface, and should be investigated
- Reservoirs at the dams are highly sedimented, severely limiting their ability to manage flood flows. The high sedimentation level could lead to overtopping during flash flooding

Adverse Maintenance Practices at Rioni Basin Dams

The TOR for the dam safety studies indicated that there was concern regarding the level of maintenance at the dams. This was considered to be a significant issue and was examined during the field visit to the dams. The review indicated that:

- Standard maintenance, that would be seen in best practice countries, has been neglected at the Rioni Basin dams
- Current maintenance practices, although not leading to failure, do constitute a hazard to worker safety and could result in operational difficulty
- More attention needs to be given to maintenance programs and implementation at the Rioni Basin Dams

Development of a Robust Dam Safety Program

One of the subtasks of the Dam Safety task was the development of a "Robust Dam Safety Program" (draft / outline). Although not explicitly stated, the program was envisaged to bring the dam safety in Georgia to international standards, address the adverse maintenance issue, and more clearly define authority and responsibility within the program. The results of the robust dam safety task are:

- Development of an expanded outline and text for a robust dam safety program for Georgia
- Recognition of the economic and technical capacity limitations in developing the program
- Provision of suggestions for "best practice" programs of other countries, that could be adapted to Georgian conditions

Mitigation of Flood Damage in New Construction

This task addressed the issue of identification of "best practice" building code provisions that could be adopted by the Government of Georgia, and its respective agencies, for mitigation of damage to planned construction of infrastructure and buildings from flash or severe flooding. The results of the task review and research indicated that:

- There are no direct provisions in the current Georgian building codes that address flood resilient design against water incursions

- Builders are able to use the building codes of their country of incorporation, although the codes of advanced countries may not specifically address flood resilience
- There are best practice codes available for modification and adaptation to Georgian construction methods (best examples are New Zealand, Australia, Mississippi (USA))

2. Project Background

The project was conceived in @))), in response to recognition that Georgia was undergoing significant economic damage due to flooding on its major rivers, and the climate change effects that were predicted to occur in the Greater Caucasus Mountains would only increase the damage effects of high flow. The situation and impacts on Georgia are best described by excerpts from the Project Document:

"Georgia is vulnerable to natural hazards including floods, flash floods, earthquakes, droughts, landslides, avalanches, and mud flows. Catastrophic events that have annual probability of occurrence of 50% threaten an economic loss for Georgia that exceeds 20% of the country's GDP[1]. Floods, including flash floods are the catastrophic events of such category of high probability"

"The February 1987 flood in the Tbilisi region alone affected 36,000 persons and caused an economic loss of US$546 million. The same year, River Rioni in western Georgia exceeded its earlier historical maximum water discharge when peak flows reached as high as 4,850m^3/s. The size of the inundated area on the Kolkheti Lowland reached 200 km^2. The losses were severe; 150 people died. Material damages reached nearly US$700 million. The flood destroyed inter alia 3,150 houses and 2,150 objects of local infrastructure, 16 km railway lines, 1.300 km roads and 1.100 km power transfer lines"

"During 1995-2009 the total cost of damage from floods and flash floods amounted to over US$1 billion. Annual risk of economic losses caused by potential hydro meteorological disasters reaches US$4 billion"

The Rioni river basin has been identified by the Second National Communication as the most vulnerable basin susceptible to various extreme climatic events, significantly enhanced by global warming. As a result of the increased frequency and intensity of these phenomena (floods, landslides and mud torrents), land erosion has intensified and greatly damaged agriculture, forests, roads and communications. For example, more than 10,000 ha of agricultural lands fell out of use in the past decade as a result of direct impact of hydro-meteorological disasters. For the country where an average land plot size per person is a mere 0.14ha this is a significant loss. Analysis of observation data on floods for the period of 1967–1989 has demonstrated that in the second half of the analysed baseline period the recurrence of floods increased by more than two-fold, and the maximum discharge has increased by 9%."

"With the melting of glaciers, there is a trend to increased sediment loads carried in the river. The silting of the river bed by glacial sediment reduces the river flow discharge capacity especially, during floods and, as well as the river bed gradient along the affected length all the way to the coast. In the Rioni Delta there is a trend towards an enhanced accumulation of sediments carried by glacier-fed rivers, caused by intensive enrichment of river sediment with moraine materials originated in the process of glacier retreat"

3. Data on the Dams in the Rioni River Basin

There are six hydroelectric dams in the Rioni River Basin, five of which are concrete. Table 1. Provides information on the dams.

Table 1. Rioni River Basin Dams

Dam	River	Year Built	Type	Height
Name				**(meters)**
Vartsikhe	Rioni	1976	Concrete Gravity	30 (estimate)
Rioni	Rioni	1933	Concrete Gravity	30 (estimate)
Gumati	Rioni	1956	Concrete Gravity	52
Tsageri	Tskhenistskali	unknown	Concrete Gravity	20 (estimate)
Lajanuri	Lajanuri	1960	Thin Arch Concrete	69
Shaori	Off channel	1955	Soil/Rock Embankment	15

Dam	Power Canal	Intake Tunnel	Penstocks	Reservoir
Name				**Volume (MM^3)**
Vartsikhe	yes	No	No	15
Rioni	No	Yes	No	Run of river
Gumati	Yes	Yes	No	39
Tsageri	Yes	Yes	No	Run of river
Lajanuri	No	Yes	No	250
Shaori	No	Yes	Yes	90

There are in addition to the Rioni River Basin Dams, another 35 or so hydroelectric, flood control and irrigation dams on other watersheds in Georgia. These dams and the projected future construction of another 60 or so dams of all sizes and reservoir capacity will benefit from any improvement of the dam safety programs in Georgia

4. Potential Risk Factors / Georgian Dams and Reservoirs

There are a number of risk factors that were considered during the reviews, research and visual observations of the Rioni Basin Dams. These risk factors also apply to all current and planned dams in Georgia, A listing of the factors that were considered include:

4.1 Dam Structural Failure

4.2 Dam Foundation or Abutment Failure
4.3 Seismic Induced Failure or Overtopping
4.4 Reservoir Slope Failure (Landslides / Mudflows)
4.5 Inadequate Spillway - Extreme Flood Inflow – Overtopping
4.6 Climate Change Impacts on Watershed
4.7 Siltation Reduction of Reservoir Capacity
4.8 Landslide Creation of 'Natural Earth Dam', followed by catastrophic failure

5. Government of Georgia Laws, Regulations and Policies with Respect to Dam Safety

An initial task of the review of the safety of dams in the Rioni Basin was the review of the laws, regulations and policies used in Georgia to ensure the safety of dams and their downstream populations. This task was carried out in three increments:

a. Review by the international consultant of available information through the internet or other English documents of the existing laws, regulations and policies used in Georgia, that applied to dam safety
b. Review by a legal consultant to the Project, of the laws, regulations and policies used for dam safety. Her review included interviews with several key individuals in the Ministry of Economics and Ministry of Energy regarding the effectiveness of the regulations and laws.
c. Evaluation of the Georgian sets of legislation and policy against the legislation and policy of several "best practice dam safety" countries (New Zealand, Canada, United States, United Kingdom)

The review and evaluation of the respective sets of Georgian and best practice legislation and policy indicated the following principal shortfalls of the Georgian program:

- The dam safety requirements were usually not specifically called out, wording was vague rather than specific
- Current dam safety practice in Georgia is primarily legislation adapted from the Russian Federation, this legislation is recognized as out of date and requiring updating
- A multitude of Ministries, Departments and Agencies are involved in various facets of dam safety. This can result in confusion in authority and responsibility

The primary lessons learned from this task completion are:

I. If a dam safety program is not called out in specific detail, it will be subject to the implementers interpretation of the provisions and certain aspects will not be given adequate priority
II. Any dam safety program needs to address all aspects of dam safety in the dam – reservoir system, operational training, and downstream impacts of dam failure

6. International Best Practice with Respect to Dam Safety

A requisite task of the dam safety area was to provide a summary of International Best Practice, for setting a baseline against which to compare the current status of dam safety practice in Georgia. International Best Practice countries were considered to be those that

are recognized by dam safety professionals and regulators as having complete and coherent programs that address all aspects and impacts of dam failure and provide a program that minimizes the probability of failure.

In developing the report for this task, the following steps were followed:

a. Based on evaluations by the International Congress on Large Dams (ICOLD), a number of countries recognized as having "best practice" dam safety programs were identified
b. From the list of "best practice" countries, diversity was sought in geographic locations that provided similar conditions to Georgia (geography, geology, rainfall and flooding), for further examination
c. Best practices as they applied to Georgia were reviewed and summarized
d. A report was generated on "best practices" in advanced countries, but with conditions similar to Georgia

The primary lessons learned during completion of this task were:

I. A country normally viewed as "emerging" or "just emerged" can have a best practice dam safety program (Turkey is a prime example)
II. Best practice programs are essentially similar in technical content; while the administrative and implementation aspectsmay differ, depending on local and regional capacity and capability
III. Most best practice countries have an overarching National Dam Safety Program, which may be exceeded by local or regional bodies

7. High Level Assessment of Rioni Basin Dam Safety

The report on the safety of the dams in the Rioni River Basin resulted from observations taken during a field visit to the basin; review of available documentation on the respective dams contained in public literature; observation of the reservoir and watershed topography and geology; and consideration of the type of dam, construction materials, dam designer, and performance of similar dams at other international locations. The results of integration of all the information obtained indicated that the dams were safe at the current time, had no immediate risk areas, but could benefit from a more specific inspection and maintenance regime.

A primary lesson learned that could be applied to all dams in Georgia would be that there needs to be more attention paid to dam safety and maintenance, with better defined authority and responsibility noted for the departments, ministries and personnel involved.

8. Adverse Maintenance Practices at Rioni Basin Dams

The development of the report on adverse maintenance practices at the Rioni Basin Dams wwas based on a brief, but critical observation process during a four day visit to the basin. Recognizing the need to develop a Robust Dam Safety Program, and cognizant that continued adverse maintenance could impact safety of the dams, the observation process included visual inspection of the condition of the dam, reservoir, access, walkways, flood gates,

spillway, canals for water transport, and downstream stilling pools. Safety signage, fencing, and lubrication of tainter gates and other surface operating machinery was also observed. From these observations and previous inspection of dams in countries with "best practice" maintenance standards (Canada, United States, Switzerland, Turkey, United Kingdom), the report on Adverse Maintenance Practices was generated

9. Robust Dam Safety Program for Georgian Dams

The development of a draft / outline for a Robust Dam Safety Program for the Republic of Georgia was done with the following procedural steps:

a. Review of the current dam safety program in Georgia and its shortfalls
b. Review of the best practice dam safety programs of several countries
c. Evaluation of the "realities" of the Georgian economy and technical capacity
d. Adaptation of the principles and sections of several best practice programs to Georgia
e. Production of a final "draft / outline" for a Robust Dam Safety Program

The process included consideration of the following safety, regulatory and procedural aspects:

- Governmental and Water Agency Organizational Responsibilities
- Siting and Permits for Dam Construction / Operation
- Site Investigations
- Environmental Requirements
- Dam Design and Design Review and Approval
- Construction Observation / Construction Records
- Reservoir Capacity / Flood Estimation / Meteorological Networks
- Dam Operations and Maintenance Personnel Qualifications
- Dam and Reservoir Inspections
- Maintenance Programs
- Watershed Evaluation and Updates
- Downstream Channel Modifications
- Risk Assessments

10. Review of Building Codes for Flood Resilience Design – Future Construction

With the incidence and intensity of flooding increasing along the rivers of Georgia, and with the expansion of development along river channels and floodplains, it was recognized that the Republic of Georgia building codes could use specific upgrading. This would focus on provision of building code provisions designed to provide resilience in new construction and construction practices, to minimize the impact of flooding on structures and the equipment and belongings contained within the structures.

The process followed in identifying best practice building code provisions for mitigation of flood impacts on structures was very similar to that used in "best practice" dam safety program task.

- Through internet research, a number of countries or states / provinces recognized as having "best practice" flood resilience programs for structures were identified

- From the list of "best practice" countries, diversity was sought in geographic locations that provided similar conditions to Georgia (type of construction, materials used, construction practices), for further examination

- Best practices as they applied to Georgia were reviewed and summarized

- A report was generated on "best practices" in advanced countries, but with conditions similar to Georgia

The primary lessons learned during this task were:

I. There are not many countries or states / provinces that have generated and adopted building code provisions that specifically address structure resilience against flooding
II. The entities that do adopt such codes are usually jurisdictions that have recently (in the past several decades) experienced significant damage loss in structures. These are areas where climate change effects and overoptimistic development have exposed structures to flooding conditions not previously anticipated
III. Proposed modifications to building codes are not onerously difficult or expensive, but require a mindset change in the developer and builder

11. Sedimentation Issues and Dam Safety / Flood Mitigation

An area that is of concern at the Rioni Basin Dams, and understood to be a chronic condition at other Georgian dams, is the extreme degree of sedimentation in the reservoirs created by the dams. In most cases the degree of siltation is described as being above 75 percent of the reservoir capacity, with some cases reaching 90 percent. This significantly reduces the capability of a reservoir providing any flood management or retention capacity during flood events or seasons.

The siltation experienced is noted as being created by several situations:

- No siltation traps or siltation bypasses were included in the original dam design or subsequent modifications
- Watersheds feeding the reservoirs are being denuded through excessive forestry, legal and illegal, as well as overgrazing within the watersheds
- The geology and topography of the river valleys and slopes tend to lead to accelerated erosion
- Climate change effects, in the form of more intense rainfall events and subsequent flash flooding, increases the sediment load

It is recommended that the issue of sedimentation of reservoirs be a priority item in future dam design, and that consideration be given to sediment removal or flushing in existing reservoirs.

12. Peripheral Factors in Dam Safety Studies and Programs

A final consideration in the overall dam safety of dams in Georgia is that all of the relevant factors that have impact on, or are impacted by, dam and reservoir construction and operations be recognized and addressed in water resources management. These factors include

Flood Plain Mapping
Early Warning Systems
Flood Plain Use Planning
Liability of Water Resource Entities
Provision for Reconstruction Funding
Mandatory Water Releases
Groundwater Recharge
Training Programs
Monitoring and Evaluation
Insurance Requirements