1.5 Environmental impact assessment: geomorphology of the Bartang and Kudara valleys[4]

1.5.1 Previous studies

Local experts have conducted some geomorphologic studies in these valleys, including studies of slope instability related to tectonic activity. However, the impacts of the flood on the geomorphology of downstream valleys have not been assessed thus far. Moreover, relationships between landforms and fauna and flora should be examined in these valleys. The field observations, therefore, were conducted along the Bartang and Kudara Rivers, immediately downstream from the lake.

1.5.2 Environmental impacts

The precise impact assessment will be possible only after the flood calculation is carried out. Nevertheless, the Environmental Impact sub-team found the following important aspects that should be considered regardless of the size of the flood: The landforms in the valleys are classified into:

1) alluvial fans/cones, which are defined as features formed by frequent debris flows from tributary valleys,
2) river terraces,
3) glacial moraines,
4) talus slopes, which are formed from rock-fall debris on steep slopes,
5) flood plains, including the one covering the old lake deposits, and
6) bedrock cliffs/walls.

Among these, landform elements (1) to (4) are especially important in terms of debris (mixture of rock fragments, sand, and mud) to be transported downstream by the outburst flood from the lake. Because the soft, loose deposits comprising such landforms are distributed from the present valley bottom to the higher slopes, these deposits could easily be incorporated into the flooded water in any flood scenario. This could lead to a debris flow, which could increase damage downstream. Also, the toes of the slopes would become much more unstable after erosional removal of the debris from the valley floor. As a result, continuous, slow retreat of the toes of the terraces and the fans/cones, on which most fauna and flora are found, would be expected.

Most fauna and flora, as well as most human settlements, are observed either on the alluvial fans/cones or on the younger river terraces that formed about 3,000-5,000 years ago. Only two settlements are located on the glacial moraines. The alluvial fans/cones and younger terraces have formed near the valley bottom These depositional landforms, serving as homes for most fauna, flora, and human settlements, could easily be washed away by an outburst flood from Lake Sarez. Downstream transport of the deposits would also lead to high suspended sediment loads, which could damage fish populations in the lower reaches, as described elsewhere in the Himalayas for glacial-lake outburst floods

Revegetatation would be possible only after the stabilization of the new landforms Geomorphologic response would start immediately after the flood. However, redevelopment of the landforms, such as alluvial fans/cones and river terraces, may require hundreds to thousands of years

1.6 Flood scenarios[5]

Two arbitrary floods were defined for modeling purposes:

- A flood produced by a rectangular breach with a length and depth of 500 m These breach dimensions produce a flood in agreement with the U.S Army Corps of Engineers (COE) breach flood at the single point - 200 km downstream from the Usoi dam - where comparison is possible.

- A flood produced by a seiche wave overtopping the dam with an average depth of 50 m over an arbitrary dam with a length of 2,000 m.

Two computer software models were used to develop the flood scenarios: (1) the (United States) National Weather Service (NWS) dynamic hydraulic model used by the COE in its flood simulation studies and supplied to this study by Dr. Mark Jourdan of COE, and (2) DAMBRK, a commercial version of the NWS software.

Throughout the 180-km reach of the river system considered in this study, differences between the breach and seiche flood depths are small, relative to the absolute size of each. In either case, the impact of a flood on the villages of the Bartang and Panj valleys, as indicated by the model, would be devastating. Modeled flood depths range from a maximum of nearly 200 m immediately downstream from the Usoi dam to a minimum of approximately 50 m upstream from Shipad for the breach scenario, and approximately 100 m to 30 m for the seiche scenario. Perhaps the most significant finding of this study is that the depth of the flood does not decrease continuously with increasing distance from the Usoi Dam For a given flood volume, depth is controlled by valley topography, largely the width of the valley floor and the slope of the valley walls. In the case of a breach flood, a secondary maximum of approximately 160 m occurs in the vicinity of the village of Suponj, approximately 100 km downstream from the Usoi dam, while in the seiche scenario, the maximum depth for the entire reach of river considered in this study was at this site.

While the results obtained from this preliminary analysis of floods resulting from either an outburst or seiche flood originating from Lake Sarez can be improved considerably by a more detailed definition of the controls on such a flood, it is considered doubtful that the precision of risk assessment for individual villages in the Bartang and Panj River valleys will show a similar improvement. A fundamental problem is the lack of empirical data against which to test the results of model scenarios. Values of peak floods will always be driven primarily by assumptions concerning the initiation of the flood, e g., the height and volume of a seiche wave overtopping the Usoi dam, the rate at which a breach is formed in the dam and the ultimate cross-sectional area of the breach, the extent to which the flood becomes a debris flow, and the dissipation of the flood crest by losses of volume to local embayments. The most precise model will be affected by the topographic accuracy of the Russian Army maps used to derive the digital elevation model used as input. The contour interval of the 1:50,000 maps is given as 20 m. This elevation interval is approximately equivalent to the elevation above the flood plain occupied by a majority of the villages of the valleys. Of all the villages in this valley system, only Rorshorv and Savnop, near the headwaters of the Bartang River are clearly above the highest possible flood crest. No amount of improvement in model results will unequivocally demonstrate that all, or portions, of the remaining villages can be considered safe from a flood. Given this fact, it would be irresponsible to base any village-level planning or training on the results of what will continue to be theoretical considerations. The most prudent assumption is that any major flood from Lake Sarez will destroy virtually all villages in the Bartang and Panj River valleys, and extend downstream for at least 1,000 km Unless additional improvements in flood modeling will prove conclusively that this assumption is incorrect, prudence suggests that the assumption should be the basis for near-term planning for a flood event in the Bartang/Panj valleys

There is one additional factor that was not considered in this analysis, but which is relevant to continued habitation in these valleys All considerations to date have been in terms of a flood with an instantaneous peak flow in the order of one million cubic metres per second. It is probable that a simple doubling of the present mean streamflow volume of 2,000 m^3/sec of the

Bartang River, measured by Soviet geoscientists at Barchidev (Kazakov, 1997), perhaps resulting from a small change in the internal structure of the Usoi dam, would destroy portions of the existing road and low-lying villages and agricultural land for more than 100 km downstream from the dam.

1.7 Monitoring and early warning systems[6]

The installation of a monitoring system (MS)/early warning system (EWS) for Lake Sarez should be given a high priority. In particular, the MS could alleviate much of the uncertainty that now is associated with the hazard from Lake Sarez. The EWS could give the people living in the villages along the Bartang and Panj valleys a reduction in risk. Therefore, a single and clear approach to the solution of the Lake Sarez problem, in terms of an EWS, depends on the quantity and, above all, on the quality of the field-monitoring data (MS).

1.7.1 Past experience

Until 1992, efforts of Russian and Tajik scientists were directed primarily toward analysis of the geotechnical aspects of the Usoi landslide dam. Monitoring, based on visual investigations and some measurements, was not always systematic (due in part to the harsh environmental conditions). The resulting EWS was developed and designed to alert Moscow and Dushanbe to the occurrence of an outburst flood from the lake. Little attention was given to the people living in the river valley downstream from the lake. The warning system, in fact, was able to alert only some of the villages and these only after an elapsed time of about 7 hours from the onset of the flood.

1.7.2 Current situation

Currently the monitoring system is based on the following two sources:

- During summer, and occasionally in winter, a team of Tajik observers is resident at the lake. The responsibilities of the team are to contact Dushanbe, Khorog, and the Usoi Master Station (2 km away from Savnob village), via a radio link, in the event of a flood. They also monitor the unstable slope on the right bank of the lake.
- On the Bartang River and on the Jzgulomdara River (a right tributary to the Bartang), near the village of Nisur, two hydrometric stations would monitor the level of the flood crest. If the flood levels rise above the levels of the hydrometric stations, the system will send, via cable connection, an automatic signal to the Usoi master station. This, in turn, will be connected via satellite to Dushanbe and Khorog.

Regarding these MS and EWS, the following remarks can be made:

- Visual monitoring cannot provide a reliable EWS, and the radio-link connection (Lake-Master Station-Khorog-Dushanbe) cannot alert the villages in time to facilitate evacuation in the event of a flood.
- The automatic system for the detection of the maximum level of the water in the rivers is too far downstream from the lake (four villages are located between the hydrometric stations and the lake).
- The satellite connection system (10 yrs old) is not free from shortcomings, mainly that this connection is not continuous. As a result, the existing system will fail to alert the population in time.

1.7.3 Environmental conditions

All of the activities (installation of instruments and equipment, operational and maintenance phases) have to consider the following difficult environmental conditions: large scale of the phenomena under observation; difficulty of access to the sites, climatic conditions (especially during the winter); absence of an access road from the Bartang valley to the lake; and absence of an electrical power supply (at the Lake Sarez camp, electricity is provided by a diesel generator on a very discontinuous basis).

1.7.4 Parameters to be monitored

Necessary field measurements and the related parameters to be monitored are as follows:

- Surface level of the lake.
- Longitudinal profile of the crest of the Usoi landslide dam.
- Movement of the right-bank landslide.
- Seismic activity of the area, which, in order to define the effective tectonic behaviour (a deep fault exists across the lake 9 km upstream from the dam), should be monitored independently in the right and left banks of the lake. A third seismic point of observation should be established on the dam itself.
- Discharge of water from the dam.

1.7.5 Criteria for design of a new monitoring system

The MS for Lake Sarez must measure the critical properties and processes defining the Usoi landslide and Lake Sarez, in order to provide a continuous record of changes in these properties and processes with time. This aim must be addressed by means of two basic tasks:

- Integration of the current state of knowledge in order to make it suitable for following development of the phenomena. This should be achieved by preparation of a data base, which, supported by adequate methods of analysis and interpretation (numerical models, scenarios, etc.), will allow monitoring of the evolving situation in real time.
- After calibration of the system, selection of significant and representative data to determine triggering values for automatic activation of the EWS.

1.7.6 Criteria for design of a new early warning system

Present data are considered inadequate to design and install a default-free EWS. This is true from both qualitative and quantitative standpoints. All existing data are in analogue format (tables, maps, drawings), and their conversion into digital format should be a requirement (qualitative aspect). Until sufficient data are obtained and interpreted, the triggering thresholds for the EWS will have to be periodically revised and updated (quantitative aspect). Consequently, the initial EWS should be based on a preliminary and simple set of triggering thresholds. Keeping these aspects in mind:

- The EWS must start automatically when pre-established values of significant parameters are detected by the MS.
- An alarm signal must be generated automatically by the data-acquisition and transmission unit located at the lake. This signal must reach all of the villages in the Bartang valley and the Central Unit at Dushanbe simultaneously.
- MS data collected at the unit on the lake should be transmitted daily to the Central Unit in Dushanbe, which should be able to call the remote station at the lake in order to revise the data-acquisition sequences if certain events under observation show significant or dangerous changes.

- This exchange of information between the Central and the Remote Units (one or more) should be regarded as the means of updating the alarm signals of the EWS.
- The warning unit located in each village of the Bartang valley should be connected to the remote and central units by satellite telephones. These units should be built according to a standard design.
- The satellite units should be equipped with oriented antennas, solar panels, and batteries. In case of the occurrence of dangerous events, two different levels of sound should be emitted by sirens (1) "get ready" and (2) "run away" to pre-identified safety zones.
- This standard module could be extended in the future to the Panj River valley

1.8 Accessibility of the Bartang River valley and Usoi Dam/Lake Sarez[7]

1.8.1 Background

The accessibility assessment had two objectives.

- To determine the feasibility of completing the existing track from Barchidev to the Usoi dam, in order to move heavy engineering equipment needed for proposed modifications of the dam.
- To determine the modifications to the existing track in the Bartang valley from Rushan to Barchidev that are necessary to ensure the all-year accessibility necessary for establishment and maintenance of monitoring and early warning systems

An accessibility assessment was considered necessary to evaluate the feasibility of any structural intervention aimed at preventing the risk of a breakout of Lake Sarez. Such measures would require heavy construction equipment to reach the lake and operate there reliably for a substantial period of time An access road for this purpose would require a paved surface, structurally adequate bridges, radius of curvature of not less than 25 m, and slopes not exceeding 9 percent Such an endeavour would require structural works (bridges, culverts, retaining walls, etc.) in order to construct a road in the local mountainous terrain

Accessibility to the Usoi landslide dam is not only a local problem, it involves the general conditions of transport in Tajikistan. The situation of road travel in Tajikistan is normally very poor: the roads are unreliable and most of the vehicles are obsolete. The Province of Gorno-Badakshan, where Lake Sarez is located, can be reached from the capital Dushanbe by means of two alternate routes:

- Via Osh, Kyrgyzstan, to the north and east of the Pamir and then south to Khorog. This is a very high and difficult route, closed for some months in wintertime. However, it currently is the primary access road to Gorno-Badakshan.
- The alternative road, presently under construction, reaches the city of Kuliab and then, following the Panj River upstream, arrives at Khorog. This route, due to its crude design and to the rough construction criteria, is even more unreliable and inaccessible to heavy traffic than the route through Osh.

1.8.2 Accessibility of Lake Sarez

It has always been thought that the easiest way to reach the Usoi dam is from downstream through the Bartang valley or the Kudara valley The accessibility from both of these valleys is very arduous because the geomorphologic conditions are difficult and the existing roads are absolutely inadequate. The required works to make these roads usable would impact substantially on both the environment and the social conditions of the local population. In addition to this, the enormous investment that this option would require strongly discourages consideration of the construction of a road suitable for heavy traffic along these valleys.

An alternative route for movement of heavy construction equipment to the dam crest that should be investigated is along a route, which, departing from the city of Murgab in the direction Khorog-Osh-Karakorum, follows the Murgab River downstream, passes over rolling hills, and reaches the upper end of Lake Sarez. If this route were found to be feasible, construction equipment could then be transported by ferry to the dam crest. The topography of the valley of the Murgab River between Murgab and Lake Sarez has yet to be well defined and is worthy of careful study.

1.8.3 Accessibility of the Bartang Valley

In addition, the accessibility of the Bartang valley from the outside is a problem that needs to be faced. The installation of communication apparatus connected with the early warning system requires the possibility of safe travel along the existing road in every season, both for operations and for maintenance. The road has the characteristics of a single-lane track: steep, bumpy, with tight, dangerous curves. It is positioned across landslides, steep rocky hillsides, alluvial fans, and torrents. Improving the general geometric characteristics of the road to make it safe and suitable for light vehicles would require an investment, which, in the best of cases, can be estimated at between US$ 300,000/km and US$ 600,000/km. These figures conflict with the extreme poverty of the valley population. In addition, an improved road built according to common construction procedures would impact the environment negatively and the economy of the valley that is based on a delicate balance of villages located over highly erodible lands, primordial but sophisticated irrigation systems, raging rivers, and unstable slopes.

1.8.4 Recommendations

The quality, performance, and economics of a road into Lake Sarez can be greatly enhanced if it is engineered using proper planning, design, construction, and maintenance strategies. Every effort should be made to develop structural designs that are consistent with local construction capabilities. Construction standards can be achieved by means of labor-intensive technologies, such as construction of retaining walls consisting of steel-meshed gabions, paved fords, and grouted rubble-paved waterways. Involvement of the local population in construction of the road would probably result in reduction of costs to below the lower bound of estimated construction costs given above (say, below US$ 300,000/km). Such basic refurbishment works would improve the rural economy of the valley.

In addition an accessible road would make contacts between villages easier, which would induce the introduction of communication systems, and improve sanitary assistance. Basic development activities (irrigation, rural electrification, radio communication, etc.) are being promoted by non-governmental organizations (notably Focus Humanitarian Assistance) in the Bartang valley. Improving the road to meet the above-described basic standards would render such development efforts more reliable and sustainable. Presently, this is the only type of road activity that promises to have a meaningful cost-benefit ratio. The same cannot be said for any higher standard road required for the transit of heavy vehicles aimed at structural interventions at the lake.

1.9 Human geography/demography[8]

The purpose of this sub-project was to investigate the population structure, location, and well-being, as well as attitudes, of the people in regard to the Lake Sarez problem and people's ability and/or willingness to respond to introduction of an early warning system.

Children of Shipad, a small village on the Panj River below its confluence with the Bartang River.

1.9.1 Prior state of knowledge

Work supported by FOCUS had already provided a much better data base than previously available, e.g., nearly twice as many villages (kishlaks) are located in the Bartang valley as had been identified previously by Russian/Tajik studies. Valuable data on the nutritional status and overall food self-sufficiency level of the inhabitants of the Province of Gorno-Badhakshan, together with much local data, are now being collected by FOCUS.

1.9.2 Current investigation

Apart from the short time spent in the town of Khorog, the work of the team was restricted to one day along the Panj River valley downstream to Shipad, one day in the Bartang River valley, and general observations during the drive out along the Panj gorge. Only a very small sample (10) of interviews with villagers could be completed. These took the form of standard questions with the aid of interpreters, followed by questions relating to attitudes and possible reactions to a catastrophic outburst flood from Lake Sarez. The situation, based on the interviews and general observations, showed that the Panj valley settlements probably should be distinguished from those in the Bartang valley.

Due to the small number of interviews, this report must depend upon the introduction of a series of working hypotheses that will need to be tested by future research:

- The older inhabitants are less concerned about the threat of Lake Sarez than the younger ones, especially those with small children. Thus the older people are much less likely to respond.

  Those living closer to the lake (especially those in the Bartang River valley) are much more sensitive to the potential dangers than those living farther away.

- Government and NGO discussions of the Lake Sarez problem in recent years have artificially increased fear of the lake hazard.

1.9.3 Present situation

Given the alertness, understanding, and willingness of the villagers to respond, there appear to be excellent prospects for successful introduction of an early warning system. The people's sense of belonging to their "homeland" is very high; in general, they want to remain in their mountain valleys. Despite this, they all agree that

they cannot become self-sufficient because of the severe shortage of cultivatable land, and that they depend upon humanitarian aid, just as outside food was provided during the Soviet period. The overall nutritional level is very low. Similarly, the level of unemployment in Gorno-Badhakshan, as a whole, is very high (90 percent, according to FOCUS), although this statement needs to be balanced against the fact that the rural families all have access to some land, however insufficient. From Rushan downstream in the Panj valley, it is significant that alternative village sites have already been selected in preparation for a move to higher ground once funds are provided (US$ 5,000 per household) and more-reliable simulation models have become available. Another interesting finding is that the entire village of Basid (Bartang) organized itself and effected a total, if temporary, evacuation in 1998 in response to rock falls and mudflows caused by heavy rains.

1.9.4 Recommendations

In general, great care is needed in discussing this complex issue of Lake Sarez to avoid unnecessary increase in the degree of local alarm. Nevertheless, and, in addition, the many villages on the Afghan side of the Panj River need to be taken into consideration.

- ***Introduction of an early warning system is feasible from the point of view of human response and ability of the local people to be trained;***
- ***A much fuller human geographic/demographic investigation is needed. Such an investigation could be undertaken in two stages:***

Stage 1:

1) Detailed interviewing of a statistically significant sample of families, home units, and settlements;

2) Incorporation of data into a GIS system;

3) Types of data from open-ended questionnaires should include:

- ***a) standard anthropological data and techniques***
- ***b) attitudes toward risk***
- ***c) willingness of local people to respond to perceived possible dangers***

Stage 2:

After completion of the simulation models, the various scenarios so developed should be introduced to the original interviewees, and their specific responses to each should be ascertained.

Together, the two stages will lay a valuable basis for training and development of village-level and regional hazard-response organizations.

In conclusion, the degree of commitment to the area and the level of traditional Pamiri culture that is evident emphasize the importance of maintaining cultural diversity as a complement to the obviously important biodiversity of the region. The proposed research will also lead to improvement of the local inhabitants' abilities to respond to the already numerous and frequently occurring mountain hazards.

1.10 Social and economic conditions in the valley of the Bartang River[9]

From 2-12 June 1999, a preliminary assessment of natural, climatic, and socio-economic conditions was conducted in the valley of the Bartang River downstream from the Usoi landslide dam and in the lower part of the Kudara River valley (a right tributary of the Bartang River valley).

In contrast to the valleys of the Vanj, Gunt, and Shakhdara Rivers, which have been fashioned by glaciers and have wide, flat bottoms, the valley of the Bartang River is the result of erosive and tectonic processes. It is characterized by a series of narrow, meandering bottoms and a large number of deep gorges. The modern riverbed is bordered by steep, bare hillsides; the bare and dissected hillsides are composed largely of shifting talus deposits and rock debris. There are many landslides that periodically narrow the valley bottom and occasionally dam the river

The valley of the Bartang River is still poorly developed. At present, there are only 28 settlements, four of which have come into being within the last 4 to 5 years.

The settlements are situated irregularly in the valley. The 11 largest villages are concentrated in the downstream 60 km of the valley (the so-called Siponj inhabited area)

Potatoes and cereals are the most common crops in the valley. Unfortunately, the growing season is short; thus, in some years there is not enough warm weather for cereals to ripen. As a result, the population of the upper and middle parts of the valley often is without bread for 2, or even 3 months before the new harvest. In addition, because there is no reliable transport to the villages of Ajirv and Barchidev, goods from the outside are delivered there only occasionally, which makes them very expensive.

There is no doubt that the present poor economic state of the inhabitants of the Bartang valley and the ensuing lack of well-targeted and proper development are to a certain extent the result of the threat associated with the Usoi landslide dam and Lake Sarez. It is also clear that the present situation will remain unchanged until the problem of the stability of the Usoi dam is solved. However, it is still possible – and what is more, it is necessary – to improve socio-economic conditions in the region, threat or no threat.

Recommendations

In order to improve socio-economic conditions in the region, it will be necessary to:

- ***Exercise control over future settlement in the Bartang valley.***
- ***Encourage further development of the high mountainous plateaus of Basid-Ajirf and Roshorf-Nisur-Ten.***
- ***Reinforce and reconstruct separate parts of the main automobile road, especially the stretches from Emu to Ajirf and from Basid to Yavshorv.***
- ***Build reliable suspension bridges across the dangerous streams along the stretch of automobile road that connects the villages of Basid and Vijravi.***
- ***Organize emergency one-time assistance in the form of food and clothing supplies to help the inhabitants of the villages of Vijrav, Garjiv, Yapshorv, Roshorv, and Barchidev in the Bartang valley and the village of Rukhch in the Kudara valley, taking into account the financial conditions of the families in these villages.***
- ***Organize periodic humanitarian assistance consisting of supplying all villages in the middle and upper parts of the Bartang valley with flour and new varieties of fast-ripening potatoes, rye, and other grain crops.***
- ***Encourage the development of traditional national trades, which may become one of the most important sources of income in many villages.***