



Peril in the Pamirs

Concerns about the risk of a calamitous flood from a mountain lake in Central Asia have scientists racing to improve evacuation plans and find an engineering fix

DUSHANBE—Once a month, Kadam Maskaev flies by helicopter to Lake Sarez, a jewel high in the Pamir Mountains in western Tajikistan. “Just knowing that nature is creating this wondrous lake before our eyes—it’s a kind of magic,” he says. Sarez is special, but there’s nothing mystical about it, and Maskaev is no starry-eyed pilgrim. He’s deputy director of Tajikistan’s emergency situations committee, and Sarez is his chief concern.

The lake was born nearly a century ago, when a mountainside crumbled during a magnitude-7.4 earthquake. The 567-meter-high landslide blocked an alpine river, forming the world’s tallest dam. Since then, the valley behind it has filled with 17 billion cubic meters of snow and glacier melt. Maskaev and others fear that the natural dam could someday give way, unleashing a wall of water from the 56-kilometer-long lake on villages along the Bartang and Panj rivers and the great waterway they feed: the Amu Darya, Central Asia’s largest river.

The possible trigger for such a catastro-

phe would be another major earthquake shaking the region. A large temblor is virtually certain: The Pamirs are a seismic hot spot, and a quake of magnitude 7 or greater rattles the faults around Sarez every century or so. But a severe jolt in itself almost certainly would not directly bring down Usoi Dam, named after a village buried in the landslide on 18 February 1911. The scenario that Maskaev and other scientists worry about is a landslide into the lake, which could trigger a tsunami-like wave that would flow over and perhaps breach the dam. Just such a disaster claimed about 2000 lives in Italy in 1963. Scientists concur that the probability of a reprise at Sarez is low. But the consequence “would be a catastrophe,” says Sharifov Gul, a chief engineer in Tajikistan’s water ministry.

Adding uncertainty over how much force Usoi might withstand, a few years ago water began trickling in greater volumes through the upper part of the dam. That reassures some experts and unsettles others. “In the short term, that may relieve

Alpine jewel. Lake Sarez, formed a century ago by a landslide, now holds 17 cubic kilometers of water.

pressure. But in the mid- to longer term, it could have a destabilizing impact by increasing fissures in the dam,” says Igor Zonn, director general of the Engineering Research Center on Water Management, Land Reclamation, and Ecology “Soyuzvodproject” in Moscow. “In either scenario,” Zonn contends, “the risk remains high for settlements downstream.”

With the sword of Damocles hanging over as many as 5.5 million people in the Amu Darya basin—including settlements in eastern Tajikistan and northern Afghanistan, Turkmenistan, and Uzbekistan—authorities are taking no chances. Tajikistan has installed a sophisticated warning system at Sarez, and officials throughout the region are crafting evacuation plans. The countries have their work cut out for them. “I’m not aware of any regional preparedness plans which would adequately address the potential risks,” says Sergei Vinogradov, an expert on water law at the University of Dundee in the United Kingdom.

Reducing the threat is a daunting challenge. Shoring up Usoi Dam is not feasible, experts concluded at a workshop last September in Nurek, Tajikistan’s gateway to the Pamirs. Rather, they agreed on the urgent need to draw down the lake, which last year reached its highest-ever water level. “The overwhelming international scientific consensus is that to guarantee long-term safety of the dam and lake, the water level should be reduced by 50 to 100 meters,” says Roger Roschnik, a project manager at Stucky, a company in Renens, Switzerland, that developed the warning system. Several ideas have been floated for lowering the waterline. Meanwhile, researchers have proposed taking cores from Usoi. “Nobody knows what the dam looks like inside,” says Maskaev. Scientific drilling, proponents say, would allow more robust estimations of the structure’s stability.

As experts mull next steps, Maskaev’s team is hewing to its prime directive: keeping vigil as the waters of Sarez rise.

One family’s nemesis

Scientists have cast a wary eye on Sarez from the start. In 1913, Russian engineers dispatched to the disaster zone found the Murghab River backing up behind roughly 2 cubic kilometers of rubble, a pile of mostly shale and sandstone nearly three times as tall as the Hoover Dam on the Colorado River. The team enlisted a local man,

Kabul Kurbonbekov, to monitor the newborn lake, which had already submerged the village of Sarez in the summer of 1912. The post of chief observer has passed from one generation to the next and now belongs to Kurbonbekov's great-great-grandson: Maskaev.

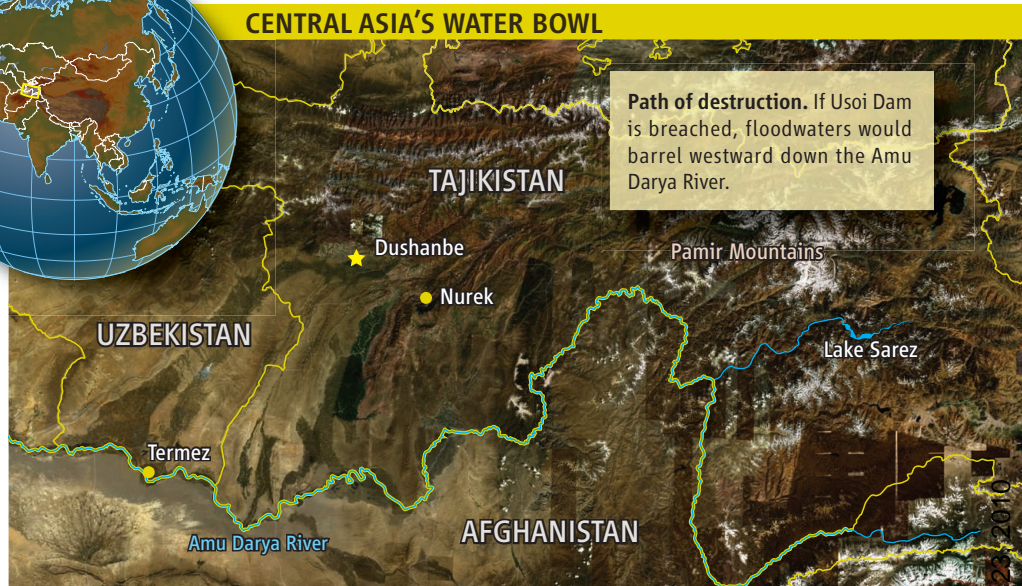
Concerns about Usoi's integrity have waxed and waned. An early fear was that a large earthquake would cause the 5-kilometer-long dam to fail. Most experts now discount that prospect. Usoi is stronger than any humanmade dam, calculations suggest. "I consider the dam safe, taking into account its dimensions and the time it has had to consolidate," says geologist Jean Schneider of the University of Natural Resources and Applied Life Sciences in Vienna.

The trouble spot, researchers say, is not Usoi but an unstable slope along Lake Sarez about 4 kilometers east of the dam. Imperceptible to the naked eye, a section of the lake's right bank is slipping about 10 centimeters a year toward the lake. There is a "relatively high possibility" that a strong earthquake would trigger a sudden collapse as the bank's saturated underwater portion liquefies in the shear zone, sending tens to hundreds of millions of cubic meters of debris plunging into Lake Sarez, says Kyoji Sassa, a disaster prevention specialist at Kyoto University in Japan and executive director of the International Consortium on Landslides.

The displacement would create a seiche wave, a kind of tsunami observed in lakes and other enclosed basins. A seiche wave at Sarez could wash over Usoi Dam, whose crest at its lowest point now sits only 38 meters above the lake's surface, says Sassa.

Just such a disaster occurred in Italy on the evening of 9 October 1963, when heavy rain triggered a massive landslide into a reservoir behind Vajont Dam north of Venice. The debris spawned a towering seiche that sent some 50 million cubic meters of water spilling over the 262-meter-high dam. The torrent, abetted by the tornado-force blast of air it displaced, obliterated five villages in its path.

The situation in Tajikistan is not nearly as precarious as it was in Italy. The reservoir's banks at Vajont were crumbling before the tragedy, suggesting that the terrain was unstable. Even if a major earthquake were to collapse Sarez's right bank, some researchers say the odds are against a disastrous seiche. "The probability is 1 in a million," asserts Jörg Hanisch of JorgeConsult in Hannover, Germany, who served on a



Keeping vigil. Tajik scientists monitor Sarez around the clock from the Dam House (left). A research team inspects the lake's underwater terrain.



panel that oversaw installation of the Stucky monitoring system by FELA Management in Diessenhofen, Switzerland. "The risk of even a partial outbreak is exaggerated," adds Schneider. "The dam will only possibly be overtopped in the far future." But Sassa and others argue that the threat is significant. The nightmare scenario is that the force of a tremendous seiche (the one at Vajont was approximately 250 meters tall) could breach and sweep away a large chunk of Usoi Dam—releasing, in minutes, much of Lake Sarez.

"Ten years ago, I was not as concerned about the risk of Usoi failing," says Maskaev. Since then, two things have changed. The 9/11 attacks revealed a vulnerability of any dam: Terrorists could blast a hole in Usoi with a hefty, well-placed bomb or by ramming a plane into it. Then in 2004, Maskaev's team noticed a marked increase in water seeping through the dam some 100 meters below the lake's surface.

The water is clear, which means it's not washing out debris and is unlikely to be weakening Usoi. "Internal erosion can be excluded," says Hanisch, who notes that such seepage is necessary for long-term stability of natural rockslide dams. Maskaev has a different take: "The filtration regime of the dam is changing, and that makes me nervous."

Planning for the worst

Whatever goes down at Lake Sarez, Maskaev's team will be the first to know. A five-person detachment keeps an eye on the lake around the clock from a station anchored with steel cables to a stable perch 150 meters above Usoi—out of the path of any seiche. "It's a perfectly safe place," Maskaev says.

Instrumentation has improved considerably since Great-Great-Grandpa Kurbonbekov's day. Stucky's \$2 million monitoring system features strong-motion accelerographs for detecting tremors, GPS to track

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Danger zone. Scientists fear that if an earthquake triggers a massive landslide into Sarez, the resulting tsunami could overtop and possibly breach Usoi Dam.

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movements of the right bank and the dam, and radar and pressure-cell sensors to monitor water levels in Sarez and in the Bartang River, downstream of Usoi. Although data are beamed by satellite to Dushanbe, a decision to evacuate would not wait for word from Tajikistan's capital. The warning system would trip if its detectors registered, for instance, a magnitude-5 or greater earthquake, a 25-centimeter rise in Sarez's level over 24 hours, or a 1-meter surge in the Bartang River below the dam.

Sirens would sound in 17 villages, and the residents of Barchidiv, the village nearest the dam, would have 17 minutes—"enough time," Maskaev assures—to reach provisioned shelters on higher ground. As they grab their children and food, villagers would listen for a radio advisory confirming a real emergency.

The Bartang valley population "is very well prepared and has gone through a number of evacuation drills," says Goulsara Pulatova, senior adviser to the U.N. International Strategy for Disaster Reduction's office in Dushanbe. Further downstream, however, preparedness falls off sharply. In Soviet days, evacuation plans were drawn up for settlements along the Amu Darya, all the way to the Aral Sea, says Maskaev. Renewed concerns over Sarez have prompted officials to dust off and revise these plans. Last summer, for instance, Termez, a major city in Uzbekistan on the Afghan border, held an evacuation drill. The conference in Nurek drew experts from Turkmenistan, which for years hadn't dispatched delegations to Sarez workshops, and from Afghanistan, which is seeking to set up a warning system on its side of the border.

Evacuation plans alone are insufficient

for addressing the threat, cautions Michael Glantz of the University of Colorado, Boulder. Another need, he says, is contingency plans for rehabilitation and reconstruction in the event of a disaster. In addition, he says, Tajikistan may want to consider moving people permanently out of harm's way.

Waiting game

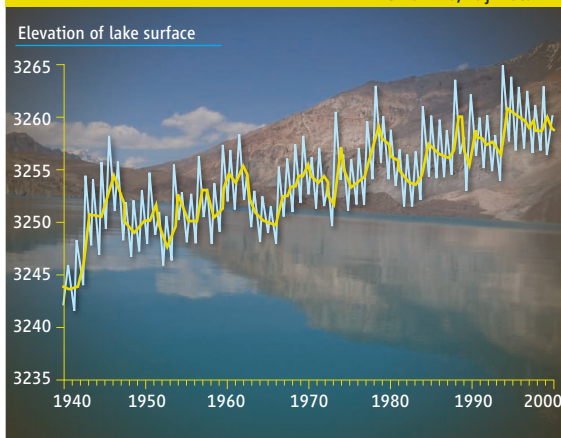
Experts have for now ruled out buttressing Usoi against a seiche. A more promising idea, they say, is to partly drain Sarez. If the lake level were lowered several dozen meters, says Hanisch, "even the highest imaginable wave could not overtop the dam."

Finding an engineering solution is easier said than done. The "best option," according to Sassa, is to tunnel through bedrock on Sarez's left flank and drain lake water via a conduit. Bearing in mind the immense pressure of 6 trillion tons of water, "it would require some very careful engineering to ensure a controlled release of water and that things didn't get out of control," says Philip Micklin, a geographer at Western Michigan University in Kalamazoo.

The project's estimated \$500 million cost could be defrayed by building a 250-megawatt hydropower plant where water exits the tunnel. "Such a project would contribute to the social and economical development of the region," says Roschnik, who notes that Stucky is conducting a feasibility study with the World Bank's International Finance Corp.

Tapping Sarez could also defuse mounting tensions over regional water supplies in Central Asia (see sidebar, p. 1616). At the World Water Forum in Istanbul last March, Tajikistan President Emomali Rahmon proposed establishing an international consortium to construct a pipeline from Sarez to

WATER LEVEL IN LAKE SAREZ The Pamirs, Tajikistan



Tale of the tape. Sarez is rising gradually, but in the absence of a major temblor, it would be decades before water spills over the dam.

neighboring Uzbekistan. "Sarez has enough volume to provide drinking water for all of Central Asia," says Gul. A consortium has yet to materialize. "So far it's all just talk," Gul says. "The main problem is money."

An alternative strategy would be to construct a spillway, similar to one that army engineers in Pakistan built to drain a lake formed by the Hattian Bala landslide, a 68-million-cubic-meter rockfall set off by the 2005 earthquake in Kashmir. Such a trench, however, would dramatically increase the hazard of a seiche wave breaking the dam, says Hanisch. Most experts favor the tunnel, which is also Tajikistan's preferred solution, Maskaev says.

As engineers mull ideas for defanging Sarez, scientists are eager to peer inside the megadam. At the September conference, Maskaev proposed taking cores from at least three sites at Usoi. In the late 1980s, engineers were preparing to drill. But the Soviet collapse in 1991 scotched that plan, and newly independent Tajikistan lacked the cash and expertise to carry it out. Both deficits remain. "We're waiting for offers of help," Maskaev says. Some researchers are not sold on the idea. "Drilling would not offer a comprehensive integrated picture of the dam's structure," says Zonn.

One initiative gaining steam is a research campaign. Sassa and colleagues from five countries are planning a detailed look at Usoi next summer, with results ready for a conference in Tajikistan in 2011 to mark the Sarez centennial. By then, says Roschnik, "we should have started working on a long-term solution." If they succeed, Maskaev would be more than happy to wind up the family business—and continue to admire Sarez, for its beauty alone.

—RICHARD STONE