Outburst of Kyagar Glacial Lake and outlook for the near future

Factsheet: 1412092.19, Yarkant River
July 31st, 2015

1. Introduction
The Kyagar Glacial Lake drained completely at the end of July 2015. Based on camera images by the Kyagar terrestrial observation station and satellite remote sensing, the timing and volume of the outburst could be reliably predicted. The implemented fully automatic GLOF early warning system successfully warned the Chinese decision-makers.

This document provides an update of the previous factsheets (no. 1412092.14, April 23rd, 2015; no. 1412092.15, June 16th 2015; no. 1412092.17, July 1st, 2015; no.1412092.18, July 24th 2015) and gives an outlook for the future glacial lake formation.

2. Glacial Lake Outburst 2015
2.1 Drainage mechanism and discharge
With a volume of more than 40 million m³ and a maximum water depth at the ice-front of at least 70 m, the level of the flotation equilibrium of the glacier tongue has been reached on July 23rd 2015 (see Factsheet no. 1412092.18 and table 1). Considering the hydrographs of the Cha Hekou and the Kuluklangan station, most of the lake drained spontaneously within only half a day (Fig. 1). The fast rising limb of the hydrograph represents the rapid increase in run-off with a peak-flow of approx. 2’260 m³/s on July 28th 2015 at 11:18 o’clock local time at Kuluklangan (according to Chinese experts). The shape of the hydrograph is typical for spontaneous subglacial lake outbursts.

The GLOF peak discharge at Cha Hekou was registered on July 27th at 23:30 o’clock. With a time-lag of approx. 14.5 hours, the peak of the flood wave reached Kuluklangan at 14:00 o’clock on July 28th (see Fig. 1). Hence the average propagation velocity of the flood wave was approx. 4 m/s.
At both terrestrial observation stations, the water level of Keleqin and Yarkant Rivers respectively, raised considerably within a short time (+ 0.9 m / 6 hours at Cha Hekou and + 1.4 m / 6 hours at Kuluklangan). The water level increase is less pronounced at Cha Hekou due to the wide river bed.
Fig. 1: Hydrographs of the terrestrial observation stations at Cha Hekou (top) and Kuluklangan (below) showing a continuous run-off increase over several days with daily fluctuations. The GLOF with a pronounced peak discharge has been registered at both stations (orange arrow).

Considering the scale historic Kyagar GLOFs, the estimated lake outburst volume of 45 – 50 million m³ in 2015 can be classified as a medium event (similar like in 2005, 1998 or 1986, see report no 1412092.16).

Table 1: Semi-quantitative glacial lake volume estimations based on satellite images (i.e. lake shore-lines) and the modified DEM of 2011.

<table>
<thead>
<tr>
<th>Date</th>
<th>lake level [m a.s.l.]</th>
<th>lake volume [million m³]</th>
<th>lake surface [km²]</th>
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3. **Early Warning System**

3.1 **Forecast of GLOF hazard level**

An accurate forecast of an outburst event is extremely complex due to the continuous processes at the ice-dam (i.e. surge-activity, ablation, and availability of subglacial discharge channels) and the highly variable water-influx into the lake basin. Sophisticated monitoring technologies, such as terrestrial observation stations and satellite remote sensing are the base of a robust GLOF hazard assessment.

The images by the terrestrial station at Kyagar Glacier were the key of the accurate forecasting. However on June 30th 2015, the station was submerged due to the rapid impoundment of the glacial lake, triggered by the surge-activity of the glacier tongue. In July, the lake formation has been observed by satellite remote sensing (sentinel-1).

**Remarks:** The forecast based on the flotation equilibrium proved to be relatively precise (Fig. 2). However, the identification of the outburst event could be substantially improved and verified by periodic camera images of the ice-dam and the lake basin. Consequently, the lead time for the implementation of emergency measures in the floodplain could be optimized.

![Fig. 2: Based on terrestrial and satellite based monitoring techniques an accurate forecast of the GLOF was possible.](image-url)
3.2 Automated alarming
The implemented automatic EWS registered the flood wave and triggered an alarm to the mobile phones of Chinese decision-makers. On July 28th 2015, 12:38 o’clock Chinese local time, an automated GLOF warning has been issued. The alarm has been triggered by the Kulukliangan station (see Fig 1). The lead time for emergency actions in the floodplain was approx. 7.5 hours.

At Cha Hekou the threshold to raise an alarm was not reached. Therefore we recommend a re-calibration of the threshold values based on the recent GLOF event.

Remarks: Due to the complex flow patterns of Keleqin River, the cross-section of the river bed is variable. Hence, the trigger-level for raising the alarm should be verified periodically (e.g. every spring), especially at Cha Hekou. Furthermore the GLOF in 2015 proved that redundant stations are needed to guarantee a reliable warning in a complex environment.

4.1 Filling and drainage of Kyagar lake
The lake completely drained on July 27th 2015 (see Annex 1). The subglacial drainage channels will probably remain open during summer/autumn 2015. No new lake is expected to form this year.

Due to the ice-pressure the subglacial channels are likely to close during winter 2015/2016. Furthermore, the surge-activity at the glacier tongue might eventually continue till 2016 and further thicken the ice-dam.

In spring 2016 a new glacial lake is expected to form. A spontaneous outburst in summer/autumn 2016 is likely.

4.2 GLOF hazard potential
The GLOF hazard potential is expected to be high in summer/autumn 2016. The outburst volumes can be similar or even larger than in 2015.

Remarks: In 2016, the continuous monitoring of the lake formation and glacier dynamics needs to be established by satellite remote sensing. The level of the flotation equilibrium needs to be verified by photogrammetric methods.
Due to climatic conditions (i.e. snow-cover, river run-off) a new terrestrial station at Kyagar Glacier can be installed in September 2016 at the earliest.
5. **Recommendations**

The on-going surge-activity of the glacier tongue and the likely impoundment of a new glacial lake in 2016 require preventive measures.

We suggest the following next steps (consistent with previous factsheets):

1. The functionality of the EWS should be periodically tested by Chinese authorities and the roles and responsibilities in case of an emergency should be clearly defined. The thresholds for raising the alarm (i.e. critical water level to trigger the alarm at Cha Hekou and Kuluklangan) should be verified and confirmed by Chinese experts.

2. Continuous observation of the dynamics of Kyagar Glacier and the lake basin by satellite remote sensing (e.g. sentinel-1).

3. Risk management procedures (i.e. emergency plan) in the floodplain along Keleqin and Yarkant River should be adjusted according to the GLOF hazard potential.

4. Planning of a maintenance field mission for 2016: A new fully automatic station can be installed at Kyagar Glacier. Furthermore, the stations at Cha Hekou and Kuluklangan should be supplied with new batteries. Budget and responsibilities for new Sino-Swiss field missions need to be clarified by SDC and MWR.

5. The exchange of know-how and experiences between Sino-Swiss experts should be continued. Newly gained knowledge of the recent GLOF and its impact should be shared among Chinese and Swiss experts. Based on the shared know-how, the early warning system can be further improved and the risk management in the floodplain (e.g. flood hazard indication map) can be verified and enhanced.

**Monitoring the dynamics of Kyagar Glacier and the continuous analysis of the GLOF hazard potential is the fundamental precondition to ensure an efficient early warning and flood risk management.**

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