Hydrol. Earth Syst. Sci. Discuss., 11, C1049–C1053, 2014
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Hydrology and Earth System Sciences
Discussions

Interactive comment on "New method for assessing the potential hazardousness of glacial lakes in the Cordillera Blanca, Peru" *by* A. Emmer and V. Vilímek

Anonymous Referee #3

Received and published: 22 April 2014

The subject of this paper is extremely topical and of significant interest especially with regard to the impact of climate change on high mountain environments such as the Cordillera Blanca, Peru. However, the paper submitted by Mssrs Emmer and Vilimek is serious flawed and requires substantial reworking before it can be considered for publication.

Firstly, the concept of 'potential hazardousness' is extremely unhelpful and effectively meaningless. Either a glacial lake system poses a hazard, the scale of which can be ranked from minimal to severe or extreme, or it does not. There are long-standing and well-accepted definitions of 'hazard', 'risk' and 'vulnerability' that exist to aid under-

standing and for clarity; 'potential hazardousness' seems to blur many issues and just increases the vagueness associated with the associated arguments, as will be seen.

On page 3, the authors describe a number of different ways that flood water is released, but it fails to recognise that in some cases, there is a combination and multiple methods may exist at a single lake over a period of time – Laguna 513 at Hualcán in the Cordillera is but one example. Separating the processes as a means of differentiating a series of scenarios is arbitrary and artificial with little physical basis.

On page 3, the authors claim that Reynolds (2003) presented a method for assessing hazards "directly on the region of the Cordillera Blanca". This is incorrect. The methods apply to any glacierised environment.

On page 4, in section 2, the authors raise what they call the "principle of regional focus" – making a claim that the glaciers in the Cordillera Blanca are a special regional case and that the causes and mechanisms of GLOFs in this region are somehow different to those elsewhere in the world. From having studied these processes from southern Patagonia to the high Himalayas, and especially the Cordillera Blanca, the glaciers behave no differently and the laws of physics apply equally everywhere. To make such a claim of regional difference is just not supportable.

On page 4, section 2 – this section introduces a number of so called principles and the discussion is written in such a way that it is thoroughly confusing and confused. It appears to be trying to separate out issues that are in fact inter-related. This whole section and the central themes underpinning this section are confused.

In Section 2.1, p5, the authors make one of their five key scenarios the triggering of GLOFs by major earthquakes in the Cordillera Blanca. By checking catalogues of earthquakes with magnitudes $\geq$6 in the region from 1940 to 2012 (35 separate events), only two (which were related; on 31st May 1970) resulted in any outbursts from glacial lakes, as described by Lliboutry et al. (1977). Only Yanacocha-chica in Quebrada Putaca and a lake in Quebrada Huichajanca emptied, whereas the lake level in Safuna

Alta dropped dramatically. Given the large number of glacial lakes in the region and the significant number of strong earthquakes, that so few floods have been triggered by earthquakes is hardly a justification for making this one of the five special scenarios.

Also on p 5, line 5, the authors state that "we feel it is not meaningful to describe the overall potential hazardousness . . . with the use of a single number". Why do they feel it is meaningful to create five different scenarios and then provide separate scoring for each? This is exemplified by Table 5 which is confusing and generally unuable.

On page 6, lines 10-13, the authors attempt to identify "the most likely scenario of the GLO for a particular lake". These scenarios are based on massive and unsupported assumptions.

On page 7, Section 2.3, the authors describe their five scenarios according to the trigger mechanisms, yet these scenarios do not take into account the likely behaviour of the lake water, and thus the form of breach processes and subsequent variations on flood hydrographs, all of which have enormous influence on the GLOF initiation process and subsequent flood dynamics.

In short, on pages 7 to 16, the various mathematical expressions have little relationship to actual physical processes or key components of the glacial lake system and appear to be based on guesses and assumptions, where the uncertainties are dressed up in mathematical equations. As an example, reference is made to Laguna 513 but the history of events that have occurred at this location is complex and the processes involved various, a fact missed by the authors of this paper. This in itself undermines their principal arguments. There are so many variations in some of the input parameters in the various equations that the uncertainties involved render the arithmetic output meaningless. For example, let us take the parameter SMax in equation (3). This is defined by the authors as "the maximal slope of the moraine surrounding the lake". Yet there are countless examples of excessively steep slopes on moraines that have no role in the geomechanical failure of the lake's dam. Just finding the steepest bit somewhere along

the moraine to plug into an equation is divorcing physical processes from the methods of assessment. This is a fundamental flaw.

On page 10, the authors discuss at length the method of calculating lake volume from lake area based on empirical data. This in itself might be useful from a water resource perspective but it has little value in relation to GLOF volumes. The shape of a lake's containing basin and where the deepest parts are in relation to its dam are critical in relation to the behaviour of the lake water to an external trigger, of whatever type. Yet the volume of water that becomes involved in an outburst flood is typically less than the total lake volume, which often does not drain completely. So making a factor dependent upon lake volume is in itself misleading.

Scenario 2 conflates the effects of two lakes. The hazard of the upstream lake can be considered on its own merits rather than conflating the two together which only compounds the uncertainties in the assessment of each, and results in another meaningless output.

The authors also seem to introduce arbitrary factors when it suits, such as on page 12, where they chose a factor of 0.05 on the vague premise of having analysed previous events (how?) and expert assessment (on what basis?). Similarly, the authors introduce a power of 2 in equation 11 to emphasis what they say is a non-linear trend and also in equation 15 to demonstrate that piping does not occur.

The way the various parameters and equations have been constructed suggests a lack of understanding of the physical processes at play in this mountain environment and of the relationship between triggering processes and how the glacial lake systems can respond. The parameterisation in the form of relationships that are not based on key processes results in a complex and confusing set of processes that result in a variety of numbers, quoted to three significant figures, for a number of arbitrary scenarios that are over simplistic or unreasonable. It is clear that there is no meaningful physical basis for the resulting arithmetic outputs and as such the methods described are completely

unhelpful and as such serve no useful purpose.

The authors also seem unaware of some of the literature concerning the Cordillera Blanca glaciers.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 2391, 2014.