U.S. Department of the Interior
U.S. Geological Survey

Scientific Investigations Map 3322

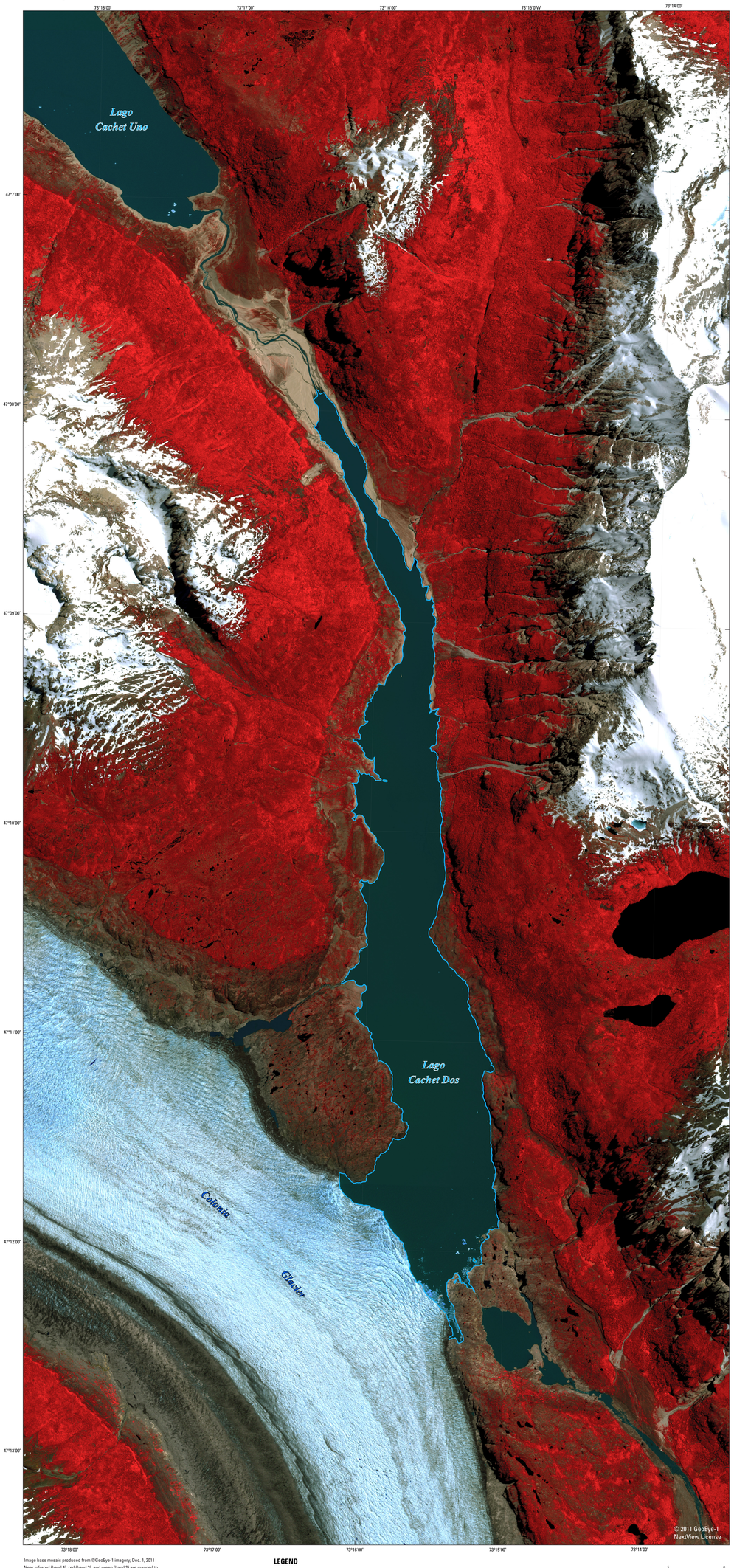


Image base mosaic produced from ©GeoEye-1 imagery, Dec. 1, 2011
Near infrared (band 4), red (band 3), and green (band 2) are mapped to RGB (red, green, blue) color space to create a false-color image composite, with healthy vegetation appearing red
Universal Transverse Mercator (UTM) projection, zone 18S
World Geodetic System of 1984 (WGS84)
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Image base mosaic produced from DigitalGlobe© WorldView-2 imagery,Sept. 27, 2013
Near infrared (band 8), red (band 5), and green (band 3) are mapped to RGB (red, green, blue) color space to create a false-color image composite, with healthy vegetation appearing red
Universal Transverse Mercator (UTM) projection, zone 18S
World Geodetic System of 1984 (WGS84)
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**LEGEND**

Lake boundaries

SCALE 1:15 000

1 KILOMETER

1 MILE

IMAGE LOCATION

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APPROXIMATE MEAN DECLINATION, 2014

# Using Satellite Images to Monitor Glacial Lake Outburst Floods—Lago Cachet Dos Drainage, Chile

By

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## SUMMARY

The U.S. Geological Survey (USGS) is monitoring and analyzing glacial-lake outburst floods (GLOFs) in the Colonia valley in the Patagonia region of southern Chile. A GLOF is a type of flood that occurs when water impounded by a glacier or a glacial moraine is released catastrophically (ICIMOD, 2011). In the Colonia valley, GLOFs originating from Lago Cachet Dos, which is dammed by the Colonia Glacier, have recurred periodically since 2008. The water discharged during these GLOFs flows under or through the Colonia Glacier into Lago Colonia and then the Rio Colonia, and finally into the Rio Baker—Chile's largest river in terms of volume of water (Escobar and others, 1992) (fig.1).

This report presents a GeoEye-1 image collected December 1, 2011 (left) and a WorldView-2 image collected September 27, 2013 (right). The 2011 image shows Lago Cachet Dos when the water level was near its maximum extent. The 2013 image shows the empty drained lake four days after a GLOF event. Both images were geometrically corrected using a USGS digital elevation model derived from stereo WorldView-1 imagery collected on October 5, 2013. This enabled us to carry out multi-temporal change detection as well as improve mapping accuracy. The images were used to delineate the differences in water surface area prior to, and immediately following, a GLOF event. Water-cover extents were extracted using eCognition image segmentation software (Trimble Navigation, Ltd., 2014). The resulting polygons were analyzed using Esri geographic information systems (GIS) software (Esri, 2014).

The image pair used here highlights the dramatic changes that typically occur during GLOFs from Lago Cachet Dos. The lake area decreased from 4.84 square kilometers ($km^2$) in 2011 (pre-GLOF) to only 0.30 $km^2$ in September 2013 (post-GLOF). The water surface lowered approximately 90 meters (m) between the pre- and post-GLOF satellite images, yielding a change in volume of approximately 217,000,000 $m^3$; this value is similar to previous estimates (about 200 million $m^3$) of the volume of flood water that flowed down the Río Colonia during some previous GLOFs (Dussaillant and others, 2010).

During 2008–2013, 14 GLOFs were released from Lago Cachet Dos and created environmental and safety concerns for downstream residents and to infrastructure (Dussaillant and others, 2010; Dirección General de Aguas, 2014, unpub. data for Lago Cachet Dos, downloaded Jan. 2, 2014, from http://dgasatel.mop.cl/). The rapid emptying of the lake (about 24 hours) during these GLOFs caused extensive erosion of lakebed deposits and an upstream expansion of Lago Cachet Dos by about 3 kilometers (km) in length. The upstream edge of the lake is now about 1.8 km from Lago Cachet Uno. If GLOFs and the consequent headward erosion continue, the moraine that creates Lago Cachet Uno could be destabilized and breached and the two lakes could merge. If the two lakes become connected, the volume of future GLOFs likely would be greater and thus cause longer and (or) more extensive flooding downstream. Quantification of the rate of sediment loss from Lago Cachet Dos, combined with ongoing mapping and elevation surveys of glacial landforms and deposits upstream, may help determine the likelihood of the creation of one large lake. Additional GLOFs from Lago Cachet Dos are expected in the future, and continued environmental monitoring could provide an early warning system as well as scientific information that could increase our understanding of GLOFs and their consequences. The USGS is collecting remotely sensed data, including multi-polarized synthetic-aperture-radar and electro-optical imagery, to help conduct and support these and other studies in the Colonia valley. GLOFs occur in glaciated areas around the world and remote sensing technologies can allow researchers to better understand—and potentially predict—future GLOF events (Post and Mayo, 1971).

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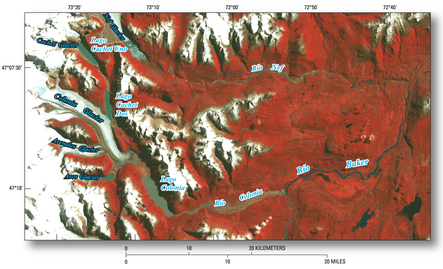


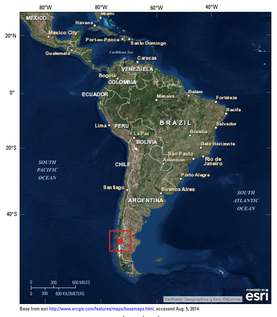

**Figure 1.** GLOFs from Lago Cachet Dos discharge to the Río Colonia and then the Rio Baker—Chile's largest river in terms of volume of water. This Landsat 7 image from March 11, 2001 shows the smaller size of Lago Cachet Dos prior to the start of the GLOFs.

**Photo 1.** Oblique aerial photograph looking southeast into the Colonia Valley and Lago Cachet Dos drainage. Lago Cachet Uno is the large lake in the center of the photograph, Lago Cachet Dos is in the top left-hand corner, and the Colonia Glacier flows from right to left across the top of the photograph. Photo courtesy of Jorge Guy Wenborne Huyghe, taken on April, 2008. Used with permission.

**Photo 2.** Lago Cachet Dos post-GLOF event showing a low water level. Photo courtesy of Jorge I. O'Kuinghttons Villena (Dirección General de Aguas, Coyhaique, Chile), taken on January 27, 2012. Used with permission.

CONVERSION FACTORS

| Multiply | By | To obtain |
|---|---|---|
| meters (m) | 3.281 | feet (ft) |
| square meters ($m^2$) | 10.76 | square foot ($ft^2$) |
| kilometers (km) | 0.6214 | mile (mi) |
| square kilometer ($km^2$) | 0.3861 | square mile ($mi^2$) |
| cubic kilometer ($km^3$) | 0.2399 | cubic mile ($mi^3$) |




Base from esri http://www.arcgis.com/features/maps/basemaps.html, accessed Aug. 5, 2014.

**Image location**

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