



Geospatial Technologies Help Mitigate the Risks of Climate Change

By Jim Baumann, Esri Writer

The National Geospatial-Intelligence Agency (NGA), among its many responsibilities, is studying the effects of various climate change phenomena throughout the world.

Originally founded in 1996 as the National Imagery and Mapping Agency, the NGA has provided geospatial intelligence (GEOINT) mapping services to the nation's intelligence agencies for more than 20 years. The NGA uses information on the effects of climate change for civilian outreach efforts, such as rescue operations and rebuilding in the wake of natural disasters and humanitarian crises, and for strengthening national security efforts.

One result of climate change is the ongoing melting of glaciers throughout the world. As a glacier recedes, a glacial lake system is formed. Water ponds either

behind the glacier forming an ice dam or in front of the glacier forming a moraine built from rock debris that was transported by the glacier. Moraines, like ice dams, are mostly made of ice and therefore susceptible to melting and failure. When glacier-created dams fail, large volumes of lake water empty in only a few hours and surge downstream in an event known as a glacial lake outburst flood (GLOF).

NGA is currently studying the GLOF phenomena in Patagonia, which encompasses the southernmost tip of South America and parts of Argentina and Chile. The area is divided by the Andes Mountains.

The Argentinean side features grasslands and deserts, while the Chilean portion is known for its glaciers, fjords, and ice fields. The southern and northern Patagonian ice fields comprise the largest mass of ice in the southern hemisphere outside of Antarctica.

Global warming has caused the Colonia Glacier in Patagonia to retreat about 2.5 kilometers during the past 30 years, while the nearby Nef Glacier has retreated 1.8 kilo-meters. Both glaciers have contributed to the water contained in the vast glacial systems that feed Chile's largest river by volume, the Rio Baker. Located in the Patagonian ice fields, the river in turn

← The bottom of Cachet Dos Lake five days after a glacial lake outburst flood (GLOF) drained its basin.

flows into Cachet Dos Lake, which has had 20 catastrophic GLOF events during the past 10 years due to the recurring melting of the ice dam that contains it.

The refilling and discharge of the lake is ongoing. As water pours into the lake from the glacial systems, a tunnel begins to form at the base of the ice dam that ultimately undermines it and releases all the water contained within it. The tunnel subsequently collapses and freezes over again, the lake refills, and after a time another tunnel forms in the ice dam and the water is once again expelled.

The calculated discharges from the lake range from 2,000 to more than 15,000 million cubic meters of water per event. These discharges flood the Rio Baker/Rio Colonia basin, often killing the inhabitants living downstream as well as destroying

infrastructure in its path.

"A number of universities, as well as the USGS [US Geological Survey] and the NGA, have studied the Colonia glacier and its recurring GLOF events for several years," said Manuel Castro, human geography analyst at the NGA. "Unfortunately, the phenomenon occurring at the Colonia Glacier and Cachet Dos Lake is rapidly becoming prevalent in many other parts of the world, which creates a need to better understand it.

The Colonia Glacier can be used as a proxy to study other glaciated zones that are inaccessible and the effects of climate change on the cryosphere. *[The cryosphere is that part of the earth that is so cold water is frozen solid.]*

What makes this area both striking and attractive for research is its magnitude. It is within the Northern Patagonian Ice Field,

One result of climate change is the ongoing melting of glaciers throughout the world.

which measures 4,200 square kilometers (km²), the second-largest continuous mass of ice outside the polar regions. Cachet Dos Lake is contained by a 437 km² glacier that holds back 200 million cubic meters of water that is released in a few hours when a GLOF occurs.

↓ Spatiotemporal dynamics of climate change are visible in areas like Patagonia. The Normalized Difference Water Index (NDWI) can efficiently detect surface water because water surfaces have a low reflectance in the near-infrared (NIR) spectral band. In contrast, vegetation is characterized by a high reflectance.

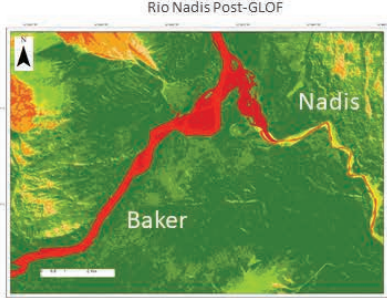
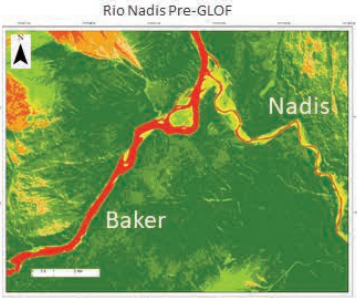
UNCLASSIFIED

The Proposal

Remote Sensing
Normalized Difference Water Index

$$NDWI_{10m} = \frac{p_3 - p_8}{p_3 + p_8}$$

- 1 - -0.52651407
- 0.52651407 - -0.41467652
- 0.41467652 - -0.296260291
- 0.296260291 - -0.158108023
- 0.158108023 - -0.013377076
- 0.013377076 - 0.124775192
- 0.124775192 - 0.276084818
- 0.276084818 - 0.420815765
- 0.420815765 - 0.585282751
- 0.585282751 - 1



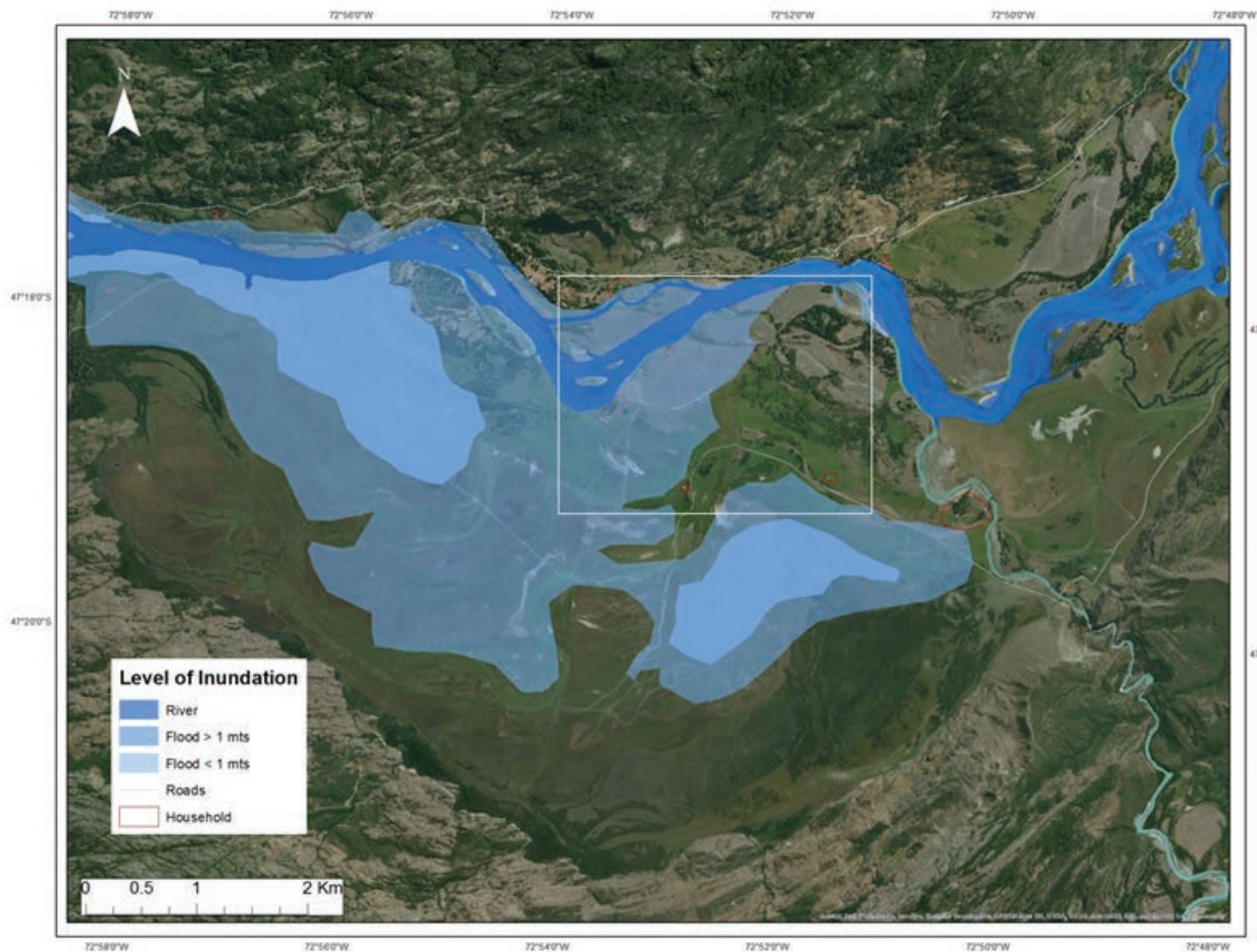
Band Number	Spatial Resolution (m)	Central Wavelength (nm)	Bandwidth (nm)
01	10	440	20
02	10	480	20
03	10	560	20
04	10	650	20
05	10	680	20
06	10	740	20
07	10	860	20
08	10	940	20
09	10	1240	20
10	10	1640	20
11	10	2130	20



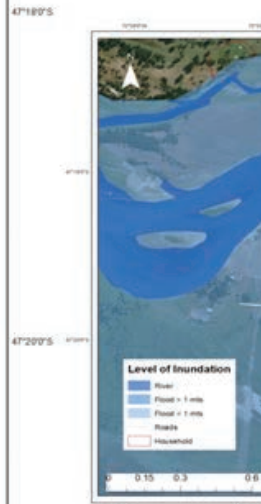
Photo: Andres Rivera



UNCLASSIFIED



Four properties are m
affected in Valle Gran
moderate flood. 60%
likely to be affected b
that connect Cochran
Impassable. Potential



Remediation Plan: Poter
Area in white box repre
is imminent. Further coo

↑ Cachet Dos Lake was completely drained after a GLOF. The lake's current depth is visible as well as its normal level.

The GLOF phenomena has the potential to affect populations throughout the world. The NGA is studying the Colonia Glacier because the methodology and models it is developing for its analyses can be applied to other places such as Alaska and Nepal. In addition, one of NGA's goals is to help national and international communities struggling with natural hazards by using its expertise in geospatial technologies.

"To research the GLOF events of the Colonia Glacier, I am using Arc Hydro to analyze the collected hydrologic data, HEC-RAS to model the hydraulics of the water flow, and ArcMap and ArcGIS Earth to process, visualize, and share the results." [Hydrologic Engineering Center

River Analysis System, or HEC-RAS, was developed by the US Army Corps of Engineers.] As part of the analysis, Castro used ArcMap to process electro-optical imagery obtained from Landsat satellites and obtain the Normalized Difference Water Index (NDWI) and map the area in the Rio Baker/Rio Colonia basin that is prone to flooding.

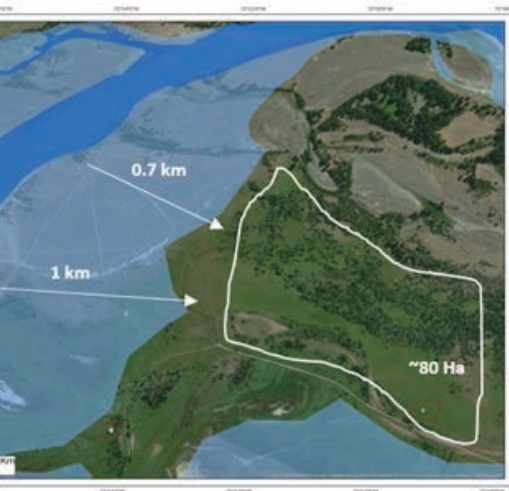
"First, I researched the Landsat imagery that included the Rio Baker/Rio Colonia basin and then compared those results with the dates of known GLOF events there," said Castro. "I was able to find a day during the summer of 2015 when there was limited cloud cover and the satellite had collected data only a few hours after the

outburst flood, so I got good imagery."

From the data indicating the extent of the GLOF, Castro created a 1,000-meter buffer around that part of the Rio Baker and the related basin and floodplain. He used the raster calculator in ArcMap to add NDWI calculations derived using the near-infrared (NIR) and shortwave infrared (SWIR) bands of the satellite imagery. To visualize the basin under normal conditions, he performed the same process using satellite data that was recorded eight days before the flood.

Castro plans to capture high-resolution imagery of key floodplain areas using an unmanned aerial vehicle and postprocessing the imagery using Drone2Map for ArcGIS.

most likely to be
de area with
of area is most
y GLOF's. Road
e with Colonia Sur
livestock loss



potential site for resources and livestock relocation.
presents a potential site for momentary assets relocation if inundation
coordination with local community is needed.

From this data, he will create a flood model that can provide a spatiotemporal representation of the Colonia Glacier GLOF. It will identify those areas that are most likely to flood and provide an estimate of the arrival time of the flood surges.

"Eventually, this work could provide the Chilean government or other stakeholder with the foundational methodology of how to operate a ground-based, high-definition survey lidar station across the Colonia Glacier and Cachet Dos Lake to collect 3D point clouds to define the shape of the glacier-water interface," said Castro. "Using near real-time data interpretation, this method can identify sudden drops in lake height as an early consequence of a GLOF with a simple change detection algorithm."

The data would be automatically

The GLOF phenomena has the potential to affect populations throughout the world.

uploaded to a satellite and accessed by researchers who would transmit a warning of an impending GLOF to local Chilean police. The lidar station will also allow the scientific community to collect valuable data about the Colonia Glacier that is important to researchers.

↓ A remediation plan is essential for measuring, modeling, and planning for the effects of a GLOF impact so that people who may be affected can be better prepared.

