

THE SUSTAINABLE WATER MANAGEMENT TEAM

OF THE AREQUIPA NEXUS INSTITUTE

Presents:

HidroAQP

User's Manual



Discovery Park

Authors: Fariborz Daneshvar,
Jane Frankenberger, Laura
Bowling, Hector Novoa, and
Katy Mazer
Arequipa Nexus Institute

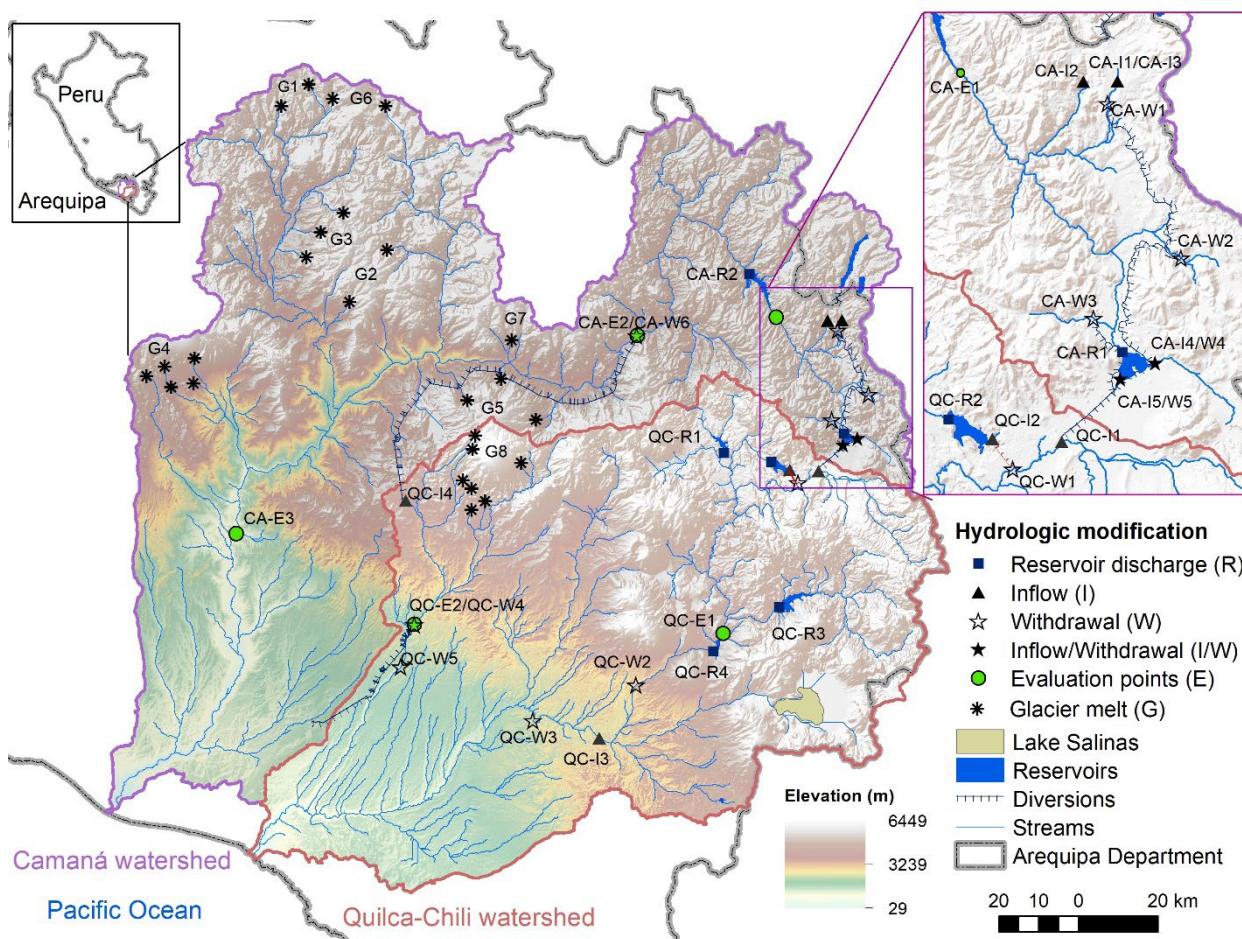
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INTRODUCTION TO TOOL

HidroAQP is a free online tool that provides streamflow information for two watersheds in the Arequipa Department, the Camana and the Quilca-Chili. Users can select any stream or river reach in these watersheds, shown in the map below, and view daily, monthly, and annual estimated flow at that location. The results can be viewed in the web browser or downloaded for analysis. Streamflow has been estimated for every river reach using the Soil and Water Assessment Tool, a hydrologic simulation model, in order to provide consistent data throughout the basin. Streamflow data monitored by SENAMHI were used to improve and verify the estimates, but because monitored data are incomplete the model was needed to have a consistent and complete record. Nine years are available, from 2009 to 2017.

In addition, estimates are also provided of what the streamflow would be without the numerous dams and reservoirs, withdrawals, and water transfers that have altered the streamflow in these watersheds. Understanding the impact of these hydrologic modifications is useful for quantifying environmental change and addressing questions about how management is affecting ecological flows in these watersheds.



TOOL DEVELOPMENT

The Soil and Water Assessment Tool (SWAT) was used to simulate the daily streamflow of the two interconnected river basins. The SWAT is a physically-based, semi-distributed watershed model that evaluates the hydrologic response of land use, land management, and climate change at the basin scale. All model inputs are described in Daneshvar et al. (in preparation), and the following summarizes what is detailed there.

Soil and land cover databases for the Department of Arequipa were developed based on regional maps from the Ministry of Environment of Peru. The databases are available for public download at the following urls:

- Estimated land cover properties for hydrologic modeling in Arequipa, Peru. <https://doi.org/10.4231/GYN8-W684>
- Estimated soil physical properties for hydrologic modeling in Arequipa, Peru <https://doi.org/10.4231/N5MX-9W30>

SWAT requires daily weather including precipitation, minimum and maximum temperature, relative humidity, solar radiation, and wind speed for hydrologic simulation, and these were obtained from Arequipa Climate Maps version 2 developed by Moraes et al. (2020), which is the same information used in the AQP-Clima tool. Meltwater contribution from eight major glaciers within the watersheds was also simulated.

Natural streamflow has been highly modified in these rivers by reservoirs, withdrawals, and interbasin transfers (Tables 1 and 2). Eight reservoirs were constructed between 1958 and 2009. There are nine withdrawals from the river system, for irrigation in semi-arid regions and water supply for the city of Arequipa. In addition, there is return flow from the Cerro Verde mine water treatment plant. There are two major interbasin water transfers, in which water is withdrawn from one river and discharged into another to supplement flow for irrigation, and one water transfer from the Sumbay River to the Pillones Reservoir in the Quilca-Chili River basin. SWAT's ability to incorporate artificial modifications to the natural hydrology such as water transfer and water use, along with its ability to simulate natural and human-made reservoirs make it a suitable tool for hydrologic simulation of these two highly engineered watersheds. The model was set up and calibrated to match the actual monitored data as closely as possible, which represents current conditions.

Table 1: Hydrologic modifications in the Camaná and Quilca-Chili basins

Reservoir	Maximum useable volume [10⁶ m³]	Year built	Map location
El Frayle	127	1958	QC-R3
Condorama	259	1960	CA-R2
El Pañe	40	1961	CA-I1& CA-I3
Aguada Blanca	30	1972	QC-R4
Dique los Españoles	9	1992	CA-R1
Pillones	78	2006	QC-R2
Chalhuanca	25	2009	QC-R1
Bamputañe	100	2009	CA-I2 ¹
Withdrawal	Annual volume [10⁶ m³/year]	Year built	Map location
City of Arequipa	62		QC-W2
La Joya irrigation project	74		QC-W3
Majes irrigation project	339	1971	QC-W4
Santa Rita irrigation project	37		QC-W5
Return flow	Annual volume [10⁶ m³/year]	Year built	Map location
Cerro Verde mining society	32		QC-I3

Table 2: Water transfers in the Camaná and Quilca-Chili basins

Name	Annual volume [10 ⁶ m ³ /year]	Year built	From (Map location)	To (Map location)
Canal Majes-Siguas	394	1971	Colca River, Camana basin (CA-W6)	Siguas River, Quilca-Chili basin (QC-I4)
Canal Pañe-Sumbay	178		El Pañe and Bamputane (CA-W1), Blanquillo River (CA-W2), Antasalla (CA-W3), Jancolacaya (CA-I4/W4), Dique los Españoles (CA-I5/W5)	Sumbay River (QC-I1)
Pillones Tunnel	51		Sumbay River (QC-W1)	Pillones Reservoir (QC-I2)

After the model was calibrated to match the current conditions, it was run with all reservoirs, withdrawals, return flows, and transfers listed above removed. These simulations of non-regulated or naturalized flow are also provided in the HidroAQP tool. Trends on the Tendencias de Flujo tab of the tool were calculated using a linear regression.

This tool was based on the SWATFlow tool (<https://mygeohub.org/groups/water-hub/swatflow>) developed by the WaterHUB project (<https://mygeohub.org/groups/water-hub/introduction>; Rajib et al. 2016)

USING THE TOOL

Getting Started: The Map Tab

The Map tab allows users to select the river reach for which streamflow data will be displayed. The map view can be adjusted by zooming in and changing the base map displayed. The user can select any stream reach, which turns red when selected. The river name, latitude and longitude are provided, and the user can select it to see streamflow.

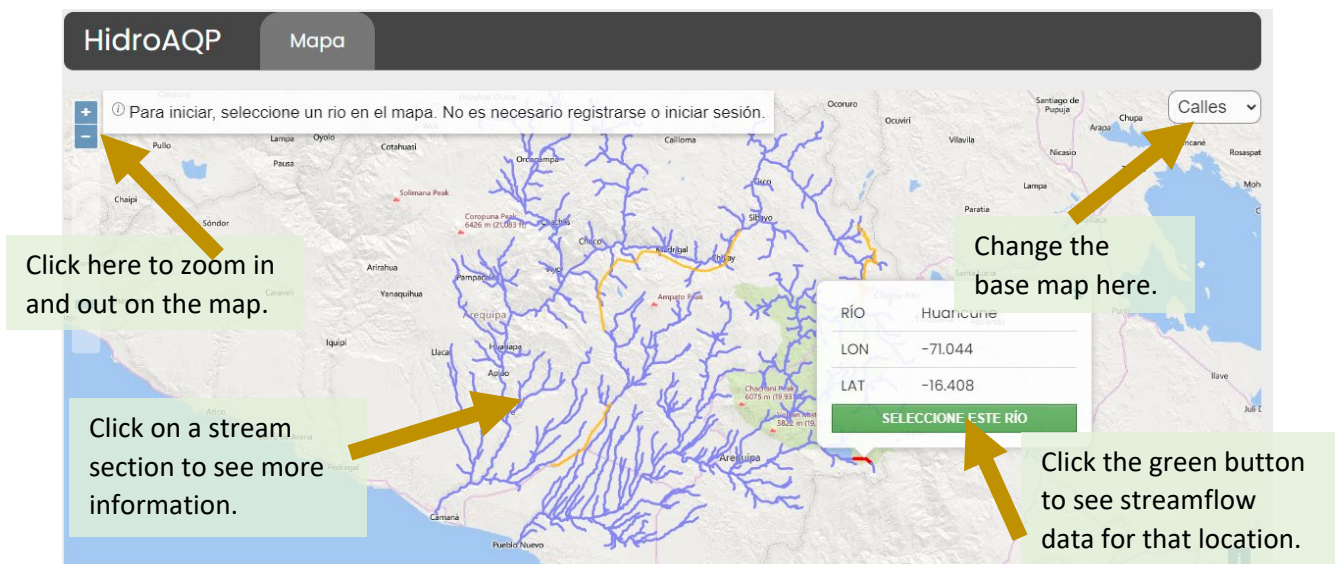


Figure 2. The map tab where users can click on a stream reach to see the river name, latitude and longitude.

Caudales Diarios Tab

After a stream is selected, this tab shows daily streamflow for the selected stream, for any timeframe between 2009 and 2017 (Figure 3). Besides seeing the pattern over the whole year, you can see the flow on any specific day. Users

can view as little as one month, or all 9 years. The date range can be changed in three ways: by expanding the area in the graph at the bottom, by selecting the date range, or a specific period in the upper left.

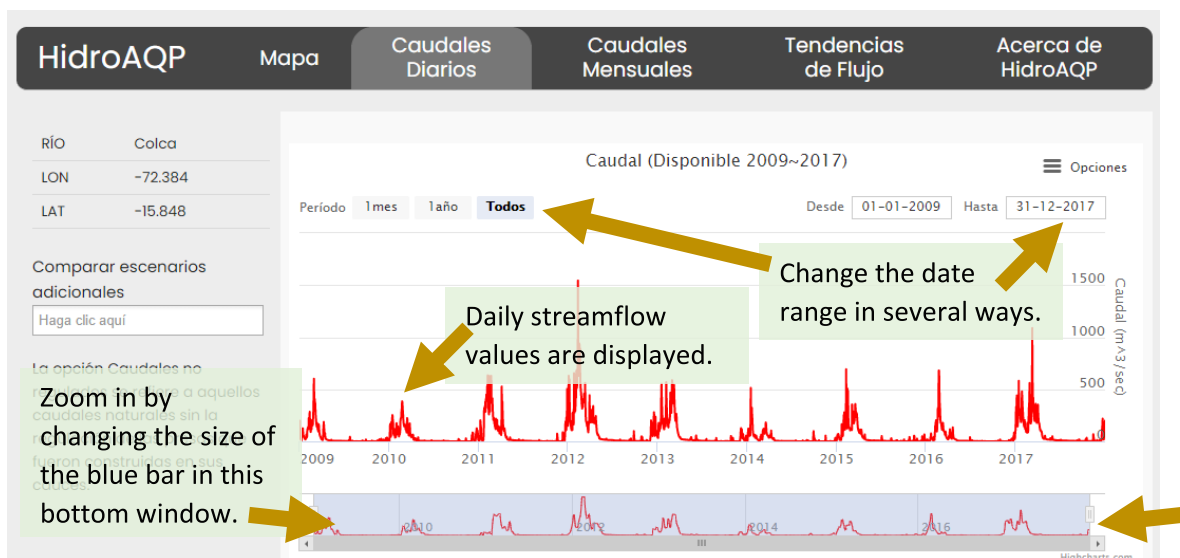


Figure 3. The daily flow tab shows daily time series of simulated streamflow.

To view the streamflow without hydrologic modifications, add the “Caudales no regulado” as shown in Figure 4.

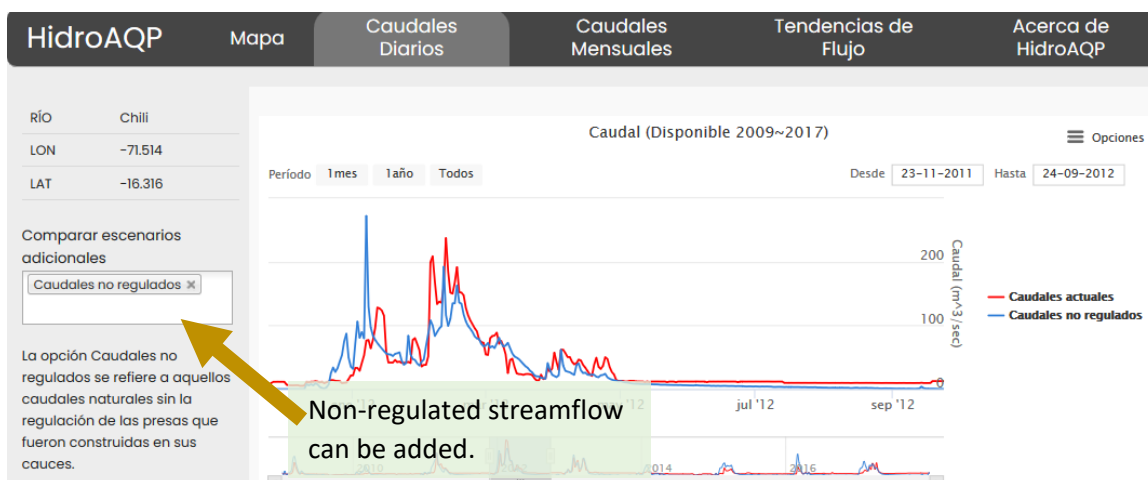


Figure 4. Comparison of daily regulated and un-regulated streamflow for 2012.

Caudales Mensuales Tab

The Monthly Flow tab shows the nine-year average flow for each month, and the maximum and minimum flow simulated for each month. This is useful for understanding when in the year water is available (Figure 5).

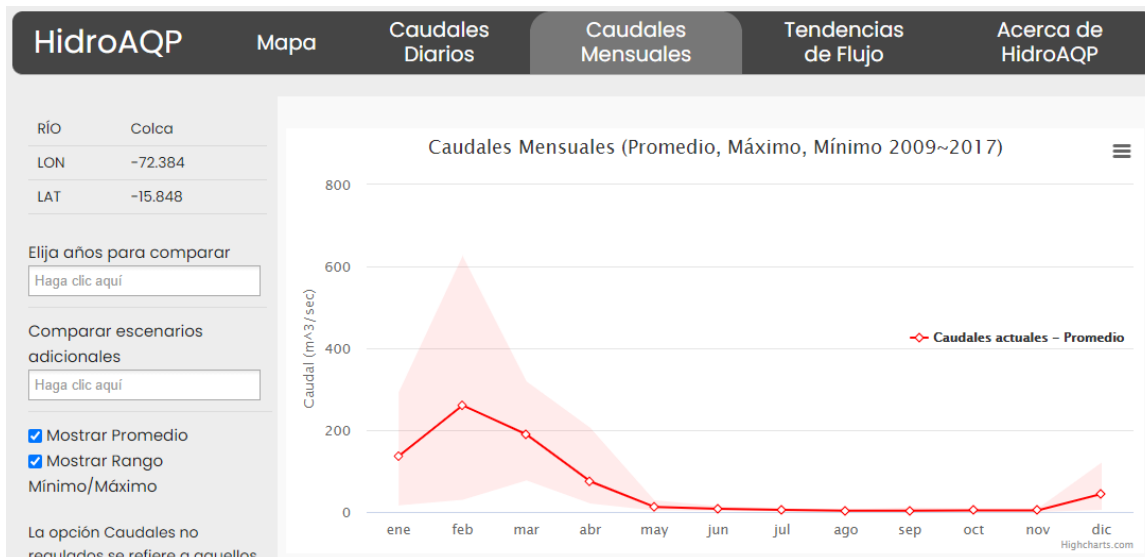


Figure 5: The monthly flow tab shows the average monthly flow calculated over all years.

Monthly flow can also be viewed for specific years. For example, Figure 6 shows a comparison of 2012, which is a year with very high flow, to 2018 which is a year with low flow. You can turn on or off the maximum/minimum function so that you can see them clearly.

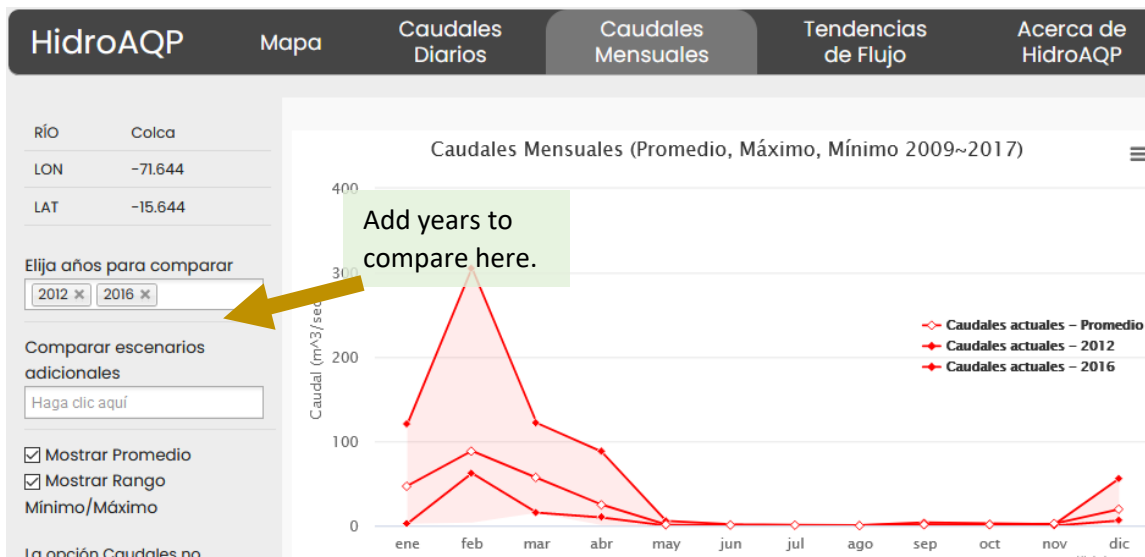


Figure 6: The monthly flow tab also allows comparison between years.

You can also view the average monthly flow for the scenario without hydrologic modifications. On average, flow would be higher in this reach without the withdrawals, and the maximum flow would also be higher (Figure 7).

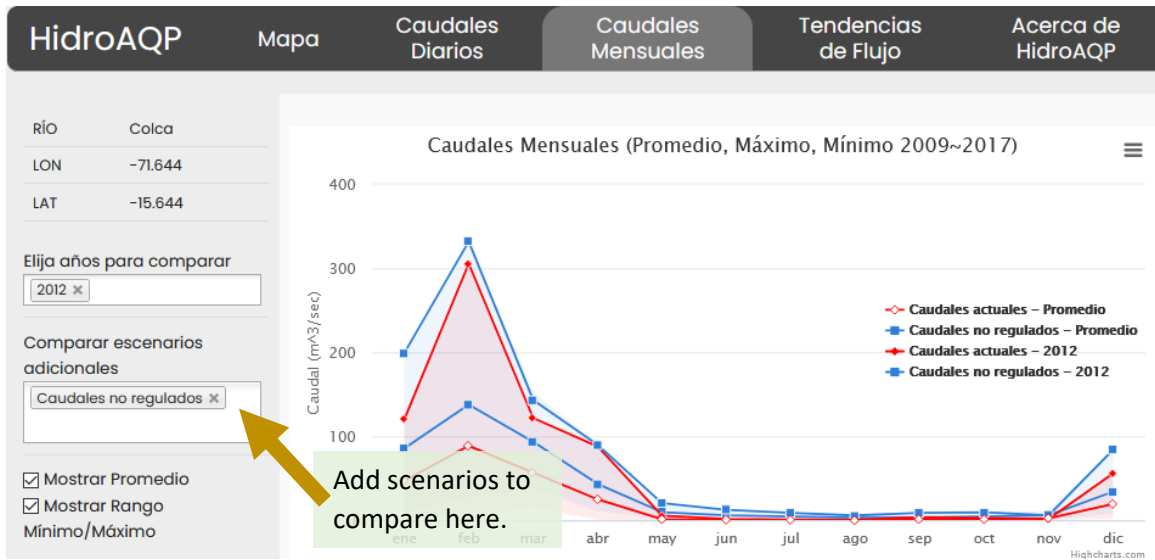


Figure 7: The monthly flow tab also allows comparison between regulated and non-regulated flow.

Tendencias de Flujo Tab

The Flow Tendency tab shows annual average streamflow for all years as a red line. It also shows the trend of annual streamflow as a black line, which gives an idea whether streamflow is increasing or decreasing. This stream has neither an increasing or decreasing trend

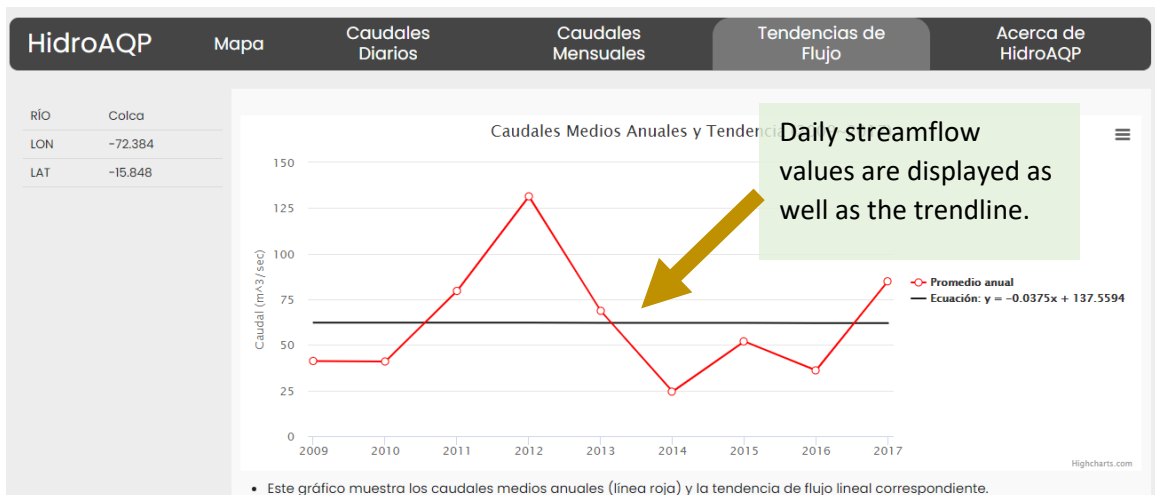


Figure 8: The flow tendency tab helps to visualize if streamflow is changing over time.

To view another location, go back to the Map tab.

Download data

Data provided on any of the tabs can be downloaded by selecting the three bars in the upper right, and then selecting to download as CSV or XLS format, as shown in Figure 9.

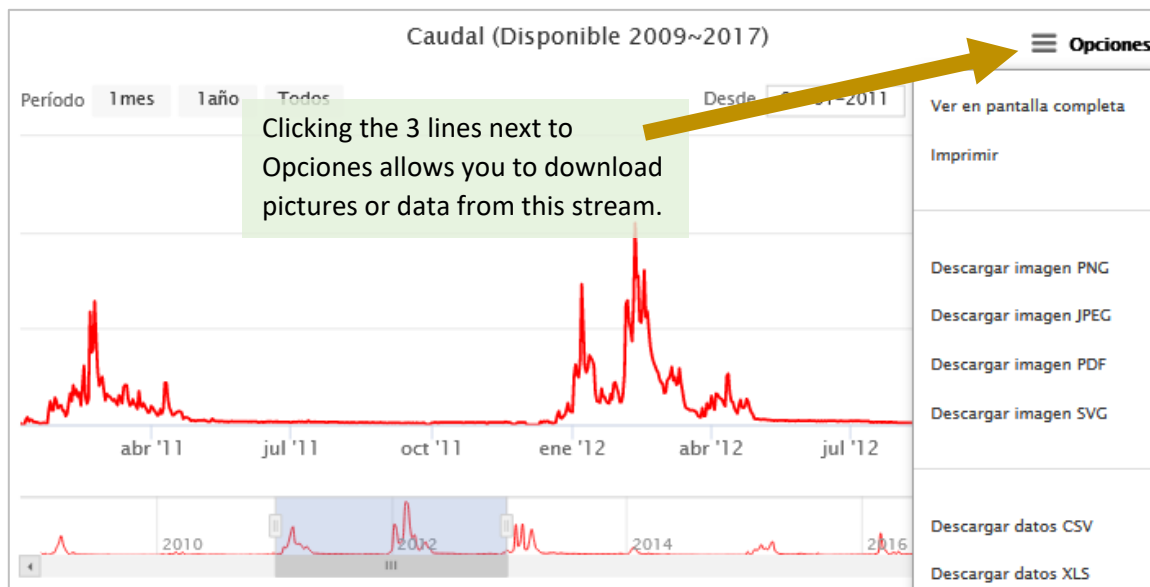


Figure 9. All of the data and graphs shown in HidroAQP are available for download. “About” tab

This tab provides information about the tool, and contact information for the developers if you should wish to contact them. This information is also available within this manual.

HidroAQP
Mapa
Caudales Diarios
Caudales Mensuales
Tendencias de Flujo
Acerca de HidroAQP

Acerca de HidroAQP

HidroAQP es una herramienta gratuita online que proporciona información de caudales para que los administradores de recursos hídricos la utilicen para comprender la disponibilidad del agua y tomar decisiones sobre la gestión del agua. Estos valores de caudal fueron simulados usando un modelo llamado: 'Herramienta de Evaluación Suelo-Agua' o SWAT.

Los investigadores utilizaron información para cada uno de los usos de la tierra en la cuenca, que se muestran en este mapa, así como información sobre cada tipo de suelo. El Uso del suelo y el Suelo mismo, influyen en la forma que fluye el agua. Los datos climáticos, incluidas las precipitaciones diarias y la temperatura fueron medidas por el SENAMHI y se accedió a ellos desde su página web. Esta herramienta puede ayudar a tomar decisiones sobre cuándo y dónde hay suficientes caudales de flujo.

Se describe el modelo calibrado de SWAT en Daneshvar, F., Frankenberger, J., Bowling, L., Cherkauer, K., Maraes, A., In Review. Development of a strategy for SWAT hydrologic modeling in data scarce regions of Peru. Submitted to J. Hydrologic Engineering.

Esta herramienta fue basado en la herramienta de SWATFlow (<https://mygeohub.org/groups/water-hub/swatflow>) desarrollado para el proyecto de WaterHUB (<https://mygeohub.org/groups/water-hub/introduction>). Referencia: Rajib, A., I.L. Kim, V. Merwade, L. Zhao and C. Song, SWATFlow: A New Platform for Communicating High Resolution River Information to Public Domain for Enhanced Water Resources Management, Research and Education, WaterSmart Innovations, October 2016, Las Vegas, NV, USA.

Desarrollado por el equipo de Gestion Sostenible del Agua del Instituto Nexus de Arequipa <https://www.agry.purdue.edu/hydrology/projects/NEXUS-SWM/es/>.

El financiamiento para apoyar la investigación del Instituto Nexus de Arequipa para la Alimentación, la Energía, el Agua y el Medio Ambiente fue proporcionado por la Universidad Nacional de San Agustín.

APPLICATIONS

The following examples demonstrate how HidroAQP can be useful in understanding streamflow in the region.

Understand streamflow behavior over time

The most basic use of the tool is to view streamflow at any location of interest to better understand how it changes through time. For example, Figure 10 shows streamflow in the Chili River at Arequipa, which is high from January

through May, but in the dry season remains constant at a low value. In 2017 this was about 11 m³/sec, as shown in the callout box that is visible when the mouse is hovered over the graph. This consistent low flow is due to regulation by upstream reservoirs, and could be compared to target ecological flow requirements for this river.

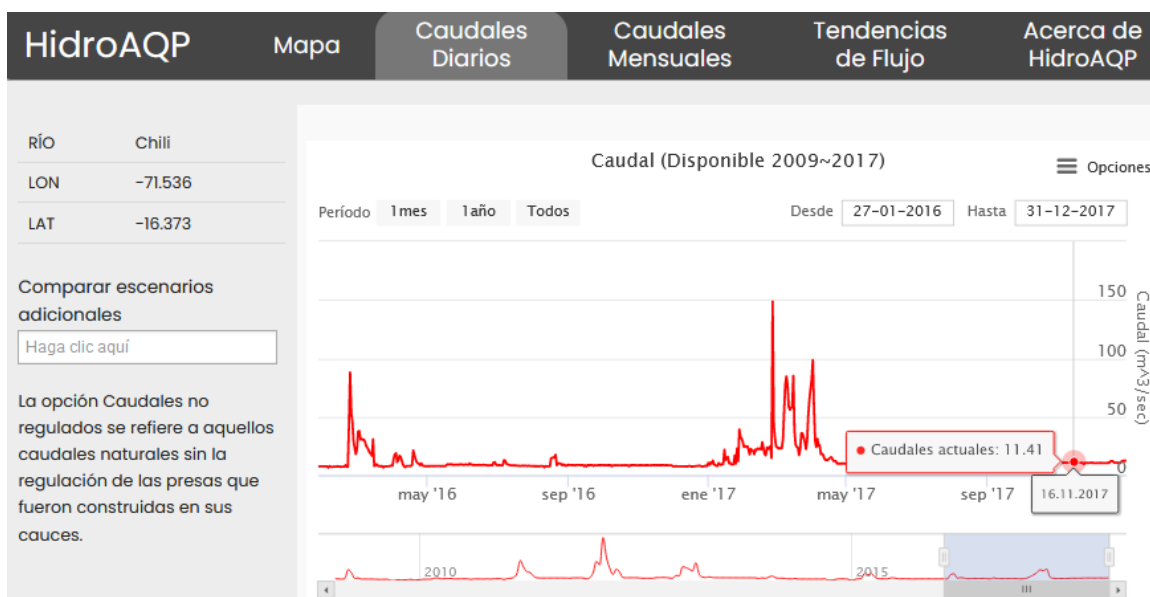


Figure 10: Streamflow in the Chili River at Arequipa for 2016-2017, with streamflow on a specific day provided in callout box.

Compare years

It may be useful to look back at historical streamflow in two different years to better understand differences and conditions that may need to trigger different management responses. This can be done with the daily data, or the monthly data by selecting any specific years. For example, streamflow in the Vitor River is shown below in Figures 11 and 12 for a low flow and high flow year, as both daily flow and monthly flow.

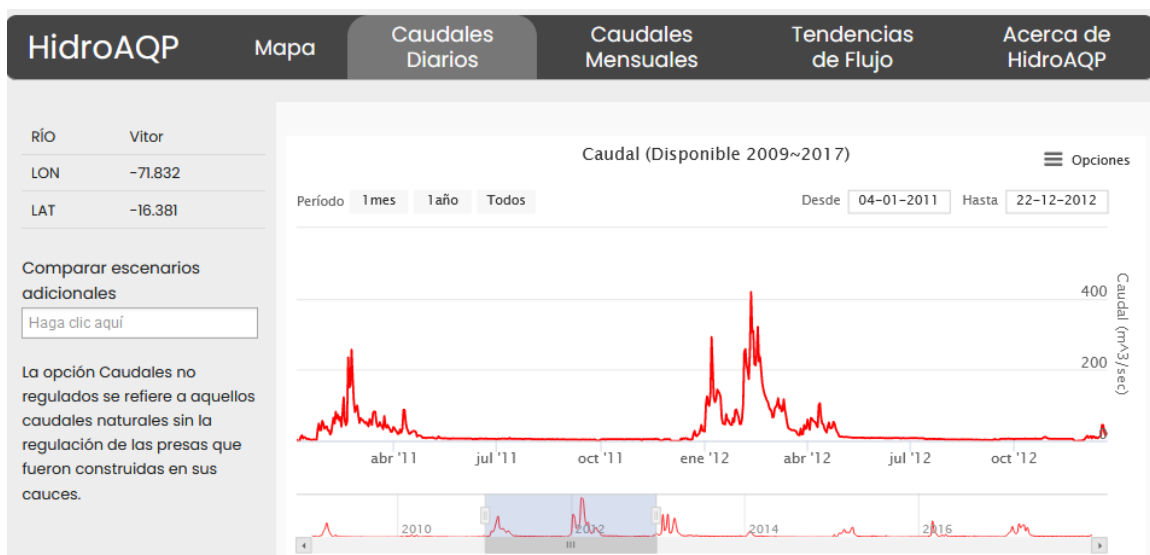


Figure 11: Daily streamflow in the Vitor River for 2011 (low flow) and 2012 (high flow)

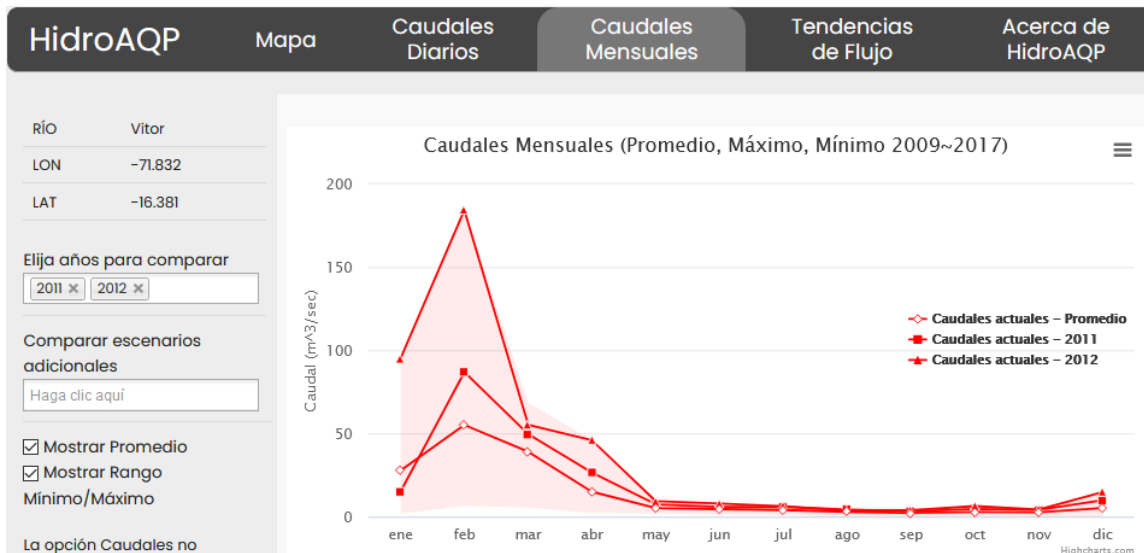


Figure 12: Monthly streamflow in the Vitor River for 2011 (low flow) and 2012 (high flow), along with the average of all years, and the range of all years shown with shading.

Understand the impact of hydrologic modification

Dams, withdrawals, and other hydrologic modifications have varying impacts. For example, the stream reach highlighted in Figure 13 is downstream of the Condorama reservoir. As shown in Figure 14, the flow is greatly reduced during the wet season, but greatly increased in the dry season when the reservoir provides water. This is visible in both the daily flow tab and the monthly average flow tab (Figure 15).

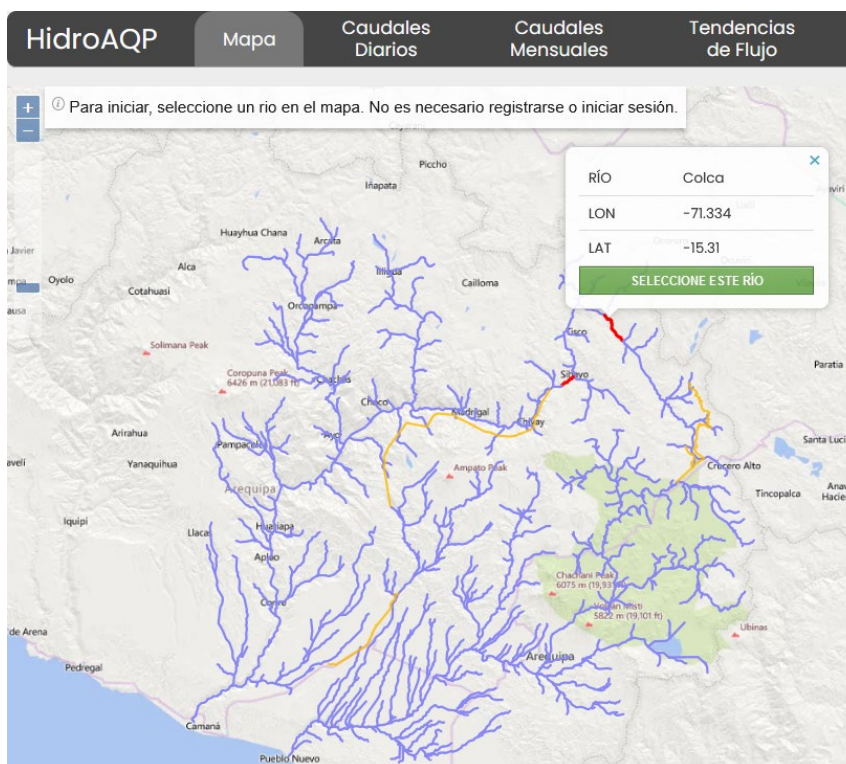


Figure 13: Location of streamflow shown in the graph below. This is the Colca River downstream of the Condorama Reservoir.

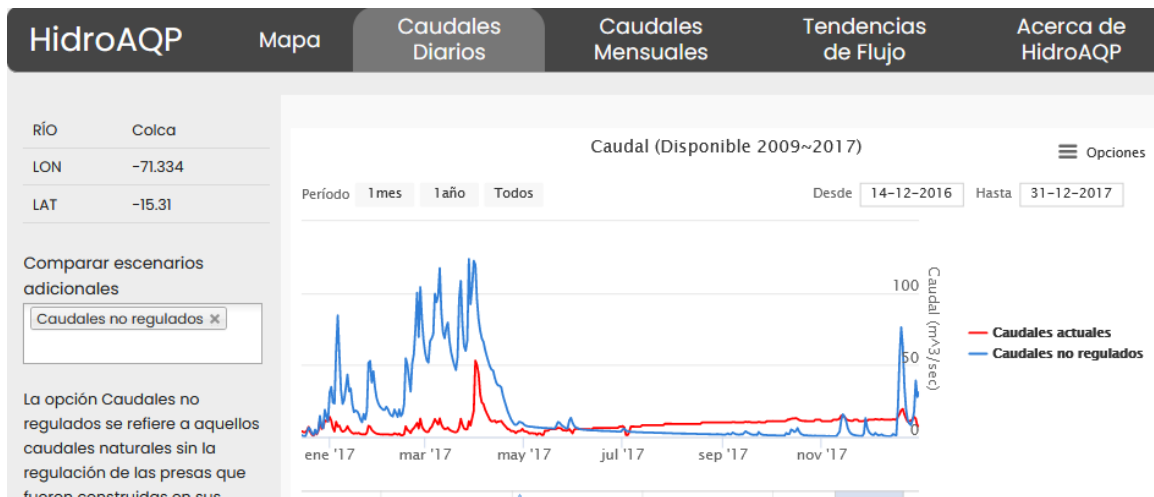


Figure 14: Daily streamflow for 2017 downstream of Condoroma Reservoir and comparison to what it would be without reservoirs and other hydrologic modifications

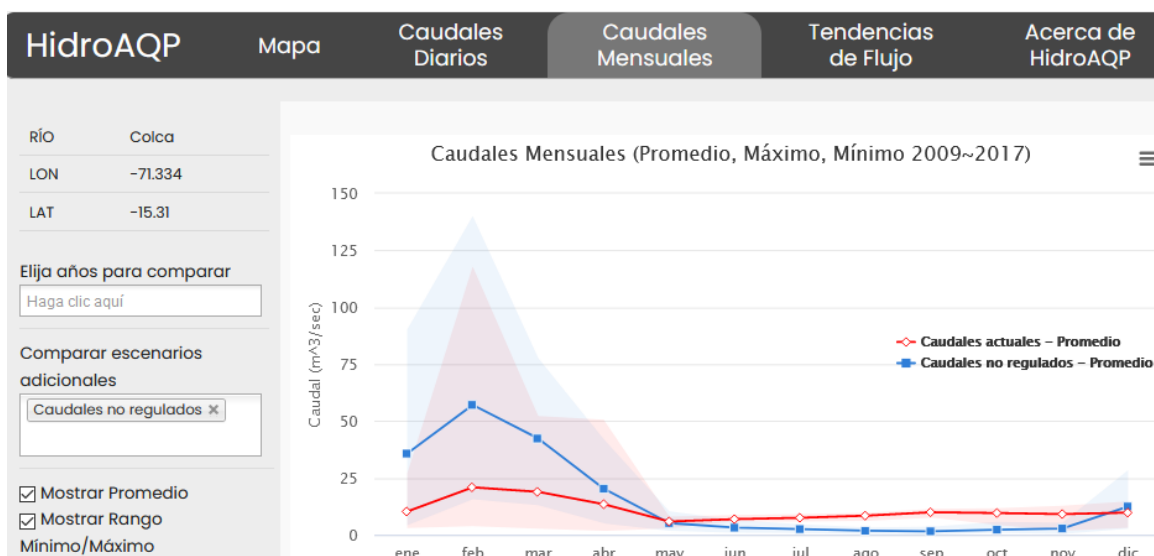


Figure 15: Average monthly streamflow over all years downstream of Condoroma Reservoir, and comparison to what it would be without reservoirs and other hydrologic modifications

Another example shows the effect of the interbasin water transfer through the Canal Majes-Siguas. Downstream of the withdrawal from the Colca River at Tuti (shown as point A in Figure 16), the flow under current conditions is consistently reduced from the natural flow (see Figure 17). Downstream of the input to the Siguas River (point B in Figure 16) the flow under current conditions is greatly increased from the natural flow (see Figure 18).



Figure 16: Location of points A and B for which streamflow is shown below.

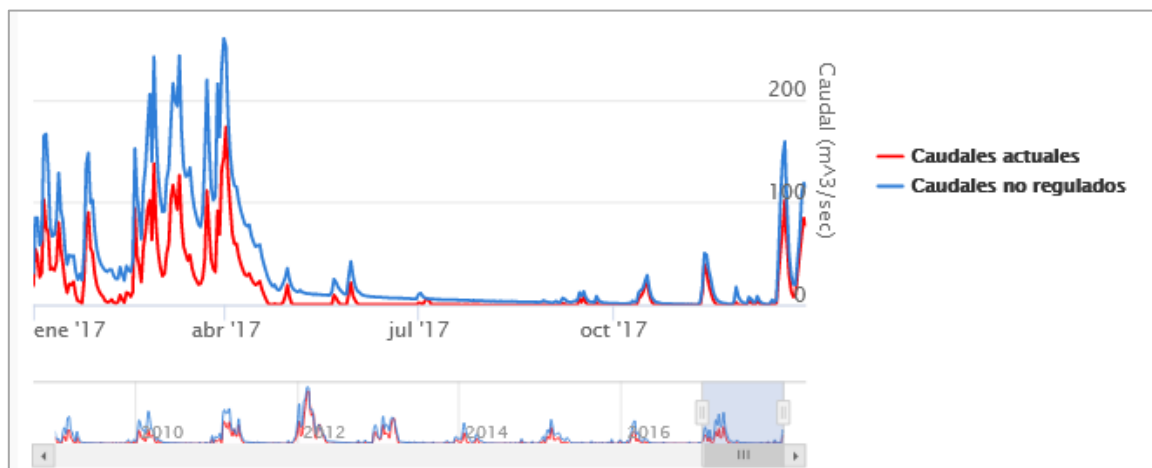


Figure 17: Streamflow for 2017 at point A, downstream of the withdrawal to the Canal Majes-Siguas, is reduced by up to 100 m³/sec from the natural flow. (This shows the combined effects of upstream reservoirs and the withdrawal.)

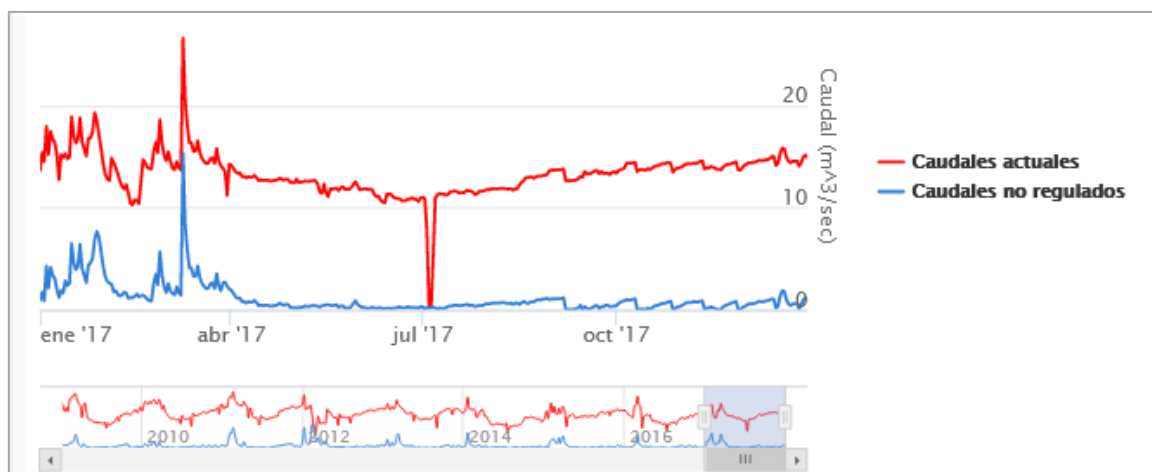


Figure 18: Streamflow for 2017 at point B, downstream of the input to the Sigwas River basin, is greatly increased from natural flow. The increase is especially evident because the natural flow is quite low in this headwater stream.

(The low flow in July is when AUTODEMA records show that there was no flow through the Canal, possibly because of repairs.)

FOR MORE INFORMATION

This tool was part of the Sustainable Water Management project of the Arequipa Nexus Institute. To see more of our tools and learn more about the SWM team, please visit our website at <https://www.agry.purdue.edu/hydrology/projects/nexus-swm/es/index.html>.

Together with this manual, there three more sources (formats) of information of how to use the tool: 1) an introduction [video](#) to the tool, 1) a tool quick guide document, and 3) the guided tour imbedded in the tool web site. Below we demonstrate most tool features.

Data accessibility

The simulated data presented in the HidroAQP tool went through extensive evaluation, but it is a simulated product and will differ from observed streamflow for a given location and time period. However, it can be used for a wide variety of applications since there are no gaps in the available data. As mentioned before, you can download it straight from the tool and use it in any analyses, just be sure to cite Daneshvar et al. (2020).

ABOUT THE TEAM

Development team

Fariborz Daneshvar is a Postdoctoral Research Associate in the Department of Agricultural and Biological Engineering at Purdue University. He conducts watershed hydrology research with respect to environmental and socioeconomic impacts.

Jane Frankenberger is a Professor of Agricultural and Biological Engineering at Purdue University. She conducts model-based analyses and engages stakeholders to improve management of watersheds and water quality.

Laura C. Bowling is a Professor of hydrology in the Department of Agronomy at Purdue University. Her research investigates the water resources impact of environmental change across multiple scales, climate regimes, and ecosystems and communicates these findings to stakeholders.

Hector Novoa is a Professor of fluid mechanics, hydraulics and hydrology at the Universidad Nacional de San Agustín de Arequipa. He has over 25 years of experience on environmental issues, including water and sewer systems, surface water hydrology, and design of hydraulic structures.

Katy Mazer is coordinator of the Sustainable Water Management team of The Nexus Institute at Purdue University. She engages with stakeholder groups in Arequipa, Peru to coproduce water management decision-making tools. [Learn more](#)

Carol Song, Lan Zhao, and I Luk Kim are part of Information Technology at Purdue (ITAP), and they collaborated with our team to adapt the SWATFlow online tool to create HidroAQP.

This tool was part of the Sustainable Water Management project of the Arequipa Nexus Institute. To see more of our tools and learn more about the SWM team, please visit our website at <https://www.agry.purdue.edu/hydrology/projects/nexus-swm/es/index.html>.

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Daneshvar, F., L.C. Bowling, K.E. Mazer, H. Novoa Andia, C. Song, L. Zhao, I.L. Kim, and J.R. Frankenberger. 2020. HidroAQP [Online tool]. Available at <https://mygeohub.org/groups/water-hub/swatflow/Arequipa>