"HYDROGEOLOGICAL EVALUATION IN THE AREA OF INFLUENCE OF A POLYMETALLIC MINE"

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SUMMARY

Man since ancient times as he was having needs removed part of the earth's crust for different activities such as food, housing, etc. The highlight it had in terms of economy was the mining activity that is very complex and varied. Within the hydrogeological cartography there is the characterization of geological formation, differentiating its permeable and impermeable properties with this coming to zone the rocks with capacity to store and transmit groundwater, called aquifers. The present work aims to develop a hydrogeological evaluation, which allows us to find new sources of water supply and that are used in human and agricultural consumption, for this the hydrogeological mapping was developed; In all stations, flows, levels, and hydrochemical parameters were taken from the field. The results indicate that the different samples extracted allow finding new sources of water supply to be used by man; In addition, field results are restricted to an underground hydrogeological assessment. It was concluded that the hydrogeology of the study area based on the permissible limits will allow finding new sources of water supply and that they are used for human and agricultural consumption.

Keywords: Aquifer, Hydrogeology, Cartography, Tests, Piezometers, Groundwater.

ABSTRACT

Since ancient times, man has been removing part of the earth's crust for different activities such as food, housing, etc., as he had needs. The most important thing in terms of economy was the mining activity, which is very complex and varied. Within the hydrogeological mapping we have the characterization of geological formation, differentiating its permeable and impermeable properties with this getting to zone the rocks with the capacity to store and transmit groundwater, called aquifers. The objective of this work is to develop a hydrogeological evaluation, which will allow us to find new sources of water supply that can be used for human and agricultural consumption, for this purpose hydrogeological mapping was developed; in all the stations flow rates, levels, and hydrochemical field parameters were taken. The results indicate that the different samples extracted allow finding new sources of water supply to be used by man; in addition, the field results are restricted to a subway hydrogeological evaluation. It was concluded that the hydrogeology of the study area based on the permissible limits will allow finding new water supply sources to be used for human and agricultural consumption.

Key words: Aquifer, Hydrogeology, Cartography, Tests, Piezometers, Groundwater.

INTRODUCTION

Man to enrich the environment that surrounds him has required since his earthly dawn to remodel and tame nature (Bunge, 2013) according to his needs, using the elements available in his environment, such as rummaging through the earth's crust whether for agricultural activities, housing or mining, the latter to obtain copper, lead, silver, gold among other minerals, which became the right of land ownership (Serfati, 2013) and the development of mining activity, which is complex, highly exposed, varied, with an impact on other economic sectors, hence it is a very profitable sector (Concha, 2017). Alexis Montes de Oca-Risco & Mayda Ulloa-Carcassés, 2013. To carry out the environmental study where the Environmental Quality (ECA) standards have been analyzed. That together with other legal devices are an obligatory part of environmental management in mining, and make possible the development of sustainable mining projects. Where geological mapping is zoned the main types of rocks, soils and structures (faults, fractures and diaclase that has influence on the percolation of groundwater and surface), giving importance to lithology.

The hydrogeological cartography, characterizes each geological formation, differentiating its permeable and impermeable properties, zoning the rocks with capacity to store and transmit groundwater, the so-called aquifers. The hydrogeological analysis of surface and groundwater was developed based on Peruvian regulations (Supreme Decree No. 004-2017-MINAM), taking into account that there is no specific regulation for groundwater quality. It is common to observe in the mines of Peru the development of drainage works (Gallardo et al. 2015) shallow and deep of groundwater for the exploitation of mining deposits, therefore, it is necessary the prior knowledge of the hydrogeology of the area, the characteristics of exploitation, available pumping units, as well as the facilities of benefit for the processing of the mineral. Mining operations are often concentrated on crystalline igneous rocks associated with calcareous and/or detrital rocks, which produce groundwater, and others that limit or control the migration of water flows, which complicates mineral extraction to varying degrees due to the presence of groundwater. with the aim of developing a hydrogeological evaluation, which allows us to find new sources of water supply and that are used in human and agricultural consumption. Contributing in this way with alternative solutions, given the lack of quality water and avoiding social conflicts between mining companies and nearby populations. For this purpose, it was necessary to carry out the hydrological and hydrogeological evaluation to estimate the drainage flow during its deepening and in addition to evaluating the hydraulic infrastructure for water management.

METHODOLOGY

The present work aims to develop a hydrogeological evaluation, which allows us to find new sources of water supply and that are used in human and agricultural consumption. Contributing in this way with alternative solutions, given the lack of quality water and avoiding social conflicts between mining companies and nearby populations. Hydrogeological mapping was developed finding few natural upwellings, including; springs, important wetlands and surface seeps, probably due to the lowering of the water table due to mining drainage. 14 existing soundings and piezometers were recorded, reading water levels and quality, establishing a monitoring network in surface courses and lagoons near the area of direct and indirect influence. The inventory of discharges and flows within the underground mine was carried out, evaluating upwellings within the works at different levels, in total 23 discharge points were identified: among them nine (9) in drills, six (6) rock seeps and three (3) discharges in shafts and four (4) drains in tunnels. In all stations, flows, levels, and hydrochemical parameters were taken from the field; T °C, EC, PH, ED, STD, etc. Samples were taken in 500 and 250 millilitre polyethylene bottles with hermetic stoppers, filtered and acidified in situ, and stored at 4°C. Finally, mathematical flow modeling was carried out to estimate the current and future discharge volume, sizing the drainage flows based on the future mining plan, for which a 3D numerical model was prepared using the Visual MODFLOW, developed by the Geological Survey of the United States of America. The domain of the numerical model covered an area of 11.6 km to be analyzed in the laboratories of ALS Peru.

GEOLOGICAL AND GEOMORPHOLOGICAL CHARACTERISTICS

GEOLOGY AND HYDROGEOLOGICAL CHARACTERIZATION

The main types of rocks, soils and structures (faults, fractures and diaclase that has influence on the percolation of groundwater), giving importance to lithology. The hydrogeological mapping characterizes each geological formation, differentiating its permeable and impermeable properties, zoning the rocks in reservoirs with the capacity to store and transmit groundwater, the so-called aquifers. Four (4) permeability tests were performed, under the Lefrang method, in fissured aquifers, the results were compared with the conventional table of permeabilities of Benítez 1963 and Custodio 1996, obtaining a hydrogeological correspondence through the hydraulic conductivity. Of the 4 trials, they were conducted in the Jumasha Formation (Lau-1, Lau2, Lau-3, Lau-4,). In Holy Formation (lower limb, Lau-5, Lau-6 and Lau-7). All tests correspond to semipermeable lithologies, they are fine-grained limestones, reddish in color of massive and impermeable appearance, but with the presence of sporadic fractures, these values allow us to classify these materials as somewhat permeable rocks and assigning a hydrogeological qualification of poor aquifer. Based on the geological mapping, the permeability tests and the source inventory map, the hydrogeological characterization table was made (Table 1).

Table 1. Hydrogeological classification of geological units

<table>
<tr><th colspan="2">Iunidad Formation</th><th>Symbology</th><th>Hydrogeological classification</th></tr>
<tr><td colspan="2">Colluvial deposits</td><td>Q-co</td><td>Sedimentary acuitard</td></tr>
<tr><td colspan="2">Alluvial deposits</td><td>Q-al</td><td>Unconsolidated porous aquifer</td></tr>
<tr><td colspan="2">Fluvioglacial deposits</td><td>Q-fg</td><td>Unconsolidated porous aquifer</td></tr>
<tr><td colspan="2">Moraine Deposits</td><td>Q-mo</td><td>Unconsolidated porous aquifer</td></tr>
<tr><td>Calipuy Group</td><td>Volcanic Rocks</td><td>Nm-ea</td><td>Volcanic aquifer</td></tr>
<tr><td colspan="2" rowspan="4">Jumasha Training</td><td>Ks-ju5</td><td>Sedimentary fissured aquifer</td></tr>
<tr><td>Ks-ju4</td><td>Sedimentary fissured aquifer</td></tr>
<tr><td>Ks-ju3</td><td>Sedimentary fissured aquifer</td></tr>
<tr><td>Ks-jull/fiu2</td><td>Sedimentary fissured aquifer</td></tr>
<tr><td colspan="2">Pariahuanca, Chulee and Pariatambo Formations</td><td>Ki-phechpt</td><td>Sedimentary aquaitard</td></tr>
</table>

Goyllarisquizga Group	Fm.Santa Carhu:iz	Ki-saca	Sedimentary aquaitard
	Fm.Chimú	Ki-ch	Sedimentary fissured aquifer
Lntrusivas rocks		Nm-to	Intrusive aquarard
		Nm-mz	
		Nm-gd	
Subvolcanic rocks		Nm-da	Sub-volcanic acuitard

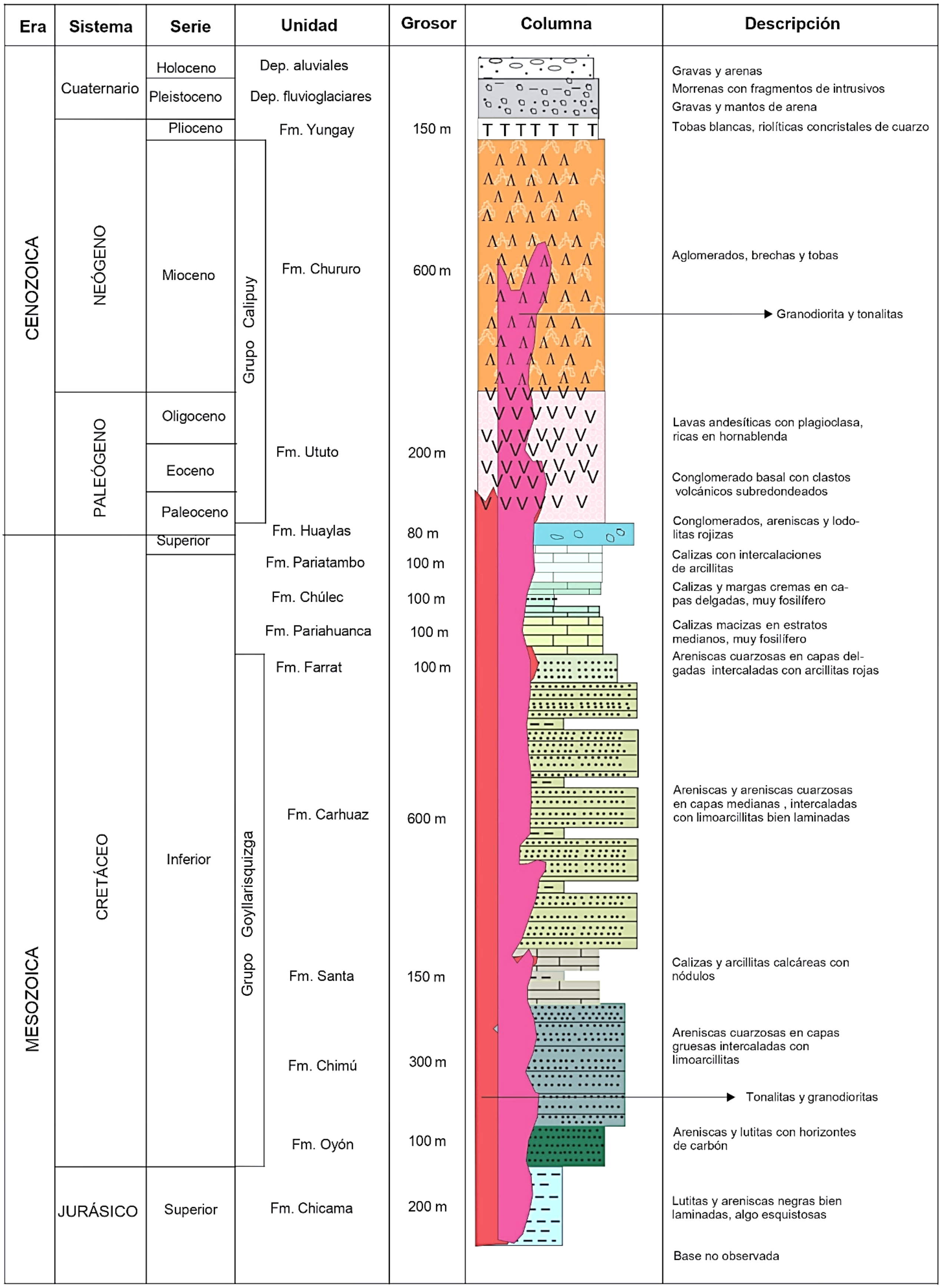
Fountain. (INGEMMET, 2020)

LITHOLOGY AND STRATIGRAPHY

The study area and its surroundings stratigraphically belong to the Cretaceous sedimentary basin and is structurally located in a zone of folds and on runoff. Powerful Cretaceous sediments are widely distributed in the area, presenting three well-defined units or horizons. The lower part consists mainly of clastic rocks, such as siliceous sandstones, limestones and shales (Chimú, Santa, Carhuaz and Farrat). The intermediate part consists of calcareous rocks associated with dolomites and shales (Pariahuanca, Chulec, Pariatambo, Jumasha and Celendín formations). Finally, the upper part contains the red layers (Casapalca Formation). All these Cretaceous formations have been covered by the Tertiary volcanic Calipuy Formation and have been instructed by tonalites, dacites and granitic porphyry.

The Paleozoic basement, on which the sedimentary basin rests, outcrops in the eastern part of the Andes. On the western flank, sediments are either covered by volcanic or instructed by coastal batholith. In its geological quadrangles that comprise the study area, describing the most important aspects for the project that can be seen in Image 1. As it is observed the chronostratigraphy of the study area that are developed through their formations and their stratigraphic lith, as well as the area they have in the concession. The study is developed on the basis of information published by the Geological Mining and Metallurgical Institute (INGEMMET, 2020)

Figure 2. Generalized Stratigraphy of the Study Area



SOURCE: INGEMMET, 2020.

CHIMÚ TRAINING

This formation consists of quartzites, sandstones and black litutes. At the top of this formation there is a transitional change with the Holy Formation. The Chimú Formation consists mainly of common strata of white and solid sandstones in layers 1 to 3 m thick and in total the complete sequence of the unit can vary between 600 and 100 m (from south to north). Physiographically it is characterized by forming high relief topography. Formed by clastic rocks such as quartzites and whitish sandstones of massive texture, medium grain and fractured with moderate diaclase. It presents oxidation by limonitization in the faces of the fractures with some isolated clay sections. Geological Mining and Metallurgical Institute (INGEMMET, 2020). HOLY FORMATION It occurs in a concordant way to the Chimú Formation and is distributed in almost all the places where it emerges; Its thickness is regular and reaches 150 m. The Santa formation consists of blue-gray limestones with thin stratification and horizons of clay and dolomitic limestones with the presence of chert or flint nodules. The study area is located longitudinally in the central part and is important for the location of replacement mineralized bodies, it has a power of 60 to 100 meters (INGEMMET, 2020).

CARHUAZ TRAINING

This Formation lies concordantly on the Holy Formation and is constituted lithologically by grey to grey-green silt. In some areas it has limestones and ferruginous sandstones. This formation consists of shales and variegated sandstones (green, red and yellowish), at the top is a horizon of red shales that serves as a guide. Locally it has a power of 600 meters. In the Mina area it is located in the central and western part of the Santa formation (INGEMMET, 2020).

FARRAT TRAINING

The Farrat Formation consists of white quartz sandstones and thin grey sandstones grading to calcareous ceiling, constituting a transition to the Pariahuanca Formation. Its thickness is from 80 to 100 m (INGEMMET, 2020).

PARIAHUANCA FORMATION

It occurs concordantly over the Carhuaz Formation. It is intensely folded in the upper part of the headwaters of the Torres River, constituting two anticlines and synclines whose course of its axes is essentially parallel to the Andes Mountains.

It has a thickness of 80 to 100 m and consists mainly of massive limestones. Morphologically it is distinguished from other formations by its topographic expression, since it forms narrow zones, in the form of corridors and discontinuous prominent zones. Important in the area due to the location of a skarn body (INGEMMET, 2020).

CHULEC TRAINING

It consists of intercalations of brown marls and weathered to yellowish cream. It has an approximate thickness of 200 m (INGEMMET, 2020).

PARIATAMBO FORMATION

This formation rests concordantly on the Chúlec Formation, has thickness of 100 m that is regularly maintained constant and in the Huayhuash mountain range reaches 500 m thick. The Pariatambo Formation consists mainly of dark brown loams that have a foul odor on fresh fracture surface. Pariatambo consists of thin intercalations of limestones, marls and shale, dark gray to black due to weathering (INGEMMET, 2020).

JUMASHA TRAINING

This formation lies concordantly with the Pariatambo Formation and underlies the Celendín Formation. The full thickness observed in the Marañón sector reaches 700 m. The rocks of the Jumasha Formation of the Late Cretaceous are distributed along the axis of a syncline in a NNO-SSE direction. They are found in the highest parts of the stratigraphic sequence. Topographically they form mountain ranges of massive and compact limestones of bluish gray color, with power of up to 1 200 m. In general the Jumasha Formation presents a regularly solid stratification lithology with gray limestones in strata of 1 to 2 m, in some places it may be a slick sequence of dark limestones towards the base comparable with the Pariatambo Formation. (INGEMMET, 2020).

STRUCTURAL GEOLOGY

They have defined three structural units

1. Unit of folds and on runoff.
2. Imbricated unit.
3. Unit of failed blocks.

The Carhuaz quadrangle is included in the Unit of folds and on runoff, which in turn extends to the quadrangles of Corongo and Pallasca. This unit occupies most of the studied region and is characterized by the presence of long, tight folds associated with large overrunn. It should be noted, that they develop exclusively in the basin facies of the Upper Jurassic and Cretaceous sediments. The folds found in this unit vary in shape and size according to the nature of the rocks in which they have developed. Cretaceous-Jurassic formations have resulted in folds up to 20 km long and 3-4 km wide; they are mostly concentric due to the massive nature of the quartzites of the Chimú Formation. However, the clays, limestones and sandstones of the Santa Formation and Carhuaz Formation, often produce a disharmonious folding. The clays of the Chicama Formation tend to produce small disharmonic folds. The folds have a preferential NW-SE orientation, in some cases with inflections that do not vary their general course.

GEOLOGICAL, HYDROGEOLOGICAL AND GEOTECHNICAL FEATURES

Geological characteristics: the endorheic continental sedimentation of the Tagus basin corresponds to alluvial deposits from the central system that pass through intermediate sediments to flow into the depocenter of the basin in intermediate sediments. These materials are divided into three lithostratigraphic units, according to their depositional medium and lithology.

Lower Unit: three lithofacies are differentiated, a terrigenous one constituted by deposits of alluvial fans, flows of landslides, floodplains and distribution channels, an intermediate facies that relate the terrigenous materials with the evaporites by gypsum and anhydrite with clays deposited in saline lake media.

Intermediate Unit: Terrigenous sediments mainly carbonated with presence of gypsum towards the central parts of the basin.

Upper Unit: the materials that make up this unit at its base are very erosive channeled facies formed by materials of diverse nature: conglomerates in the massive banks of metric power, horizontal structure and creamy white, grayish color. The underlying materials correspond to a fluvial detrital unit with variations of facies and important powers; Gravels and conglomerates of the mining deposits the lithological units outcropping in the study area belong to the páramo series (MIOCENE AGE, PILOCENE). With quaternary materials deposited discordantly to the ceiling.

WEATHER STATIONS

PRECIPITATION

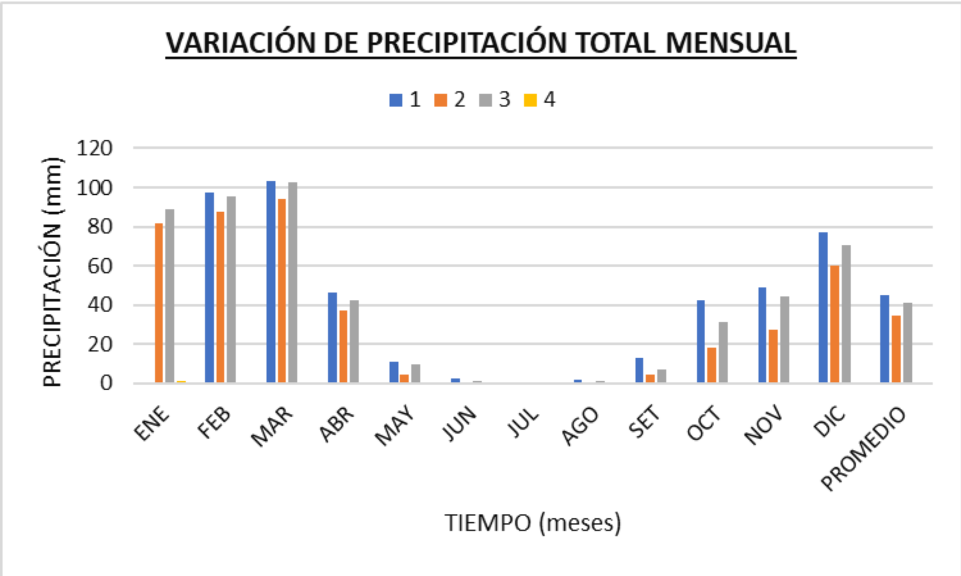
The study area presents the following total monthly rainfall (annual average) for each of its seasons, which are:

- Station 1: 542.1 mm.
- Station 2: 416.0 mm.
- Station 3: 494.4 mm.
- Station 4: 319.2 mm.

Below is a comparison of rainfall from the study area stations in Figure 1.

Figure 1. a Comparison of the variation of Precipitation by Seasons.

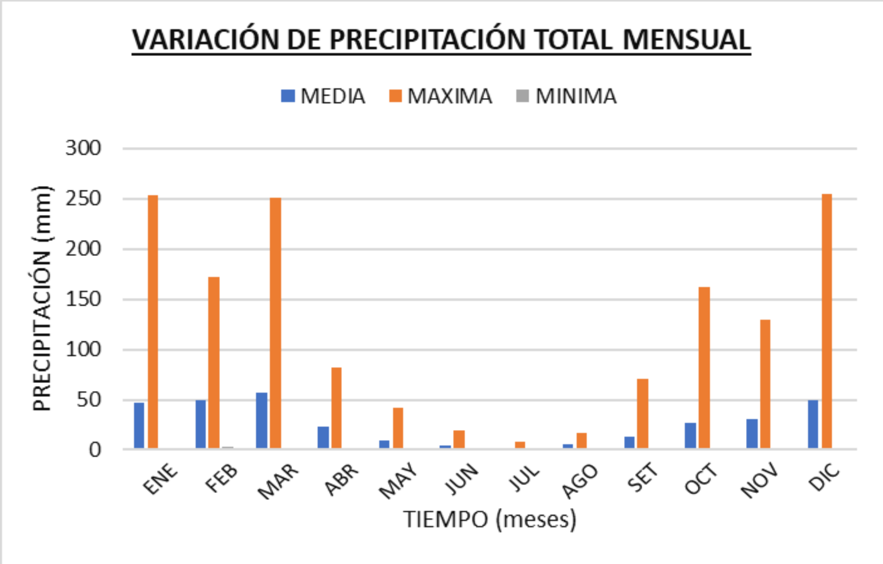
ESTACIÓN	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SET	OCT	NOV	DIC	PROMEDIO
1	97.733	97.455	103.46	46.46	11.082	2.2955	0.8174	1.6565	13.13	42.343	48.843	76.774	45.17
2	81.467	87.467	93.95	36.918	4.5773	0.3136	0.25	0.6045	4.6955	18.195	27.482	60.05	34.66
3	88.64	95.08	102.46	42.58	9.57	1.21	0.31	0.96	6.88	31.55	44.38	70.82	41.2
4	46.86	49.82	57.53	23.22	9.82	4.77	1.67	5.25	12.77	27.04	31.12	49.33	26.6



For the present study, stations 5 and 4 were taken as a reference, which have records of total monthly rainfall, corresponding to the years 1967 – 1982 and 1995 – 2008 respectively, located east of the project area, in monthly total precipitation data Station 4 was used, which has a minimum monthly rainfall of 0.8 mm, an average monthly rainfall of 26.6 mm and a maximum monthly rainfall of 254.1 mm, the monthly rainfall variation is shown below in Figure 2.

Figure 2. Monthly Total Precipitation Variation -Station 4

	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SET	OCT	NOV	DIC
MEDIA	46.9	49.8	57.5	23.2	9.8	4.8	1.7	5.3	12.8	27	31.1	49.3
MAXIMA	253.3	171.9	251.5	82	41.4	19.7	7.8	17.2	70.3	162.6	129.8	254.1
MINIMA	0	2.8	1.1	0.8	0	0	0	0	0	0.8	1.1	1.6

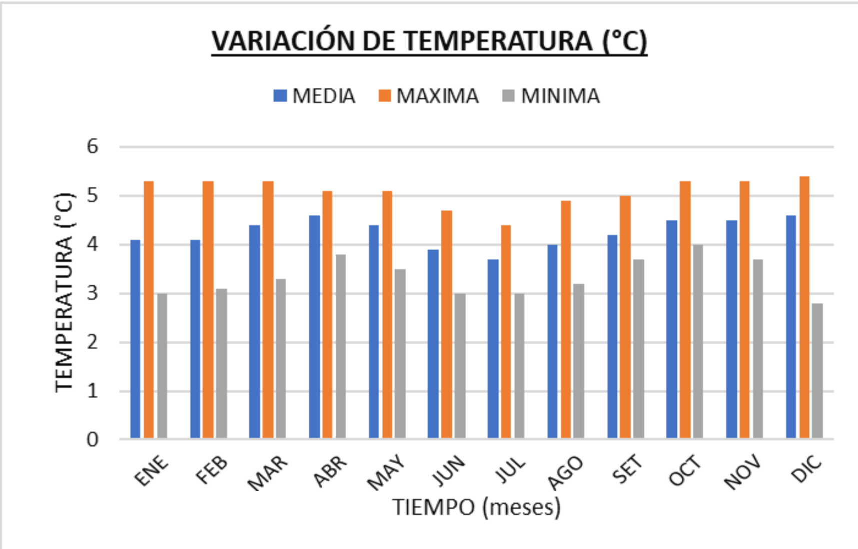


TEMPERATURE

For the purposes of this study, the temperature data recorded at station 5 have been considered, as shown in Figure 3. The average monthly temperature value is 4.3 °C.

Figure 3. Temperature Variation - Station 5

	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SET	OCT	NOV	DIC
MEDIA	4.1	4.1	4.4	4.6	4.4	3.9	3.7	4	4.2	4.5	4.5	4.6
MAXIMA	5.3	5.3	5.3	5.1	5.1	4.7	4.4	4.9	5	5.3	5.3	5.4
MINIMA	3	3.1	3.3	3.8	3.5	3	3	3.2	3.7	4	3.7	2.8

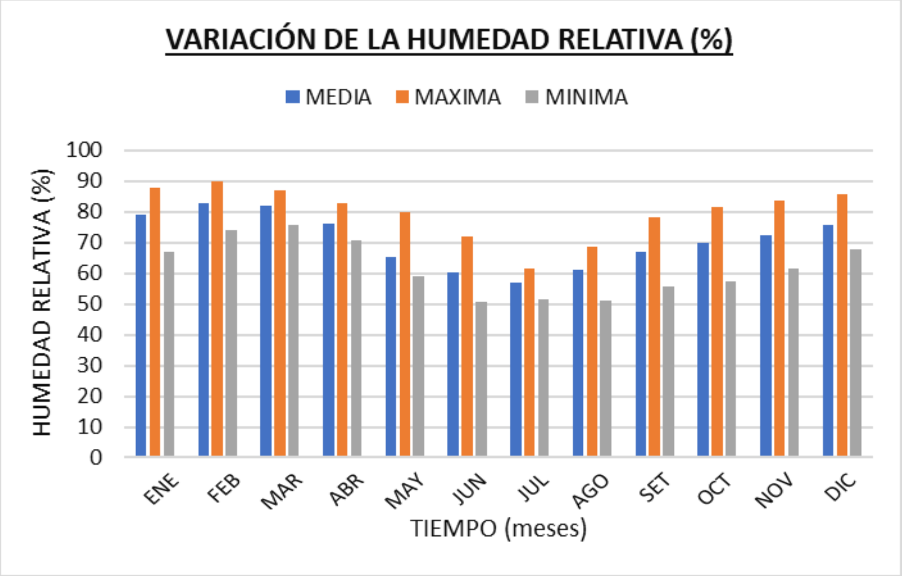


RELATIVE HUMIDITY

For the following parameter, the values of Station 5 are being taken into consideration, in which a minimum registered Relative Humidity of 50.6% is presented, the average humidity recorded is 70.8% and the maximum relative humidity registered is 89.8%, this variation is shown below in Figure 4.

Figure 4. Relative Humidity Variation - Station 5

	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SET	OCT	NOV	DIC
MEDIA	79.2	83	82.1	76.2	65.1	60.4	57.1	61.1	67.1	69.8	72.4	75.7
MAXIMA	87.9	89.8	86.9	82.8	79.8	72.1	61.5	68.6	78.4	81.5	83.8	85.8
MINIMA	66.9	74.1	75.7	70.9	59.1	50.6	51.5	51.3	55.8	57.4	61.7	68



RESULTS AND DISCUSSION

Considering geological mapping at scale 1:25 000, where the main types of rocks, soils and structures (faults, fractures and joints that influence the percolation of groundwater) are zoned, giving importance to lithology. Hydrogeological mapping characterized each geological formation formation, differentiating its permeable and impermeable properties and zoning rock reservoirs with their ability to store and transmit groundwater, called aquifers.

In the fieldwork, 04 control piezometers were drilled to determine the hydraulic parameters and groundwater quality control, these tests helped to obtain a hydrogeological correspondence through hydraulic conductivity (Custodio, 1983).

The hydrogeological characterization considered as basic information the geological cartography, with a lithological and structural analysis, the permeability tests and the inventory of sources, identifying the groundwater outcrops, with their respective discharge conditions and physicochemical properties. This characterization served to elaborate the hydrogeological map, zoning rocks and soils with characteristics of storage and movement of groundwater, as well as rocks and soils with impermeable properties.

DRILLING AND INSTALLATION OF PIEZOMETERS

Drilling for piezometers and observation wells facilitates efficient implementation in agricultural areas, industrial facilities or in any operation with subsoil and aquifer monitoring needs. Such facilities vary from, refineries, hydrocarbon warehouses, mining tailings, stables with industrial volumes, etc. Drilling for piezometers and observation wells are mainly used for two types of tasks.

A. Monitoring of toxic levels, contamination of aquifers and subsoil.
B. Water table behavior for performance studies.

PIEZOMETER DRILLING

04 control piezometers were drilled to determine the hydraulic parameters and quality control of groundwater, in the area of influence of the Quarry.

The following Image 5 shows the Ingetrol Model Explorer Plus WL drill in full drilling work of Piezómetro No 01 (Pz-01) in the environment.

Figure 5. Piercing of the Piezometer

Source: DMG Drilling Peru observation wells.

INSTALLATION OF PIEZOMETERS

Once the perforation of the piezometers was completed, the piezometers were piped with PVC pipes 21/4 inches blind and grooved according to the technical design of the piezometers, which will serve the purposes mentioned in this study. The installation of piezometers (Pz-01 and Pz-02) complying with the Standard Operating Procedure (SOP), necessary to guarantee the quality and safety of the installation of control piezometers as can be seen in Image 6.

Figure 6. Blind Pipe Installation

Source: DMG Drilling Peru observation wells.

INVENTORY OF GROUNDWATER SOURCES

Waters can be classified by mentioning only the most important cation and anion, e.g. Ca-SO4, or mentioning ions that exceed a certain percentage. The most common is to characterize the type of water by ions exceeding 10 % c(eq). The nomenclature begins with the most important cation, ordering the following cations according to their decreasing percentage and continuing the same with the anions. Al (Aluminium) and Fe (Iron) sometimes exceed 10 % c(eq) in waters with pH < 4.5, due to the previous oxidation of metal sulphides and the high solubility of metals in these acidic waters.

COLLECTION OF GROUNDWATER SAMPLES

Regarding the collection of groundwater samples, field parameters were taken from 04 control points corresponding to piezometers (PZ-01, PZ-03, PZ-04 and E-12).

Table 2. Location of groundwater sampling points.

COD	Location	Elevation, Land masl	Sampling date
PZ-01	Hidden Geniococha	4806	21/08/2009
PZ-03	Lower Tinyag (road)	4591	20/08/2009
PZ-04	Tagus Tinyag 1	4592	21/08/2009
E-12	Dry Lagoon	4452	22/08/2009

Source: Exploratory drilling from April to November 2012.

STATE OF THE WELLS

From the inventory of all piezometers in the study area, the static level was found at 04 piezometers, below are the depths of the static levels found in the inventoried piezometers:

1) PZ-01 at 5.35 meters deep.
2) PZ-02 (dry).
3) PZ-03 at 7.88 meters deep.
4) PZ-04 at 2.90 meters depth.
5) E-12 at 26.97 meters deep.

USE OF WELLS

For the present study, 04 wells have been inventoried, of which all are used purely for groundwater monitoring purposes by the Unidad Minera Mina S.A., in their entirety are in operation. The most important units are found in the sedimentary sequences of the Casapalca, and also in the crystalline intrusive rocks of monzonite quartz, the strata present great heterogeneity, and reduced primary permeability contributed by the concentration of fractures, so the recharge is limited to these units, controlled by the presence of faults, fractures and weathered areas.

The discharge of groundwater occurs by means of mineralized veins and drusen 1.5 to 4 m thick, drainage lines are centered on galleries and lateral and deepening chimneys. The results of the surface and depth hydraulic tests are shown in Table 3.

Table 3. Summary of hydraulic characteristics by hydrogeological unit.

Stratigraphic unit	Hydrogeological Unit	Lithology	Hydraulic Conductivity	
			M/s	m/d
Quaternary	Fluvioglacials	Clay with gravel	8.0 E-7 - 6.9 E-6	0,07-0,6
Fm Casapalca	Inferior	Marls and Limonites	2.5 E-5 - 9.8 E-5	0,002-0,3
	Middle	Vetas, deep work	2.5 E-5 - 9.8E-5	0,28-3.0
	Middle	Sandstone, quartz, fractured	1.9E-5 - 2.3E-5	1.7-2.0

Source: exploratory drilling from April to November 2012.

CONCLUSIONS

It was concluded that the hydrogeology of the study area based on the permissible limits will allow to find new sources of water supply and that are used in human and agricultural consumption, to evaluate the current situation of the resource, the main factors that affect the quality of water, have character of semi-detailed studies, supported by recognition and analysis information. Based on the geological mapping, the permeability tests and the source inventory map, the hydrogeological characterization table has been made. The study area and its surroundings stratigraphically belong to the Cretaceous sedimentary basin and is structurally located in a zone of folds and on runoff. Field results are limited to underground hydrogeological studies. All the tests correspond to a semipermeable lithology, the values allow us to classify these materials as moderately permeable rocks and assign them a poor hydrogeological evaluation of the aquifer.

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