Prospective Analysis of Water Supply Through Analytical Methods for a High Andean Population

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Abstract

The main objective of this article is to find an adequate hydrological development plan worldwide, taking into account the resources that Peru has, through different databases such as scientific articles, magazines, and national and international theses, demonstrating that various countries have a relative abundance of water resources that represent a large percentage of the world's water capital. The methodology presents four methods for the calculation of the future population and later the calculation of the necessary flow to supply the high Andean population.

The results are presented using two methods: graphic and numerical. Based on the results, an interpretation of the data obtained was made. Finally, this paper provides conclusions that are based on the decrease in water supply in the high Andean areas, for which it was possible to estimate the demand for water for the development of the high Andean areas and an improvement in the quality of life for their population. In summary, it has finished analyzing the approximation between the years 2022 and 2037 as well as the data collected for the investigation.

Keywords

Water Management, Hidric Resource, Shortage, Hydrological and Investigation

1. Introducción

In recent years, awareness has begun to be raised about the importance of the entire population having a water supply, and even more so of having an estimate of how the population is increasing and how it will continue to be supplied in the coming years. Water governance is a broader concept than water management. (Moench 2003). and refers to "the range of political, social, economic, and administrative systems that exist to regulate the development and management of water resources and the provision of water services at different levels of society" (Rogers and Hall 2003). Over the past few decades, considerable progress has been made to expand access to water and sanitation services globally.

The lack of drinking water in rural areas of our country results in the presence of acute diarrheal diseases (ADD) in its population, which are the second leading cause of death in children under 5 years of age (according to WHO 2019), due to That is why it is critical that all populations have complete access to safe drinking water.However, "Water scarcity can be defined as the point at which user consumption affects the supply or quality of water, such that the demand cannot be fully satisfied." (The UN Refugee Agency 2019). That is why, according to the WHO/UNICEF Joint Monitoring Program (JMP 2017), the number of people who access basic water and sanitation services increased from 350 million to 700 million in the world. In addition, according to data from the World Resources Institute (WRI 2019), more than 1,000 million people currently live in regions with water scarcity, and up to 3,500 million could suffer from water scarcity in 2025. The projection mentioned above is very worrying, and in Peru there are still many places that do not have that water service, as our study area does not have this basic service, specifically the Rancha Populated Center, which is taken as an example to present the changes that the population will have during the following years in relation to its lack of water.

These communities are often remote from urban settings, where investment in water and sanitation infrastructure is often warranted (RWSN 2018).

These resources are present in urban areas. In rural and isolated settlements, they are scarce as investments in infrastructure, labor, and external support from public and private entities often do not meet the requirements of the community. All people should have access to this necessity. Water is a critical resource for human communities; since 1948, the UN has recognized water as a human right (Gleick 1998).

Peru is one of the richest countries in the world in terms of water; the problem lies mainly in the unequal distribution of this resource. According to the National Water Authority, the average annual volume of water in Peru is 1.768172 million cubic meters, which could lead one to think that the country does not present any problem in supplying this resource; however, 97.27% of the water availability is distributed in the Sierra and Amazonia, which are home to only 30.76% of the population.

On the other hand, 2.18% of the water availability is found on the Pacific slope, which is home to 65.98% of the population. Water stress on the Peruvian coast is high and worrying. According to the INEI National Household Survey (ENAHO 2018), more than 3.6 million Peruvians do not have access to drinking water. Of this number, some 342,000 people live in Lima and are supplied, above all, through tanker trucks, which means a high cost for them, unlike households that have this service. (Care 2021)

In Peru, sanitation services, be they drinking water, sanitary sewerage, wastewater treatment, or sanitary disposal of excreta, are provided in urban areas by provider companies (EPS) and in small cities, which are outside the scope of an EPS, by municipalities through municipal management units (UGM) or specialized operators. Meanwhile, in rural areas, those in charge are the community organizations that supply the population centers. (Supreme Decree and National Sanitation Plan 2021)

The purpose of this article is to contribute to the growing body of knowledge about the provision of water service to small towns and to learn about the peculiarities and challenges of providing public services in rural areas.

1.1 Objectives

- Describe, with data obtained from reliable sources, what is the current situation in Peru regarding access to water through the public network.
- Determine the future population of a populated center that would benefit from access to water through the public network.
- Determine the flows to supply the water demand of the population.
- Analyze the data obtained to demonstrate the feasibility of a water supply project, plotting a possible solution alternative, to reduce the rates of water deficit by public network in Peru.

2. Theoretical Framework

Water is a fundamental human need. According to the United Nations, each person on earth requires at least 20 to 50 liters of clean and safe drinking water per day to drink, cook, and simply stay clean. It regards access to clean water as a basic human right and as an essential step towards a better standard of living throughout the world. Communities lacking water resources are generally economically poor, and their residents are trapped in a vicious cycle of poverty.

Access to drinking water service in Peru

According to data obtained by the National Institute of Statistics and Informatics (INEI 2019), in the rolling year May 2019–April 2020, 90.8% (or 29 million and 525 thousand) of the country's population accesses water for human consumption from the public network (inside the home, outside the home, but inside the building or pylon for public use).

Table 1. Peru: Population that consumes water from the public network, by area of residence

Perú: Población que consume agua proveniente de red pública, por área de residencia
Año móvil: Mayo 2019 - Abril 2020
(Porcentaje)

Año móvil	Nacional	Urbana	Rural
Indicadores anuales			
Abr 2018 - Mar 2019	90,9	95,2	75,2
May 2018 - Abr 2019	90,8	95,1	75,3
Jun 2018 - May 2019	90,9	95,2	75,5
Jul 2018 - Jun 2019	90,8	95,1	75,1
Ago 2018 - Jul 2019	90,7	95,1	75,0
Set 2018 - Ago 2019	90,7	95,0	75,0
Oct 2018 - Set 2019	90,7	95,0	75,0
Nov 2018 - Oct 2019	90,7	94,9	75,3
Dic 2018 - Nov 2019	90,8	95,0	75,3
Ene 2019 - Dic 2019	90,8	94,9	75,6
Feb 2019 - Ene 2020	90,8	95,0	75,5
Mar 2019 - Feb 2020	91,0	95,1	75,8
Abr 2019 - Mar 2020	91,2	95,0	76,8
May 2019 - Abr 2020 P/	90,8	94,8	76,3
Diferencia con similar año anterior (puntos porcentuales)			
May 2018 - Abr 2019/ May 2019 - Abr 2020	0,0	-0,4	1,0

Source: Peru: Forms of Access to Water and Basic Sanitation (2020)

As we can see from the previous figure, 94.8% of people access water from the public network in urban areas and 76.3% in rural areas.

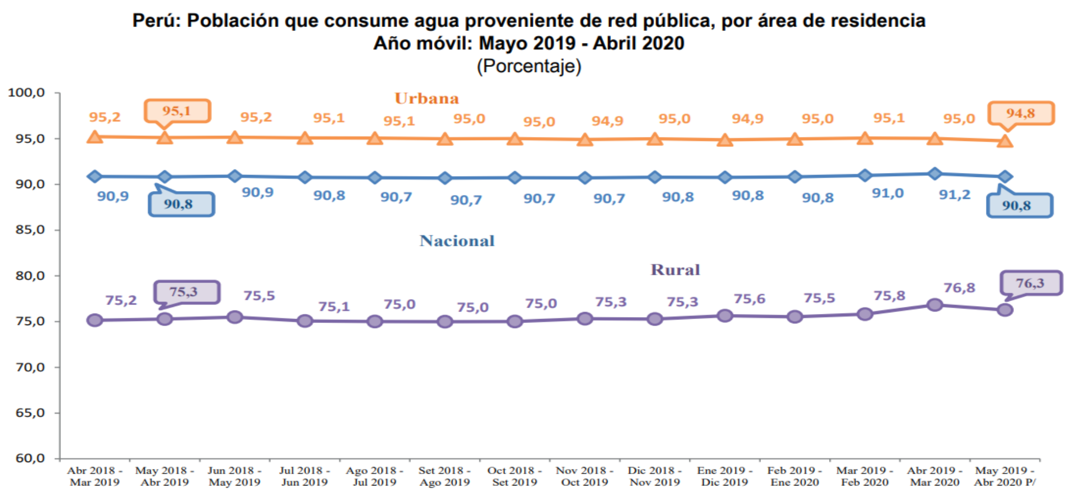

Figure 1. Peru: Population that consumes water from the public network, by area of residence
Source: Peru: Forms of Access to Water and Basic Sanitation (2020)

However, we also have the population with a deficit in water coverage by the public network, and according to the data obtained by (INEI 2020), it tells us that in the mobile year May 2019-April 2020, 9.2% of the total population of the country does not have access to water through the public network, that is, they are supplied with water in other ways: tanker truck (1.2%), well (1.6%), river, ditch, spring (3 .5%) and others (2.8%).

Access to water through public network according to natural region

In 2019, according to the regional level, 95.1% of households on the coast are supplied with drinking water by public network, in the mountains with 88.0% and in the jungle with 78%.

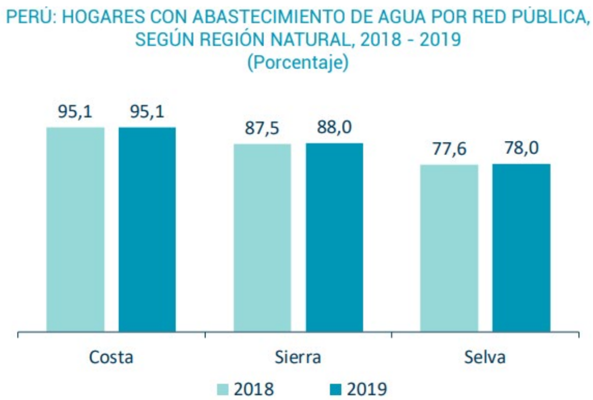

Figure 2. Peru: Households with water supply by public network, according to natural region, 2018–2019
Source: Access to basic services in private homes.

According to the graph shown, it can be seen that in 2018 and 2019, drinking water can be supplied, but it is a very small percentage. In the mountains, it increased by 0.5%, and in the jungle, it increased by 0.4%. That means that not much work has been done on water supply and that there are many places without access to water in their homes.

Access to water through the public network by department

As of 2019, in 14 departments, more than 91% of the population consumes water from the public network (inside the home, outside the home, but inside the building or pylon for public use), highlighting within this group the departments of Moquegua, Tacna, the Constitutional Province of Callao, Apurmac, Arequipa, the Province of Lima, ncash, and Lambayeque. Meanwhile, the population of the departments of Tumbes (78.8%), Ucayali (75.7%), Huánuco (73.1%), Puno (71.6%), and Loreto (56.3%) presents less water coverage by the public network.

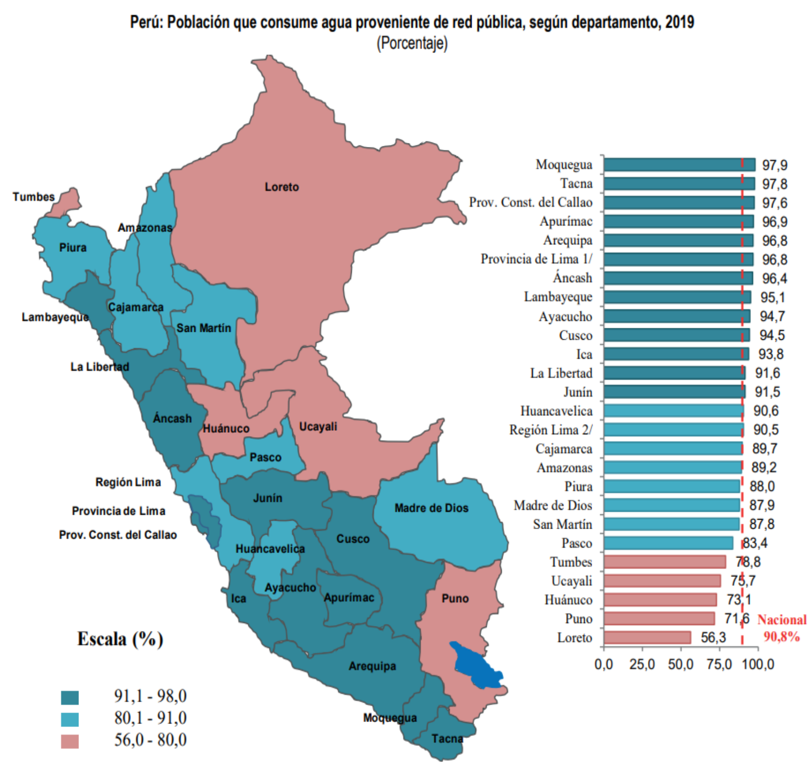

Figure 3. Peru: Population that consumes water from the public network, by department, 2019
Source: Peru: Forms of Access to Water and Basic Sanitation (2020)

Although progress has been made in providing these services, there are still deficiencies, especially in rural areas and marginal urban areas occupied by populations with higher levels of vulnerability due to the conditions of poverty in which they live.

3. Metodología

The research methodology in this mathematical case will allow us to take an average of the three closest methods to determine the future population that will benefit from the water supply in the Rancha Populated Center; therefore, the following mathematical methods were used:
3.1. Método Aritmético

It is defined as the average rate of population increase that is assumed to be constant from decade to decade. This increase from decade to decade is based on census data obtained by the country's office in charge of census and statistics (Mekonnen 2018). The data obtained and the number of decades necessary for the calculation are added to the current population of the city; this future population will be calculated with the following formula:

$$P = P_0 + r(t - t_0) \quad (1)$$

$$\frac{dP}{dt} = cte. \quad (2)$$

Where:
P = Population to calculate
Po = Initial Population
r = Growth Rate
t = Future tense
to = Initial Time

a) <u>Intercensal Population</u>

$$r = \frac{P_{i+1} - P_i}{t_{i+1} - t_i} \quad (3)$$

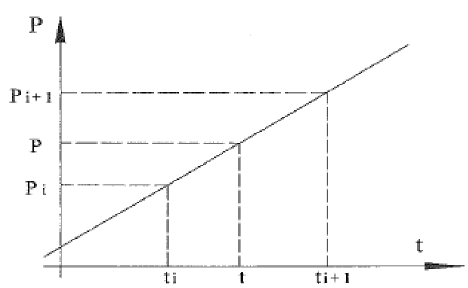

Figure 4: Water supply and sewerage- Vierendel

3.2. Simple Interest Method

The method is applicable for slow-growing populations since it gives low values; money grows as a capital subject to simple interest.

$$P = Po * [1 + r(t - to)] \quad (4)$$

$$r = \frac{P_{i+1} - P_i}{P_i(t_{i+1} - t_i)} \quad (5)$$

Where:
P = Population to calculate
Po = Initial Population
r = Growth Rate
t = Future tense
to = Initial Time

3.3. Geometric method

The population grows in the same way that a capital invested at compound interest grows. This method is used when the population is in the initiation or saturation phase, but not when it is in the phase of free growth.

$$P = P_O * r^{(t-t_o)} \quad (6)$$

$$r = \sqrt[t_{i+1}-t_i]{\frac{P_{i+1}}{P_i}} \quad (7)$$

Donde:
P_f = Population to calculate
P_o = Initial Population
t = Time in which the population is calculated
t_o = Final Time
r = Population change factor
Note: For ease of calculation, use the difference.

3.4. Compound Interest Method

This method gives higher values; that is, it is applicable for populations that are in the initiation stage or because the population is growing as a capital subject to compound interest.

$$Pf = P_0(1 + \bar{r})^t \quad (8)$$

$$r_i = \left(\frac{P_{i+1}}{P_i}\right)^{\left(\frac{1}{t_{i+1}-t_i}\right)} \quad (9)$$

$$\bar{r} = \frac{\sum_{i=1}^{i=n}\left(\sqrt[t_{i+1}-t_i]{\frac{P_{i+1}}{P_i}}\right)}{n-1} \quad (10)$$

Donde:
P_f = Future Population
P_o = Initial Population
r_i = Intercensal growth rate
$\bar{r}$ = Average growth rate (average ri)
t = Time in years between PF and PO.

n = Count of data from census information

4. Data collection

1. Zone delimited by Google Earth Pro:

   The first step we took as a group to create the topographic plan was to delimit our work area with reference to the 410 lots we worked on:

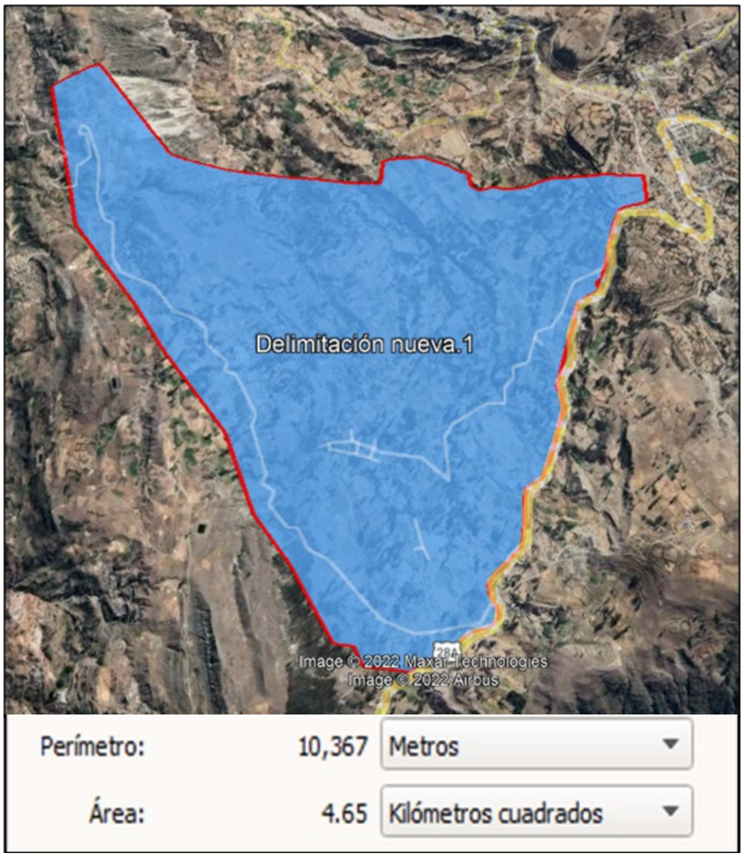

Figure 5: Delimitation of the study area
Source: Own elaboration

Data on the total number of inhabitants extracted from the INEI from the national censuses of 1993, 2007, and 2017 were used to determine the future population benefiting from the water supply in Rancha.

1. INEI census from 1993, with a total population of 565 people.
2. INEI census from 2007 shows a total population of 571 people.
3. According to the 2017 INEI census, the population is 657 people.

5. Results
5.1. Numerical result

As we can see, censuses were taken in 1993, 2007, and 2017, with an initial population of 565, 571, and 657, respectively. Then you see the table where the number of inhabitants is established with a range of years, which helps us to interpolate and find an approximate future time for which the project will be designed. As shown in Table 2:

Table 2. Interpolation for a future time.

Census	Po INEI
1993	565
2007	571
2017	657

400-2000	10 A 15
2000-10000	15-20
HIGHER	20-30

400	10		
657	X	10,803125	**11**
2000	15		

It will be designed for a future age of 11 years.

Source: Own elaboration

With the time obtained, we projected from 2026, which ends the execution of the project, to 2037. Later, we obtained the average r2, r1, and r for each specified method. Likewise, the future population was calculated for each year, as specified in the following tables, with the respective formulas that can be seen in the methodology section of this article.

Table 3. Arithmetic method

ARITHMETIC METHOD	
r2	8,6
r1	0,428571429
rprom	4,514285714

AÑO	POBLACIÓN
1993	565
2007	571
2017	657
2022	680
2023	684
2024	689
2025	693
2026	698
2027	702
2028	707
2029	711
2030	716
2031	720
2032	725
2033	729
2034	734
2035	738
2036	743
2037	747

Table 4. Simple interest method

SIMPLE INTEREST METHOD	
r2	0,0150613
r1	0,00075853
rprom	0,00790991

AÑO	POBLACIÓN
1993	565
2007	571
2017	657
2022	683
2023	688
2024	693
2025	699
2026	704
2027	709
2028	714
2029	719
2030	725
2031	730
2032	735
2033	740
2034	745
2035	751
2036	756
2037	761

Source: Own elaboration

Table 5. Growth method

GEOMETRIC GROWTH METHOD	
r2	0,014128356
r1	0,001056906
rprom	0,007592631

AÑO	POBLACIÓN
1993	565
2007	571
2017	657
2022	682
2023	688
2024	693
2025	698
2026	703
2027	709
2028	714
2029	719
2030	725
2031	730
2032	736
2033	742
2034	747
2035	753
2036	759
2037	764

Table 6. Compound interest method

COMPOUND INTEREST METHOD	
r1	0,00075482
r2	0,01412836
rpromedio	0,00744159

AÑO	POBLACIÓN
1993	565
2007	571
2017	657
2022	682
2023	687
2024	692
2025	697
2026	702
2027	708
2028	713
2029	718
2030	723
2031	729
2032	734
2033	740
2034	745
2035	751
2036	756
2037	762

Source: Own elaboration

5.2. Graphic Result

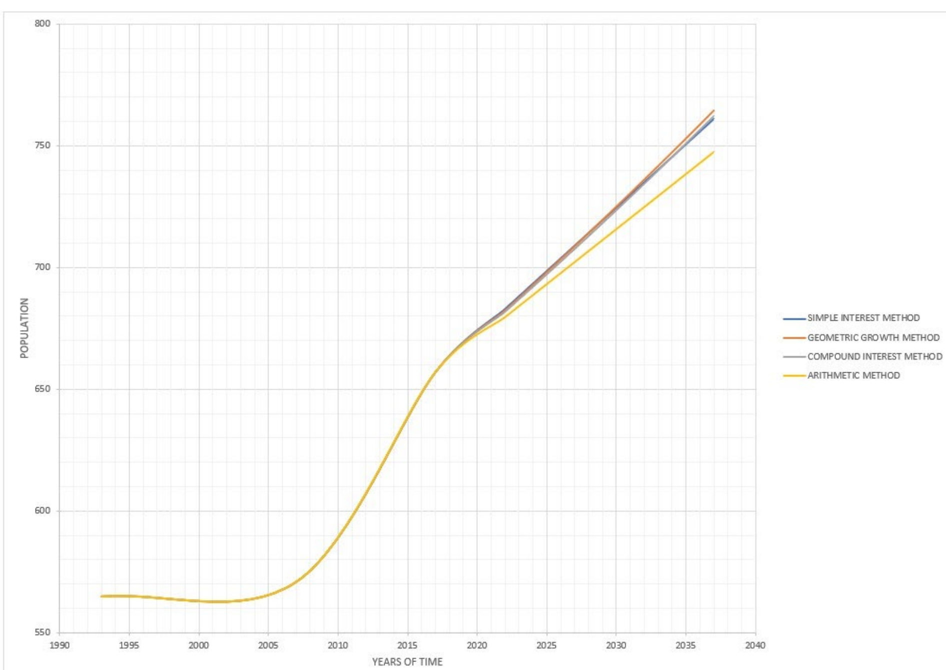

Figure 6. Curves for comparison of methods.
Source: Own elaboration

We apply the average of the three most similar future populations, obtaining:

$$Pf = (761+764+762) / 3$$
$$Pf = 762$$

Having already obtained the results of each method, we chose the most feasible for the population and the project. In this case, the simple interest method was the most feasible, so these are the data that would be taken for the execution of a possible project in this populated center.

To determine flow rates:

Having a population of 657 people in 2017, we have to find the current population in 2022 with the formula of the simple interest method, giving us a total of 683. Next, we also calculated the number of inhabitants for 2037, giving us a total of 761 inhabitants. Finally, we proceeded to calculate the average flow, maximum daily demand flow, maximum hourly demand flow, and MDD using the formulas indicated in the methodology section.

Table 7. Table for calculating flows and maximum daily demand

Populated	**2017**	**2022**	**2037**	**Qp**	**Qmd**	**Qmh**	**MDD**
Rancha	**657 Hab**	**683 Hab**	**761 Hab**	**1.28**	**1.66**	**3.2**	**111**

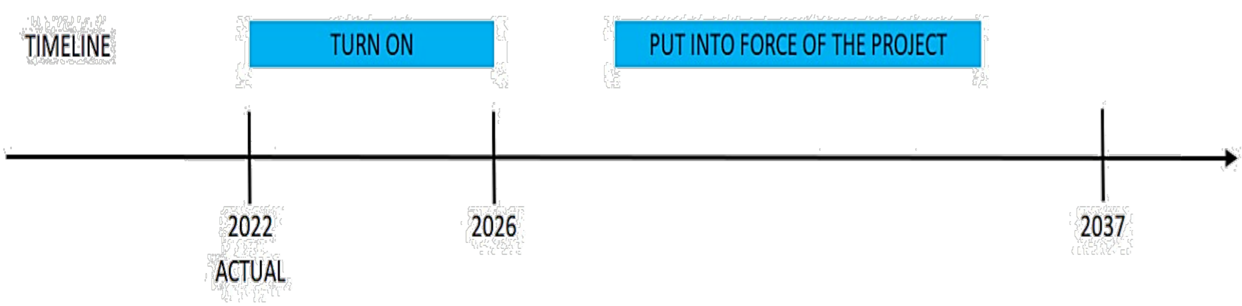

Figure 7. Timeline of project deadlines
Source: Self-made

Water source

In our study area, the closest source of water was from a canal located in the district of Huamanga, with:

- Coordinates: 579276.00 m E - 8538893.00 m S.
- Flow: 2.5 m3/sec
- Elevation: 3543 m.s.n.m.

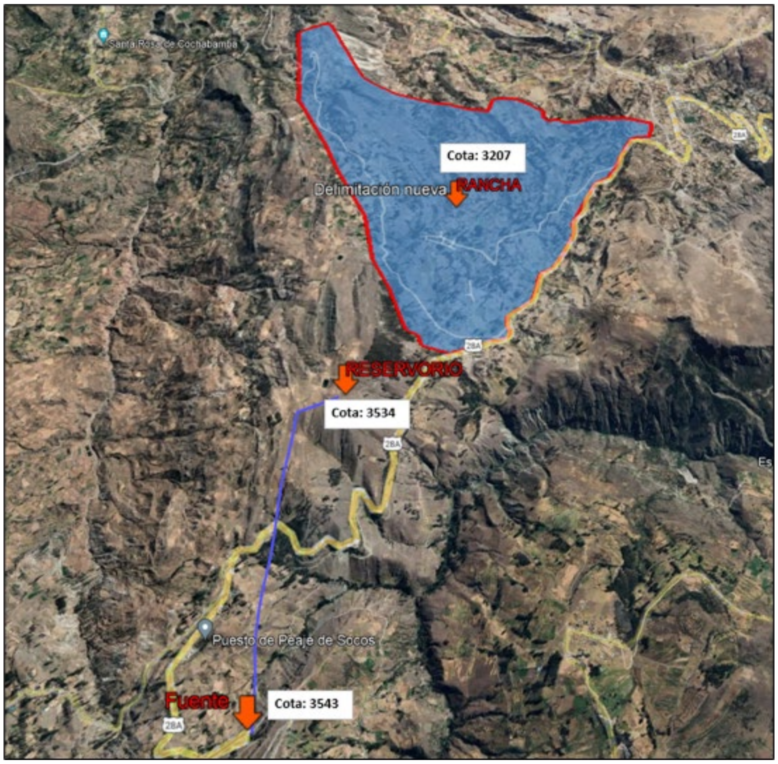

Figure 8. Design of a possible collection source
Source: Own elaboration in Google Earth Pro.

6. Conclusions

- The methods presented have been updated and corrected over time (1993, 2007, and 2017); as a result, the method that behaves most appropriately with the data provided by the INEI is the simple interest method, because finding a population in rural areas is more feasible.
- The future population obtained and benefited, which makes us notice that it is possible to reduce the water supply deficit in our country. Only in Huamanga would the gap be reduced by 7% of the non-beneficiary population.
- The research carried out shows us the reality that Peruvians live in the high Andean (rural) areas without access to drinking water. In the particular case of the Rancha Town Center, it was possible to estimate the demand for water for the development of the Town Center and an improvement in the quality of life for its population.
- The maximum daily flows and maximum hourly flows have been calculated for the town of La Rancha, for its subsequent conduit and distribution design.
- According to the article, we have a future population in which there is a slight increase, and with this, we have already found the population intercensal rate using the formulas with which the reserve volume that will supply the population will be determined.

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Biographies

Jair Gómez Mendoza, a Peruvian born in Huamanga, Ayacucho, in 1996, is currently a university student at the Ricardo Palma University in the Faculty of Engineering, Civil Engineering professional school; the specialization in roads and transport was chosen.

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Paulo César Huanaco Ccorahua was born in Lima, Peru, on October 26, 2000. He entered Ricardo Palma University at the age of 18. He is currently a student and is in the 8th cycle of his civil engineering career.

Leonardo Porras, a Peruvian born in Lima, Peru, in 1998, is currently a Civil Engineering student at the Ricardo Palma University in Lima, Peru. area of interest in geotechnics, specifically in the mining sector. One of his achievements is belonging to the ACI-URP, being part of the conferences given as a student group, and having performed on site.

Ladhy Sierra Yaya is currently a civil engineering student at the Ricardo Palma University in Lima, Peru. He wants to focus on the highway area because he loves helping people, which allows him to find and connect with different people. With their experience, knowledge, and attitude, they have led her to meet wonderful people who enrich her life.

