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Hydrogeological Comparison of Three Wells with a Basin Approach in the Nandaime-Rivas Aquifer, 2021

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Abstract

In general, the content of this study is aimed at presenting a comparative analysis of the hydrogeological results of three underground sources. The points or sources of analysis are the Dolores 01, Dolores 02 and Mecatepillo wells, which are registered at the following coordinates: East 610561, North 1292576, East 610234, North 1293090, East 611482, North 1293881, respectively, according to the UTM WGS system 84 Zone 16N, the analysis is done with a basin approach in the Nandaime-Rivas aquifer. According to the above, bibliographic resources have been consulted that help to further understand the comparative criteria such as transmissibility, storage coefficient, a radius of influence and thickness of the aquifer, providing complementary and additional information.

Keywords

Hydrogeology, Well, Transmissibility, Hydraulic Conductivity, Flow Rate, Thickness, Radius of Influence

1. Introduction

The main sources for use for irrigation are surface and groundwater. Therefore, the protection and sustained use of the water resource contained in the hydrological unit, is important; therefore, "knowledge of the availability and hydrodynamics of aquifers is a tool that contributes to the strategic planning of management and management of water resources" [1].

The hydrogeological analysis will be done with a basin approach, and according to its origin, for this case, the Dolores 01, Dolores 02 and Mecatepillo sources will be studied, which are underground sources located at the following coordinates: East 610561, North 1292576, East 610234, North 1293090 and East 611482, North 1293881 respectively according to the UTM WGS-84 Zone 16N system.

According to [2], for the year 2004 a good inventory was carried out in the Nandaime-Rivas aquifer, both drilled wells and excavated wells, totaling 124 wells.

He continues to state [2], that the groundwater flows are variable depending on the place, the demand and the potential of the aquifer, and that in the southeastern area the values range between 8 to 341 m^3/h, likewise in the southeast zone from 136 to 314 m^3/h. In the northeast, it varies from 24 to 296 m^3/h.

To verify the analysis of [2], the study of three wells was carried out as an underground source with a basin approach in which a hydrogeological comparison is integrated into a said aquifer.

For the hydraulic characteristics of the aquifer, information was obtained from pumping tests of 44 wells from the files of the INETER Hydrology Directorate and from pumping tests carried out in the study.

In the southeastern part of the area, the transmissibility values vary between 128 to 1132 m^2/day, distributed in Las Mercedes, El Peludo, and Rio Chiquito. In the center of the town of Nandaime, Finca el Paraíso, the values found are from 620 to 2000 m^2/day.

Likewise, in the southeastern part of the area, the values range between 128 to 1132 m^2/day, located in the Los Porvenires, El Paraíso, Candelaria dam, Las Conchitas, etc. In the northeastern part of the area, these range from 368 to 2144 m^2/day. In Barrio la Orilla, la Barranca, Los Ranchones, San Felipe farm, el Carmen.

Likewise, in the southeastern zone in the town of La Hormiga, San Rafael, there is no information on wells. In this case, the range with geology $1 < T < 10$, called LOW, was determined.

Geographical Location of the Study

Specifically, the study of underground sources is located at km 77 of the Rivas Nandaime road, 1 km to the east. According to the hydrographic basins of Nicaragua, the sites of interest are circumscribed within the 69 Rio San Juan basin, at an elevation of 68.8 meters above sea level for Dolores 01, 67.7 meters above sea level for Dolores 02 and 67.9 meters above sea level for Mecatepillo, the coordinates of the points are East 610561, North 1292576, East 610234, North 1293090 and East 611482, North 1293881. See **Figure 1**.

2. Methodology

Kind of investigation

The research design is quantitative since the hydrogeological behavior of three wells was analyzed through the hydraulic characteristics in the Nandaime-Rivas aquifer in the year 2021.

Execution time

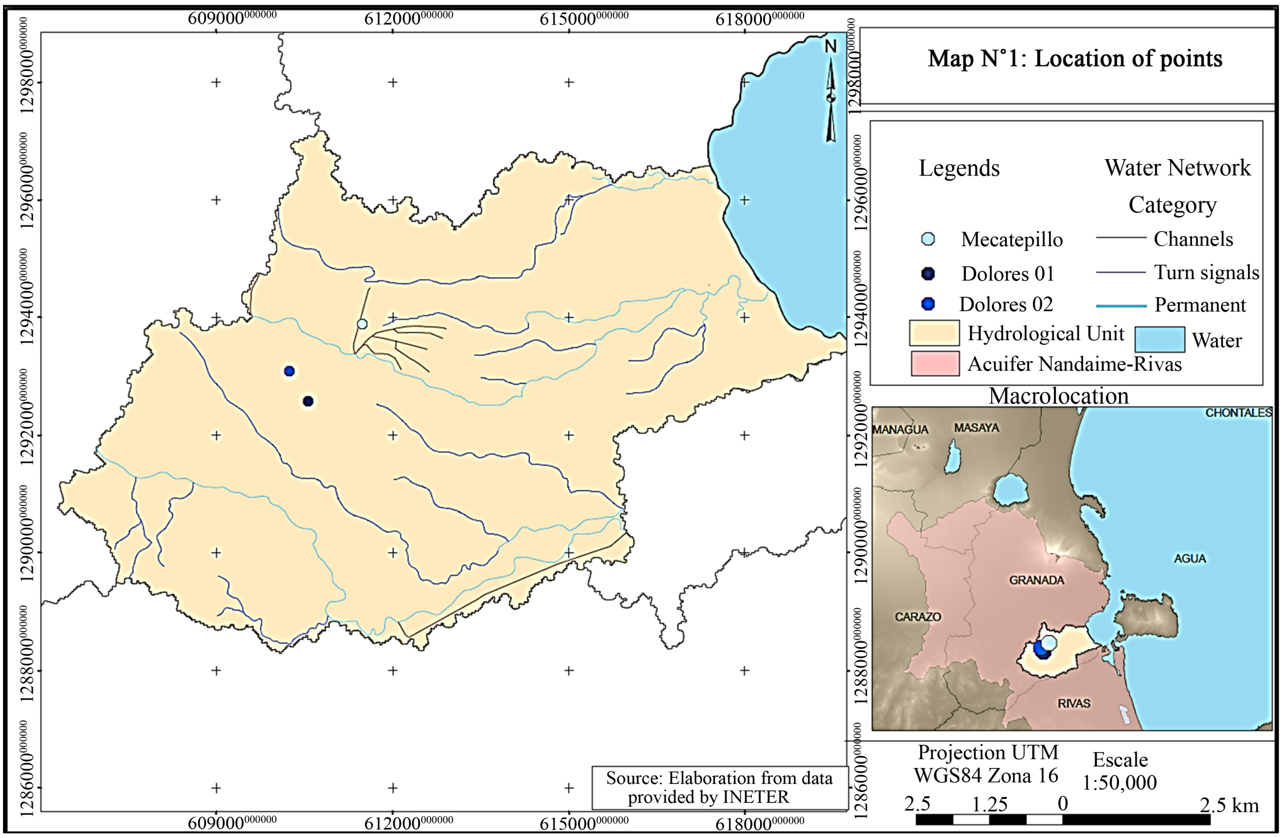

Figure 1. Location of study points. Source: [3].

The development of the research, to meet the proposed objectives, was carried out in a single time, in a month of work, a day of data collection, 15 days for data analysis and 15 days to present results in the June period to July 2021.

Data Collection Techniques and Methods

Primary Sources

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Secondary Sources

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(UANA-Managua).

Library of the National University of Engineering (UNI).

Center for Research on Aquatic Resources of Nicaragua, Managua (CIRA-UNAN-Managua).

Archives of the National Water Authority (ANA).

Universe

They are all the underground waters of Nicaragua, that is, all the aquifers including the Nandaime-Rivas aquifer.

Sample

It will be the Nandaime-Rivas aquifer, specifically the three wells described above, Dolores 01, Dolores 02 and Mecatepillo

Inclusion criteria

Underground water sources,

The sources belonging to the Nandaime-Rivas aquifer.

Exclusion criteria

Surface water sources,

Sources that do not belong to the Nandaime-Rivas aquifer.

Hydraulic Characterization of Groundwater

According to [3], the hydraulic characterization of groundwater is listed in the following ways:

Transmissibility

It is the amount of water that an aquifer transmits through the entire saturated thickness in a unit area per unit of time (t). [4] and [5]

It is determined from the following expression:

$$T_{pozo} = 0.183 \frac{Q\left(\frac{\mathrm{m}^3}{\mathrm{dia}}\right)}{\Delta S(\mathrm{m})} \tag{1}$$

where:

Q = flow rate in m^3/day,

ΔS = Drawdown drop in m.

To determine the transmissibility of the aquifer, it is done from **Table 1**.

Hydraulic Conductivity (K)

The hydraulic conductivity is related to the saturated thickness tested, also considered as the volume of gravific water that percolates during the unit of time through a surface unit of a section of land under a hydraulic gradient equal to the unit [8]

$$K = \frac{T\left(\frac{\mathrm{m}^2}{\mathrm{dia}}\right)}{M(\mathrm{m})} \tag{2}$$

where:

T = Transmissibility m^2/day,

M = Tested saturated thickness.

Table 1. Coefficient, class, denomination of transmissibility.

Transmissibility coefficient		Aquifer transmissibility		Regional comparative parameters corresponding to the transmissibility coefficient				Aproximate performance of wells a descent of 5 m	
				not logarithmic specific flow (q)			Logarithmic index Y		
m^2/day	gl/day/feet	Class	Denomination	m^3/h/m	l/s.m	gpm/feet		l/s	gpm
		I	Very high					>50	>793
1000	80,520			36	10	48.32	7		
		II	high					5 - 50	79.3 - 793
100	8052			3.6	1	4.83	6		
		III	moderate					0.5 - 5	7.93 - 79.3
10	805.2			0.36	0.1	0.48	5		
		IV	short					0.05 - 0.5	0.79 - 7.93
1	80.52			0.036	0.01	0.048	4		
		V	very low					0.005 - 0.05	0.079 - 0.79
0.1	8.052	IV	imperceptible	0.0036	0.001	0.0048	3	<0.005	<0.079

Source: retrieved from [6] and [7].

Determine the hydraulic conductivity of the aquifer, is done from the following Table 2.

Storage Coefficient

[9] and [10] It is dimensionless. It refers to the volume that the aquifer is capable of releasing when the piezometric level (or pressure) drops by one unit. It is defined as the volume of water that can be released by a vertical prism of the aquifer, with a section equal to the unit and height equal to the saturated thickness. The result corresponds to 0.01

Specific Capacity

[11] The specific capacity is the relationship between the flow rate and the saturated thickness.

Radius of Influence

[11] The radius of influence is the distance that the cone of depression reaches in the aquifer, when a well is pumped for a given time (t). The result depends on the transmissibility (T m^2/day) and the storage coefficient (S-dimensionless unit).

$$R = 1.5\sqrt{\frac{T \times \frac{t}{24}}{S}} \tag{3}$$

where:

T = transmissibility in m^2/day;

t = pumping time in hours;

S = Storage coefficient.

One way of characterizing the aquifer from the radius of influence can be seen in the following Table 3.

Table 2. Hydraulic conductivity rating.

K (m/day)	Qualification	Behaviour	
$K < 10^{-2}$	Very low	Waterproof	
$10^{-2} < K < 1$	Short	Poor aquifer	
$1 < K < 10$	Half		$K_h > K_V$ (K_h 10 to 20 times greater)
$10 < K < 100$	High	Good aquifers	
$K > 100$	Very high		

Source: retrieved from [6] and [7].

Table 3. Aquifer operation as a function of radius of influence.

Type of permeable material	How the aquifer works	Possible values of the radius of influence R
Kárstico	Free	700 m - 1000 m
	semi confined	1000 m - 1500 m
	Captive	1500 m - 2000 m
Intergranular porous	Free	400 m - 700 m
	semi confined	700 m - 900 m
	Captive	900 m - 1200 m
Kárstico and porous	Free	500 m - 1000 m

Source: retrieved from [6] and [7].

Material and methods

For the hydraulic analysis, the base information provided was provided on the gauged flows in the Dolores 01, Dolores 02 and Mecatepillo 08 sources, currently in use for irrigation; the calculation will be done individually to have a better appreciation of the use of the resource in the basin, with its respective hydraulic characteristics.

A single calculation methodology will be carried out since the same procedure is extended to the other wells; only the synthesized results will be presented.

Step 1: determination of transmissibility, with ecaution 1;

Step 2: determination of Hydraulic Conductivity, ecuation 2;

Step 3: calulation of Storage Coefficient and Specific Capacity;

Step 4: calculation of Radius of Influence, with ecuation 3.

3. Results

Table 4 summarizes the flows, depths, descent and diameter for each well studied.

Tables 5-7 describe the hydraulic characterization of each well.

Flow Versus Thickness

See the following Graph 1

Table 4. Results of flows, depth, descent and diameter.

Description	Flow (gpm) (m^3/d)	Depth (feet) (m)	Decline (feet) (m)	Diameter (Inch)
Dolores 01	820.34 gpm (4471.44 m^3/día)	300 pies (91.44 m)	0.68 pies (0.21 m)	10 pulg
Dolores 02	1056.57 gpm (5759.28 m^3/día)	300 pies (91.44 m)	2.35 pies (0.72 m)	10 pulg
Mecatepillo 08	845 gpm (4606.08 m^3/día)	220 pies (67.06 m)	0.69 pies (0.21 m)	8 pulg

Source: self-made (2021).

Table 5. Hydraulic characterization of the wells under study.

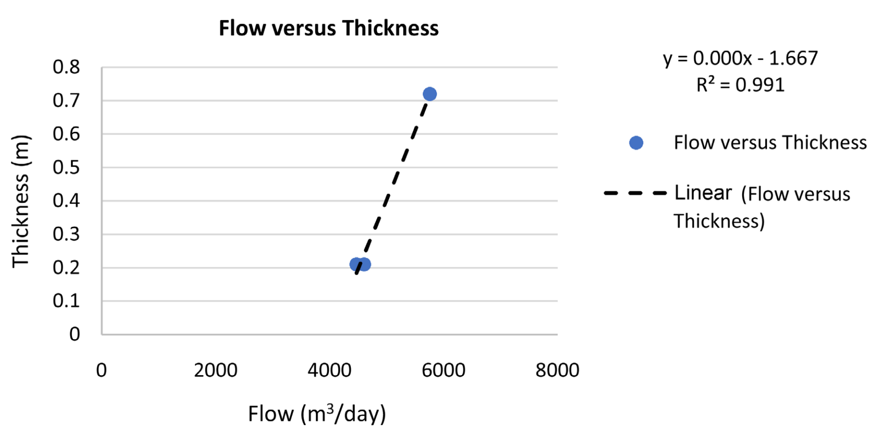
Source	Q (m^3/día)	ΔS (m)	T (m^2/día)	Denomination	Saturated thickness feet (m)
Dolores 01	4471.44 m^3/día	0.21m	3896.54 m^2/día	Very high	76.91 feet (23.44 m)
Dolores 02	5759.28 m^3/día	0.72m	1463.82 m^2/día	Very high	84.50 feet (25.75 m)
Mecatepillo 08	4606.08 m^3/día	0.21m	4013.87 m^2/día	Very high	90.50 feet (27.58 m)

Source: self-made (2021).

Table 6. Hydraulic characterization continued.

Source	K (m/day)	Qualification	Behavior	Ca (S)
Dolores 01	166.23 m/day	Very high		0.01
Dolores 02	56.84 m/day	Very high	good aquifers	0.01
Mecatepillo 08	145.54 m/day	Very high		0.01

Source: self-made (2021).



Graph 1. Thickness trend as a function of flow. Source: self-made (2021).

Table 7. Continuation and final hydraulic characterization.

Source	Ce (gpm/feet)	T (hrs)	Ri (m)
Dolores 01	10.67 gpm/feet	8.5	371.48 m
Dolores 02	12.504 gpm/feet	8.5	227.69 m
Mecatepillo 08	9.34 gpm/feet	24	633.55 m

Source: self-made (2021).

According to the graph, it is shown that there is a relationship between the flow and the thickness of the drawdown; this correlation is equal to 0.991. This means that by obtaining the flow, the thickness of the aquifer can be determined with the linear trend equation obtained.

Flow Versus Transmissibility

See the following Graph 2

The graph shows a trend of the negative slope, which is interpreted as, the higher the volume measured in the place, the lower the transmissibility, always maintaining a correlation of 0.9816.

Flow Versus Hydraulic Conductivity

See the following Graph 3

The graph shows a trend of the negative slope as well as the transmissibility with the flow, which is interpreted as, the higher the flow gauged in the place, the lower the hydraulic conductivity, always maintaining a correlation of 0.993.

Flow Versus Radius of Influence

See the following Graph 4

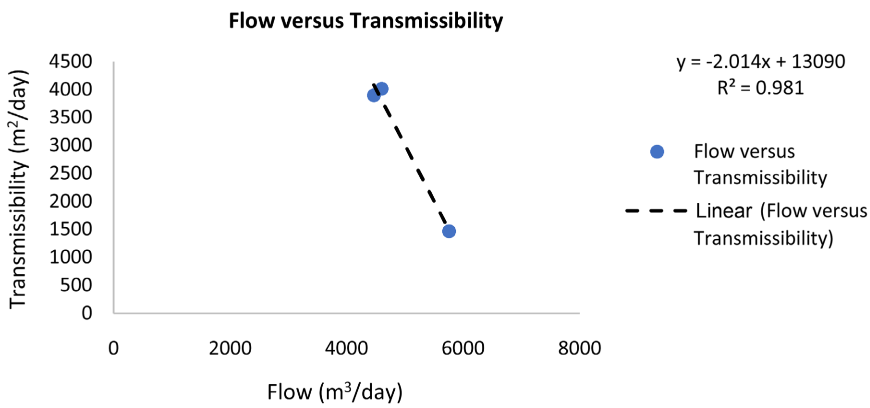
According to the results of the comparison of the hydraulic radius with the flow, a low correlation of 0.499 is manifested. In a speculated way, the result is due to the type of soil found in the area, if the use of the linear trend equation is recommended, discretion for well study purposes.

4. Analysis of the Results

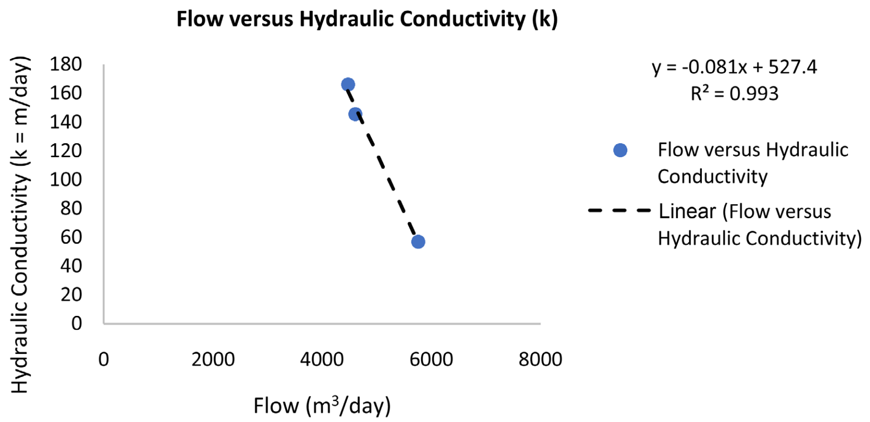
Regarding the flow versus the thickness, this presents a high correlation of 0.991, with a linear trend with a positive slope; that is, as the flow increases, the thickness of the depletion cone also increases, and this can be adjusted to $y = 0.0004X - 1.6679$.

With the comparison of the flow versus the transmissibility, this presents a high correlation of 0.9816, with a linear trend with a negative slope; that is, as the flow increases, the transmissibility decreases, and this can be adjusted to $y = -2.0149X + 13{,}090$.

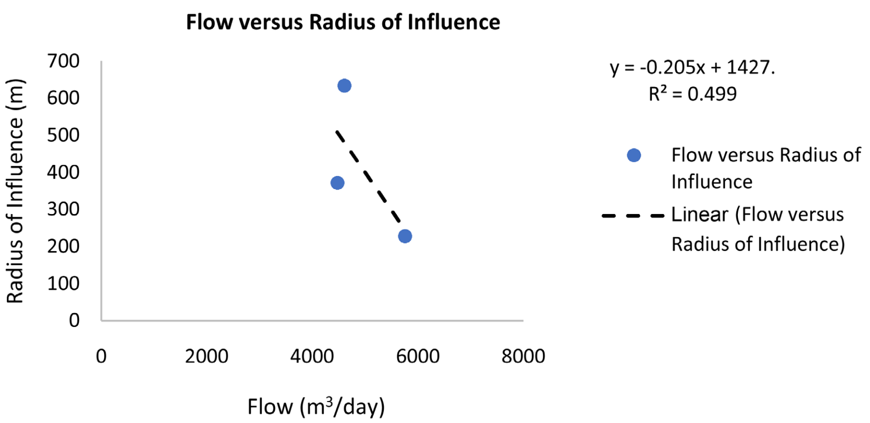
Continuing with the comparison of the flow rate versus the hydraulic conductivity, this presents a high correlation of 0.993, with a linear trend with a negative slope; that is, as the flow rate increases, the hydraulic conductivity decreases, and this can be adjusted to $y = -0.0818X + 527.45$.



Graph 2. Transmissibility trend as a function of flow. Source: self-made (2021).



Graph 3. Hydraulic conductivity trend as a function of flow rate. Source: self-made (2021).



Graph 4. Trend of the radius of influence as a function of the flow. Source: self-made (2021).

Finally, the comparison of the flow versus the radius of influence presents a low correlation and is equal to 0.4999, with a linear trend with a negative slope; the use of the adjustment equation is left to discretion, probably with more data on the site will approach a high correlation.

5. Conclusions

The hydrogeological analysis of the hydraulic parameters of the Nandaime-Rivas aquifer was carried out with a basin approach; the flow was compared with transmissibility, drawdown thickness, hydraulic conductivity, and the radius of influence.

The comparative trend of the result, gave as a result the linear for all the parameters, in comparative relation of the flow with the thickness of the drawdown, this gave a positive slope, with the other parameters it gave a negative slope, but with high correlations. With the radius of influence parameter, the trend is linear, only the correlation is low.

The linear trend equations obtained in relation to the flow with, the thickness, the transmissibility, the hydraulic conductivity are shown, and the discretionary use of the linear trend equation obtained with the radius of influence.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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