Application of the Single-Well Technique through Labeling the Whole Piezometric Column Using the Radioactive Tracer $^{131}\text{INa}$ - An Alternative Analysis for Quantitative assessment of in site Hydraulic Parameters

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SUMMARY

The movement of the water through granular and rocky means is reason of constant queries. The determination of hydraulic parameters based on field rehearsals uses presented theoretical and empiric formulations traditionally, being in many occasions the only alternative to uses; however, since the hypothetical conditions for its application, plow not completed strictly, it is common that results it plows obtained with high grade of uncertainty.

Before such situation it is necessary to have an alternative, an for the application of technical that allows to corroborates you or to you evaluate yourself the parameters determined by direct methods efficiently.

An auxiliary tool for the solution of some problems that you/they plows presented in the fields of the underground hydrology, CFE uses to practical and simple methodology that there is fundamental like it bases the application of the radioactive plotter $^{131}\text{INa}$ whose characteristic of low cost, life half and easy handling, they give him to special utility.

The sequence is described for the application of the plotter, and give to know and example where it was possible to deduces hydraulic parameters" in site", those that provided an additional back to the direct techniques.

1 THE RADIOACTIVE TRACER $^{131}\text{INa}$

- Employee as $\text{NaI}$
- Miscible in the water
- Originator $\gamma, \beta$
- Period of life half short 8,03 days
- Appropriate for experiences of short duration
- Not very retained for the land
- Not onerous and of easy acquisition in the market
- Not toxic in appropriate proportions
- Constant of very small dissociation
2  THE METHOD

- Applicable in means fisurados, when water is used or. foamy as perforation fluid.
  WELLS IN EXPLORATORY STAGE

- For granular means it is difficult to execute the technique, due to the interference that is produced by the cake of muds of perforation.
  WELLS IN STAGE OF PRODUCTION

- Properly development and appraised.
  PIEZOMETERS

- They should have their suitability tests so that it is. feasible to execute the technique.

APPLICATIONS MORE COMMONS

- Determination of permeable levels and of stagnation.
- Corroboration of results starting from geophysical profiles.
- Confirmation of constructive designs.
- Determination of hydraulic parameters (in site).
  1. Filtration speed or of Darcy.
  2. Real speed of flow.
  3. Hydraulic conductivity.
  4. Transmissivity.
- Preferential Direction of flow.
  - Descending or upward flows.
- Entrance flows or exit in an aquifer system.
- Determination of the Coefficients of Longitudinal Dispersivity (Dox). and Traverse ((Doy), to feed mathematical models of flow and of transport of mass.
- Works of artificial recharge.
- Detection of flights in dams.

3  THE TECHNIQUE

INSTANTANEOUS METHOD OF THE MARKED ONE OF THE WHOLE COLUMN PIEZOMETRIC AND MARKED PUNCTUAL

- Team of geophysical registrations of wells.
- Recipient for blended armored.
- Tube of flexible plastic of high resistance.
- Test tubes.
- Protection masks.
- Syringes.
- Gloves of plastic.

INSTRUMENTATION FOR INJECTION

- It sounds out combined of the registration team of: wells ( it consists of a detector made up of a SCINTILOMETER).

INSTRUMENTATION FOR DETECTION

- Personal dosimeter.
- Exposimetros (direct reading).
- Alarms

INSTRUMENTS OF SECURITY RADIOLOGICAL

PERMISSIBLE LIMITS OF RADIOLOGICAL SECURITY

- P.O.E. = 20 mSv / year.
- For an aquifer system, it implies that not you. affect to the means neither the population, ( life mediates short and it is diluted in big volumes of water) NORMS of the O I E A 1 mCi = 0,037. GBq / m³.
Addition of radioactive solution

Radioactive solution

Cable of the malacate

Phreatic level

Tube of plastic

Detecting

Instantaneous injection

Lodging of the radioactive cloud

Behavior of the radioactive cloud after happening the phenomenon of molecular diffusion

Continuous observation of the radioactive cloud in the time. The dilution phenomenon is presented in permeable levels
THE PROCESS

Has like base the exam of the behavior for dilution of the injected radioactive cloud, versus time. Without providing it values numeric.

QUALITATIVE ANALYSIS

QUANTITATIVE ANALYSIS

It drives to numeric securities, with those that it is possible to evaluate hydraulic parameters (IN SITE).

Basic algorithm: \( V_f = \frac{2.3 \cdot V_o}{St / \log \frac{Co}{Cn} \cdot \alpha} \)

\( V_f = \) filtration Speed or of DARCY.
\( t = \) Time lapsed starting from the semihomogeneous of the radioactive cloud,
until a considerable dilution.
\( V_o = \) Volume of the column of the well.

\[ \pi d^2 \over 4 \]
\( d = \) Diameter of the well.
\( l = \) length of the marked column.

\( S = \) Section of the well in the level of interest. ( l. d )
\( Co = \) Concentration of the radioisotope at the same time \( t = o \) ( c.p.s ).
\( Cn = \) Concentration of the radioisotope at the same time \( t = n \) ( c.p.s ).
\( \alpha = \) Appropriate correction factor to the well and the aquifer.

HYDRAULIC PARAMETERS

Real speed
\( V_f r = V_f \cdot \downarrow \)
\( V_f r = K \cdot i \)

\( K = \) hydraulic Conductivity

\( i = \) hydraulic Gradient

\( \downarrow = \) Effective porosity

\( V_f = \) Speed of Darcy

Transmissivity

\( T = K \cdot b \)

Hydraulic conductivity

\( b = \) Thickness of the valued level
\( \nabla = \) half Speed of the fluid (curve pick to pick of the plotter).
\( A = \) effective Area of the conduit.

Circulating flows
\( Q_c = \nabla \cdot A \)

FLOWS OF ENTRANCE OR OF EXIT IN A SYSTEM

\[ \sum_{J-1}^{J-n} Q = b.k.i.L_1 \]

\( Q = \) Flow for cell

\( b = \) Thickness of the valued level

\( k = \) hydraulic Conductivity of the valued medium

\( i = \) hydraulic Gradient

\( L_1 = \) Longitude of the portion of the system to evaluate
5 PARTICULAR APPLICATION

The application sequence that we will try, reflective in great measure the effectiveness of the technique whose back you property in the multiple radioactive rehearsals taken to end like integral part of geophysical studies and geohidrologics, by means of which it was possible to identify geometries and hydraulic operation of systems with those that it is supplied Centrals Thermoelectrics.

Central Thermoelectric" Guadalupe Victoria"

Medium (granulate-rocky)

General aspects

The system energy center north of Mexico, clasp the states of Durango, Coahuila and Chihuahua, being sustained with Central diverse Thermoelectric, which don't satisfy the populational and industrial demand of energy properly, what rebounds in depending from the cross-trigger system to national level, resulting in the high cost and deficiency in the electric service.

Before this situation, CFE was given to the task of making some studies of engineering of projects, among those that the geohidrologics stands out whose purpose was of selecting to place that gathered appropriate characteristics for the location of to new Thermoelectric Power station, with which went possible to help to palliate the energy demands, mainly in the District Lagunera.

These studies culminated with the selection of an area that presented characteristic attractive to give per second of the order of 280 per second of underground water of good quality, and at least to maintain that flow during their operation stage, estimated in 30 years.

The mentioned area is located geographically limited among the parallel ones 25° 23' 12" and 25° 37' of north latitude and the meridians 103° 30'y 103° 50' of longitude west covering to surface of approximately 825 km² (figure No. 1).
The supply sources visualized in the area, were two:

The first one understands underground water, coming from an aquifer in granulating and possibly rocky materials and the second, derived of superficial waters of the River Nazas. It was opted by the first one, because the river only presents glide flow during six months to year.

The River Nazas is the main source of feeding of the granular and rocky aquifers of the area of Cd. Juárez, Dgo., besides that also recharges the main aquifer (old Lagoon of Mayrán) of the District Lagunera that involves to the watering district No.17, which highlights for their agricultural productivity.

One has knowledge that the main aquifer presents to very strong deficit, because its natural recharge i surpassed, causing the depression and deterioration in the quality of the water.

On the other hand, the demand of supply of drinking water of the municipalities of Turret, Coah., Gómez Palacio and Dull, Dgo., they have originated to depression bigger than the main aquifer, increasing even lives the sobreexplotación problem; of here the restlessness on the part of SAHOP and the SARH, to have new supply sources.

The only supply source to future, it is sustained for these municipalities in the aquifer of Cd. Juárez, Dgo., since the valley presents conditions stably different to the main aquifer, since in this area the River Nazas is not lined, it contributes considerable volumes to the aforementioned aquifer system.

At the moment between SAHOP and SARH they have hydraulic infrastructure, summoned in the valley, with which you/they is considered to cover the demand for the years 1994 and 1995 with to flow of approximately 1 m$^3$ per second.

For not arriving to on exploiting this valley of Cd. Juárez, Dgo., it is of supreme importance to have to strict control and to quantify in to rational way the resources hidraulics of the same one, so much municipal stops uses, ejidal and for the uses that seeks to give him CFE.

This way it will be possible to optimize the exploitation of the aquifer without deteriorating the levels of underground water; the exploitation of the aquifer has like it bases the fact of obtaining to bigger recharge on the part of the river, causing to decrease of the levels in the low water cheats stops later on to it captures to bigger recharge when one there is glide flow.

Information of studies

The geologic studies, locate fisiográficamente the area in question in the northeastern portion of the Sierra Oriental Mother transverse sector (Raise1964), geomorfologic, the area understands the mountains The Jaquey, Spain, Villa Juárez, San Carlos, the Noas, The Mangy one and The Church, guided with address NW-SE and with elevations of the order of 1 360 msnm in the Sierra of Cd. Juárez at 1 900 in the Sierra Spain.

Among the mountains The Church, Villa Juárez and San Carlos, the Valley of Cd i located. Juárez, Dgo. in the one that appears the Hill the Stones, small HILLS to the southeast of the thermoelectric power station (Guadalupe Victoria), besides to small promontory to the north of the town The Ray.

The area presents to mature stage, in which the superficial glides acted together with the breakup processes creating to fluvial valley. In their biggest part the rain water precipitated in the area, i slippery toward the valley of Cd. Juárez, Dgo.

The type of observed drainage in the mountains i of parallel type with streams halfway to each other. The geologic recognitions identify in the area five formations and two geologic series, those that dates of the Jurassic one Half to the Recent one. The column cronoestratigráfica groups for ends geohidrológicos in three subdivisions:

**Permeable to granulate and rocky units.** They form it the granular materials of filler (Qal) and the series Comancheana. The to granulate materials of filler, due to their high primary permeability, constitute the main aquifer; the limestone of the Formation Aurora that appears in San Carlos' Mountains and the Church, presents secondary permeability for breaking and dissolution.

**Semi-permeable rocky units.** Inside these they plows the formations Zuloaga, The House, Cupid, The Rock and the Santa Inés. The gritty of the Formation The House and the calcareousStratifieds with gritty of the Formation Cupid, they plows transmisoras of water, due to their permeability for breaking.
• Rocky unit of null permeability. It is attributed to the Formation Nazas (CJn) and the Formation Coal merchants (CKob), their physical characteristics make that to these formations they plows considered an of low permeability, although the possibility i not discarded that mainly in the shallow portions of the Formation Nazas breaking exists and therefore permeable be.

APPLICATION OF THE RADIOACTIVE TRACER $^{131}$Ina

Since shortly the Power station will enter in operation, the necessity was seen of enlarging the knowledge of the geometry of the aquifer system and its hydraulic operation (mainly in the granular sedimentary materials), increasing with this studies pursuit geohidrolologics whose purpose i observing in continuous form the system, this way to upgrade the pattern geohidrologic managed in previous studies.

To fulfill the outlined objectives it proceeded to subdivides the investigation in the following activities:

1. Analysis and integration of the dates generated with the geophysical you discipline - geohidrologics applied in stages of previous studies.

2. Obtaining of thermal profiles, so much in wells of CFE, like in wells of SAHOP. This campaign was carried out when the river Nazas had glide flow.

3. Generation of stratigraphic information by means of profiles natural gamma, in wells property of SAHOP.

4. Execution of radioactive layouts in 10 available hydraulic infrastructure of CFE and SAHOP, also made when the river Nazas, had glide.

The described activities were executed in the wells No.3, 5, 8, 9, 10 and piezometer 1 of CFE, located in the right riverbank of the river and in the wells No.1 bis, II, III, VI, VII and X property of SAHOP, located in the left riverbank of the river (figure No. 2).

In the investigation of the aquifer system it was appealed to the denominated technique" Marked instantaneous of the whole column piezometric and of punctual injection."
RESULTS

Starting from the analysis of the geophysical dates generated in previous stages to the investigation of the plotter and integrating the derivative results of this, two sections plows presented considered a representative of the geometry of the aquifer system, where it is observed with definition the distribution of the granular sedimentary materials of high and low yield, a well an the rocky one that you/they prevail in the valley it lives; besides the hydraulic operation of the system.

The section A-A’ it is located parallel to the river Nazas and perpendicular to the structures, section D-D’ located perpendicular to the river Nazas and almost parallel to the structures (figure No. 3).

In these sections from to widespread point of view three units stand out:

- Unit U1 (Qal). is formed mainly for thick gravels and sands with scarce clay, it is considered a the unit of lives yield, their thickness certain average is of 80 m, except in the area where the wells No. VI plow located and I-bis summoned by SAHOP, where the thickness is bigger to the 100 m.
The ranges detected resistivities plows from 70 to 300 ohm-m, reflecting the domain of thick materials with water of good quality, the hydraulic parameter of transmissivity, derived with the radioactive method, it reaches securities from 3 600 to 6 300 m²/day that support the aforementioned characteristics and they imply high hydraulic conductivity. The expenses average obtained in the located wells for this unit plows of the order of 80 liters per second.

The lateral distribution of this unit is indicated in the figure No. 4, where it is presented like average 800 m in both riverbanks of the river; it is feasible that this limit has relationship with old stream and to geologic accident that gave origin to system of parallel and perpendicular flaws to the main structures.

By means of the thermal prospectings they were determined smaller securities of temperature to 24° C, with very low gradients that reflect the great circulation of water that one has in that unit that correlates also with the high dilution experienced by the injected radioactive clouds, an example of such to behavior of these it is shown in the figures No. 5.

It is important to point out that inside this unit two excellent singularities exist:

For the first one an area of smaller characteristics is evidenced ace for yields, located in the central portion (area shady figure No. 4) where the detected securities of temperature went bigger to the 26° C and the transmissivities of the order of 3 000 m²/day, besides smaller resistivities to the 80 ohm.m; these physical and hydraulic parameters plows indicative of to bigger content of it dies to granulate silts. In this area they it plows located the wells No.5 of CFE, II and VII of SAHOP.

The second singularity is that to the exit of the aquifer system, mainly in the area where the wells No. VI plow located, I and I-bis of SAHOP, descending vertical flows were detected approximately with horizontal displacement to the 80 m of depth, this behavior was comes immediately with punctual injections. In the it does figure No. 6 the behavior of the described flow is demonstrated. Also, this behavior was confirms later on with to detail piezometric carried out in the month of February of 1990 (figure No. 7), where in the portion framed by the wells No. I and I-bis of SAHOP an is detected" water-course", related with the presence of vertical flows detected by means of the plotter; it fits to point out that for the month of February the river doesn't have glide flow.
RESULTS OF THE LAYOUT RADIATIVE
C. T. GUADALUPE VICTORIA, DGO.
WELL C. F. E No. 9

Figure No. 5
RESULT OF THE LAYOUT RADIOACTIVE
C. T. GUADALUPE VICTORIA, DGO.
WELL SAHOP No. (bis)

Behavior of the punctual radioactive
injection (85.00 to 105.00 m)

Figure No. 6
This descending vertical flow was not possible to evidence it with the radioactive plotter in the shallow, due levels possibly to the resultant of the vectorial horizontal speed, which is bigger than the vertical one; however, when it diminishes its influence it is manifested in the deep levels.

For the valley in general horizontal preferential flows were detected, related with the address of the flow of the aquifer that is from west to this.

**Unit Ua (Qal-ar).** It is characterized to have been detected mainly in the lateral portions of the Unit U1 (Qal), chord with their ranges resistivities of 4 to 26 ohm.m; it is sedimentary materials of grain an they dies it plows the clays and sands, joined to water of regulating to bad quality.

It is considered an unit of low yield whose thickness is variable. The distribution clasps great part of the Valley (figure No. 3) where it i indicated ace complex of low yield, examples of this behavior plows the well No.7 of CFE, an wells public land and matters summoned in this unit.

**Unit U2 (Cg).** Chord with the answers of detected resistivities of 36 to 56 ohm.m, a well an the securities of lives temperature at the 25°C (the gradient of temperature spreads to be increased due to the absence of flow) and of the behavior of the injected radioactive clouds, which didn't experience dilution in this unit (figure 5) it is possible to associate them with mainly loamy materials that pack to you record and sands of high saturation but of low hydraulic conductivity.

According to the stratigraphic chronology of the described unit it is possible that it belongs to the Formation Santa Inés or Ahuichila. The thickness is in function of the contact with the Jurassic rocks and Cretaceous of the valley.

**Rocky sedimentary materials**

Unit U8 (Jlg). For the evidences that plows had a for the yield of the well CFE No.1 (90 liters per second) and the piezometers PZ-1, is the rocky unit of live hydraulic conductivity; the range of obtained transmisivity with the plotter is of the order of 22 250 m² / day, what gives devises of to half highly transmitter.

Given these results, the possibility is not discarded that in other formations of the Group Cretaceous, and still of the Jurassic one that you/they were not studied in this stage breaking it exists in its shallow portions.
COMMENTS

- By means of the geophysical investigation, using the technique of tracer radioactive, the geometry of the aquifer system was tuned, mainly in the granular sedimentary materials.
- The concept of to free aquifer remains in granulating materials of high-performance whose thickness average is of 80 meters, and lateral extension of 800 meters for both riverbanks of the river Nazas, and along the whole valley, with water of good quality, the valued average is of 675 ppm, of STD, being the family of bicarbonate - calcic or sodium dominant water.
- The main recharge source to the granular aquifer system and still to the rocky one it is the river Nazas.
- The identification of vertical flows located to the exit of the system stands out, what implies an escape or feeding of the granular aquifer of the valley of Cd. Juárez toward the formations Cretaceus, meaning to possible recharge toward the valley of the District Lagunera (old Lagoon of Mayrán).
- At the moment the aquifer system is in dynamic balance, and it only satisfies the volume of current pumping and that of drain of the aquifer system.
- The dates generated with the investigation, were basic for the generation of to mathematical model of simulation, where it is contemplated the necessities of underground water of the municipalities of Lerdo and Gómez Palacio, Dgo. and Torreón, Coah., and those of the central thermoelectric power station Guadalupe Victoria.

6 summations

The developed investigations by means of the uses of the radioactive plotter $^{131}$Na, joined to technical geophysical diverse and geohidrológicas, brings I am able to show the effectiveness of the so much technique in underground hydrology.

The exposed results denotes the technician-economic benefits that dog be obtained, provided it is used advisably.

There with it is possible to support technical direct of other similar branches of the sciences of the earth, which can find suitable solutions to their constant queries.

It is expected that the described technique, help to wake up the interest of people that you/they seek to solve some of the problems that plows presented frequently in studies to any stage, increasing this way the wealth regarding the uses of tracer radioactive added to the means.

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