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Research article

MODELING NONLINEAR VELOCITY ON GRAVEL DEPOSITIONS INFLUENCED BY POROSITY IN HETEROGENEOUS SEMICONFINED BED AT AHOADA, NIGER DELTA OF NIGERIA

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Abstract

The depositions of non linear velocity of flow were considered to be the most pressured parameter in semiconfined bed. Semi confined bed in the study location were to monitor the rate nonlinear velocity of flow in depositions, vacillation of porosity degrees in gravel formation were observed to reflect on the rate of nonlinear velocity in the study location, the developed model examined various influences that may also pressure the deposition of nonlinear velocity of flow in such deltaic environment, heterogeneous formation were another influences that were discovered to pressure the velocity of flow in nonlinear condition, the study location were deposited by lacustrine formation, these are were predominant pressure of nonlinear velocity are observed in the study area, the developed model will definitely monitor the rate of flow in nonlinear condition on gravel formation. Experts will definitely applied this model to evaluated flow rate in such heterogeneous formation in the study area.

Keywords; modeling velocity Gravel depositions, heterogeneous, and semi confined

1. Introduction

Water is recognized to be a worldwide solvent. These are one of the natural resources tapped by man, animals and plants to meet their requirements for life nourishment. The world's water resources include the whole range of natural waters on earth, either in vapour, liquid or solid form. Water is placed as surface water or groundwater. While Surface water comprise rain water collected into rivers, lakes, reservoirs and oceans ,more so groundwater comprise natural springs, well and boreholes. Groundwater is commonly understood as water occupying the voids within a geologic stratum, groundwater is free from suspend matter and bacteria. It can be said to be pure, clear and colourless. Groundwater has greater quality than surface water (Kazeem 2010). Generally, industries require approximately one quarter to one third of the public water supply under normal condition the easiest and most convenient way to meet the public demand for water is to utilize surface water resources, but unfortunately, water such as river, lake, stream e.t.c. are less plentiful than can be imagined. It can be recorded that surface water resources account for less than 2 percent of the world's fresh water. The latter fresh water available however is unevenly distributed while the sources that are available have been either contaminated or polluted. (Hamill and Bell, 1986). Groundwater accounts for about 98 percent of the world's fresh water and is fairly evenly distributed throughout the world. It provides a reasonable constant supply which is not completely susceptible to drying up under natural condition unlike surface water (World water balance and water resources of the earth UNECO Copyright 1978). All over the globe, groundwater has been a very good and important source of water supply. It has been of continuous and tremendous use in irrigation industries and urban centers, as well as in rural communities (Kazeem, 2010). Groundwater is the main resource of drinking water in many parts of the world. Contamination resulting from industry, urbanization and agriculture poses a threat to the groundwater quality (Amadi, 2007, 2009 and 2010). The task of balancing groundwater protection and economic activities is challenging. Therefore, understanding the effects of different water management strategies and the role of climate change is essential for the sustainable use of coastal groundwater resources (Prasad and Narayana, 2004). According to Olobaniyi and Owoyemi (2006), the coastal regions of the world are the most densely populated areas in the world. More than one third of the world's populations are living within 100 km of the coastline (Hughes, et al., 1998). At the same time, the coastal regions provide about one third of the world's ecosystem services and natural capital (Aris, et al., 2007). Such growth is accompanied by increasing demand for water supply leading to the over-exploitation of the aquifer system and excessive drainage for land reclamation purposes. Contamination of the groundwater by natural means (seawater intrusion) and through anthropogenic means (human activities) cannot be ruled out in the area. Ahoada in rivers state part of treasure base of the nation' is situated about 80 km from the open sea lies between longitude 6o55'E to 7o10'E of the Greenwich meridian and latitude 4o38'N to 4o54'N (Fig. 1) of the Equator, covering a total distance of about 804 km2 (Akpokodje 2001). In terms of drainage, the area is situated on the top of Bonny River and is entirely lowland with an average elevation of about 15 m above sea level (Nwankwoala, 2005). The topography is under the influence of tides which results in flooding especially during rainy season (Nwankwoala and Mmom, 2007). Climatically, the city is situated within the sub-equatorial region with the tropical monsoon climate characterized by high temperatures, low pressure and high relative humidity all the year round. The mean annual temperature, rainfall and relative humidity are 30oC, 2,300 mm and 90% respectively (Ashton-Jones, 1998). The

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soil in the area is mainly silty-clay with interaction of sand and gravel while the vegetation is a combination of mangrove swamp forest and rainforest (Teme, 2002).

Ahoada also falls within the Niger Delta Basin of Southern Nigeria which is defined geologically by three sub-surface sedimentary facies: Akata, Agbada and Benin formations (Whiteman, 1982). The Benin Formation (Oligocene to Recent) is the aquiferous formation in the study area with an average thickness of about 2100 m at the centre of the basin and consists of coarse to medium grained sandstone, gravels and clay with an average thickness of about 2100 m at the centre of the basin and consists of coarse to medium grained sandstone, gravels and clay (Etu-Efeotor and Akpokodje, 1990). The Agbada Formation consists of alternating deltaic (fluvial, coastal, fluviomarine) and shale, while Akata Formation is the basal sedimentary unit of the entire Niger Delta, consisting of low density, high pressure shallow marine to deep water shale (Schield, 1978).

2. Theoretical background

Monitoring of flow path of fluid are based on several formation characteristics. To predict the nonlinear velocity movement of fluid is through several conditions. The interaction between surface water and groundwater bodies are determined by several hydrogeological setting under the influence of geological depositions in soil and water environment. To monitor the nonlinear velocity of flow of semi-confined beds influenced by from geological setting, it confirms to deposit heterogeneous formation in the study location. The interaction of surface and groundwater observed different rate of fluid flows under the influence of structural deposition of heterogeneous soils. Semi-confined beds are influenced by compressibility of fluids through the formation of overburden pressure in soil. Such conditions are found to experience nonlinear velocity of flow from semi-impermeable layers or penetrating aquifers. This conceptual framework experienced in the study location where the hydrogeological setting observed to deposit heterogeneous formations, structural depositions of the formation are confirm in the study location, but not predominant in the study area. Semi-confined bed may be found to be influenced from these formations, because it is influenced by compressibility of above formation, the study express nonlinear direction of flow from the hydrogeological setting makes it imperative to develop a mathematical model that will monitor the nonlinear velocity depositions in semi-confined beds, hydrogeological studies has confirm the influenced by compressibility of soil influences deposited through heterogeneous formation.

3. Governing Equation

$$\frac{\partial vi}{\partial x}\left(Kij\frac{\partial v}{\partial x}\right) = \frac{\partial v}{\partial t} + W \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (1)$$

Applying physical splitting techniques on equation (1) we have

The developed expression apply splitting approach were the derived solutions expressions are base on the variables, these will always monitor the system, the behaviour of the system defined the predominant variables that pressures other parameters in the deposition of non linear velocity at several phase of the system, these applications are imperative because the functionalities of the variables will be articulated at various stage by considering the flowing process on gravel formation.

$$\frac{\partial v}{\partial x} = Kij \frac{\partial vi}{\partial x} \qquad \text{(2)}$$

$$\left.\begin{array}{l} x = 0 \\ v_{(o)} = vo \\ \left.\frac{\partial vi}{\partial x}\right|_{x=0} = 0 \end{array}\right\} \qquad \text{(3)}$$

$$\frac{\partial v_2}{\partial x} = \frac{\partial v}{\partial t} + W \qquad \text{(4)}$$

$$\left.\begin{array}{l} x = 0 \\ t = 0 \\ v_{(o)} = vo \\ \left.\frac{\partial v_3}{\partial x}\right|_{x=0,\beta} = 0 \end{array}\right\} \qquad \text{(5)}$$

$$Kij \frac{\partial v_3}{\partial v} = -\frac{\partial v_3}{\partial t} + W \qquad \text{(6)}$$

$$\left.\begin{array}{l} x = 0 \\ t = 0 \\ h_{(o)} = 0 \end{array}\right\} \qquad \text{(7)}$$

Applying direct integration on (2)

$$\frac{\partial vi}{\partial x} = Kij\ v + Zi \qquad \text{(8)}$$

Again, integrating equation (8) directly, yields

$$h = Kvx + Zix + Z_2 \qquad \text{(9)}$$

Subject to equation (3), we have

$$vo = K_2 \qquad \text{(10)}$$

And subjecting equation (8) to (3)

At $\left.\frac{\partial vi}{\partial x}\right|_{x=0,\ v_{(o)} = v_o} = 0$

Yield

$$0 = Kv + Z_2$$

$$\Rightarrow \quad K_1 = Kv_o \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

So that, we put (10) and (11) into (9), we have

$$vi = Kijvix - Kv(o)x + vo \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

$$vi - Kijvix = vo - Kvox \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

$$\Rightarrow \quad vi\left(-K,a \right) = vo\left(-Kx \right)$$

$$\Rightarrow \quad vi = vo \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

Hence equation (14), entails that at any given distance, x, we have constant transitory flow in the systems.

The developed expression here evaluate some influences in the formation, this include permeability and porosity degrees of the formation and the micropores, this parameters determine the rate of constant rate of nonlinear velocity of flow in the gravel formation, the derived solution expressed this dimension considering this condition in the system, the degree rate of micropores in the formation where found to play more role, these are due the deposition influence from the stated parameters depositing nonlinear under homogeneous setting. These conditions express the influences from change in depths with respect to non linear variations on deposited gravel formation

Now, we consider equation (4), which is a linear exponential flow of the system

$$\frac{\partial v_2}{\partial x} = \frac{\partial v}{\partial t} + W \quad \ldots\ldots\ldots \quad (4)$$

We approach this system by using the Bernoulli's method of separation of variables

i.e. $$v_2 = XT \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

i.e. $$\frac{\partial v_2}{\partial x} = X^1T^1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (16)$$

$$\frac{\partial v_2}{\partial t} + W = XT^1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (17)$$

Put (16) and (17) into (15), so that we have

$$XT^1 = XT^1W \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (18)$$

i.e. $$\frac{X^1}{X} = \frac{T^1W}{T} = -\lambda^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (19)$$

Hence $$\frac{X^1}{X} + \lambda^2 = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (20)$$

That is, $X^{1} + \lambda^{2} X = 0$ .... (21)

$$T^{1}W + \lambda^{2}T = 0 \qquad (22)$$

From (21), $X = \frac{A Cos\lambda}{\sqrt{X}} + \frac{B Sin\lambda}{\sqrt{\beta}}$ .... (23)

And (16) gives

$$T = v\ell^{\frac{-\lambda^{2}}{W}t} \qquad (24)$$

The expression is the developed model monitor the system with respect to time of nonlinear velocity of flow, furthermore, expressing this condition following the principle of plug flow system on time, it implies that the deposition of nonlinear through heterogeneous setting are from the formation deposition that definitely must varies depending on the flow paths, the expressed model are developed base on the stated formation, the condition of gravel depositions implies that the sediments disintegration in heterogeneous through geological setting, the flow path influenced by structural deposition generate nonlinear flow, this developed model consider porosity deposition even if not predominant in the system, but it has its an influence rate on nonlinear velocity with respect to flow rate in gravel formation. Therefore time factors in nonlinear flow influenced by other slight formation characteristics, these conditions continue to develop variations as expressed on the model. Heterogeneous gravel formations from the micropoles also deposit different hydraulic conductivity of fluid, this generate different time as express on the model phase of the studies

By substituting (23) and (24) into (15), we get

$$v_{2} = \left(A Cos\frac{\lambda}{\sqrt{x}} + B Sin\frac{\lambda}{\sqrt{x}} \right) v\ell^{\frac{-\lambda^{2}}{W}t} \qquad (25)$$

subject to this relations, it has been observed in from the substitution in (23) and (24) that both phase are integrated into (15), the developed model were correlated to interact with other parameters through the influence of exponential state, there is the tendency of depositing variation increase of velocity, this condition can only be determined through the rate of flow path in the formation with respect to time and change in depths. Furthermore, these expressed model conditions determine the rate of nonlinear velocity in the strata, such influences are from slight depositions of porosity between the soil strata in semi confined bed.

Subject equation (25) to conditions in (5), so that we have

$$v_{o} = AC \qquad (26)$$

From equation (26) becomes

$$v_2 = v_o \, \ell^{\frac{-\lambda^2}{W} t} \; Cos \frac{\lambda}{\sqrt{x}} \qquad \text{......................................} \qquad (27)$$

Again, at

$$\left. \frac{\partial v_2}{\partial x} \right|_{x = 0, \; B} = 0, \; t = 0$$

Equation (27) becomes

$$\frac{\partial v_2}{\partial x} = \frac{\lambda^2}{\sqrt{x}} \; h_o \, \ell^{\frac{-\lambda^2}{W} t} \; Sin \frac{\lambda}{x} \qquad \text{....................................} \qquad (28)$$

$$0 = - v_o \frac{\lambda}{\sqrt{x}} \; Sin \frac{\lambda}{\sqrt{x}} \; 0 \qquad \text{......................................} \qquad (29)$$

i.e.

$$v_o \frac{\lambda^2}{\sqrt{x}} \neq 0 \quad \text{Considering flow path ways}$$

$$0 = - v_o \frac{\lambda^2}{\sqrt{x}} \; Sin \frac{\lambda}{\sqrt{x}} \beta \qquad \text{......................................} \qquad (30)$$

$$\Rightarrow \; \frac{\lambda}{\sqrt{x}} = \frac{n \pi}{2}, \; n = 1, 2, 3 \qquad \text{......................................} \qquad (31)$$

So that equation (27) becomes

$$v_2 = v_o \, \ell^{\frac{n^2 \pi^2 x}{2W} t \; Cos \frac{n \pi \sqrt{x}}{2 \sqrt{x}}} \qquad \text{......................................} \qquad (32)$$

$$\therefore \Rightarrow \; v_2 = - v_o \, \ell^{\frac{-n^2 \pi^2 x}{2W} t \; Cos \frac{n \pi}{2} x} \qquad \text{......................................} \qquad (33)$$

The developed model in these phase express when there is high degree of permeability and porosity, there is the tendency of increase in nonlinear velocity within the gravel formations, this condition may generate high velocity and will definitely deposit high flow in semi confined bed, the geological setting within the nonlinear zone experience high vacillation, the deposition on fluid flow generate overburden pressure very fast, since the study location may deposit gravel in some strata that generated overburden pressure are observed in some region of the formation. This expressed model handle this condition on the rate of flow rate of the study, but formation characteristics such porosity at different degrees determine the rate of deposition of nonlinear velocity of flow in gravel formation, thus in such heterogeneous formation express other variables in the system.

Now, we consider equation (6) which is the steady-flow state of the system

$$Kij \frac{\partial v_3}{\partial x} = \frac{\partial v_3}{\partial x} + W \text{ …………} \qquad (6)$$

Applying Bernoulli's method, we have

$$V_3 = XT \quad \text{…………………………………} \quad (34)$$

$$\frac{\partial v_3}{\partial x} = X^1 T \quad \text{…………………………………} \quad (35$$

$$\frac{\partial v_3}{\partial t} = XT^1 \quad \text{…………………………………} \quad (36)$$

Put (35) and (36) into (6), so that we have

$$KijX^1T = XT^1W \quad \text{…………………………………} \quad (37)$$

i.e. $Kij \frac{X^1}{X} = -\frac{XT^1W}{T} = \varphi$ ………………………………… (38)

$$Kij \frac{X^1}{X} = \varphi \quad \text{…………………………………} \quad (39)$$

$$-\frac{XT^1W}{T} = \varphi \quad \text{………………………………} \quad (40)$$

$$\boxed{X = A\ell^{\frac{\varphi}{Kij}x}} \quad \text{………………………………} \quad (41)$$

And

$$\boxed{T = \beta\ell^{\frac{-\varphi}{W}t}} \quad \text{…………………………………} \quad (42)$$

The developed model in 42 and 43 shows the rate of nonlinear deposition of fluid, this are under the pressure of the gravel strata that experience heterogeneous stratification structured in semi confined bed. The developed model also consider variation in hydrostatic pressure, including slight degree of porosity in some region, this definitely experience partial deposition of overburden pressure in the strata, therefore 42 and 43 developed model in these stage of the derived solution monitor the rate of nonlinear velocity of flow with respect to time and depths in semi unconfined bed.

Put (41) and (42) into (34), gives

$$v_3 = A\ell^{\frac{\varphi}{W}x} \quad \beta\ell^{\frac{-\varphi}{W}t} \quad \text{………………………………..} \quad (43)$$

$$v_3 = AB\ell^{(x-t)\frac{\varphi}{W}} \qquad \text{.................................} \qquad (44)$$

Subject equation (44) to (7), yield

$$v_3 = (o) = V_o \qquad \text{.................................} \qquad (45)$$

So that equation (45), becomes

$$v_3 = v_o\,\ell^{(x-t)\frac{\varphi}{W}} \qquad \text{.................................} \qquad (46)$$

Now assuming that at the steady state flow, there is no any sources of solute, our concentration here is zero, so that equation (46) become

$$V_3 = 0 \qquad \text{.................................} \qquad (47)$$

Therefore, solution of the system is of the form

$$V = v_1 + v_2 + v_3 \qquad \text{.................................} \qquad (48)$$

We now substitute (14), (33) and (47) into (48), so that we have the model of the form

$$V = v_o + v_o\,\ell^{\frac{-n^2\pi^2}{2W}t \quad Cos\ \frac{n\pi}{2}x} \qquad \text{.................................} \qquad (49)$$

$$\boxed{V = v_o\left(1 + \ell^{\frac{-n^2\pi^2}{2W}t \quad Cos\ \frac{n\pi}{2}x}\right)} \qquad \text{.................................} \qquad (50)$$

Discussing the flow variations that generates nonlinear velocity were to ensure the final expressed model monitored the rate of nonlinear velocity in semi confined beds, this were developed at several stage, because the rate of nonlinear velocity flow are influenced by predominant permeability and slight degree of porosity, these were considered parameters from under formation characteristics in soil and water environment. These condition were expressed in the system to determine various influenced that leads to nonlinear velocity of flow in semi confined aquifers, the developed models in these phase were finally coupled together to generate final mathematical model, these expression are integrated considering various phase that is significant in the study, the derived model stated at 50 will definitely solve the problem of nonlinear velocity of flow semi confined bed aquifers influenced permeability in the study area i

4. Conclusion

Nonlinear velocities of flow in semi confined are base on the structural variation and its deposition of soil through the geological setting in study location. Soil structural deposition determine the rate of nonlinear velocity in semi confined bed in gravel formation , structural deposition in heterogeneous formation generate nonlinear velocity of flow in some conditions, these situation were observed in some region thus base on the geological setting that influence semi confine bed in the study location. To monitor the rate of nonlinear velocity in semi confined bed it should be under the influence from heterogeneous gravel formation, base on these developed system, mathematical model were generated through the expressed variables from predominant formation characteristics, the developed model were derived through formulated governing equation, the model were derived in phases according the behaviour of on nonlinear velocity of fluid flow movement in soil, this is considered to develop nonlinear velocity of flow condition in semi confine aquifers, the study is essential because the rate heterogeneous velocity in semi confined bed are through the influence of predominant permeability, experts in water resources and environmental engineers including hydro geologist will applied these model to monitor the rate of influence in nonlinear deposition in the study area. Heterogeneous velocity of fluid through the deposition of over burden pressure were observed in the study area, these can also determined through hydrogeological studies, this will be useful because professionals will applied the model to design ground water system that will determine the movement of velocity of fluid flow semi confined formation in the study location.

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