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# CHARACTERIZATION OF FLUID FLOW USING DISCRETE VORTEX MODELLING

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## ABSTRACT

There has been growing need to characterize the fluid flow through a simplified model. This paper reports the ”random walk model” for characterization of fluid flow through the use of ‘boundary layers by discrete vortex modeling’ The soil erosion is considered as a case study. The research work covered three distinct regions of fluid flow namely the laminar region, the transition region and the turbulent region. Appropriate flow charts and FORTRAN source codes were developed to solve relevant fluid flow governing equations. Reynolds number which is the control parameter from 10,000 at an interval of 10,000 to 1,000,000 is used as the control parameter to tune from laminar to turbulent flow and the result is displayed using Microsoft Excel Graph. The first region characterizes laminar region with regularity, stability, high momentum diffusion and low momentum convection. The second region is the transition region, which shows the onset of irregularity and instability. After several stages of transition process due to Helmholtz instability, the turbulent region is reached which is characterized by irregularity, instability, low momentum diffusion, high momentum convection and rapid variation of velocity. The result shows that fluid flow can be characterized through the use of discrete vortex modeling.

**KEYWORDS:** Discrete Vortex Modeling, Distinct Regions, Fluid Flow, Momentum Convection, Momentum Diffusion, Regularity, Reynolds Number, Soil Erosion, Stability

## INTRODUCTION

A random walk is formalization in Mathematics, Computer Science and Physics of the intuitive ideas of taking successive steps, each in a random direction. The simplest random walk considers a walker that takes steps of length L to the left or right along a line while more complex random walks include fancies consideration such as given each step velocity and allowing the random walker to pause for random amount of time in between the steps.

Ojoawo (2007) investigated random walker in three dimensional Euclidean space. The random method to model the diffusion of vorticity was first proposed by Chorin(1978). In order to simulate the diffusion of vorticity in vortex flow, the positions of the vortices are given random displacements (Chorin and Marsden, 1990). The basic idea of the random walk method as applied to fluid flow is that the random displacements spread out the vorticity. Several studies investigated the theoretical and numerical aspect of the random walk method. Marchiora and Pulvienti (1982), Goodman (1987) and Long (1988) have shown that for flow in free space, the random walk solution converges to that of the Navier-Stokes equations as the number of vortices is increased, Cheer (1989) has applied the random walk method to flows over a cylinder. Lewis (1990) has used the random walk method for flow over airflow cascade while Chui (1993) used the random walk method to study thermal boundary layers. Adegbola and Ajide (2012) have implemented the random walk method to characterized the turbulent flow in two dimensions. The random walk method has several advantages. It is simple to use and it can easily handle flows around complicated boundaries. The method also conserves the total circulation. This is in application to inviscid flows.

The soil erosion considered is the detachment of materials from the bed or sides of a channel. The water flowing through stream performs three types of geologic work. Moving water erodes materials from the bed or side of the channel and transports the eroded material to a new location and deposits it. After the material has been detached from the channel, it can be transported. The two different types of real fluid flow are laminar flow and turbulent flow. The laminar flow is a flow over a smooth surface with vorticity that appear highly ordered while turbulent flow is a flow regime characterized by chaotic, disordered and stotastic changes. The Reynolds number governs laminar-turbulent transition. It also characterizes whether the flow conditions lead to laminar or turbulent flow. Transition to turbulent can occur over a range of Reynolds numbers depending on many factors such as surface roughness, heat transfer, vibration, noise and other disturbances. The objective of this work is to develop a simplified model to characterize the fluid flow through the use of discrete vortex modelling. The study intends to explore the distinguishing features of the distinct regions in fluid flow through the use of random walk model.

The problems of erosion in farmland cannot be overstressed. It is great challenge in agricultural industries. The research project is significant to the advancement of Science and Engineering. It is justified for the following reasons:

- The random walk model can be used to analyze flows in floods.
- The discrete vortex modelling is a simplified model that can help in analysis of farmland erosion and hence aid enhanced food production.

The paper reports a "random walk model" for characterization of fluid flow through the use of 'boundary layers by discrete vortex modeling' The research work is expected to cover the three distinct regions namely laminar, transition and turbulent.

## MODEL FORMULATION

The first practical scheme for simulation of a boundary layer by discrete vortices was proposed by Chorin (1978) based on his earlier conception of the random walk model for high Reynolds number bluff body wake flows. The boundary layer flow can be approximated by placing at appropriate location some vortices in a parallel flow. This forms the basis of the vortex element method.

The motion of a diffusing vortex of initial vorticity strength (Γ) entered on the origin of the (r,Θ,) is described by the diffusion equation from which we may obtain the well known solution for subsequent vorticity w(r,t) in space and time.

$$\omega\,(r,t) = \frac{\Gamma}{4\pi v t} e^{\left(-r^2/4vt\right)} \tag{1}$$

Vorticity strength is a function of radius r and time t. For a vortex of unit strength split into N elements. Let us assume that n vortex elements are scattered into the small area $r\Delta\theta\Delta\phi\Delta r$ after time t, the total amount of vorticity $P_v$ in this element of area then follows from :

$$P_v = \frac{n}{N} = \left[\frac{1}{4\pi v t} e^{\left(-r^2/4vt\right)}\right] r\,\Delta\theta\Delta\phi\Delta r \tag{2}$$

Where π is the ratio of the circumference of a circle to its diameter and υ is the kinematic viscosity. An appropriate strategy is to displace each element in the in the radial and angular directions by amounts $r_{i,}$ $\theta_i$ and $\phi_i$ over time interval 0 to t. Thus we may define θ and ϕ values independently of $r_i$ values by the equation :

$$\theta_i = 2\pi Q_i \tag{3}$$

$$\phi_i = \pi Q_i \tag{4}$$

Where $Q_i$ is a random number within the range $0 < Q_I < 1.0$. The probability P that an element will be within a circle of radius r is given by the equation

$$P = 1 - e^{\left(-r^2 / 4vt\right)} \tag{5}$$

The for the $n^{th}$ vortex element equation (5) becomes

$$P_i = 1 - e^{\left(-r_i^2 / 4vt\right)} \tag{6}$$

From which we obtain its radial random shift

$$r_i = \left(4vt \ln\left(\frac{1}{1-p_i}\right)\right)^{1/2} \tag{7}$$

Considering diffusion over a succession of small time increments Δt, the displacements of element i during time Δt will then be

$$\Delta\theta_i = 2\pi Q_i \tag{8}$$

$$\Delta\phi_i = \pi Q_i \tag{9}$$

$$\Delta r_i = \left(4vt \ln\left(\frac{1}{1-P_i}\right)\right)^{1/2} \tag{10}$$

Thus after the increment Δt, the new coordinate location ($x_i'$, $y_i'$, $z_i'$) of the $n^{th}$ element will become

$$x_i' = x_i + \Delta r_i \sin\theta_i \cos\phi_i \tag{11}$$

$$y_i' = y_i + \Delta r_i \sin\theta_i \cos\phi_i \tag{12}$$

$$z_i' = z_i + \Delta r_i \cos\phi_i \tag{13}$$

Where $x_i$ = old x – coordinate of $n^{th}$ element

$y_i$ = old y – coordinate of $n^{th}$ element

$z_i$ = old z – coordinate of $n^{th}$ element

The displacement from the origin is given by the equation:

$$D_i = \sqrt{\left((x_i' - x_0)^2 + (y_i' - y_0)^2 + (z_i' - z_0)^2\right)} \tag{14}$$

Where $x_0$, $y_0$ and $z_0$ are the origin.

**Boundary Layers by Discrete Vortex Modeling**

Convective motion were completely ignored for the diffusion point flow which have just been considered, an assumption which is permissible in view of symmetry in these special cases and justified for very low Reynolds numbers.

Boundary layer flows on the other hand are more complex involving:

- Externally imposed convection due to the main stream U, the significance of which is determined by the body scale Reynolds number $\left(\frac{UL}{v}\right)$

  L is the characteristic length of the particular flow.

- Continuous creation of vorticity at the contact surface between fluid and wall, replacing the vorticity removed by diffusion and convection.

**Random Number Generation**

Algorithms were developed to produce long sequences of apparently random results, which are in fact completely determined by a shorted initial value known as a seed.

**Application of Random Walk Method**

The application of the random walk will result in the loss of half of the newly created vorticity due to diffusion across the walls and therefore out of the active flow domain if vorticity is not conserved during the diffusion and convection processes for each time step. The single strength sheet is used through bouncing back vortices which attempt to cross the wall by assigning the value $y_i$ = abs ($y_i$)

**Selection of Element Size and Time Step**

A reasonable approach to the selection of an appropriate time Δt is to focus attention on the average displacements of the discrete vortices due to convection and diffusion. The average convective displacement may be approximated by:

$$\delta_C = \frac{1}{2}U\Delta t \tag{15}$$

The average diffusive displacement may be approximated by:

$$\delta_D = \sqrt{(4v\Delta t \ln 2)} \tag{16}$$

To maintain equal discretisation of the fluid motion due to convection and diffusion we may equate $\delta_c$ and $\delta_D$ resulting in the expression

$$\Delta t = \frac{16L \ln 2}{U \,\mathrm{Re}} \tag{17}$$

Where Re = $\frac{UL}{v}$ is the plate Reynolds number

It would also be reasonable to select surface element size Δs at twice $\delta_c$ leading to

$$\Delta s = U\Delta t \tag{18}$$

$$\Delta s = \frac{16L\ln 2}{\text{Re}} \tag{19}$$

The required number of surface elements for satisfactory discretisation of the plate is then given by

$$M = \frac{L}{\Delta s} \tag{20}$$

$$M = \frac{\text{Re}}{16\ln 2} \tag{21}$$

It is clear from this study that enforcing equal discretisation scales $\delta_C$ and $\delta_D$ for convention and diffusion will lead to computational difficulties at high Reynolds numbers. For example, the boundary layer considered for Re = 500, yields M = 45. On the other hand for a typical engineering system value of Re = $10^5$, yields roughly M = 9017, thereby imposing severe pressure upon computational requirements.

The related time increment $\Delta t = 0.00011$ would also require $10^4$ time steps to achieve one flow pass. It is thus clear that practical computational limitations will rule out vortex modeling for typical engineering system Reynolds numbers if we attempt to impose the constraint $\delta_C = \delta_D$ to the foregoing calculation.

**Some Considerations for High Reynolds Number Flows**

One way to reduce these difficulties for high Reynolds number would be to select different time steps for diffusion ($\Delta t_D$) and convection ($\Delta t_C$). Since convection now dominates the flow, it will be preferable to select the scale of convection displacements through:

$$k = \frac{\delta_c}{\Delta s} \tag{22}$$

Where k can be set to be equal to 0.5

The convective time step is:

$$\Delta t_c = \frac{2k\Delta s}{U} \tag{23}$$

$$\Delta t_c = \frac{2k}{M}\left(\frac{L}{U}\right) \tag{24}$$

Although it would be perfectly in order to perform both the convection and random walk processes over the same time step $\Delta t_C$, a saving in computational effort could be achieved by undertaking only one random walk for every $N_t$ convection step with

$$\Delta t_D = N_t\,\Delta t_C \tag{25}$$

The upper limit of $N_t$ obtained from equating the scales $\delta_C$ and $\delta_D N^t$ is

$N_t$ = kRe

8Mln2 (26)

## SIMULATION

The governing equation is developed for the fluid flow. The Reynolds number served as the control parameter that governed the laminar-turbulent transition. This is followed by the formulation of algorithms for the model, which is illustrated by the flow chart. The flow chart is used in writing the FORTRAN–90 program. The program is then run to generate desire output. The result obtained was used to plot the graphs through Microsoft Excel.

## RESULTS AND DISCUSSIONS

Table 1 shows the result of Reynolds number and time increment. It also shows the number of time steps, number of elements, and log of average distance against log of time steps. The index is the slope obtained from the graph of log of average distance against log of time steps. The time increment decreases with increase in Reynolds number. The Reynolds number increases with increase in the number of time steps and number of elements or trials. Initially, the Reynolds number increases with the index, but from the Reynolds number of 70,000 there is onset of fluctuation in index.

**Table 1: Characterization of Fluid Flow**

| Reynolds Number (Re) | Time Increment (Δt) | Number of Time Steps (N) | Number of Elements or Trials (M) | Log of Average Distance Against Log of Time Steps (y=mx+c) | Index (m) |
|---|---|---|---|---|---|
| 10,000 | 0.11090 | 9 | 9 | y = 0.5865 x + 0.2821 | 0.5865 |
| 20,000 | 0.05545 | 18 | 18 | y = 0.7218 x + 0.2165 | 0.7218 |
| 30,000 | 0.03697 | 27 | 27 | y = 0.8182 x + 0.1355 | 0.8182 |
| 40,000 | 0.02773 | 36 | 36 | y =0.8243 x + 0.1274 | 0.8243 |
| 50,000 | 0.02218 | 45 | 45 | y = 0.8266 x + 0.1647 | 0.8266 |
| 60,000 | 0.01848 | 54 | 54 | y = 0.8281 x + 0.1517 | 0.8281 |
| 70,000 | 0.01584 | 63 | 63 | y = 0.8558 x + 0.1131 | 0.8558 |
| 80,000 | 0.01386 | 72 | 72 | y = 0.8817 x + 0.9490 | 0.8817 |
| 90,000 | 0.01232 | 81 | 81 | y = 0.875 x + 0.1003 | 0.875 |
| 100,000 | 0.01109 | 90 | 90 | y = 0.8908 x + 0.0874 | 0.8908 |
| 110,000 | 0.01008 | 99 | 99 | y = 0.8859 x + 0.0230 | 0.8859 |
| 120,000 | 0.00924 | 108 | 108 | y = 0.8806 x + 0.0929 | 0.8806 |
| 130,000 | 0.00853 | 117 | 117 | y = 0.8906 x + 0.0863 | 0.8906 |
| 140,000 | 0.00792 | 126 | 126 | y = 0.8953 x + 0.0713 | 0.8953 |
| 150,000 | 0.00739 | 135 | 135 | y = 0.8948 x + 0.0780 | 0.8948 |
| 160,000 | 0.00693 | 144 | 144 | y = 0.0919 x + 0.0722 | 0.919 |
| 170,000 | 0.00652 | 153 | 153 | y = 0.9125 x + 0.052 | 0.9125 |
| 180,000 | 0.00616 | 162 | 162 | y = 0.9087 x + 0.0561 | 0.9087 |
| 190,000 | 0.00584 | 171 | 171 | y = 0.921 x + 0.0361 | 0.921 |
| 200,000 | 0.00555 | 180 | 180 | y = 0.9232 x + 0.0317 | 0.9232 |
| 210,000 | 0.00528 | 189 | 189 | y = 0.9170 x + 0.0456 | 0.9170 |
| 220,000 | 0.00504 | 198 | 198 | y = 0.9236 x + 0.0346 | 0.9236 |
| 230,000 | 0.00482 | 207 | 207 | y = 0.9250 x + 0.0311 | 0.9250 |
| 240,000 | 0.00462 | 216 | 216 | y = 0.9193 x + 0.0450 | 0.9193 |
| 250,000 | 0.00444 | 225 | 225 | y = 0.9220 x + 0.0468 | 0.9220 |
| 260,000 | 0.00427 | 234 | 234 | y = 0.9268 x + 0.0361 | 0.9268 |
| 270,000 | 0.00411 | 243 | 243 | y = 0.9293 x + 0.0295 | 0.9293 |
| 280,000 | 0.00396 | 252 | 252 | y = 0.9367 x + 0.0118 | 0.9367 |
| 290,000 | 0.00382 | 261 | 261 | y = 0.933 x + 0.0238 | 0.933 |
| 300,000 | 0.00370 | 271 | 271 | y = 0.9338 x + 0.0208 | 0.9338 |
| 310,000 | 0.00358 | 280 | 280 | y = 0.9295 x + 0.0353 | 0.9295 |
| 320,000 | 0.00347 | 289 | 289 | y = 0.9375 x + 0.0158 | 0.9375 |
| 330,000 | 0.00336 | 298 | 298 | y = 0.9329 x + 0.0264 | 0.9329 |
| 340,000 | 0.00326 | 307 | 307 | y = 0.9357 x + 0.0217 | 0.9357 |
| 350,000 | 0.00317 | 316 | 316 | y = 0.9373 x + 0.0172 | 0.9373 |
| 360,000 | 0.00308 | 325 | 325 | y = 0.9368x + 0.0192 | 0.9368 |

**Table 1: Contd.,**

| | | | | | |
|---|---|---|---|---|---|
| 370,000 | 0.00300 | 334 | 334 | y = 0.9413 x + 0.0107 | 0.9413 |
| 380,000 | 0.00292 | 343 | 343 | y = 0.9454 x + 0.0035 | 0.9454 |
| 390,000 | 0.00284 | 352 | 352 | y = 0.9406 x + 0.0136 | 0.9406 |
| 400,000 | 0.00277 | 361 | 361 | y = 0.9445 x + 0.005 | 0.9445 |
| 410,000 | 0.00270 | 370 | 370 | y = 0.9450 x + 0.002 | 0.9450 |
| 420,000 | 0.00264 | 379 | 379 | y = 0.9450 x + 0.0032 | 0.9470 |
| 430,000 | 0.00258 | 388 | 388 | y = 0.9470 x - 0.0003 | 0.9470 |
| 440,000 | 0.00252 | 397 | 397 | y =0.9457 x + 0.0038 | 0.9457 |
| 450,000 | 0.00246 | 406 | 406 | y = 0.9548 x – 0.0173 | 0.9548 |
| 460,000 | 0.00241 | 415 | 415 | y = 0.9479 x – 0.0008 | 0.9479 |
| 470,000 | 0.00236 | 424 | 424 | y = 0.9470 x + 0.0001 | 0.9470 |
| 480,000 | 0.00231 | 433 | 433 | y = 0.9539 x – 0.0129 | 0.9539 |
| 490,000 | 0.00226 | 441 | 441 | y = 0.9495 x – 0.0028 | 0.9495 |
| 500,000 | 0.00222 | 451 | 451 | y = 0.9525 x – 0.0095 | 0.9525 |
| 510,000 | 0.00217 | 460 | 460 | y = 0.954 x – 0.0134 | 0.954 |
| 520,000 | 0.00213 | 469 | 469 | y = 0.9531 x – 0.0109 | 0.9531 |
| 530,000 | 0.00209 | 478 | 478 | y = 0.9534 x – 0.0110 | 0.9534 |
| 540,000 | 0.00205 | 487 | 487 | y = 0.9551 x – 0.0050 | 0.9551 |
| 550,000 | 0.00202 | 496 | 496 | y = 0.9524 x – 0.0070 | 0.9524 |
| 560,000 | 0.00198 | 505 | 505 | y = 0.9570 x – 0.0179 | 0.9570 |
| 570,000 | 0.00195 | 514 | 514 | y = 0.9541 x – 0.0117 | 0.9541 |
| 580,000 | 0.00191 | 523 | 523 | y = 0.9538 x – 0.0095 | 0.9538 |
| 590,000 | 0.00188 | 532 | 532 | y = 0.9574 x – 0.0199 | 0.9574 |
| 600000 | 0.00185 | 541 | 541 | y = 0.9569 x – 0.0168 | 0.9569 |
| 610,000 | 0.00182 | 550 | 550 | y = 0.9578 x – 0.0194 | 0.9578 |
| 620,000 | 0.00179 | 559 | 559 | y = 0.9587 x – 0.0212 | 0.9587 |
| 630,000 | 0.00176 | 568 | 568 | y = 0.9593 x – 0.0230 | 0.9593 |
| 640,000 | 0.00173 | 577 | 577 | y = 0.9620 x – 0.0029 | 0.9620 |
| 650,000 | 0.00171 | 586 | 586 | y = 0.9582 x – 0.0180 | 0.9582 |
| 660,000 | 0.00168 | 595 | 595 | y = 0.9572 x – 0.0161 | 0.9572 |
| 670,000 | 0.00166 | 604 | 604 | y = 0.9595 x – 0.0235 | 0.9595 |
| 680,000 | 0.00163 | 613 | 613 | y = 0.9589 x – 0.0203 | 0.9589 |
| 690,000 | 0.00161 | 622 | 622 | y = 0.9618 x – 0.0277 | 0.9618 |
| 700,000 | 0.00158 | 631 | 631 | y = 0.9599 x – 0.0242 | 0.9599 |
| 710,000 | 0.00156 | 640 | 640 | y = 0.9586 x – 0.0194 | 0.9586 |
| 720,000 | 0.00154 | 649 | 649 | y = 0.9628 x – 0.03 | 0.9628 |
| 730,000 | 0.00152 | 658 | 658 | y = 0.9604 x – 0.0224 | 0.9604 |
| 740,000 | 0.00150 | 667 | 667 | y = 0.9600 x – 0.0212 | 0.9600 |
| 750,000 | 0.00148 | 676 | 676 | y = 0.9625 x – 0.0273 | 0.9625 |
| 760,000 | 0.00146 | 685 | 685 | y = 0.9612 x – 0.0235 | 0.9612 |
| 770,000 | 0.00144 | 614 | 614 | y = 0.9652 x – 0.0357 | 0.9652 |
| 780,000 | 0.00142 | 703 | 703 | y = 0.9624 x – 0.0268 | 0.9624 |
| 790,000 | 0.00140 | 712 | 712 | y = 0.9627 x – 0.0274 | 0.9627 |
| 800,000 | 0.00139 | 721 | 721 | y = 0.9625 x – 0.0275 | 0.9625 |
| 810,000 | 0.00137 | 730 | 730 | y = 0.9630 x – 0.028 | 0.9630 |
| 820,000 | 0.00135 | 739 | 739 | y = 0.9650 x – 0.0333 | 0.9650 |
| 830,000 | 0.00134 | 748 | 748 | y = 0.9611 x – 0.0226 | 0.9611 |
| 840,000 | 0.00132 | 757 | 757 | y = 0.9625 x – 0.0251 | 0.9625 |
| 850,000 | 0.00130 | 766 | 766 | y = 0.9637 x – 0.0298 | 0.9637 |
| 860,000 | 0.00129 | 775 | 775 | y = 0.9649 x – 0.0321 | 0.9649 |
| 870,000 | 0.00127 | 784 | 784 | y = 0.9634 x – 0.0274 | 0.9634 |
| 880,000 | 0.00126 | 793 | 793 | y = 0.9658 x – 0.0348 | 0.9658 |
| 890,000 | 0.00125 | 802 | 802 | y = 0.9642 x – 0.0302 | 0.9642 |
| 900,000 | 0.00123 | 812 | 812 | y = 0.9653 x – 0.0323 | 0.9653 |
| 910,000 | 0.00122 | 821 | 821 | y = 0.9644 x – 0.03 | 0.9644 |
| 920,000 | 0.00121 | 830 | 830 | y = 0.9632 x – 0.0268 | 0.9632 |
| 930,000 | 0.00119 | 839 | 839 | y = 0.9681 x – 0.0402 | 0.9681 |
| 940,000 | 0.00118 | 848 | 848 | y = 0.9684 x – 0.0398 | 0.9684 |

**Table 1: Contd.,**

| | | | | | |
|---|---|---|---|---|---|
| 950,000 | 0.00117 | 857 | 857 | y = 0.9672 x – 0.0371 | 0.9672 |
| 960,000 | 0.00116 | 866 | 866 | y = 0.9688 x – 0.0415 | 0.9688 |
| 970,000 | 0.00114 | 875 | 875 | y = 0.9666 x – 0.035 | 0.9666 |
| 980,000 | 0.00113 | 884 | 884 | y = 0.9694 x – 0.0417 | 0.9694 |
| 990,000 | 0.00112 | 893 | 893 | y = 0.9697 x – 0.0432 | 0.9697 |
| 1000000 | 0.00111 | 902 | 902 | y = 0.9696 x – 0.0428 | 0.9696 |

The characterizing parameters are the index and Reynolds number. The graph of Index and Reynolds number displayed three distinct regions (figure 2) The concept of critical Reynolds number proves quite useful in demarcating the regimes of laminar and turbulent flows. The lower limit of critical Reynolds $(Re)_{cr}$ exists and its value is approximately 70,000. The upper limit of critical value of $(Re)_{cr}$ which characterizes full attainment of transition lie between 90,000 and 310,000. The lower critical Reynolds number is of greater engineering importance as it defines the limit below which all turbulence, no matter how severe, entering the flow from any source will eventually be damped out by viscous action.

The first region characterizes laminar region with regularity, stability, straight-line segment, high momentum diffusion and low momentum convection. (figure 3) In this region, the Reynolds number is less than 70,000.The second region is the transition region which is in form of way-line segments (figure 4) There is onset of instability or waviness (moving to and fro or up and down of lines in series).

This region is from Reynolds number of 70,000 to 310,000. The third region is the turbulent region in which higher wavy-line segments are shown (figure 5) The transition of a boundary layer form laminar to turbulent motion takes place at very high Reynolds number due to Kelvin-Helmholtz instability. The region starts from Reynolds number of 320,000. It is characterized by irregularity, instability, low momentum diffusion, high momentum convection and rapid variation of velocity.

## CONCLUSIONS

The study has explored the use of random walk model to characterize the fluid flow (soil erosion). The index number increases with increase in Reynolds number. Rate of increase of index number is highest in the laminar region and smallest in turbulent region. The laminar region is characterized by regularity, stability, high momentum diffusion and low momentum convection. There is onset of instability at the transition region while turbulent region is characterized by irregularity, instability, low momentum diffusion, high momentum convection and rapid variation of velocity.

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