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# Hydraulic's model based on HEC-GeoRAS; HEC-HMS and ARC-MAP computer programs to assess Sediments stored on HE sink

**Abstract**

The sediments store capacity of the Escobar Brothers (HE) Sink in Juárez City, Chihuahua, Mexico is at risk of being exceeded. Therefore, it deserves to be revised and redesigned to provide security to the inhabitants of the area. It is common that during the summer season, periodical storms of high intensity and short duration provokes water as well storage of coarse and fine soils. In summary, this research focuses on finding the geotechnical and hydraulic response produced by the storms typical of the arid region. This response is reflected in the rate of sediment carried by the main streams of the watershed. The aim of this research is: Sediment evaluation which in turn depends on the intensity and time of precipitation which involves an analysis of the rains of varying intensity and frequency. Therefore, the amount of fine sediment (silt-clay soils) and colloidal (silt transport) were evaluated. After that, hydraulic and hydrological models for erosion, transportation and deposition of coarse sediments (gravel-sands) were applied. To achieve this, three computer programs were used. The program Arc-Map 10.2 which was feed with Lydar database points to produce the Digital Elevation Model (DEM). With this model and by the use of the HEC-HMS program were performed watersheds and hydrological models. Finally, the program HEC-GeoRAS and HEC-RAS was used to simulate the hydraulic model and assessing the coarse sediments eroded, transported and deposited.

**Keywords:** hydraulic, hydrological, Sediments, Arc-Map 10.2, HEC-HMS, HEC-RAS

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## Introduction and research aims

Structures capacity like sinks, dykes and drainage networks deserve special attention in order to provide security to people who live around them. For instance, the brother's Escobar sink (HE) which is located in a large urbanized area are facing flooding risk as well sink reduction capacity. The problem of this reservoir is that during the summer seasons, high intensity and periodically storms provide high volume of water and sediment which are transported and stored at the Sink. Briefly, the aims of this research concerned to the relation between rainfall intensity and sediments rate derived from runoff events so three main stages were covered. The first stage is to evaluate sediment production which in turn depends on rainfall intensity and duration then characterization was performed in order to assess the quantity of sediments as a function of precipitation events. In addition, the influence on the sink capacity regarded to fine sediments like silt and clay. Finally, In order to assess this first stage two important programs were used. On the one hand, the Arc-Map 10.2 version program to assess hydrological and morphometric parameters of the basin. These hydrology components are included in the geoprocessing tools which are part of the spatial analysis tools of ARC-MAP program. The complementary programs that were used as: HEC RAS 5.0[13] HEC-GeoRAS[13]; and HEC-HMS 4.0[12] that allow to assess rainfall-runoff simulation models as well sediments for extreme climate areas like that of the study area. These programs are able to import shape (shp) files derived from Arc-Map 10.2.

### Study area location and main features

Juárez city is located in a dessert environment with few rainfall events mostly of high intensity and short duration. However, in average, rainfall in the city is nearly 254mm by year. As a result, many surficial dikes have been lost capacity; therefore, it is urgent to implement a pilot plan in order to face the problem. Ciudad Juárez Chihuahua, México is located northern of México and southern USA, so the Bravo River (solid red line) of Figure 1 functions like a political division with El Paso Texas. The main feature on the study area is: ESCOBAR sink, it is marked with a red color polygon; Juárez Mountains (MJ) and valley areas are marked in agree with topographic elevation derived from ARC-MAP geospatial delineation; urbanized area of the city is indicated as network black color. The key (legend) was extracted from the layout that was performed in ARC-MAP 10.2 and is represented by different colors in agree with its elevation; Lomas del Rey basin perimeter marked in dashed red color means the watershed of the ESCOBAR sink and are the main features (Figure 1).

## Methods

In order to assess morphometric parameters like basin areas as well network drainage system, a digital elevation raster model was done based on a point lidar dataset. This 1 meter offset points show enough resolution to perform the surface of the study area (Figure 1). Once, the Lidar points were collected from UACJ (2011)[14] and imported to Arc-Map 10.2, a raster data set named (Lomrey dataset) was assessed. After that, Hydrology tools included on Arc-Map spatial analysis were used to perform sub basins and drainage systems routines as: fill raster; flow direction; flow accumulation; flow length; basin; pour snap point; stream order; stream to features and watershed.

Finally, once the raster models were done a conversion into features were acquired and saved in (.shp) format. The attributes of basin area was recorded into the program for three sub-basins showed in color blue, green and red. Also, a network drainage system for the total basin study area showed in color white. In addition, the drainage presented on the map suggests a polarization between this drainage systems, the urbanized area as well features such as: streets and channels that are easy to distinguish (Figure 2). Features allocated on the study area such as: drainage network (white color) ESCOBAR sink derived from Lomas del Rey basin data set (red color); Basin to the west area (blue color); Center Basin (green color); Juan Gabriel street (blue color line); Casas Grandes Street (axe red color line); Teofilo Borunda west street (point red color line); Teofilo Borunda street (dashed red color line) coordinates are UTM datum WGS 1984. Finally, the third issue performed was evaluation of Lag-time using the 60% of (Tc) (see SCS (1983) in HEC-HMS 3.5 and (see Zuñiga1 ). Under these considerations, features as: (Juan Gabriel; Casas Grandes; Teofilo Borunda west and east streets were identified). Finally, the red color sub-basin named Lomas Del Rey that is the concern of this research is shown (Figure 2).

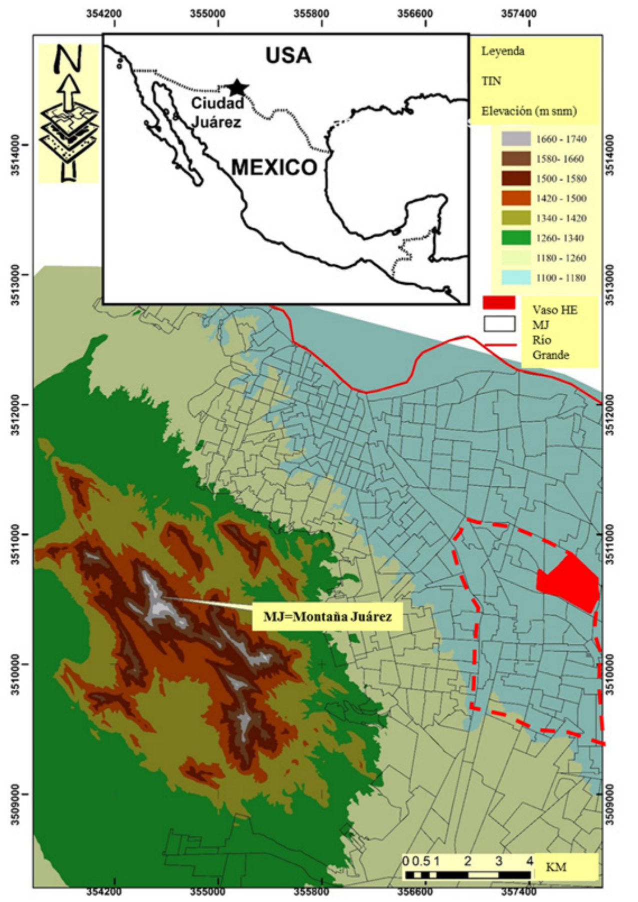


**Figure 1** Location of the study area: Digital elevation model see legend on the upper right map; Streets network (gray lines); Escobar sink (red color polygon); limits of the study area including Lomas del Rey sub-basin (dashed red color line); Bravo River also named (Rio Grande) red color line. UTM datum WGS 1984.

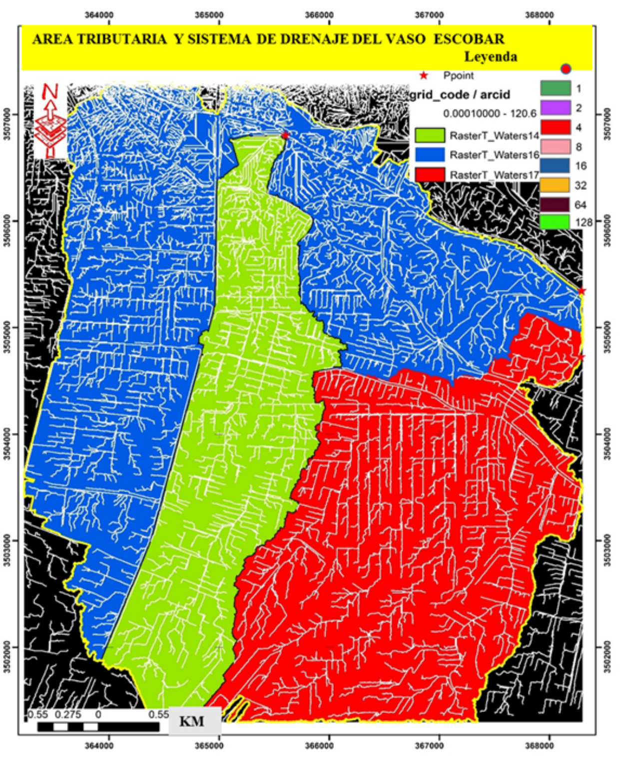


**Figure 2** Features allocated on the study area.

## Second stage

This part is related to the rainfall runoff model performed using Hydrology Engineering Center/Hydrology Modelling System program (HEC-HMS). This program is able to model direct runoff associated with rainfall storm events for several return periods. In the present research a 100 years rainfall return periods was used, so design storm of 55.5 mm was considered Zuñiga,[1] As soon as the morphometric parameters of sub-basins such as: area, perimeters and length of drainage network were assessed, then HEC-HMS program modelling was performed (Figure 3). A field inventory for the three sub-basin was done to assess: **CN** runoff coefficients for Lomas del Rey sub-basin. These parameters were researched in agree with the land-use as well infiltration rates for hydrological soils as: (A, B, C and D). In addition, parameters such as: Impervious areas and main streams length were defined like reaches connected between Upper, Middle and Lower sub-basin in order to calculate its concentration time (Tc). Regarded to direct runoff evaluation for upper Middle and lower sub-basins three main steps were considered.

a. Initial abstractions of (0.2) were discounted in order to consider rainfall losses as recommended in the method. After that, impervious areas were defined as streets and many platforms as parked areas included in them.
b. This part was covered by measure in the field length of the main streams or reaches as well its slope and manning coefficient (n) all these, in order to evaluate the concentration time (Tc) (see SCS (1983) in HEC-HMS 3.5).

**Citation:** león DZ, Chicas AD, Urias HQ. Hydraulic's model based on HEC-GeoRAS; HEC-HMS and ARC-MAP computer programs to assess Sediments stored on HE sink. *Int J Hydro.* 2018;2(4):433–443. DOI: 10.15406/ijh.2018.02.00107

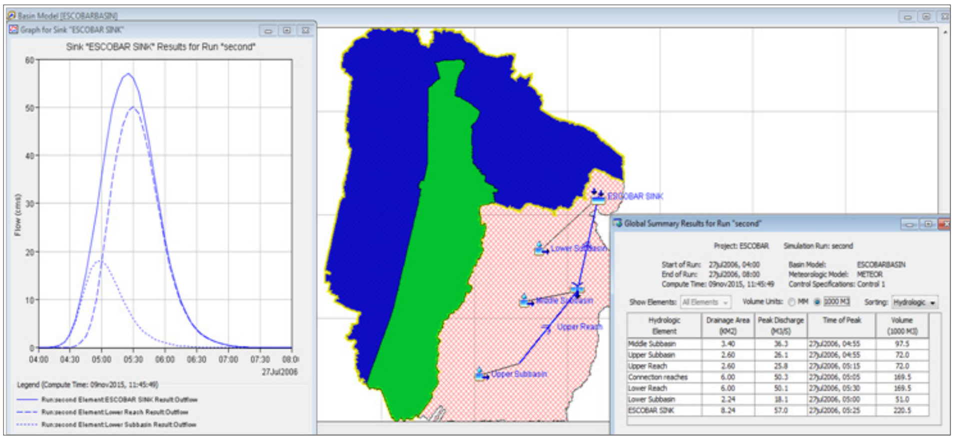


**Figure 3** HEC-HMS Rainfall-Runoff model results for Sub-basins: ESCOBAR sink stored water and discharge for 55 mm intensity and 1hour duration red assured area.

In short second stage is HEC-HMS simulation and results are shown in Figure 3 but only two findings are highlighted in this research such as: 220,500m$^3$ of water which is stored in the ESCOBAR sink, also 57m$^3$/sec of discharge derive by two reaches and two sub-basins. Finally, fine soils deposited on the ESCOBAR sink were assessed during three rainfall events: One (0,689 kg/m$^3$=1mm) recorded on march 17 from 14:20 to 15:20, other (0.455kg/m$^3$=0.8mm) recorded on August 10 from 23:45 to 00:45 and the other (1.6kg/m$^3$=1.8mm) recorded on August 24 from 1:15 to 2:15. Therefore, deposits of 1.13kg/m$^3$ for every 1mm of rainfall were measured. The ESCOBAR sink it's at risk of overfill as well loss its capacity because a great amount of fine sediments would be deposited. Originally, its capacity was 214,000m$^3$.[2] However, the rate of soil deposit of 1.13kg/m$^3$ for every 1mm of rainfall would produce 3154 ton of sediments per year, nearly (2118m$^3$). As a result, the ESCOBAR sink would have a useful life of 53 years. On the other hand, rainfall-runoff model for an event of 55 mm corresponded to 100 years return period would produce flooding of ESCOBAR sink because 220,500m$^3$ overload its capacity of 214,000m$^3$ (Figure 3**).**

Third stage here we define the hydraulic model that includes erosion; transport as well sediment of mixed particle size. These sediments were deposited and affects capacity of the sink. The model used was originally created by Meyer-Peter and Muller (MPM) and is considered appropriate for a range of well-graduated particle size (0.4-29mm) with particle-specific gravity between (1.25-4); Particle friction factor for the soil bed given by Darcy-Weisbach formulae. See the equations (1-13) that are referenced by: Wong & Parker,[3] Rijin[4] Thomas & Chang,[5] Parker,[6,7] Whipple,[8] Yanta Cui et al.,[9]

$$[kr/k'r]^{0.66} = \gamma RS = 0.047(\gamma_s - \gamma)d_m + 0.25[\gamma / g]^{0.33}[(\gamma_s - \gamma)/\gamma_s]^{0.66}(g_s)^{0.66} \quad (1)$$

$g_s$=Unitary rate of sediment transport;

kr=roughness coefficient of the sediment sample obtained from the stream bed;

k'r=roughness coefficient based on the different types or class of grains (i).

γ=water-spreading weight.

$\gamma_s$ =unitary weight of sediments;

g=acceleration of gravity;

$d_m$=average particle diameter;

R=hydraulic radius;

S=Energy gradient.

## Hydraulic sedimentation continuity model (Thomas Exner 5)

In order to give continuity to the sedimentation process, the (equations 2 and 3) were used. The porosity of the soil, the width of the stream bed, the stream of water and the time interval were considered. These, in order to allow the particles to be deposited and fill the gaps in the soil mass at an appropriate time interval (equation 4, 5 and 6). These equation are given in the following paragraphs:

$$(1-\lambda_p)B\delta\eta / \delta t = -\delta Qs / \delta x \quad (2)$$

B=Width of the principal stream bed or river

$\lambda_p$ =Porosity of the active layer performed by Soil mechanics laboratory test.

η=flow water elevation of the principal stream bed or river.

t=Time interval.

x=Distance.

$Q_s$ = Load of sediment soil transported by the flow.

## Premise

Sediments entering and exiting the control volume must be stored or removed from storage. The only characteristic of the Exner5 equation is that the sediments are stored in the bed in a multi-phase medium mixed with water. Therefore, the change occurs in the gaps that are in the porous medium of the soil and is where the change is generated. Therefore, this is considered as erosion or deposit. The transport capacity is defined for each type of soil grain multiplying the percent by their content and using equation 3 below.

$$Tc = \Sigma_1^n \beta jTj \quad (3)$$

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Tc=Transport capacity of total sediments.

n=Number of grain types (j)

βj=Percent of the active layer corresponded to the sediments of grain class type (j).

Tj=Percent transport potential evaluated for the grain class (j).

## Continuity limits

Two antagonistic forces are present during the sediment transport process (Figure 4). The drag Force (Fd) (equation 5) and the Falling Force (Fg) (Equation 6). These, are based on hydrodynamic factors that at the same time depend on the kind of grain of the sediments involved in the soil sample. On the other hand, equation 4 determines the temporal deposit coefficient (Cd) and Equation 7 and Figure 5 define temporal erosion.

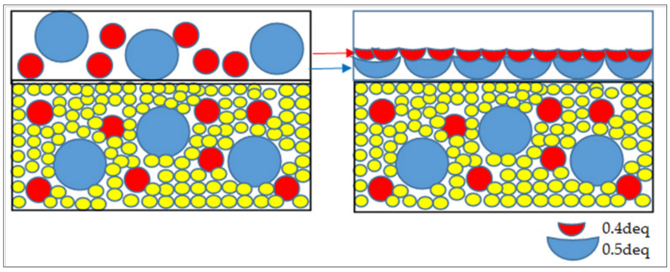


**Figure 4** Idealized examples. Coverage of three kind of grain: Upper and sub-surface layer showing the equivalent particle of main size. Source: Fort Randall Dam (Livsey, 1963).

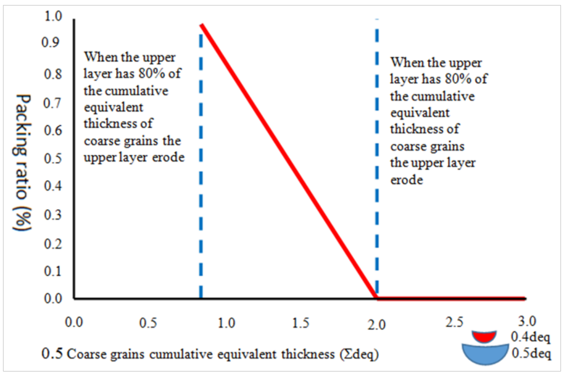


**Figure 5** Arming and packing relationship considered in the Thomas method.

## Temporal deposition

$$C_d = V_s(i)\ \Delta t / D_e(i) \qquad (4)$$

$$F_d = [\,½\,]\,\pi\rho C_d\,[D/2]^2\, v_s^2 \qquad (5)$$

$$F_g = [4/3]\,\pi\rho R_a g\,[D/2]^3 \qquad (6)$$

$C_d$=Drag coefficient.

$V_s$(i) =Fall velocity for the class grain (i).

Δt =Time interval.

$D_e$=effective depth of water column above the grain class transported (i).

$F_d$=Drag force of the particle of grain class (i)

D=Diameter of grain class (i)

g=Gravity acceleration.

ρ=Specific weight of grains class (i)

$F_g$=Fall gravity force.

## Temporal erosion limit:

$$Ce = 1.368 - e^{-[L/30D]} \qquad (7)$$

Ce=Entrapment coefficient.

D=Flow depth.

L=Control volume length.

**Note:** If the length exceeds the flow depth by 30 times or more the entrapment coefficient (Ce) tends to be 1 and HEC-RAS assigns erosion to this missing one. At the lower limit, as the length approaches the depth the second term of the equation (Ce) tends to 1 so there is a minimum trap value of 0.368. However, at least 36.8% of the erosion deficit is allowed.

## Limits of draw and armed

In this context, the Thomas Exner 5 criterion was adopted to the selection process of packed and sort of the actives layers and their equivalent thickness respectively. A static packing can be a result of differential transport of fine particles that leave coarse particles aside until they arm the support bed causing future erosion. The process of static assembly often occurs downstream of dams or dikes where the flow regime is attenuated and are very competent to move fine but not coarse particles. Dynamic armor, can also form layers in a system where great fluxes are able to move several types of sediments that were produced. Drag, transport and sediments deposit of the "VASOHE" was performed by simulation hydraulic models already available (see cited references). Soil mechanic parameters as class grain distribution bed stream were performed and are shown in Table 1 & Table 2. These samples were testing on the soil mechanics laboratory of UACJ (2016).[15] Also, the hydraulic model was started using parameters such as: Initial flow and boundary conditions given by: RIVERHE and VASOHE. Therefore, the initial station was located in the upper part of the stream (3210.432m) and the final was given at the beginning and lower part of the stream were the sink (VASOHE) is located. Also, the Rating Curve was used during this first hydraulic simulation stage (Table 1).

**Table 1** Initial sediment and boundary conditions for principal stream of HE Sink

| Rating curve | | Sediment load series | Equilibrium load |
|---|---|---|---|
| Flow weighted sediment split | | Thershold weighted sediment split | sediment split by grain class |
| River HE | VASO HE | 3210.432 | Rating curve |

**Citation:** león DZ, Chicas AD, Urias HQ. Hydraulic's model based on HEC-GeoRAS; HEC-HMS and ARC-MAP computer programs to assess Sediments stored on HE sink. *Int J Hydro.* 2018;2(4):433‒443. DOI: 10.15406/ijh.2018.02.00107

**Table 2** Size grains distribution of soil simple extracted from principal stream bed which discharge on VASOHE source soils mechanics laboratory of (UACJ (2016)

| Rating curve for river HE 3210.432 | | | |
|---|---|---|---|
| **Number of tons-load points 2 sets** | | | |
| **Flow m³/sec** | | **10** | **50** |
| **Total load tons/day** | | **0.5** | **10** |
| 1 | Arcilla (0.002-0.004) | | |
| 2 | VFM (0.004-0.008) | | |
| 3 | FM (0.008-0.016) | | |
| 4 | MM (0.016-0.032) | | |
| 5 | CM (0.032-0.0625) | 1.2 | 1.2 |
| 6 | VFS (0.0625-0.125) | 1.96 | 1.96 |
| 7 | FS (0.125-0.250) | 1.02 | 1.02 |
| 8 | MS (0.25-0.5) | 2.73 | 2.73 |
| 9 | CS (0.5-1) | 4.91 | 4.91 |
| 10 | VCS (1-2) | 0.82 | 0.82 |
| 11 | VFG (2-4) | 4.2 | 4.2 |
| 12 | FG (4-8) | 12.72 | 12.72 |
| 13 | MG (8-16) | 19.23 | 19.23 |
| 14 | CG (16-32) | 38.95 | 38.95 |
| 15 | VCG (32-64) | 2.24 | 2.24 |
| 16 | SC (64-128) | | |
| | Define diversión | plot | |

## Equilibrium depth

There are 3 conditions for the Adjustment model for the active layer based on the criterion developed by Copeland[10,11] In this context an equivalent Diameter (De) is predicted for the different particles of spherical shape that enter and leave the control volume according to their density and size. The active layer is adjusted to the equilibrium depth for 3 conditions:

i. Equilibrium depth less than the water depth.

ii. Equilibrium depth contained within the active layer.

iii. Depth of balance deeper than the active layer.

The depth of equilibrium (Deq) is based on a relationship between hydraulic energy, roughness of the particles contained in the main stream bed and the intensity of sediment transport. The Thomas Exner 5 method combines the Manning formulae (equation 8) for the flow velocity, the Strickler equation (equation 9) for the roughness of the particles and the Einsten equation to measure the intensity of transport for equilibrium depth evaluation (Deq).

Manning; $V = \left(1.49 / n\right) R^{0.66} S^{0.5}$ (8)

Strickler; $n = d^{0.166} / 29.3$ (9)

Sediments transport equation Einsten;

$$\Psi = [(\rho_s - \rho_w) / \rho_w]\left(d / DS_f\right) \quad (10)$$

The main innovation of the Thomas Exner 5 model was to divide the active layer into two large layers, the upper layer and the sub-surface, the algorithm calculates the transport capacity based on the total layer but the upper layer grows independently and regulates erosion from the rest of the active layer (sub-surface layer). At the start of the bed mixing stage, a thickness of the active layer based on (Deq) is calculated. On the upper layer, the layer of the previously calculated stage is placed, but the sub-surface layer is regenerated each time based on this new layer thickness calculated for the depth of equilibrium (Deq) (HEC-RAS 5.0).

## Equivalent diameter of particles

The Thomas equation calculates the packing of the top layer based on an equivalent diameter of the initial particles. This may be difficult to conceptualize but it is the key to understanding the algorithm. The equivalent diameter of the particles (Deq) converts the mass of each grain class into an equivalent thickness expressed as a function or multiple of the diameter of the grain class (i). For example, if the large grain class (blue) in Figure 4 were evenly distributed over the control volume it could form a thickness equivalent to about half the diameter of said particle (0.5Deq), similarly if the class medium grain (red) could have 40% of said diameter (O.40Deq). That is, the equivalent diameter of the particles defines the mass of each kind of grain (i) as an equivalent thickness normalized to the diameter of said particular (Figure 4). The equation of EINSTEN supposes erosion of particles when Ψ>=30 and the density of the submerged particles (ρs-ρw)/ρw = 1.65 so, replacing in the Einsten equation (equation 10) it remains as (equation 11).

$$S_f = d / 18.18D \quad (11)$$

HEC-RAS solves these three equations for discharge (q) reemplasing the hydraulic ratio into the manning equation and the (n) value into the Strickler equation (see equation 12).

$$q = [1.49] / \left[\left(d^{0.166}/29.3\right)\right] D^{0.66} [d/18D]^{0.5} \quad (12.1)$$

$$q = 10.21 D^{0.33} d_i^{\,0.66} \quad (12.2)$$

$d_i$=Particle diameter of grain (i)

D=Depth that does not convey the grain class or Equilibrium depth (Deq). Finally, the equivalent diameter of the soil particles entering and leaving the control volume is established by equation 13.

$$D_{eq} = \left[\left(q/10.21 d_i^{0.33}\right)\right]^{0.857} \quad (13)$$

## Packing grade evaluation

Thomas method (Exner 5) determines the packing ratio from the thickest accumulated diameter according to consideration given in Figure 4. In it, interpolation between the lower limit where no erosion effects and the upper limit where the packaging layer completely prevents erosion from the sub-surface layer.

## Lower limit

If this is less than a thick cumulative equivalent diameter in the upper layer (Σdeq <1) then the upper layer can't continue the process. For (Deq<0.80), 20% of the sub-surface layer is exposed. In all this thickness, the method assumes that the upper layer has many spaces to be able to regulate the sub-surface layer. Thomas's method does not reduce erosion in this case.

## Upper limit

At the other extreme, if the sum of the equivalent grain diameters becomes thicker, that is to say that the classes (i) are greater than 2 (ΣDeq>2) the upper layer can't allow erosion of any kind of grain from the sub-surficial layer. The above is derived from empirical evidences where it has been verified that the flow can't suck fine sediment particles along more than two packing diameters of immobile armed layers. Thomas's method interpolates between these two extreme points. No packing; Armor=1=missing=erosion for (Deq<0.8); No Erosion; Armor=0=erosion=0 for (Deq>2); (Figures 4) (Figure 5).

## Erosion of the grain class (i) from the sub superficial layer

Reducing the gap by the packing ratio HEC-RAS multiplies the sediment gap for each kind of grain (i) by the packing ratio in such a way that it reduces erosion for each kind of grain (i) according to the following expression: EROSION (gi)=Degree of packaging (gi) plus Sediment absent (gi). For the example in Figure 4 & Figure 5 (Σdeq=0.9) Thomas' method considers a value of Deq=0.91, then HEC-RAS can remove 91% of the shortage of fine grains from the sub-surface layer.

## Hydraulic model of sediment drag

Firstly, using the Arc-Map 10.2 program, the Digital Elevation Model (DEM) was obtained in Tringular Irregular Network (TIN) format based on Lydar points 1 meter offset. Afterwards, the axis of the main stream, the banks of the stream bed, the limits of influence of the stream and the cross sections, along the 3210.43 meters of length of the stream, were defined. Therefore, the Arc-Map 10.2, aided by the Geometry Module contained in the HEC-Geo RAS was used. Once these routines were carried out, these parameters were exported to the HEC-RAS program in which the Hydraulic Sediment Traction Model was made. In the HEC-RAS program, the previously exported (.dss) file is opened. Therefore, it was possible to have access to the geometry of the profile and sections that were revised so that the limits of banks and values of roughness coefficients of Manning were entered into the model. Subsequently, runoff was simulated considering conditions of Quasy-stable flow and return period of 100 years. With these expenses, the sediment drag simulation was carried out, so it was necessary to obtain the soil samples to indicate its size distribution (Table 1); Prior to this, flow parameters were evaluated for boundary conditions under Quasy-unstable flow in order to represent the model in a discrete manner and with time intervals of 0.25 hours see Figure 6, Table 3, Table 4 & Table 5.

After that, if this is the case, additional lateral flow; boundary conditions and flow series combinations are needed for any additional tributary stream in the network drainage as are sown in Figure 6, Table 6, Table 7 & Table 8 Boundary conditions and flow series considered for VASOHE (Flow series considering normal depth of the main stream from its beginning (3210.432m) to its outlet in the vessel (26.5897m). Source: HEC-RAS 5.0. Then, the width and depth parameters for the profile and sections of the main stream are incorporated into the transport model (HEC-RAS 5.0) to determine the process of erosion, transport and deposition of sediments see Figures 7, Table 9, Table 10 & Figure 8. Incorporation of geometric parameters of width and depth for the profile of the main stream axis and cross sections from its source (3200.43m) to its mouth in the VASOHE (26.50m) (Figures 8) & (Figure 9). To determine erosion, transportation and sediments deposition resulted see Figure 9 below.

**Table 3** Temperature simulation: source HEC-RAS 5.0[13]

| # | Simulation time (hr) | Elapsed time (hr) | Duration (hr) | Temp (C) |
|---|---|---|---|---|
| 1 | 01/April/2017 24:00 | 0.5 | 0.5 | 25 |
| 2 | 02/April/2017 00:30 | 1 | 0.5 | 25 |
| 3 | 02/April/2017 01:00 | 1.5 | 0.5 | 25 |
| 4 | 02/April/2017 02:00 | 2 | 0.5 | 25 |
| 5 | 02/April/2017 02:30 | 2.5 | 0.5 | 25 |
| 6 | 02/April/2017 03:00 | 3 | 0.5 | 25 |

**Table 4** Friction coefficient, Source: HEC-RAS 5.0[13]

| Downstream border | |
|---|---|
| Friction gradient parameter | 0.004 |

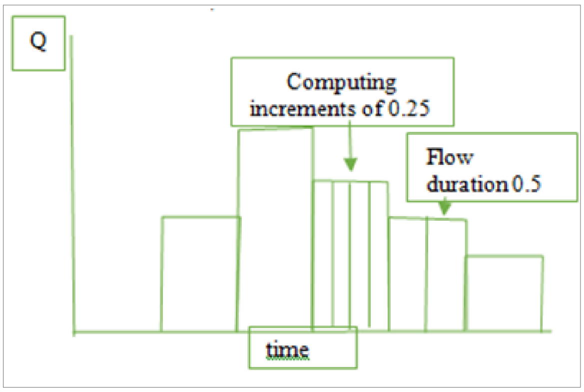


**Figure 6** Compute increments and flow duration (Q), Source: HEC-RAS 5.0.[13]

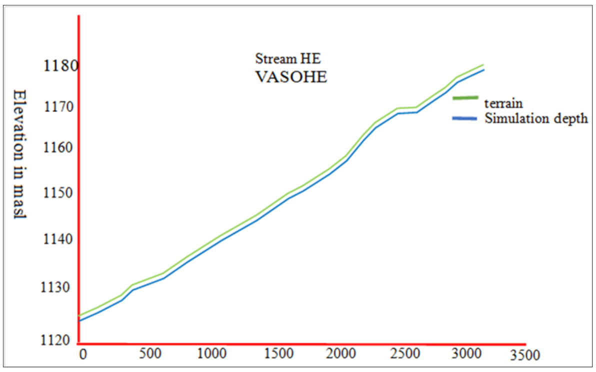


**Figure 7** Profile showed Station in meter and elevation above sea leabel (masl).

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**Table 5** Principal stream flow series time intervals within the expenditure for increments of time based on estimated expenditures for computation intervals for the main VASOHE stream. Source: HEC-RAS 5.0[13]

| # | Simulation time (hr) | Elapsed time (hr) | Duration (hr) | Compute interval (hr) | Flow ($m^3$/seg) |
|---|---|---|---|---|---|
| 1 | 01/April/2017 24:00 | 0.5 | 0.5 | 0.25 | 5 |
| 2 | 02/April/2017 00:30 | 1 | 0.5 | 0.25 | 10 |
| 3 | 02/April/2017 01:00 | 1.5 | 0.5 | 0.25 | 15 |
| 4 | 02/April/2017 02:00 | 2 | 0.5 | 0.25 | 20 |
| 5 | 02/April/2017 02:30 | 2.5 | 0.5 | 0.25 | 25 |
| 6 | 02/April/2017 03:00 | 3 | 0.5 | 0.25 | 30 |
| 7 | 02/April/2017 03:30 | 3.5 | 0.5 | 0.25 | 35 |
| 8 | 02/April/2017 04:00 | 4 | 0.5 | 0.25 | 40 |
| 9 | 02/April/2017 04:30 | 4.5 | 0.5 | 0.25 | 45 |
| 10 | 02/April/2017 05:00 | 5 | 0.5 | 0.25 | 50 |
| 11 | 02/April/2017 05:30 | 5.5 | 0.5 | 0.25 | 55 |
| 12 | 02/April/2017 06:00 | 6 | 0.5 | 0.25 | 60 |

**Table 6** Uniform lateral flow for flow series given. Source: HEC-RAS 5.0[13]

| Flow series | Flow series | Uniform lateral flow |
|---|---|---|
| Normal depth | Stages series | Curve ratio |
| T.S= open gates | Boundary Condition location | Quasi-Unsteady flow editor |

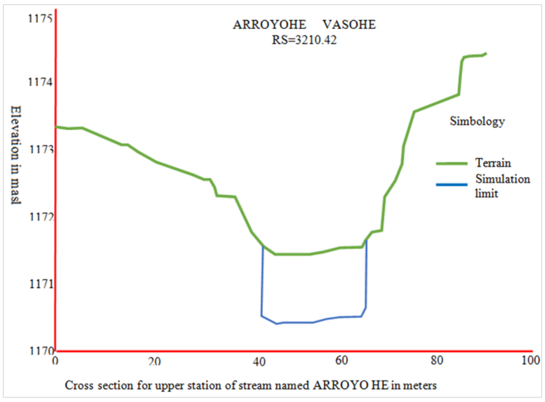


**Figure 8** Cross sections considered in the main stream, delimiting the left and right of the axis in order to define the influence of the stream bed in which the simulation is carried out. In the table the geometric parameters introduced for each of the stations of the stream are appreciated. Source: HEC-RAS 5.0.[13]

**Table 7** Boundary conditions and flow series considered for VASOHE (Flow series considering normal depth of the main stream from its beginning (3210.432m) to its outlet in the vessel (26.5897m). Source: HEC-RAS 5.0[13]

| # | stream | Channel | RS | Boundary conditions |
|---|---|---|---|---|
| 1 | ARROYOHE | VASOHE | 3210.432 | Flow series |
| 2 | ARROYOHE | VASOHE | 26.58975 | Normal depth |

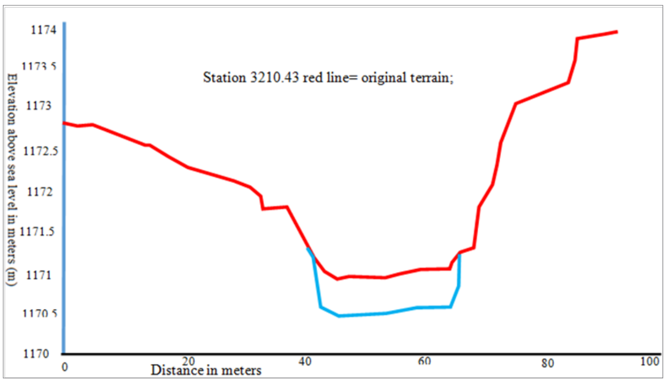


**Figure 9** Figure shown that at station 3210. 432 erosion occurred during the 24 hours of design precipitation. Source: HEC-RAS 5.0[13]

**Citation:** león DZ, Chicas AD, Urias HQ. Hydraulic's model based on HEC-GeoRAS; HEC-HMS and ARC-MAP computer programs to assess Sediments stored on HE sink. *Int J Hydro.* 2018;2(4):433‒443. DOI: 10.15406/ijh.2018.02.00107

**Table 8** Lateral flow series of tributaries that are incorporated into the main stream for 1 hour intervals and 0.1 hour computational increments for the illustrated expenditures. Source: HEC-RAS 5.0[13]

| **Flow series for uniform reaches combination of reach against reaches: O.5303 to reaches 0.50384; 0.50006; 0.49628; 0.4925; 0.4887; 0.4849; 0.4811; 0.4775 etc.** | | | | | |
|---|---|---|---|---|---|
| **#** | **Time of simulation** | **Time Elapsed** | **Duration of flow** | **Increments computation** | **Flow Lateral** |
| | **Date** | **Hours** | **Hours** | **Hours** | **($m^3$/seg)** |
| 1 | 01 January 2000 000 | 1 | 1 | 0.1 | 49 |
| 2 | 01 January 2000 100 | 1 | 1 | 0.1 | 134.35 |
| 3 | 01 January 2000 200 | 1 | 1 | 0.1 | 219.71 |
| 4 | 01 January 2000 300 | 1 | 1 | 0.1 | 305.06 |
| 5 | 01 January 2000 400 | 1 | 1 | 0.1 | 390.41 |
| 6 | 01 January 2000 500 | 1 | 1 | 0.1 | 475.76 |
| 7 | 01 January 2000 600 | 1 | 1 | 0.1 | 561.12 |
| 8 | 01 January 2000 700 | 1 | 1 | 0.1 | 646.17 |
| 9 | 01 January 2000 800 | 1 | 1 | 0.1 | 731.82 |
| 10 | 01 January 2000 900 | 1 | 1 | 0.1 | 817.18 |

**Table 9** Transport, sorting and fall velocity methods for hydraulic simulation, Source: HEC-RAS 5.0[13]

| **Streams all** | | **Transport function** | **Meyer-peter-muller** | **Stream bed graduation** |
|---|---|---|---|---|
| Channel name | | Sorting method | Thomas (Ex5) | |
| Number of stream movil beds | 1 | Fall velocity method | Ruby | |

**Table 10** It is considered 1 meter of maximum depth and lateral stations to the left and right of the main stream as well as the granulometric distribution in% (upper). The table shows the parameters for each station and the method considered for the hydraulic model. Source: HEC-RAS 5.0[13]

| **#** | **Stream** | **Channel** | **Station** | **Station** | **Max. depth** | **Min depth** | **Left** | **Right** | **Soil bed** |
|---|---|---|---|---|---|---|---|---|---|
| 1 | HE | VASOHE | 3210.43 | 1171.38 | 1 | | 41.64 | 65.94 | upper |
| 2 | HE | VASOHE | 3110.12 | 1170.25 | 1 | | 48.3 | 61.05 | upper |
| 3 | HE | VASOHE | 3005.71 | 1168.92 | 1 | | 71.24 | 88.38 | upper |
| 4 | HE | VASOHE | 2900.41 | 1167.25 | 1 | | 51.13 | 68.06 | upper |
| 5 | HE | VASOHE | 2810.74 | 1165.75 | 1 | | 56.28 | 76.23 | upper |
| 6 | HE | VASOHE | 2673.34 | 1163.65 | 1 | | 93.71 | 129.3 | upper |
| 7 | HE | VASOHE | 2528.544 | 1163.455 | 1 | | 112 | 127 | upper |
| 8 | HE | VASOHE | 2352.08 | 1160.75 | 1 | | 70.02 | 89.75 | upper |
| 9 | HE | VASOHE | 2262.757 | 1158.44 | 1 | | 78.9 | 85.05 | upper |
| 10 | HE | VASOHE | 2124.61 | 1154.75 | 1 | | 55.4 | 95.91 | upper |
| 21 | HE | VASOHE | 1994.95 | 1152.5 | 1 | | 92.99 | 108.4 | upper |
| 12 | HE | VASOHE | 1786.94 | 1148.25 | 1 | | 45.79 | 58.65 | upper |
| 13 | HE | VASOHE | 1668.17 | 1147.58 | 1 | | 38.93 | 49.17 | upper |
| 14 | HE | VASOHE | 1413.8 | 1143.69 | 1 | | 13.78 | 33.34 | upper |
| 15 | HE | VASOHE | 1145.43 | 1139.74 | 1 | | 57.15 | 68.97 | upper |
| 16 | HE | VASOHE | 880.314 | 1136.13 | 1 | | 166 | 185.3 | upper |
| 17 | HE | VASOHE | 704.055 | 1133.25 | 1 | | 170.3 | 185.5 | upper |
| 18 | HE | VASOHE | 454.684 | 1131 | 1 | | 74.24 | 94.84 | upper |
| 19 | HE | VASOHE | 363.235 | 1129 | 1 | | 66.48 | 89.74 | upper |
| 20 | HE | VASOHE | 183.375 | 1126.75 | 1 | | 134.3 | 168.7 | upper |
| 21 | HE | VASOHE | 26.5879 | 1124.35 | 1 | | 58.69 | 98.38 | upper |

## Results

The hydraulic simulation model is sensitive to: Selection of the soil sample; time series considered; computational increments of the algorithm and size distribution characterization of grains to name a few. However, these must correspond to the appropriate model according to the type of grains. The HEC-RAS 5.0 program shows all the resulting hydrodynamic information. In this, results are shown in the form of tables and graphs such as: Distribution of mass change along the main stream for different time intervals; Cumulative mass change distribution in tons for the total time interval and by grain category along the main stream, showing the erosion with negative values and the deposit with positive values. The total amount of mixed sediments accumulated in the catchment area (VASOHE) and the location of the sections for different grain types as well as the mass change distribution in tons for the total time interval and by grain category along the main stream. For reasons of space, this research shows only those that show the sediments deposited in the sink named VASOHE collection vessel see Table 11. In Figure 10; the time, the simulation date and the amount of total sediment accumulated over time are appreciated; In Table 11 it is shown that at the initial station of the main stream (3210.432m) erosion occurred during the 24-hour design precipitation; In Figure 10 it is shown that at the mouth of the main stream (station 26.58m) there was a deposit during the 24-hour design rain period. Finally, in Table 3 and Table 12 shows the mass curve of mixed sediments accumulated in the different stations along the main stream. The results of erosion below the axis or negatives and deposit above the axis or positive values, is specific for each time interval and mileage of the stream the values and change in the mass of the gross total sediments in tons.[12,13] The following graph shows the accumulated mass curve diagram for the different stations in which the Principal stream was divided. These are referred from (3210.43m) to (26.5897m) which is the mouth of the stream, that is to say the Hermanos Escobar catchment vessel (VASOHE) (Figure 11).[14–16]

**Table 11** Cumulative total mass distribution including all types of sediments deposited in the VASOHE in tons during the 24 hours of design precipitation. In this figure, the total amount of coarse sediments accumulated in the catchment area is determined. The table shows 1182,138 tons of sediments. Source: HEC-RAS 5.0[13]

| Time intervals (hours) | Date simulation time | Mass-curve (tons) |
|---|---|---|
| 1 | 30 December of 2017 from 00- 15 | 15.581 |
| 2 | 30 December of 2017 from 00-30 | 30.144 |
| 3 | 30 December of 2017 from 00-45 | 58.172 |
| 4 | 30 December of 2017 from 00- 1.00 | 85.539 |
| 5 | 30 December of 2017 from 1.00-1.15 | 127.565 |
| 6 | 30 December of 2017 from 1.00-1.30 | 171.051 |
| 7 | 30 December of 2017 from 1.00-1.45 | 217.916 |
| 8 | 30 December of 2017 from 1.00-2.00 | 264.141 |
| 9 | 30 December of 2017 from 2.00-2.15 | 297.858 |
| 10 | 30 December of 2017 from 2.00-2.30 | 331.33 |
| 11 | 30 December of 2107 from 2.00-2.45 | 370.01 |
| 12 | 30 December of 2017 from 2.00 -3.00 | 408.576 |
| 13 | 30 December of 2017 from 3.00-3.15 | 451.019 |
| 14 | 30 December of 2107 from 3.00-3.30 | 493.193 |
| 15 | 30 December of 2017 from 3.00-3.45 | 548.713 |
| 16 | 30 December of 2017 from 3.00-4.00 | 601.933 |
| 17 | 30 December of 2017 from 4.00-4.15 | 653.383 |
| 18 | 30 December of 2107 from 4.00-4.30 | 704.427 |
| 19 | 30 December of 2017 from 4.00-4.45 | 780.566 |
| 20 | 30 December of 2017 from 4.00-5.00 | 847.976 |
| 21 | 30 December of 2017 from 5.00-5.15 | 939.01 |
| 22 | 30 December of 2107 from 5.00-5.30 | 1031.109 |
| 23 | 30 December of 2017 from 5.00-5.45 | 1132.665 |
| 24 | 30 December of 2017 from 5.00-6.00 | 1182.138 |

Table continued..

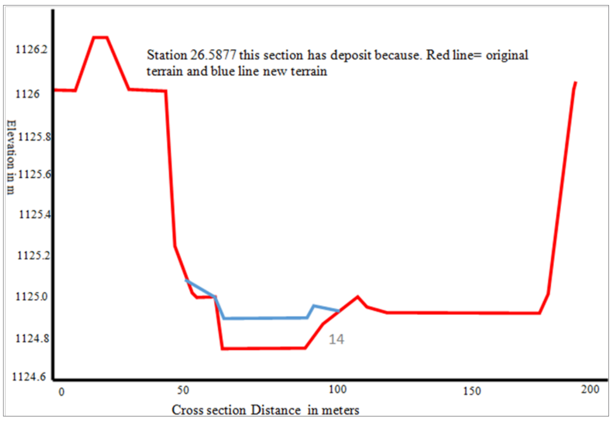


**Figure 10** Figure shows that at station 26.587, which is the outlet of the sediments to the VASOHE, a deposit was produced during the 24 hours of design precipitation. Source: HEC-RAS 5.0.[13]

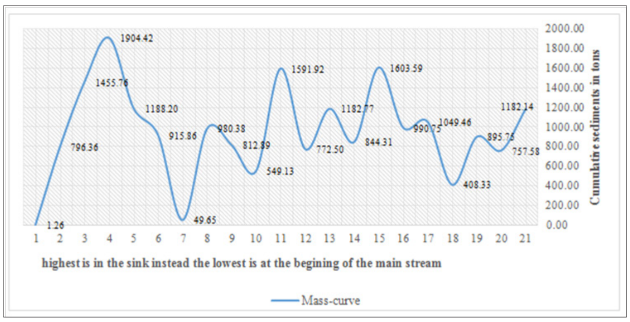


**Figure 11** Graph of mass curve distribution of total sediments. Source: HEC-RAS 5.0.[13]

**Citation:** león DZ, Chicas AD, Urias HQ. Hydraulic's model based on HEC-GeoRAS; HEC-HMS and ARC-MAP computer programs to assess Sediments stored on HE sink. *Int J Hydro.* 2018;2(4):433–443. DOI: 10.15406/ijh.2018.02.00107

**Table 12** The accumulated mass curve in tons for each station is shown from the furthest one (3210.432m) to the mouth in the VASOHE (26.58975m). The table shows the amount of sediment carried and deposited as a function of the topography where it is appreciated how the values rise and fall depending on whether there was erosion or deposition of them. Source: HEC-RAS 5.0[13]

| Station | Mass-curve (ton) | Station (m) | Mass-curve (ton) | Station (m) | Mass-curve (ton) |
|---|---|---|---|---|---|
| 3210.432 | 1.257 | 2352.089 | 980.382 | 1145.439 | 1603.593 |
| 3110.127 | 796.364 | 2262.757 | 812.89 | 880.3142 | 990.753 |
| 3005.714 | 1455.762 | 2124.61 | 549.133 | 704.0554 | 1049.455 |
| 2900.415 | 1904.423 | 1994.953 | 1591.916 | 454.62.49 | 408.328 |
| 2810.745 | 1188.197 | 1786.948 | 772.5 | 363.2352 | 895.753 |
| 2673.344 | 915.858 | 1668.176 | 1182.771 | 183.3758 | 757.584 |
| 2528.544 | 49.651 | 1413.809 | 844.311 | 26.58975 | 1182.138 |

## Discussion

As already mentioned, at the beginning during the first stage of this investigation, the Brothers Escobar catchment vessel presents permanent risk of flooding, overfilled with very fine soils, mostly silt, clays and colloids and coarse that are causing loss of capacity. This is because most of the volume of fine particles that are deposited in the sink as a response to the intense rains hot summer season. This is highlighted given that its original capacity is approximately 214,000m$^3$ JMAS.[2] However, the deposit rate of fine soils currently determined is 1.13kg/m$^3$ per 1mm of precipitation, which would produce 3154 tons of silt per year, approximately (2118m$^3$). As a result, the Hermanos Escobar vessel would have a lifespan of 53 years. This is, only considering the risk of overfilling of said vessel. On the other hand, the rate of rain/runoff defined in the HEC-HMS model in this work described at the beginning, for a rain event of 55 mm that corresponds to a return period of 100 years can produce an overflow of the vessel ESCOBAR because 220,500m$^3$ exceeds its capacity of 214,000m$^3$ (Figure 3). As already mentioned in stage 1 and 2. It is emphasized that the original capacity of the Escobar Brothers (VASOHE) catchment vessel is approximately 214,000m$^3$ JMAS.[2] However, the deposit rate determined was 1.13kg/m$^3$ per 1mm of precipitation, which would produce 3154 tons of sediment per year, approximately (2118m$^3$).[17–23]

## Conclusion

During the hydraulic modeling of coarse soils of mixed grains. The accumulated total amount deposited in the Hermanos Escobar sinkVASO for the 100-year design storm is 1182.38 tons per day (Figures 10) & (Figure 11). This value is converted to M$^3$ by dividing by 1,489 which is the volumetric weight of the sediment grains: Because of the above, there is a volume of 794.07M$^3$ of coarse sediments. Sediments deposited in the collection vessel for an intense rainfall of 55mm. On the other hand, it has to be that the quantity of fine-material bricks in the vessel was 3154 tons. Therefore, the total accumulated sediments, both fine and coarse, would be 4336.38 tons. For the above reasons, if we add 2118m$^3$ of fine material and 794.07m$^3$ of coarse material, we obtain a total accumulated volume in the VASOHE of 6433m$^3$. The above, allows us to conclude that the Hermanos Escobar catchment vessel presents a permanent risk of flooding, overfilled with very fine soils, mostly silt, clays and colloids, which are causing a loss of capacity. This is because most of the volume of fine particles that are deposited in the glass as a response to the intense rains of the hot summer season.

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## Conflict of interest

The author declare there is no conflict of interest.

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