MODELING OF SEDIMENT TRANSPORT IN THE DRAINAGE CHANNELS WAY OF REHABILITATION- CASE OF BOUTHEA -NORTH EST PLAIN OF ALGERIA

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ABSTRACT

The Drainage of agricultural land has become a top priority in agriculture, at the level of developing countries it is directly related to human life and economic development of the state. The objective of this article is to quantify and estimate morphological evolution in the medium term. the morphological evolution of the canals under the influence of sedimentary transport processes. The study area consists of agricultural land located in the plain of Bouteldja, in the north-east of Algeria. This zone was developed in 2006 as part of a hydro-agricultural project through the creation of networks of open-air drainage channels, but until now submerged with adjacent farmland. The causes may be: i) the lack of cleaning maintenance since completion, ii) the existence of drained males. To model the sediment transport process in the drainage canals, we used the empirical formulas and models of the HEC-RAS software. These models were calibrated to actual data obtained during the observation period from 2017 to 2018 for the various rain events, the model results give good criteria.

Keywords: modelization, drainage, channels, solid transport, HEC RAS

نمذجة نقل الرواسب في قنوات الصرف وطريقة اعادة التأهيل حالة بوثلدة شمال الشرقي من الجزائر

فؤاد تمارا عبد الله

المستخلص

اصبح تصريف الاراضي الزراعية اولوية قصوى في الزراعة على المستوى البلدان النامية مايرتبط ارتباطاً مباشراً بالحياة البشرية والتنمية الاقتصادية للدولة والهدف من هذه الدراسة هو تقدير التطور المورفولجي على المستوى المتوسط للقنوات تحت تأثير عمليات النتقل الرسوبية تتكون منطقة الدراسة من اراضي زراعية تقع في سهل بوثلدة وفي شمال الشرقي من الجزائر. تم تطوير هذه المنطقة عام 2006 كجزء من مشروع المزارعة المروية من خلال انشاء قنوات الصرف المكشوفة ولكن لحد الان مغمورة مع الاراضي الزراعية المجاورة قد تكون الاسباب في عدم وجود صيانة منذ الانتهاء في وجود استنزاف في نمذجة عملية نقل الرواسب من القنوات ثم استعمال الصبغ والنماذج التجريبية لبرنامج HEC– RAS تحت معايرة هذه النماذج وفقاً للبيانات الفعلية التي تم الحصول عليها خلال فترة المراقبة من 2017 الى2018 كمختلف الاتجاهات وكانت النماذج المستعملة جيدة ودقيقة

كلمات مفتاحية: تنمية الاقتصادية, قنوات الصرف, القنوات المكشوفة

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INTRODUCTION

The proper management of sediments in canal beds is one of the major challenges of the improvement work, as a large part of the annual maintenance and implementation budget is spent annually on the removal of deposited sediments(9) Before undertaking the rehabilitation of the drainage network, it was important to determine the effectiveness of the old system, control of surface flows, and more precisely the morphological evolution of the bottom of the channels by sedimentation and their influence on flow. during the floods consequently flooding agricultural land (4). It was therefore necessary to research plans and old photographs, profiles along and through the canals in archive is very useful is interested in the evolutionary trend of the rivers (11). in order to know, on the one hand the effect of the change of the profiles of the channels in the time and the space and the influence on the submersion of the lands Bordering on everything in a plain as our case "plain of Bouteldja" wilaya of El Tarf North East of Algeria, Therefore Sediment transport processes in watercourses depend both on hydraulic parameters, physical characteristics of catchments and sediment properties (7). The knowledge of these parameters is therefore essential in fluvial hydraulics and hydraulic modeling, in particular to the different models of fluid mechanics (Navier Stokes models, Saint Venant 2D and 1D models, etc ...) also describing the propagation of flows in streams. Several models have been developed in the literature, such as empirical, conceptual and numerical models for the quantification of solid transport in rivers and channels (6 ,11). They are useful for the modeling of Sediment transport and its effects on morphological changes in drainage canals in particular. The D 03 channel (Figure 1b) which is part of the drainage system was chosen as the object of this study. The canal was built as part of the agricultural development of the plain since 2006 and carries drainage water to river El Kebir. The shape of its cross section is trapezoidal and its length is 4350 m. The channel model was developed and calibrated based on current operational conditions. Canal bottom deformation is then simpler to determine since the eroded or deposited volume is directly related to the change in the bottom elevation .

MATERIALS AND METHODS

Study Area:

the study area is an agricultural plain is located in the municipality of Bouteldja located 12km from the capital of the Wilaya EL TARF, included in the hydro system of the watershed El Kebir extends over a longitude of 7 ° 45 'to 8 ° 58' and a latitude of 36 °20 'to 36 ° 45', is part of the MAFRAGH catchment area and is bounded by: to the north by the dune side and Mediterranean sea, to the east by the Mexa dam and the Tunisian borders, to the west by Annaba wilaya to the south by Bounamoussa dam (Cheffia) and wilaya of Souk Ahras (figure01) .the plain covers an area of 10572ha and about 6425 ha are agricultural land.

- Rainfall is characterized by heavy rains, often showers in winter, which decrease almost regularly in the spring and eventually reach a total of a few millimeters per month in summer The eastern part of the perimeter is a little wetter. (Ain El Assel 916.38mm / yr, Cheffia 803.63mm / yr) relative to the western part (lac des oiseaux 674.82 mm / yr)., And the average annual water slide elapsed is: 182.04 mm. The temperature over a period of 11 years (2005-2016) show that the average annual temperature for the three stations reached 19.24 ° C., the month of February is the coldest with a low temperature reached at 12.80 ° C, over the months from July and August temperatures exceed 25C.

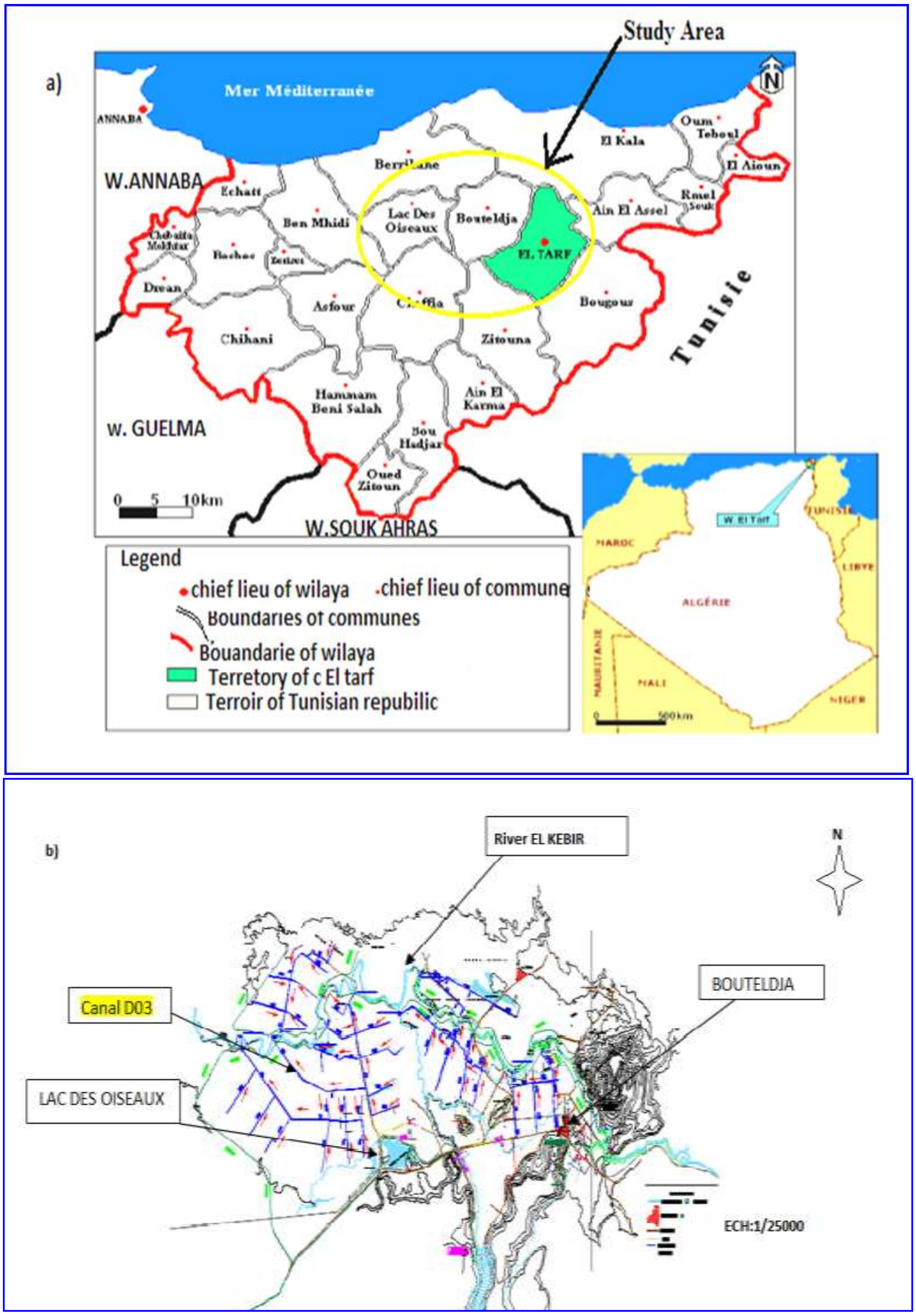


Figure 1. Location of study area a) and drainage network b)

Our case study is based on the topographic and geometric network data of the drainage channels (Figure 1, b) and the results of the channel ground tests, with measurements and field diagnosis. The soil texture study was done in the LNHC laboratory of Ain Assel, ENTENE El Tarf and Water and Soil Laboratory (Faculty of Engineering Sciences Annaba University). The results of particle size and sedimentométric analysis and the measurement of the mechanical physics properties of the materials along the channel lines are presented in Table 1 and in the curve of Figure 2. Finally, the bed sediments of the channels have a limit of liquidity of wl = 54% and a plasticity limit wp = 27% where a plasticity index IP = 27.23% reflects a sensitivity to water, based on the Casagrande plasticity diagram the sediment is in the class very plastic clays.

Table 1. Soil test results

Particle size analysis And sedimentometric	Physico-mechanical propretés
- d90% = 0.06mm - d65%= 0.045mm - d60%= 0.042mm - dm 50%= 0.04mm - d10%= 0.004mm dm,90 ,65... :partcle diametr	-Moist density: ɣh= 1.92 g/cm3 -Specific mass density: ɣs = 2.653 g / cm3 -Dry density: ɣd = 1.56 g / cm3 -the porosity: (p) = 0.28 = 28% -permeability: (k) = 2.77 * 10-6m / s

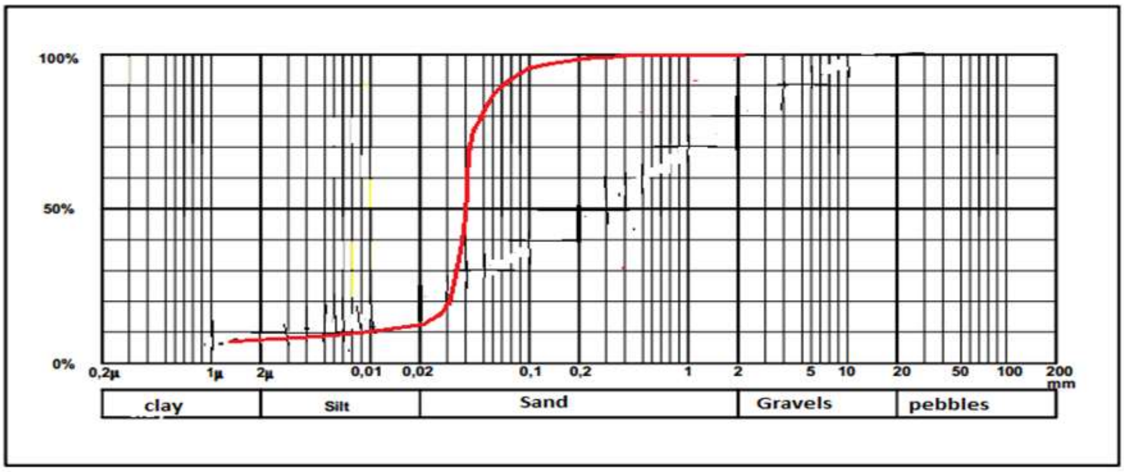


Figure 2. Size curve of bed soil of canals

Methodology

The methodology of the study is presented in Figure 3 in the form of the flowchart. According to the stages presented, this study aims at estimating the evolution of the bottom of the D03 channel during the period of 11 years after its realization between (2006-2017). The study was conducted on the basis of the topographic data of the longitudinal and transverse canal profiles from the proofing plan that was made by the Algerian ENHYD design office with ENERGOPROJEKT BET YUGOSLAVIE (2004) (data source: ONID National Irrigation Office and El Tarf drainage) in the framework of hydro-agricultural development in the area. with the interpolation of the two initial and current topographic surveys in the field, we compared the results obtained by the empirical computation and the simulation according to the HEC RAS model and calibrated its models to the measured data for the observation period from 2017 to 2018 years. on 12 sections at the D03 channel to choose the most appropriate model.

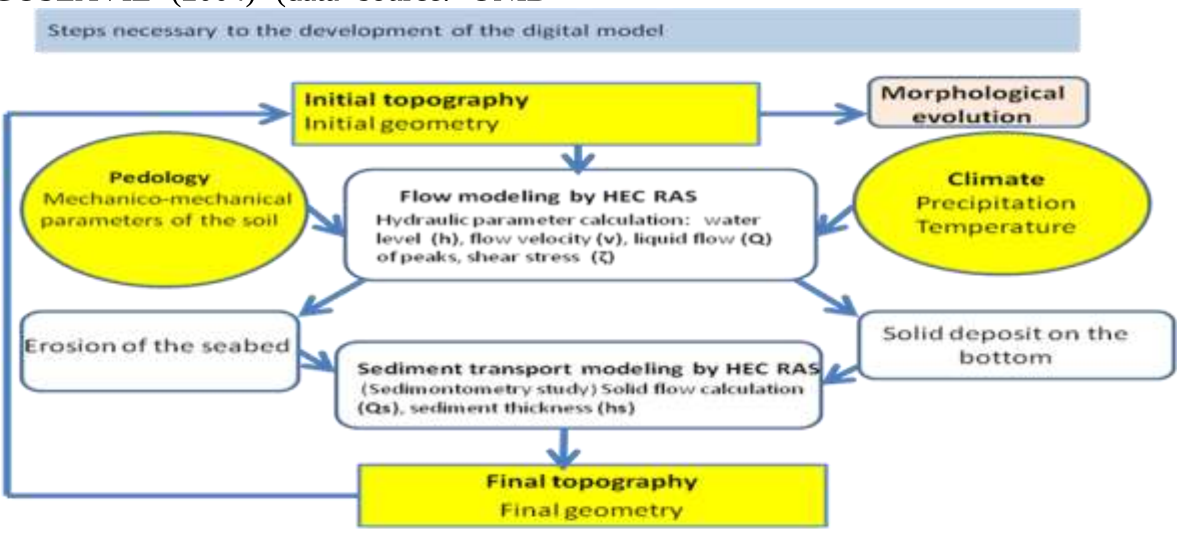


Figure 3 . Organization chart of the methodology

Peak flow estimation:

The first stage of flow modeling is the peak flow estimation, Two methods were used:

Empirical methods:

The calculation methods identified using different empirical formulas take into account three essential factors: the intensity of rain, the surface of the watershed, the time of concentration. The empirical methods tested in our case are the rational method and the method of CRUPUDIX,

Soil Conservation Service (SCS) method:

In this method runoff is modeled using the Hydrological Modeling System (HEC-HMS), it is designed to simulate the precipitation-discharge process of watersheds.

Modeling of the flow and sedimentary transport:

Development of the mathematical model:

Many models have been developed to address the various problems encountered in nature, including the simulation of non-cohesive and cohesive sediment transport, channel widening and meandering, roughness, turbulence, vegetation presence, etc. (10).

The sedimentary transport models are very diverse and always start with the resolution of the Saint-Venant basic one-dimensional equations (1D) (equation (1) for the liquid phase and the sediment mass conservation law and deformation of the bed by two-dimensional equation (2D) of Exner (equation (4) for the solid phase.

$$\frac{\partial s}{\partial t}+\frac{\partial Q}{\partial x}=ql \quad \frac{\partial s}{\partial t}+\frac{\partial Q}{\partial x}=ql. \qquad (1)$$

$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{Q^2}{S}\right)+gs\frac{\partial he}{\partial x}-gs\frac{\partial hf}{dx}+g\,s\,J=0 \qquad (2)$$

$$\frac{\partial v}{\partial t}+\frac{\partial v^2}{\partial x}+g\frac{\partial he}{\partial x}=g(I-J) \qquad (3)$$

with I the slope of the bottom and J: the loss of energy given by the formula: $J=\frac{Q^2}{k^2\,S^2R^{4/3}}$

$$(1-p)\frac{\partial hf}{\partial t}+\frac{\partial Q\,sx}{\partial x}+\frac{\partial Q\,sy}{\partial y}=0 \qquad (4)$$

To compare the results of the liquid phase concerning the water depth in the channel during the max daily rain event found by the HEC RAS 4.0 simulation model, we have used the Manning-Strickler formula (5) for the calculation the Auto Cad was used to graphically extract the wet surface and perimeter wet with iteration of water depth.

Manning-Strickler Formula: $V=\frac{1}{n}*R^{2/3}*I^{1/2}$ (5)

with **V**: the flow rate, **n** :Manning roughness coefficient depends on the nature of the walls of the channels ($\frac{1}{n}=$ K coefficient de strickler), *R*: Hydraulic radius, *I :* the slope of the bottom On the other hand, to calculate the solid transport, there are several empirical formulas, but the difficulty lies first in the choice of an appropriate formula among the tens of formulas available, each being constrained to conditions of use a priori strictly limited to those which prevailed during their validation. "The first parameter explored is thus that concerning the field of application of the different transport formulas according to the mode of transport either thrusting, suspension or total limited by the shear stress of the bottom. (parameter de shields ζ*) and sediment size (dm), among the formulas Smart and *Jaeggi (1983)* , *Schoklitsch(1962)* , *Parker(1982), Vin Rijn(1984)* , *Yong, Englund et Hansen(1967)* , *Ackers et White (1973).* (Recking, Al. 2010) give solid transport **QS** : in the form of a flow, to the solid volume **VS** we use the following formula (Gérard Degoutte 2012).

VS = QS * Δ t (6)

where **Δ *t* :** the time interval.

we take Δ t = 0.25h = 15 min, usually taken for a return period of 10 years (Montana), and we take Δt = 90 s for the observation period: (22/ 05 / 2017- 20 /02 / 2018).

Presentation of the models:

HEC RAS '(Hydrologic Engineering Center - River Analysis System)

it is a software used to model flows and sediment transport in streams or channels. Concerning solid transport, the HEC-RAS software makes it possible to model both the thrust and the suspension. For this, proposes to define three functions: a transport function, the software proposes seven formulas and a function of evolution of the sedimentary bed, this function determines the height of the sedimentary bed thanks to a mass balance applying on the sediments. Two models are offered by the software: the Exner model and the so-called "Active Layer" model, as well as a sedimentation rate function. The software proposes three formulas, otherwise it sets the boundary conditions. The formulas that we used in our model (Exner) the formula *Englund* and *Hansen* and the formula of *Ackers* and *White*, for the solid transport but for the sedimentation rate the Van Rijin formula.

RESULTS AND DISCUSSION

The first step of the study is the estimation of the peak flow. To achieve this, the D03 channel was divided into three sections according to the route (Figure 5.). The watersheds corresponding to each section have been designated SBO1, SB02 and SB03 respectively and this from upstream to downstream of the channel. The flow values calculated by the empirical method and the SCS model simulated by HEC HMS and those of the measured flow are given in Table 2.

With **TC**: concentration time, **CN**: curve number , **Q MAX**: max flow.

Table 2. Peak flow estimation results

Under basins	BV area (ha)	Length (L) (m)	TC(min)	CN	Q MAX Calculated (m3 / s)	Q MAX Measured (m3 / s)	Q MAX Simulated (m3 / s) HEC RAS
SB01	127.70	1598	485.39	88	1.67	3.45	3.30
SB02+ SB01	86.64	1127.5	367.22	88	3.14	4.18	4.1
SB03+ SB02+SB01	135.66	1624.5	491.82	88	4.89	5.06	5.50

For example, Figure 4 shows the hydrograph of the sub-basin downstream of the canal.

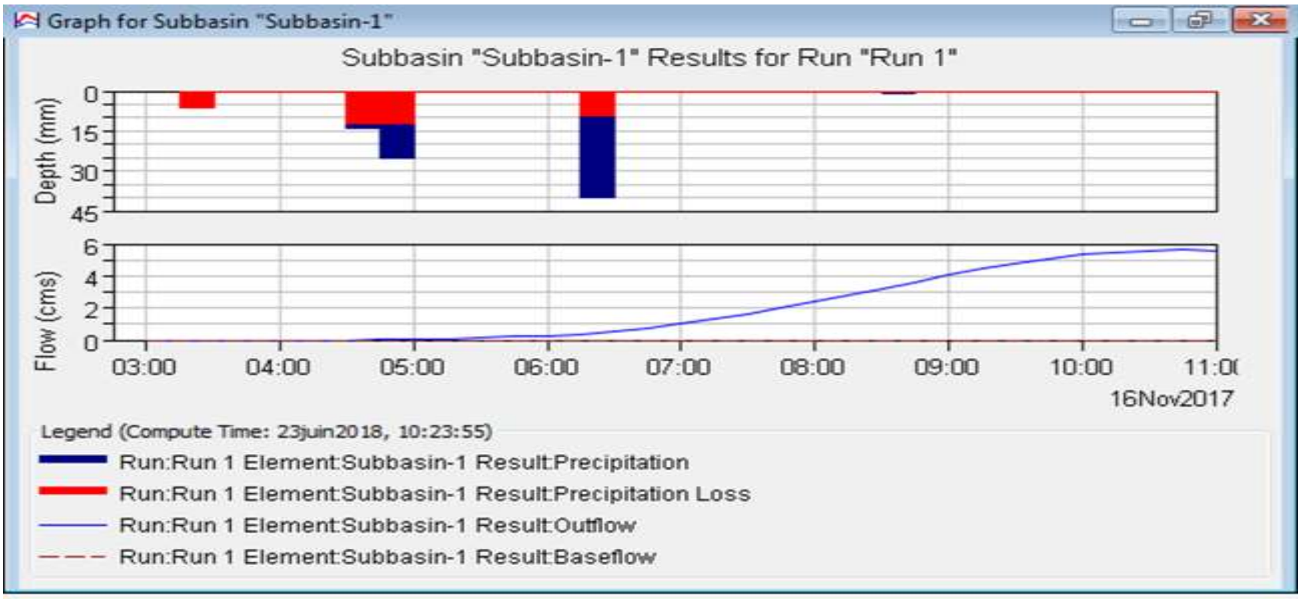


Figure 4 .Hydrograph sub basin in downstream channel using HEC HMS

In the first phase according to the flow simulation by the HEC RAS 4.0 software with measured flow rates (3.45, 4.18, 5.06) m 3 / s, for the initial geometry of the channel (May 2006), and current in (22/05/2017) figure (06a, b) and (07 a, b) it is an enhancement of the water line because of deposit sediment along the channel which causes the overflow of the channel in all the sections .the comparison of the longitudinal profile results for 12 simulated and measured calculated sections (Figure 8,9) led to the calibration of our one-dimensional model (1D) to a Manning coefficient for the bottom and the banks, n = 0.028, representative of the roughness for the study area after tested initial value of n = 0.02, to better visualize the correlation between the observed values and the simulated values, and in order to know the effectiveness of the proposed model it is necessary to calculate certain criteria called "performance criteria", a Good performance of a hydrological model should include at least two performance criteria. In our case study, two types of criteria were used: the correlation coefficient R2 = 0.58, The Nash criterion = 0.67, and therefore the acceptable model results that are close to those observed with respect to the empirically calculated results.

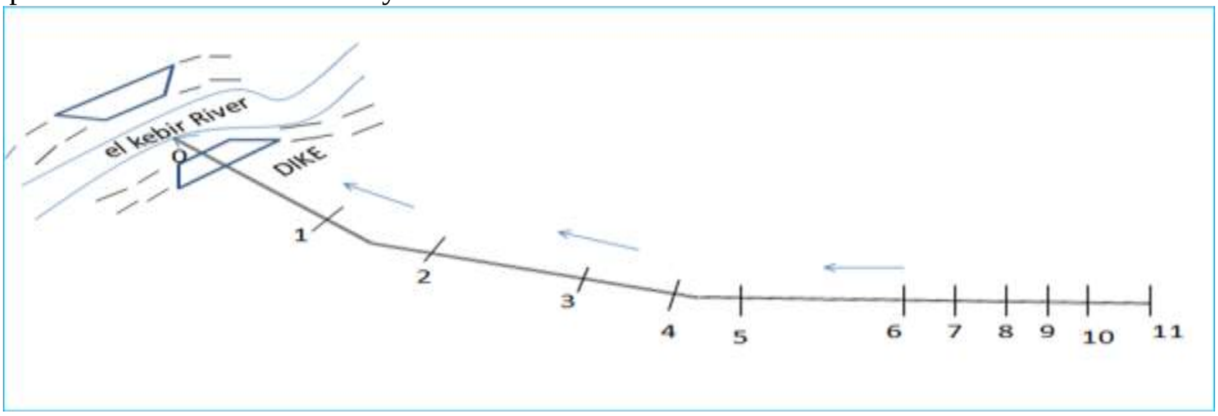
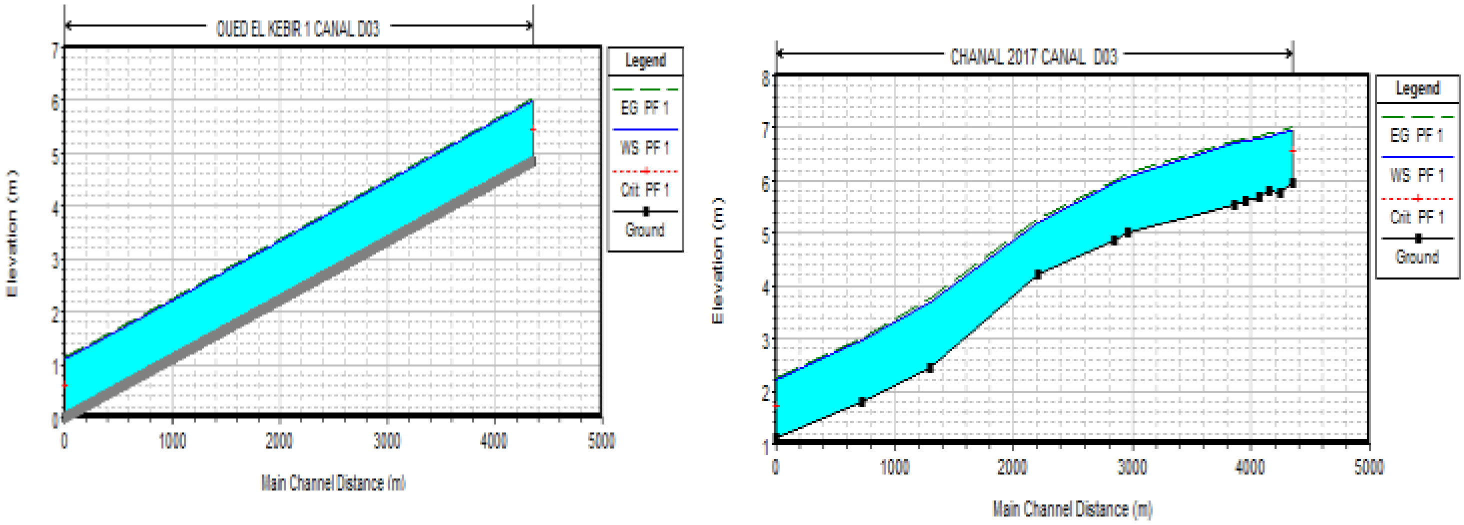


Figure 5. Plot of the profile of the channel through



a) b)

Figure 6.Profile along of the simulated water line initial geometry (05/2006) a) and after 11 years (22/05/2017)

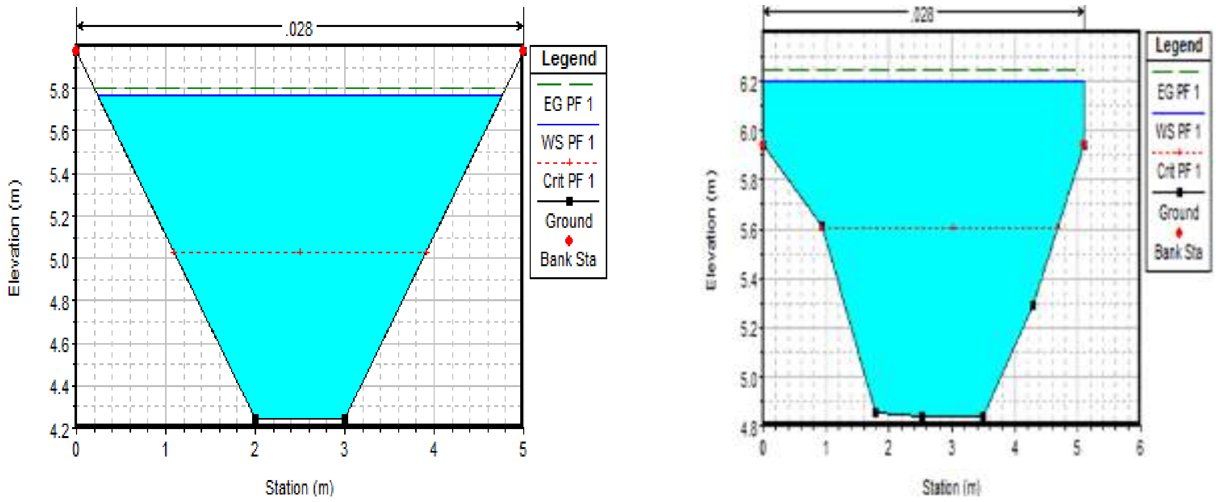


Figure 7. Profile across the simulated water line section 11 the initial geometry (05/2006) a) and after 11 years (22/05/2017) b).

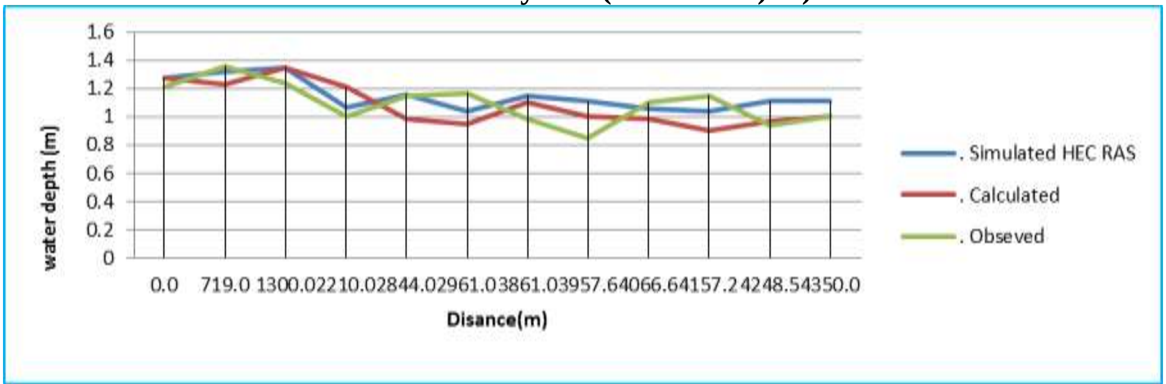


Figure 8. Comparison of the water level in the channel during the event of (22/05/2017) .

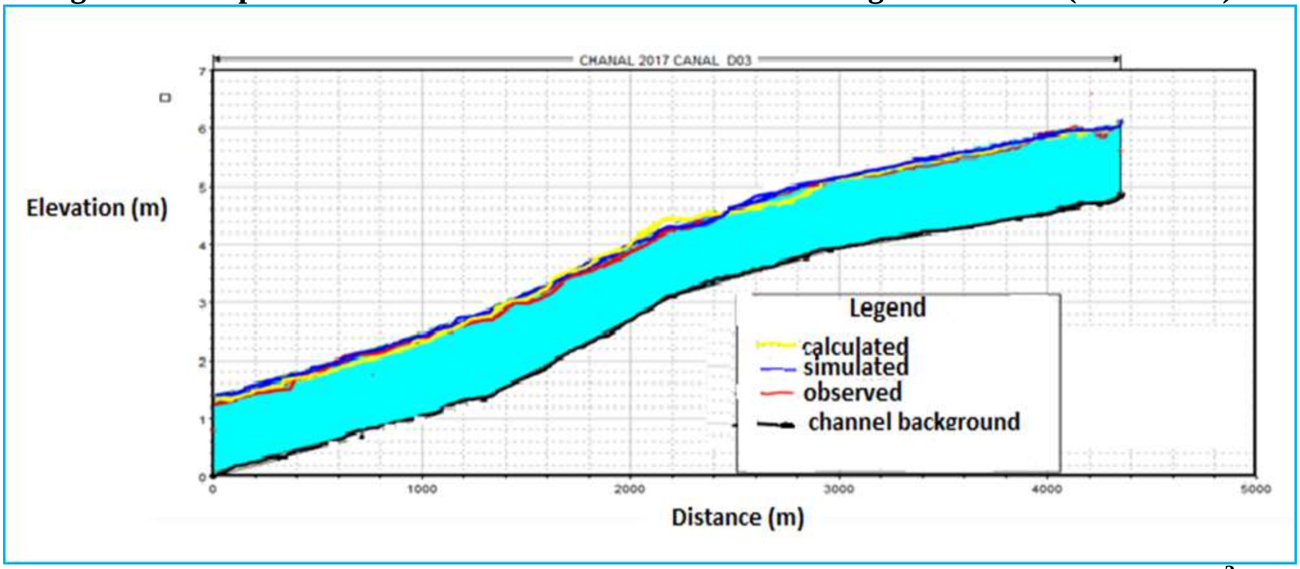
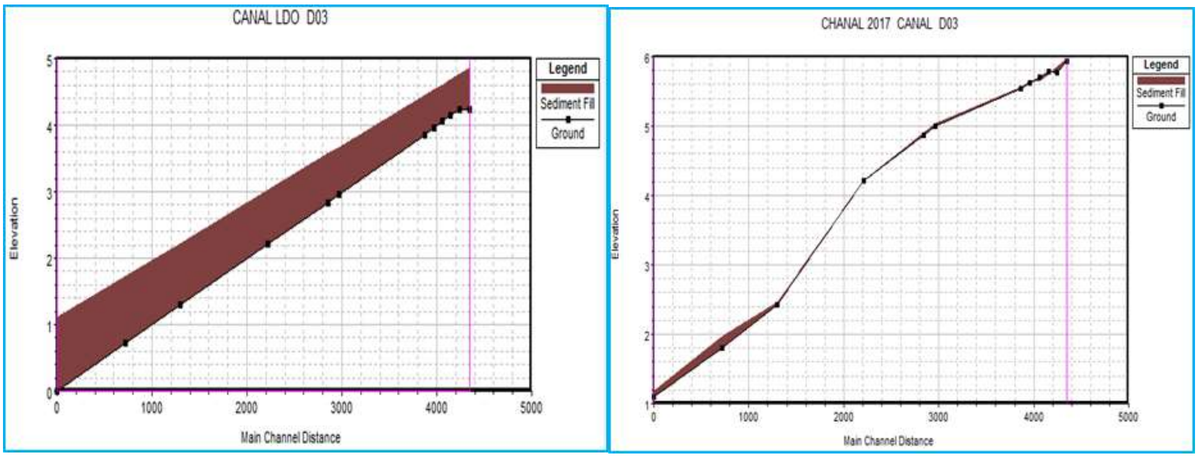


Figure 9. Longitudinal profile of comparison with the channel water line for Q=5.06m^3/S.

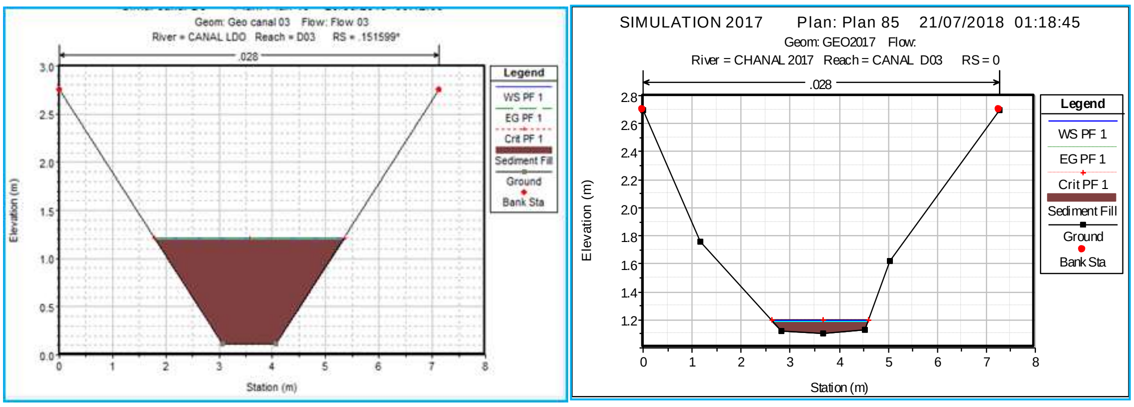
In the second phase of sediment transport modeling, the results show the thickness of the deposit (hs) ,so solid flow greater than the capacity of transport(11). increasing progressively from upstream to downstream because of the existence of the flap valve figure10, at the level of rejection of the underpass (the outlet on El Kebir river), which favors the sedimentation braking and creates a loss on the one hand and the sediment size from the median diameter (d50) decreasing from upstream to downstream of the canal, a comparison of the results of morphological evolution at the bottom give acceptable results against the simulation results by HEC RAS software after 20 different combinations, with sedimentation boundary conditions. downstream are closer to the field real which allowed the model wedging with the combination of the *Engelund and Hansen* solid transport equation and the *Van Rijin* sedimentation velocity equation (1984) etched into the model after fitted the Manning roughness coefficient (n = 0.028), the model was validated on the field control level calculated by the application of solid transport formulas and simulated by the HEC RAS version 4 .0 (figure10,11 a, b) compared to the field real after the interpolation topographic surveys and control series on the seabed (Figure 15). The sedimentation thickness calculation results (hs) obtained by the application of the solid transport formulas according to the range of validity, they present considerable errors. . Except that the results of the two total solid transport formulas), event which gives correlation performance criteria (R2 = 0.91) Nash = 0.95 for an error of 5cm in the sediment thickness (hs), finally one can quantify a cumulative sediment for 12 years of 16775.63 tons for a thickness average of 0.74 m occupies average rate of 33.66% of the section of the channel.

Figure 10. Discharge work under dike leads into El Kebir river canal D03 (photo Sennaoui . F 2016



a **b**

Figure 11. Simulated long sedimentation profile over 11years (05/2006) a) and period (22 /05/2017-20 /02/2018) b)



a b

Figure 12. Simulated sedimentation cross section over 11 years (05/2006) a) and period (22 /05/2017-20 /02/2018) b)

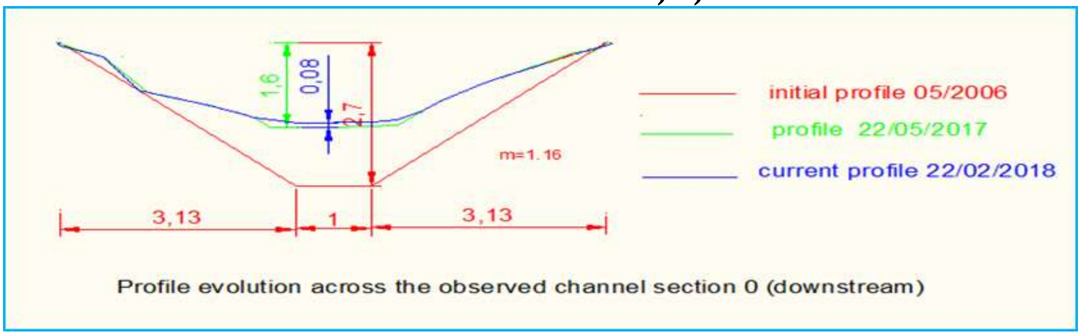


Figure 13.Evolution the profile across section the observed channel upstream section on control events

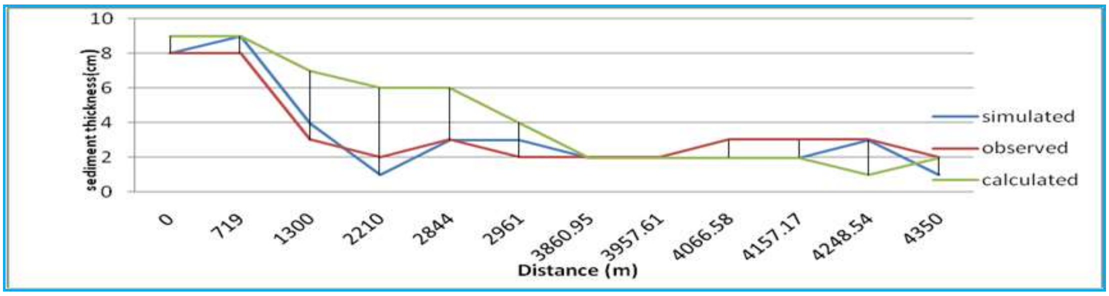


Figure 14. Comparaison of the results of sedimentation thickness (hs)period (22 /05/2017-20 /02/2018).

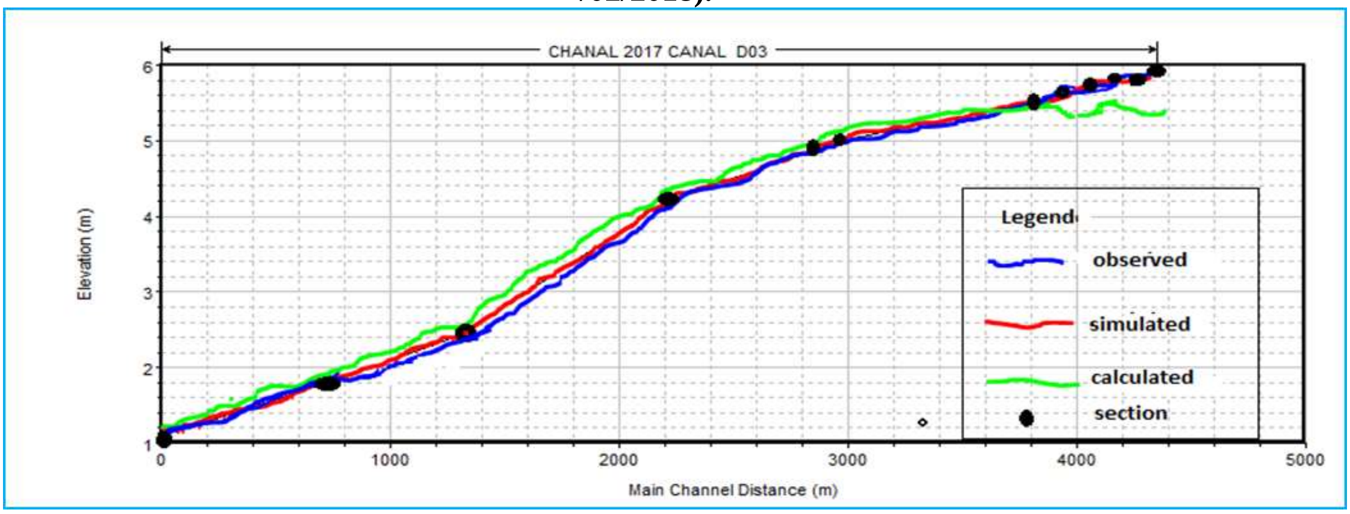


Figure 15.Comparaison of longitudinal profile for the bottom of the final channel

After adjusting the size of the grains in the bottom of the channel by noble materials (sand, gravel, to test the diminution of the sedimentary load, the results presented in Table 3 and the graph figure16 shows when we change the grains of the bottom by the laying of coarse grains so the projected a layer of coarse gravel (30-60 mm) on the bottom of the channel allowed to avoid the sedimentary deposit on the downstream trench of the canal, it is the most important is to decrease the total sediment load along the canal from 1677.63 tons to 8.44 tons and offers several advantages such as: economic compared to the concreting of the channel, drained the soil of the bottom and bank in a regular way, the layer of coarse gravel plays role of alarm for arrived at the old bottom pendant the periodic cleaning.

Table 3. results of solid flow tests according to sediment class

Classification of sediments dm(mm)	QS (upstream) m3/s	QS (downstream) m3/s
Fine Clay dm= 0.001	4.30E-02	1.29E-01
Fine silt dm=0.01	4.30E-03	1.29E-02
'Coarse silt dm=0.04	1.08E-03	3.20E-03
'Very fine sand dm=0.1	4.34E-04	1.28E-03
Very coarse sand dm=1	4.35E-05	1.29E-04
Very fine gravel dm =3	1.45E-05	4.30E-05
Fine gravel dm=5	8.70E-06	2.60E-05
Medium gravel dm=10	4.30E-06	1.30E-06
Coarse gravel dm=30	0.00E+00	4.00E-06
Very coarse gravel dm=60	0.00E+00	2.00E-06

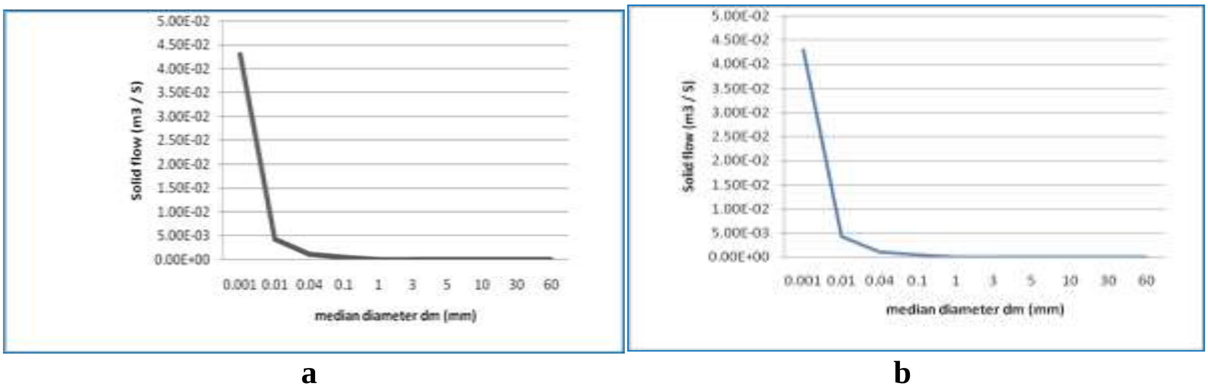


Figure 16. Graph variation of (Qs) as function of (dm) upstream channel a) Downstream b)

Through this modeling, the quantities of sediments transported in the drainage channel during the rainy events and their effects on the morphological changes of the latter were analyzed. In this analysis we used: the hydraulic and sedimentary software model HEC-RAS (the *Engelund and Hansen* equation describing *Van Rijin* solid transport and sediment velocity formula) and the empirical formulas for the calibration of models of HEC-RAS validated over a period of observation from 22/05/2017 to 20/02/2018) after adjusting a Manning roughness coefficient n = 0.028 gave results closer to real on ground than those of calculation by the formulas empirical with Nash performance criterion equal to 0.95 and R2 correlation equal to 0.91. The analysis showed that the sedimentary bottom in the earth drainage channels in our study area does not evaluate only during the high floods but also during the rainy events less the events of the observation period. Calibration of the models has also revealed that the changes in the geometry of the channel depend greatly on the size of the sediment, the hydraulic parameters, the roughness of the channel bottom, so the main key parameter that must be corrected and taken into account. the designer and the engineer at the beginning is the grain size at the bottom of the channel, so it must be projected a layer of coarse gravel especially in the downstream edge to avoid the sedimentary load and plays the role of an alarm for to reach the deep end and avoid arbitrary cleansing, and consequently the flooding of adjacent agricultural lands. For this purpose, it can be concluded that the modeling of solid transport is a means that can be used in the planning of the rehabilitation of the drainage channels of the plain. Surface drainage designs taking into account the economic side.

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