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***Abstract*—Predicting pollutant transport in coastal ecosystems has become an important topic in many industrial and environmental projects, because of the degradation of water quality and conflicts related to multiple use of coastal resources. Most numerical studies on coastal catchment do not consider flow and pollutant fluxes through wetlands, or simulates theses transfers using "black box" based on linear regressions that greatly simplifies the complexity of the underlying processes.**

This paper presents a numerical study on the simulation of pesticide transport and degradation in the artificial wetland drainage channels of the Breton-Vendéen marsh (west coast of France). The one-dimensional (1-D), open source MASCARET modelling tool is used. The 1-D unsteady water flow through a network of open channels is represented by the shallow water equations. The water quality module of MASCARET simulates solute transport processes, consisting of advection, dispersion and mass reduction/generation by physical, chemical and biological mechanisms. Results show that the 1-D model is a reliable tool for simulating pollutant transfer through the coastal wetlands drainage channels. Moreover, it is possible to link landward and seaward models to MASCARET, which allows simulating water and pollutant propagation from watershed to coastal sea through wetland drainage channels with a high level of confidence

I. Introduction

The maritime marshes are wetlands where there is an interface between the watersheds and the coastal area. The particular conditions of these environments favour the development of specific flora and fauna with rare or threatened species. In accordance with their nature, they are used in diverse human activities, pasturing of prairies, reduce reeds, fishing, fish husbandry in fresh or salt water, shellfish farming and salt production on the coast, hunting, activities of discovering nature [10]. Since their international recognition in 1971, the preservation and the management of these sustainable humid zones have been placed in the framework of sustainable management of the natural resources and the preservation of the biodiversity [8]. On the European scale, these actions are notably promoted by the Water Framework Directive with the objective to attain a good ecological potential and a good chemical state of all bodies of water [1]. Developing a agro-hydrologic model for watersheds, coupled with a hydrodynamic model for the coastal area constructs a tool for the development of an integrated coastal zone management. This study goes further in developing a model for the pesticide transfer through the wetland drainage channels. The calculation and validation of the models is not finished but this article will present the modification of the source code, the method, discussion and perspective.

II. Modification of the Source Code

Among the six water quality models which are contained in the model *Tracer*, there was no model in which the degradation of pesticide is possible. The choice was to modify the transport of the tracers model *Transport_Pur* and to throw a degradation kinetic of the first order (1) and following open a source of the MASCARET code.

$$C_t = C_0 \times e^{(-k.t)} \qquad (1)$$

with

$$k = -\frac{\ln(0.5)}{DT_{50}} \qquad (2)$$

where C_t: concentration of pesticide over time t (µg.s^{-1}), C_0: initial concentration of pesticide (µg.s^{-1}), k: rate of degradation or constant dissipation (T^{-1}), DT_{50}: time of half-life (days).

The pesticide chosen is the glyposate. It is the most found in the studied zone. Its time of half-life is 69 days for a PH of 7 [Agritox]. The coefficient k is equal at 1.162686 x 10^{-7} s^{-1} (Fig. 1).

```
SUBROUTINE CALCS_RIEN( RNU , S , &
                       Nbsect , NBTRA , Nbsing , &
                       Q , A , H , RH , ST , C , &
                       SA , T , DT )

   use M_PRECISION
   use M_CONSTANTES_TRACER_T
   use M_PARAMETRES_QUALITE_EAU_T

   Implicit none

   real(DOUBLE) , Dimension(:,:) , intent(inout) :: RNU , S , SA
   real(DOUBLE) , Dimension(:)   , intent(in   ) :: Q , A , H , ST, RH
   real(DOUBLE) , Dimension(:,:) , intent(inout) :: C
   INTEGER      :: Nbsect , NBTRA , nbsing
   REAL(DOUBLE) :: T, DT

   REAL(DOUBLE), Dimension (Nbsect,nbtra) :: RNUS , SS , SSA , SV
   INTEGER I, K

   DO K = 1 , Nbtra
      DO I = 1 , nbsect
         S(I,K)   = SA(I,K) - C(I,K)*1.162686D-7
         RNU(I,K) = 0
      ENDDO
   ENDDO

   RETURN
END SUBROUTINE CALCS_RIEN
```

Figure 1. Modification of model.

III. METHOD

The place of study is the marsh of Breton-Vendéen, the fifth largest French metropolitan coastal wetland, situated in south of the estuary of the Loire. It is the receptacle of the water fluxes of the catchment where they continue to the Bourgneuf bay (Fig. 2).

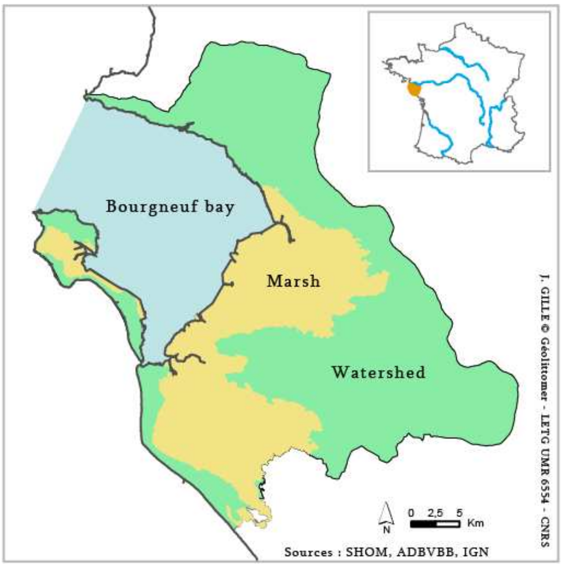

Figure 2. The geographic map off the section of study.

The marsh is fed by the river draining into the small watershed of an area of 10 km², except the one of the Falleron river of an area of 137 km². The flow of the Falleron river is known at the inlet to the marsh. For the other rivers, the distribution of the flow was realized according to the function of the under watershed area.

The period of study is May 26, 2007 to December 6, 2007 the discharge was less to 3 $m^3.s^{-1}$. This discharge threshold marks the overflow of river. It generally goes over between 30-50 days per year during the years. The mean annual discharge is equal to 1.2 $m^3.s^{-1}$ (Fig. 3).

The objective is to follow the transfer of the water flow in the Bourgneuf bay catchment. The model is carried out in the pilot area situated in north of Breton-Vendéen marsh (Fig. 5). The one dimensional (1-D) numerical modelling MASCARET is used [2]. The main drainage channels are defined by 20 reaches and 153 channel sections (Fig. 6). The channel section are created by measures of the ground. The length (AB) and depth (AL) of the channel are known (Fig.4). Finally to reconstruct the entire channel section, it was chosen to take an angle a equal to 30 degrees when it’s possible, otherwise equal to 70 degrees for the maximum the points M and N are similar.

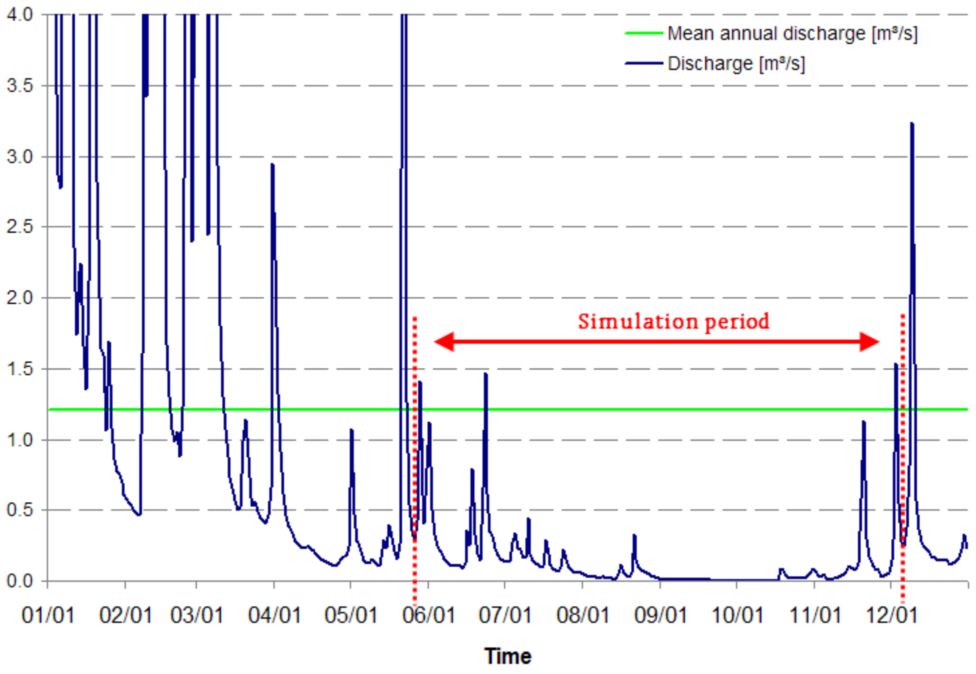

Figure 3. Discharge at the entrance of the marsh in 2007.

The bottom slope is 0.03 ‰, the mesh of 1 m, the planimetry of 0.01 m and the downstream side is constantly equal to 1.8 m. The calculation time is 60 s.

The concentrations of the glyphostate measured in the main river vary between 0.2 and 1.6 µg.L^{-1}. The inlets are forced to a average concentration of 1 µg.L^{-1}.

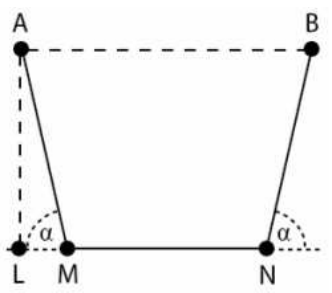

Figure 4. Drawing of the channel section.

IV. Discussion and Perspectives

In these hydro-geomorphologic and hydrodynamics conditions, the longitudinal dispersion coefficient is less influent. The finite-difference method 2 (FD2) is less dispersive to those of finite-difference 1 (FD1). Only the roughness seems to have an important impact of the discharge superior to 1 m^3.s^{-1} (Fig. 7). In the hypothesis where the hydraulic management are not modified the flow circulation, the time of pesticide transfer in the marsh is estimated at about 1.5 day for a discharge of 2 m^3.s^{-1} and about 8 days for a discharge of 0.5 m^3.s^{-1}.

From the 43rd day, the concentration of glyphosate evolved in a manner similar to the outlet of the marsh, like the dispersion coefficient and the Strickler coefficient. The discharge is too weak for these coefficients to impact sufficiently the concentration of glyphosate.

Where the marsh does not carry glyphosate, the reduction can get to 50% when it goes out of the marsh during the study period. This model can equally permit the differences between the dilution loss and the degradation loss. In this case, the difference comes up to a maximum of 0.2 µg.L^{-1}.

Finally if these first estimations remain to refine and to validate, they are already particularly interesting for economic activities as the shellfish farming, for which the quality of the water is essential. These last years, strong mortalities are observed on the French coast. Pesticides are suspected by the shellfish farmers to be there partially originally. The chaining of the agro-hydrologic model SWAT [7] with the hydrodynamic model MARS 2D [6] was already able to allow to bring some elements of answer for shellfish ponds of Croisic and Pen-Bé [5], of the Payré channels [4] and of the Thau lagoon [9].

By adding it the modelling marsh (Fig. 8), this kind of study can allow to follow the quality of the water from the watershed to the bay (Fig. 9), to test scenarios aiming at the improvement of the quality of coastal waters and conservation of the activities bound to the marine cultures and so to contribute to the implementation of an integrated coastal zone management [3].

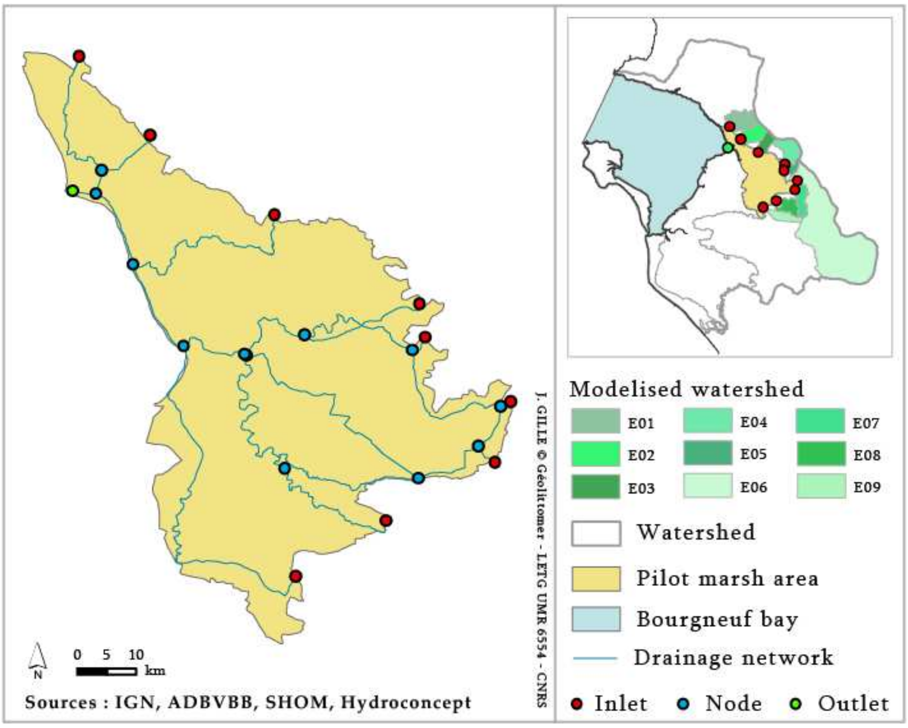

Figure 5. Drainage channel in the pilot area.

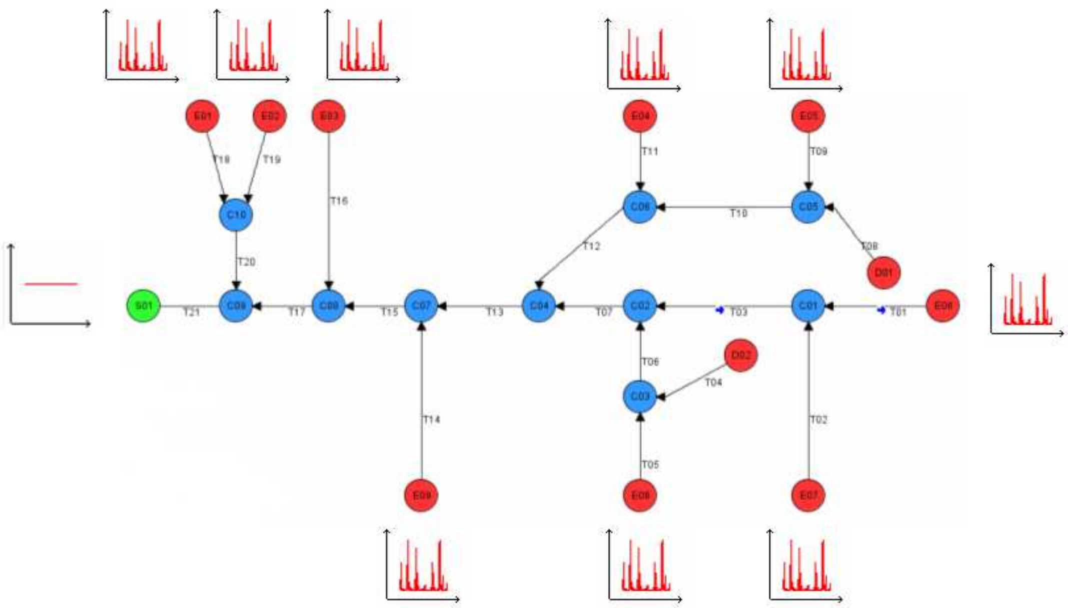

Figure 6. Architecture of the modelling channel in MASCARET with the hydraulic laws in extremities.

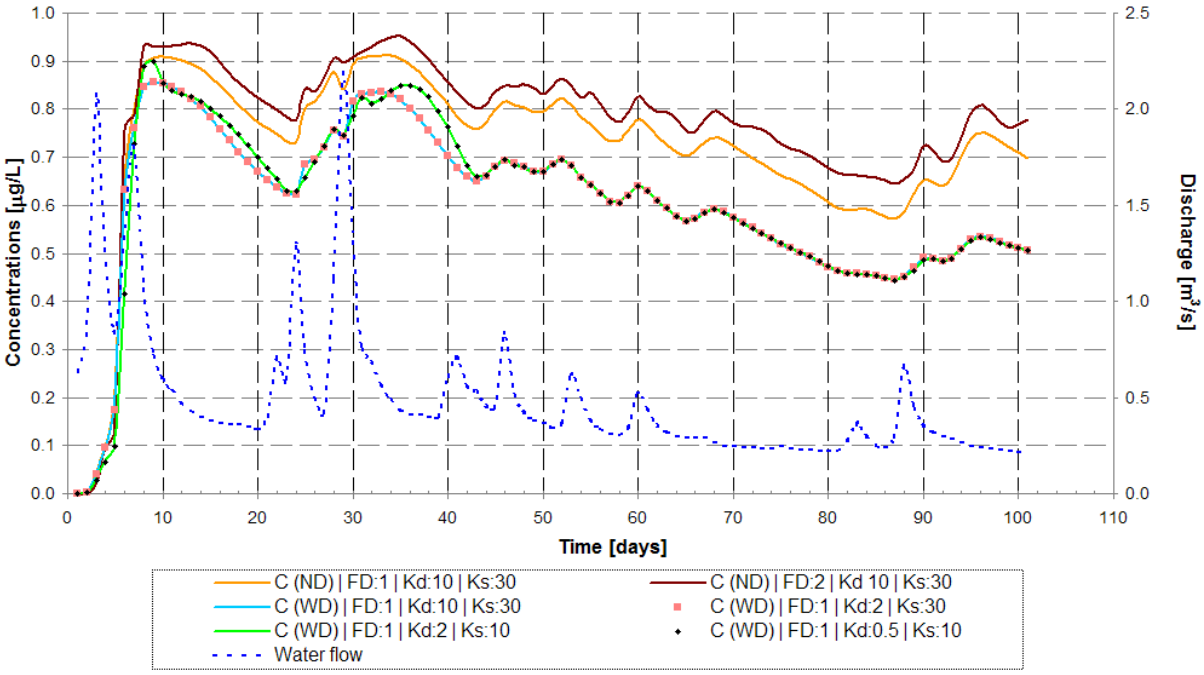

Figure 7. Evolution of discharge and concentration of glyphosate at the port of Collet
(C: concentration, ND: no degradation, WD: with degradation, FD: finite-difference method, Kd: dispersion coefficient, Ks: Strickler coefficient).

Figure 8. Chaining of models.

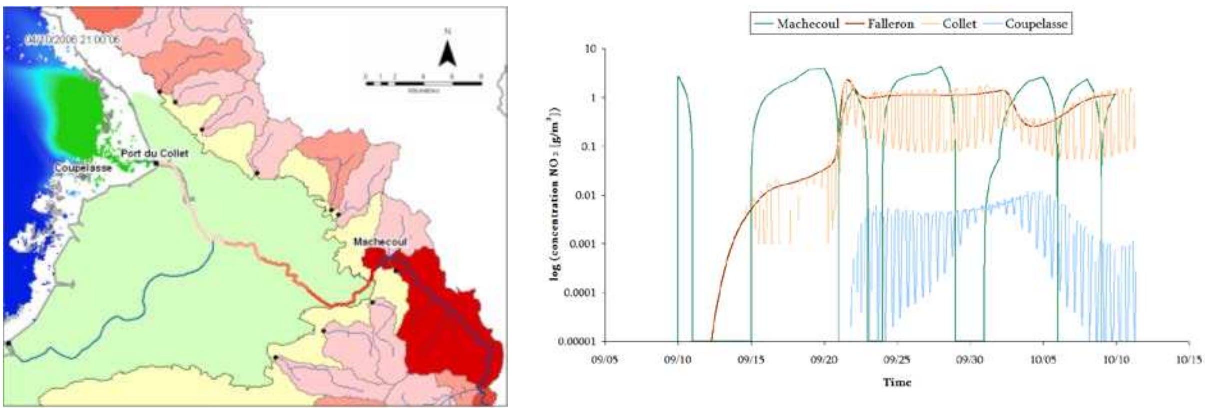

Figure 9. Pollutant evolution in the environment
(left: red for the highest concentrations, blue for the weakest;
right: concentration in the inlet marsh (Machecoul) and the outlet marsh (Falleron and Collet), in the oyster park (Coupelasse)).

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REFERENCES

[1] CE (2000): "Directive 2000/60/CE du Parlement Européen et du Conseil du 23 octobre 2000 établissant un cadre pour une politique communautaire dans le domaine de l'eau", Journal Officiel des Communautés Européennes, L 327, 22 décembre 2000, 72p.

[2] CETMEF (2008): "Guide de prise en main de Fudaa-Mascaret 3.0", Notice n°GT 08.01, Avril 2008, 137p.

[3] Gille J., Gaillard S., Hitier B., Robin M., Oger-Jeanneret H., Lecomte P. (2010): "Modélisation des apports des bassins versants en baie de Bourgneuf" in, Actes des XIèmes Journées Nationales Génie Côtier – Génie Civil, 22-25 juin 2010, © Editions Paralia CFL, Les Sables d'Olonne, pp.275-282

[4] IFREMER (2007): "Mesure des flux hydrauliques dans les chenaux du Payré : lien avec la contamination microbiologique des zones ostréicoles - Approche hydrodynamique", Appel à proposition 2007 du Comité Scientifique et Technique et du SMIDAP pour la Région des Pays de la Loire, 15p.

[5] Jeanneret H., Gendronneau M., Haure J., Le Merrer Y., Lequette C., Lomakine C., Martin J.-L., Papin M., Ponthoreau C., Robin M. (2006): "Étude des secteurs du Croisic et de Pen-Bé : estimation des apports continentaux et évaluation des stocks conchylicoles", Fiche documentaire, Ifremer, Mars 2006, 118p. + annexes

[6] Lazure P., Dumas F. (2008): "An external-internal mode coupling for a 3D hydrodynamical model for applications at regional scale (MARS)", Advances in Water Resources, 31(2), pp.233-250

[7] Neitsch S.L., Arnold J.G., Kiniry J.R., Williams J.R., King K.W. (2002): "Soil and Water Assessment Tool", Theoretical documentation, 506p.

[8] ONU (1971): "Convention relative aux zones humides d'importance internationale, particulièrement comme habitats des oiseaux d'eau", 2 février 1971, Ramsar (Iran), 6p.

[9] Plus M., Maurer D., Stanisière J.-Y., Dumas F. (2006): "Caractérisation des composantes hydrodynamiques d'une lagune mésotidale, le Bassin d'Arcachon", Ifremer - Laboratoire Environnement littoral - Ressources aquacoles d'ARcachon, 01 novembre 2006, 54p.

[10] Verger F. (2005): "Marais et estuaires du littoral français", Belin, Paris, 335p.