The Dynamic River Model
DRM version 1.0

User Manual

Femke Hilhorst

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Author
Femke Hilhorst

Supervisors
Claudia Brauer
Paul Torfs

Hydrology and Quantitative Water Management Group
Wageningen University
The Netherlands
www.wageningenur.nl/hwm

E-mail contact
femke.hilhorst@wur.nl

DRM downloads
www.github.com/FemkeHilhorst/DRM

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1 | Introduction

The Dynamic River Model (DRM) is a spatial and time dependent river model that simulates fundamental river processes of lowland catchments with shallow groundwater, in the most simplistic way. The DRM is developed at the Hydrology and Quantitative Water Management Group of Wageningen University in 2016 to extend the Wageningen Lowland Runoff Simulator (WALRUS) with a river model with similar model framework principles (mass balance conserving, fast, programmed in R, applicable for only lowland area's and freely downloadable). There are no river models that complement WALRUS yet, mainly because these river models are too comprehensive. The computed DRM is in particular valuable during peak discharge events, so for flood risk prevention. The Dynamic River Model is described in detail in the master thesis of Hilhorst et al. (2016). In this manual I will give instructions of how to use the DRM. The basics of the model code are explained as well.

2 | Model Description

In this Chapter, I provide a description of the model input variables and model simulation technique. There are four input variables of the DRM: the model forcing, the geometry, the initial conditions and the model parameter as shown in Figure 2.1. The model simulation is performed with the finite volume discretization technique. A flow function that depends on celerity and diffusion is the theoretical basis of the model simulation.

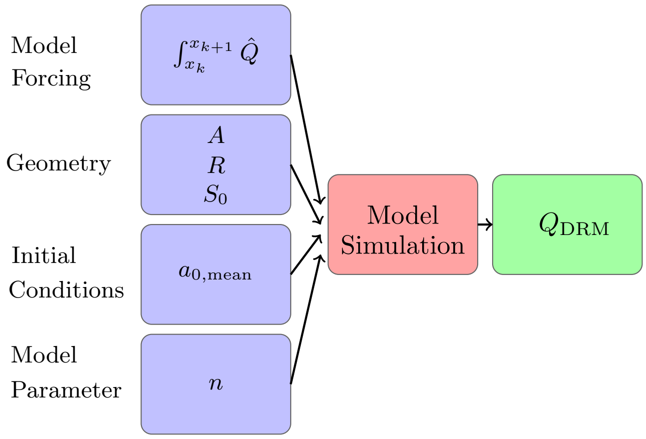


Figure 2.1: Model Framework: input (blue boxes) and output (Q_{DRM}) of the dynamic river model.

With $\int_{x_k}^{x_{k+1}} \hat{Q}$ spatial forcing by WALRUS, A wetted area of the cross-section of the river $[\text{m}^2]$, R hydraulic radius of the cross-section of the river $[\text{m}]$, S_0 water-level slope $[-]$, $a_{0,\text{mean}}$ mean initial water level $[\text{m}]$ and n Manning coefficient $[\text{s m}^{-1/3}]$.

2.1 Model Input

Model Forcing

The DRM is spatially forced along the river with WALRUS output (Q_{WALRUS}). This forcing method is visualized in Figure 2.2.

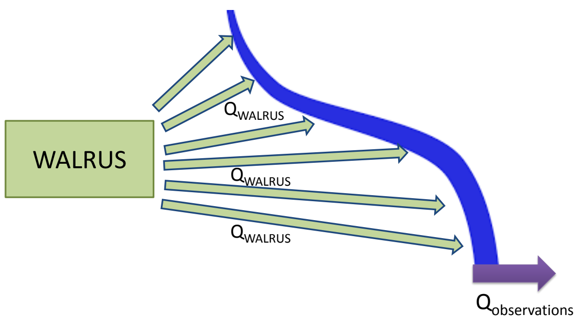


Figure 2.2: A schematisation of how the DRM is spatially forced by WALRUS.

WALRUS is injected into the DRM as an external forcing flux $\int_{x_k}^{x_{k+1}} \hat{Q}$. So to run the dynamic river component, it is necessary that WALRUS is run first. WALRUS is described in a free available user manual (Brauer et al., 2015).

Geometry and Initial conditions

The input variables of the DRM are the initial waterlevel a_0, the width of the river b and the bottom height of the river zb measured at three locations. Figure 2.3 shows how the initial waterlevel and the width at of the river are represented in the model structure.

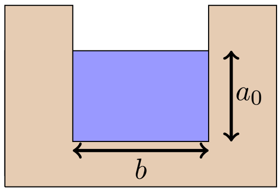


Figure 2.3: The rectangular cross-section.

It is recommended to measure a_0, b and zb at three locations along the river: the source, mid-way and at the outlet of the river. The measurement method is demonstrated in Figure 2.4.

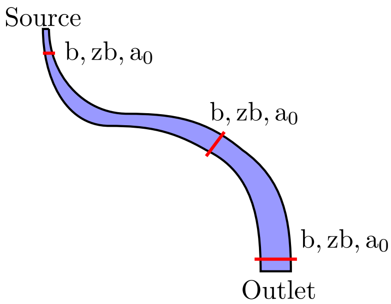


Figure 2.4: The measurement method.

By use of the waterlevel and width, the wetted area A and hydraulic radius R can be calculated. This are input variables for the model simulation. The bottom slope S_0 can be calculated by use of the measurement locations x, with corresponding bottom depth zb:

$$S_0 = \frac{z_{b,k} - z_{b,k+1}}{x_k - x_{k+1}} = \frac{\Delta zb}{\Delta x} \qquad \text{for } k = 0, 1, ...N. \tag{2.1}$$

This calculation is visualized in Figure 2.5.

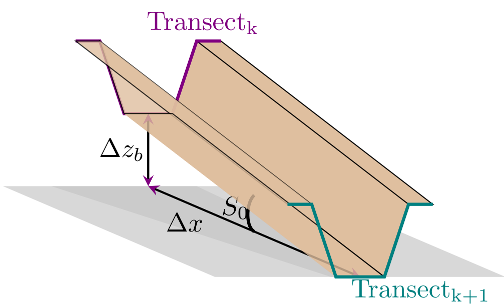


Figure 2.5: Method to calculate the bottom slope, S_0.

Model Parameter

The Manning coefficient n is the only parameter of the DRM that requires calibration, because the roughness of a river cannot be measured directly and is highly empirical (Limerinos, 1970). A reasonable range of the Manning coefficient for lowland areas lies between 0.01 and 0.05 $\mathrm{s/m^{1/3}}$.

2.2 Model Simulation

To simulate fundamental river processes in lowland areas, a flow function that depends on celerity and diffusion is constructed:

$$Q = \frac{1}{n}\sqrt{S_0} - \frac{1}{2n}\frac{1}{\sqrt{S_0}}\frac{\partial a}{\partial x} * AR^{\frac{2}{3}} \quad . \tag{2.2}$$

As is shown, all variables to calculate Q are defined in the previous Sections. The finite volume technique is the spatial discretization method of the DRM. The time discretization technique of the DRM is explicit. The outlet of the river is represented in the DRM as a boundary with a fixed flux and state (Cauchy boundary). This is because most lowland areas have a weir at the outlet. The rectangular weir Equation is used to calculate the flow rate over the weir.

3 | Model Applicability

The dynamic river model can be downloaded as zip file from GitHub www.github.com/FemkeHilhorst/DRM. The dynamic river model is subdivided into several R scripts. In this Chapter, screen shots of the scripts are demonstrated to show you how to run the DRM. Figure 3.1 shows the layout of the DRM folder. It is required that the DRM folder is placed in the WALRUS folder to run successfully. As example, I will use Reusel catchment data as input of WALRUS.

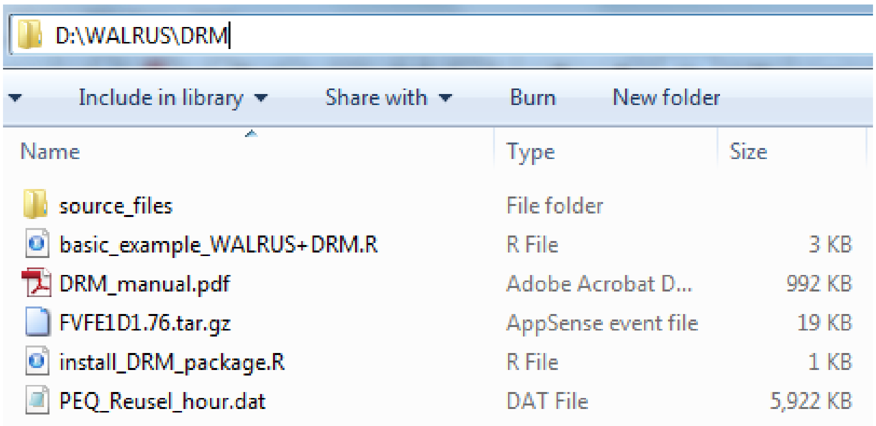


Figure 3.1: The DRM folder.

3.1 Install Finite Volume Package

At first, the finite volume package has to be downloaded. To do so, you should open "install_DRM_package.R" in the DRM folder. If you open this R script, you should see a R script that looks similar as Figure 3.2. When you run this script, the DRM package is downloaded. For the dynamic river model (DRM), the FVFE1D package is used. The "FVFE1D1.76.tar.gz" file (see Figure 3.1) is a finite volume and elements package that is created by Torfs (2015). This package provides a basis to simulate 1D flow with the finite volume or finite element discretization technique.

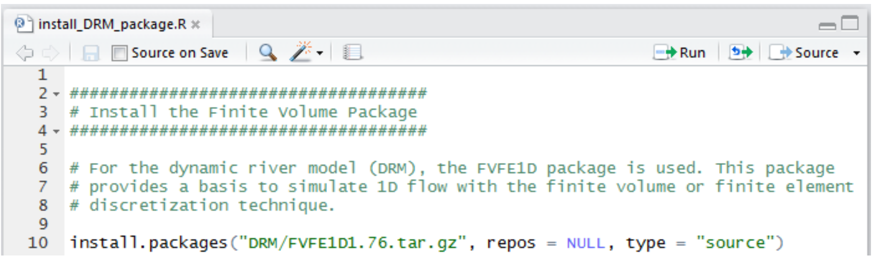
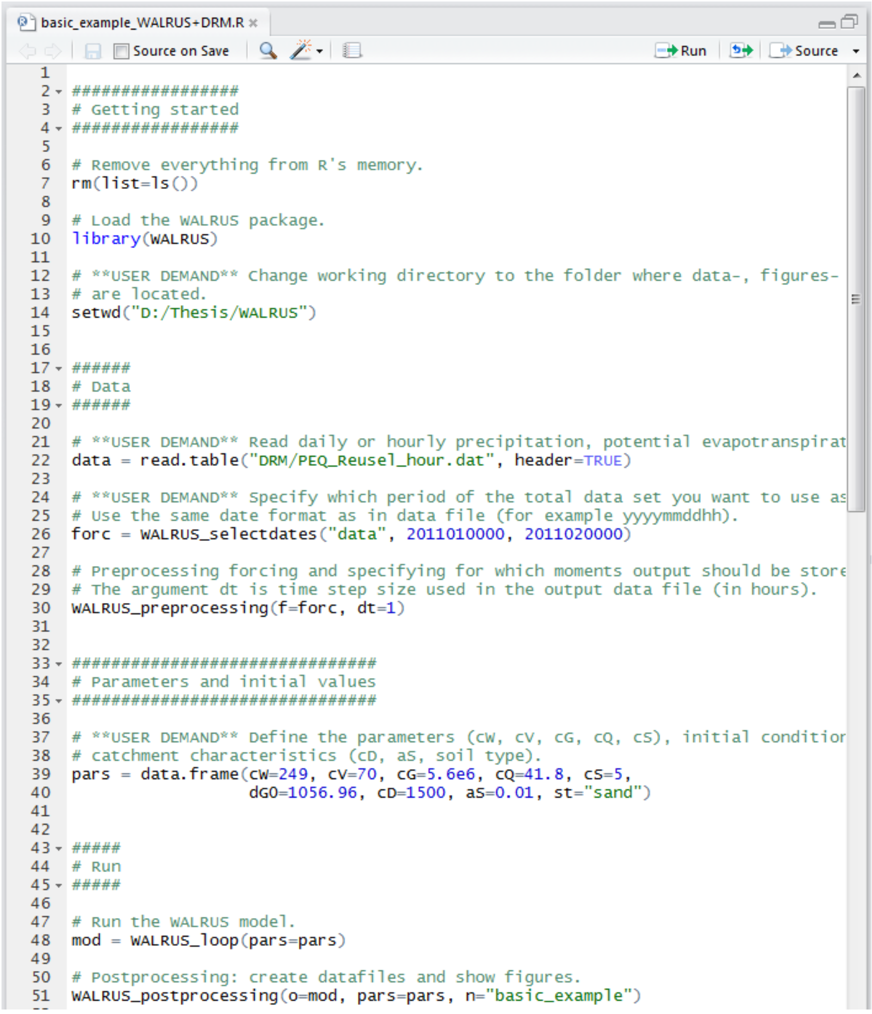


Figure 3.2: Install the finite volume package.

3.2 Run WALRUS

When you installed the finite volume package, open "basic_example_WALRUS+DRM.R". This R script contains two parts. The first part (from line 1 to 51) is a basic example of a WALRUS run. These lines are represented in Figure 3.3. A WALRUS manual is available to understand the input variables implementation and source files of WALRUS (Brauer et al., 2015). Run these lines to obtain WALRUS output (Q_{WALRUS}).




```
1
2  #################
3  # Getting started
4  #################
5
6  # Remove everything from R's memory.
7  rm(list=ls())
8
9  # Load the WALRUS package.
10 library(WALRUS)
11
12 # **USER DEMAND** Change working directory to the folder where data-, figures-
13 # are located.
14 setwd("D:/Thesis/WALRUS")
15
16
17 ######
18 # Data
19 ######
20
21 # **USER DEMAND** Read daily or hourly precipitation, potential evapotranspirat
22 data = read.table("DRM/PEQ_Reusel_hour.dat", header=TRUE)
23
24 # **USER DEMAND** Specify which period of the total data set you want to use as
25 # Use the same date format as in data file (for example yyyymmddhh).
26 forc = WALRUS_selectdates("data", 2011010000, 2011020000)
27
28 # Preprocessing forcing and specifying for which moments output should be store
29 # The argument dt is time step size used in the output data file (in hours).
30 WALRUS_preprocessing(f=forc, dt=1)
31
32
33 ###############################
34 # Parameters and initial values
35 ###############################
36
37 # **USER DEMAND** Define the parameters (cW, cV, cG, cQ, cS), initial conditior
38 # catchment characteristics (cD, aS, soil type).
39 pars = data.frame(cW=249, cV=70, cG=5.6e6, cQ=41.8, cS=5,
40                   dG0=1056.96, cD=1500, aS=0.01, st="sand")
41
42
43 #####
44 # Run
45 #####
46
47 # Run the WALRUS model.
48 mod = WALRUS_loop(pars=pars)
49
50 # Postprocessing: create datafiles and show figures.
51 WALRUS_postprocessing(o=mod, pars=pars, n="basic_example")
```

Figure 3.3: A basic WALRUS run.

3.3 Implement River Characteristics

The second part of the "basic_example_WALRUS+DRM.R" script is from line 52 to 104, which is shown in Figure 3.4. This is the part were you need to fill in:

- the measured waterlevel a_0 $[\mathrm{m}]$;
- the width of the river b $[\mathrm{m}]$;
- the bottom depth of the river zb $[\mathrm{m}]$;
- the measurement locations x $[\mathrm{m}]$;
- a well considered Manning coefficient n $[\mathrm{s/m^{1/3}}]$

You are required to fill a_0, b, zb and x in for three locations along the river: at the source, mid-way and at the outlet of the river. This is in greater detail explained in Section 2.1. When you have filled these river characteristics in, the dynamic river model can simulate discharge. The source files (which are located in the map: "DRM/source_files") are the codes where the model simulation is based on. To understand these codes, I recommend you to read the study of Hilhorst et al. (2016).

basic_example_WALRUS+DRM.R

Source on Save | Run | Source

```
53  ################################
54  # Specify River Characteristics
55  ################################
56
57  # **USER DEMAND** Specify the input variables of the dynamic river component.
58  # This is the waterlevel a0, the width at water level b.a0 and the bottom
59  # depth of the river measured at three locations along the river. With:
60  # 1: at the outlet of the river
61  # 2: at the middle of the river
62  # 3: at the origin of the river
63
64  # Initial waterlevel along the river:
65  a0 = data.frame(a1=1.4, a2=0.9, a3=1.1) # meter
66
67  # Width at initial water level:
68  b.a0 = data.frame(b1=4, b2=1.9, b3=0.2) # meter
69
70  # Bottom depth of the river:
71  bot.depth = data.frame(zb1=5.4, zb2=14.8, zb3=31.1) # meter
72
73  # Measurment locations along the river:
74  bottom.x = data.frame(x1=0, x2=15000, x1=33455) # meter
75
76  # **USER DEMAND** Set the Manning coefficient to a reasonable value:
77  n = 0.038 #s/m^1/3
78
79
80  ##############################
81  # Preprocess DRM
82  ##############################
83
84  # Load the FV Package
85  library(FVFE1D)
86
87  # Preprocessing with river characteristics as input
88  source(file="DRM/source_files/DRM_preprocessing.R")
89
90
91  ##############################
92  # Run the Dynamic River Model
93  ##############################
94
95  # Run the Dynamic River Model
96  source(file="DRM/source_files/DRM_run.R")
97
98
99  ##################################
100 # Output Files and Figures of DRM
101 ##################################
102
103 # Postprocessing: create datafiles and show figures of DRM
104 source(file="DRM/source_files/DRM_postprocessing.R")
```

Figure 3.4: Fill in river characteristics and simulate discharge by use of the DRM.

3.4 DRM output

When you followed the steps that are explained in the previous Sections, the DRM creates a Figure with the WALRUS output versus the DRM output with corresponding Nash-Sutcliffe efficiencies (NS; Schaefli and Gupta, 2007; Gupta et al., 2009). Your created plot will then have the same character as Figure 3.5. The black line represents the observed data, the red line is the WALRUS output and the green line is the DRM output. "NS DRM" means the NS efficiency of the dynamic river model and "NS WALRUS" corresponds to the NS value of WALRUS .

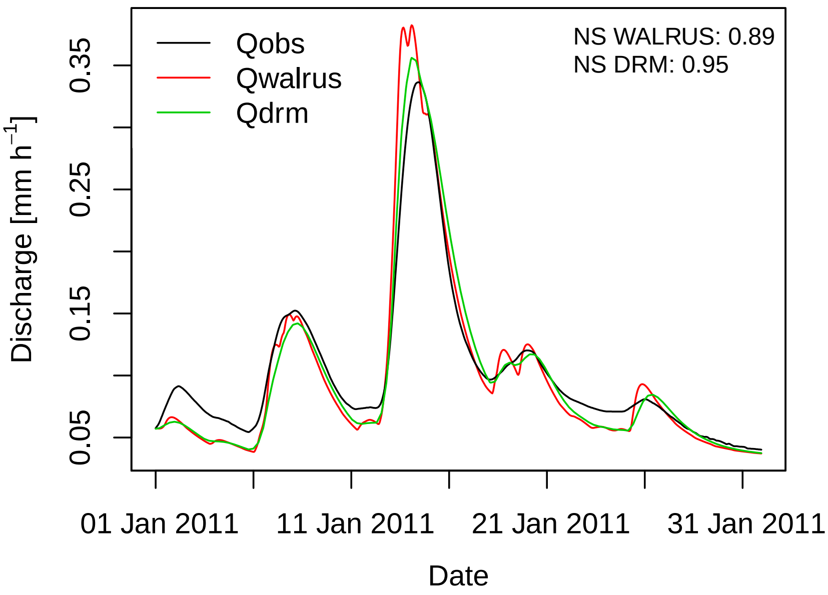


Figure 3.5: Example of an output of the dynamic river model.

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