INTEGREATED HYDROLOGICAL AND RIVER MODEL

Mike 11& Eco lab

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Contents

Assignment 1

-River Modelling Using MIKE 11-

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1a) Describe the model setup steps you have followed to develop your model.

The objective of this model using Mike 11 is to simulate the water dynamic in the specified stream. The Mike 11 separates the model to five components, such as river network, boundary, initial conditions and roughness, cross-section, and simulation file set those data to the proper sites. Thus, there are five data files and one control file prepared to run the model, as shown in the following:

1. River network file (.nwk11)

The location and the river length are defined using the x, y coordinates and chainage, and the connection between river branches is determined. Figure 1.1 shows clearly the overlook of the river network. There are one main river from north to west and one tributary from northeast to southwest with 93285 meters and 38192 meters long respectively, and the junction of the branch river is in the downstream of the main river of 41560 meters in chainage. Moreover, the distance of created profiles of the simulated temporal data (e.g. water level or discharge) can be set with a maximum dx of 5000 meters in this file.

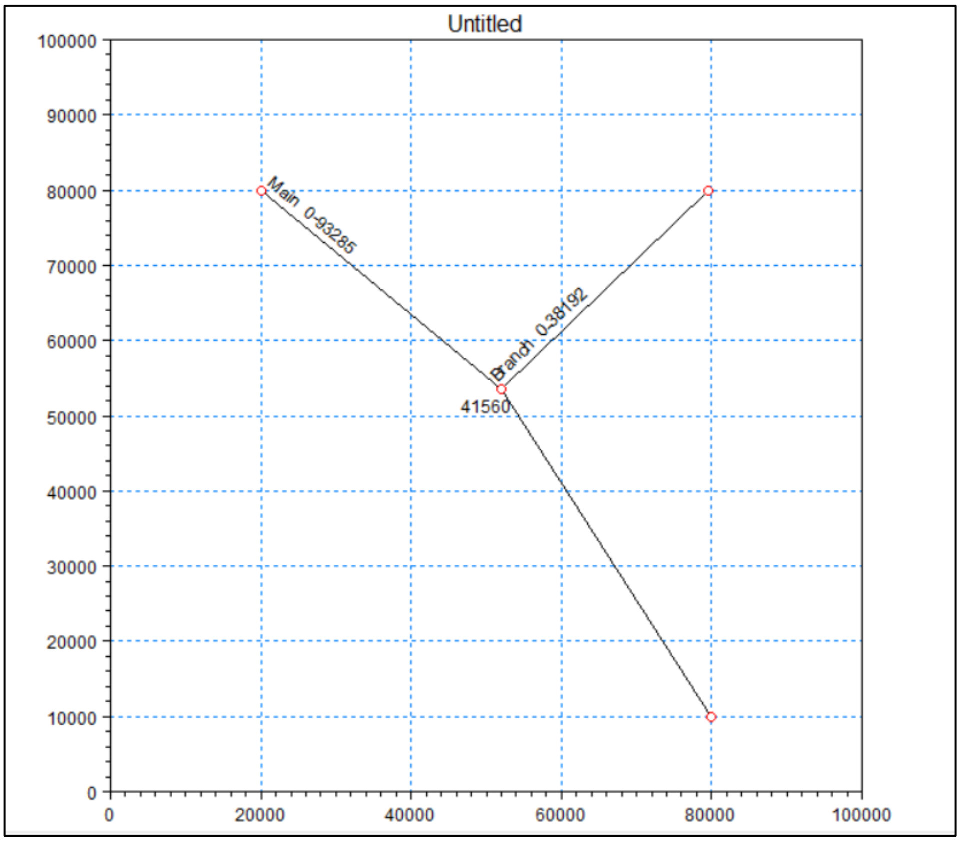


Figure 1.1 the overlook diagram of the river

2. River cross-sections (.xns11)

The cross-sections of the river with elevation are to make the computer understand the river shape and the vertical positions. Therefore, each river should have two cross-sections at least to delineate the shape of the river. In this case, the data input manually and show in fig. 1.2. There are the rectangle shapes with different datum in a total of five profiles, and the boundary and lowest points were determined manually.   Meanwhile, the resistance type is the relative resistance with the uniform of 1.

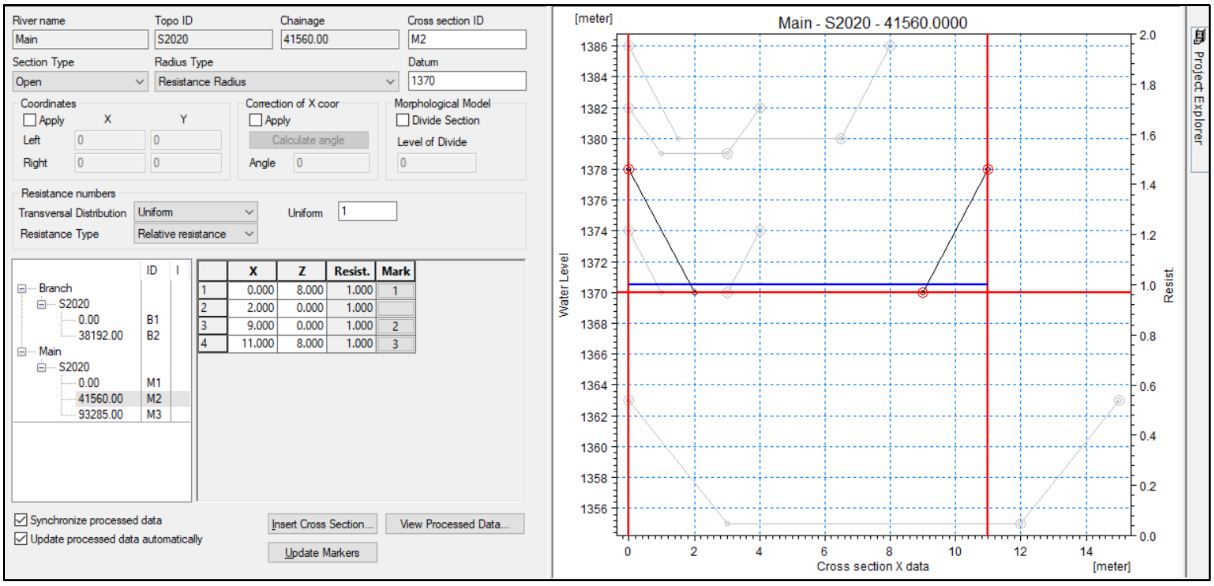
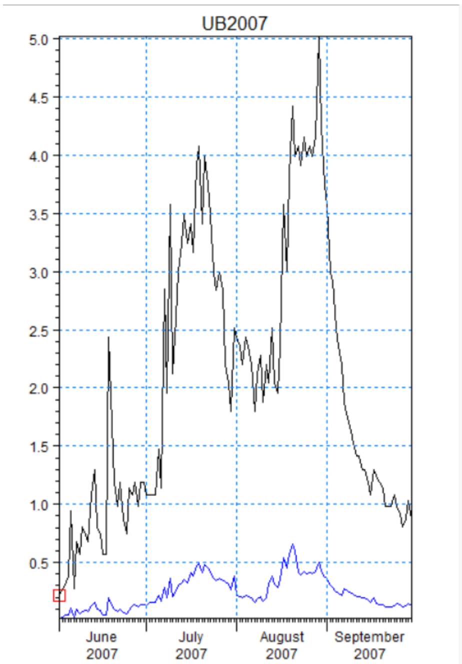


Figure 1.2 Interface window of the cross-section file

3. Boundary data (.bnd11)

The boundary data file indicate the amount of inflow changing over time and discharges in the downstream boundary, which relate to water level. However, the time-series data from 1 June to 30 Sepetember, did not directly input the boundary file and were rearranged in the time series file (.dsf0), as shown in fig. 1.3. Then the time series file links to the boundary file in fig.1.4. Especially, figure 1.3 shows that there are two periods of inflow with a relatively high amount.



	Time	1:MainQ [meter^3/sec]	2:BranchQ [meter^3/sec]
0	6/1/2007 00:00:00	0.22	0.02
1	6/2/2007 00:00:00	0.28	0.03
2	6/3/2007 00:00:00	0.3	0.05
3	6/4/2007 00:00:00	0.38	0.05
4	6/5/2007 00:00:00	0.94	0.11
5	6/6/2007 00:00:00	0.28	0.03
6	6/7/2007 00:00:00	0.68	0.1
7	6/8/2007 00:00:00	0.57	0.06
8	6/9/2007 00:00:00	0.81	0.08
9	6/10/2007 00:00:00	0.74	0.09
10	6/11/2007 00:00:00	0.68	0.08
11	6/12/2007 00:00:00	1.08	0.13
12	6/13/2007 00:00:00	1.3	0.16
13	6/14/2007 00:00:00	0.81	0.1
14	6/15/2007 00:00:00	0.75	0.09
15	6/16/2007 00:00:00	0.57	0.05
16	6/17/2007 00:00:00	0.57	0.05
17	6/18/2007 00:00:00	2.44	0.2
18	6/19/2007 00:00:00	1.69	0.14
19	6/20/2007 00:00:00	1.19	0.1
20	6/21/2007 00:00:00	0.98	0.08
21	6/22/2007 00:00:00	1.19	0.1
22	6/23/2007 00:00:00	0.87	0.07
23	6/24/2007 00:00:00	0.75	0.06
24	6/25/2007 00:00:00	1.14	0.09
25	6/26/2007 00:00:00	1.08	0.13
26	6/27/2007 00:00:00	1.19	0.14
27	6/28/2007 00:00:00	0.98	0.12
28	6/29/2007 00:00:00	1.19	0.14
29	6/30/2007 00:00:00	1.19	0.14
30	7/1/2007 00:00:00	1.08	0.13

Figure 1.3 Temporal inflow data

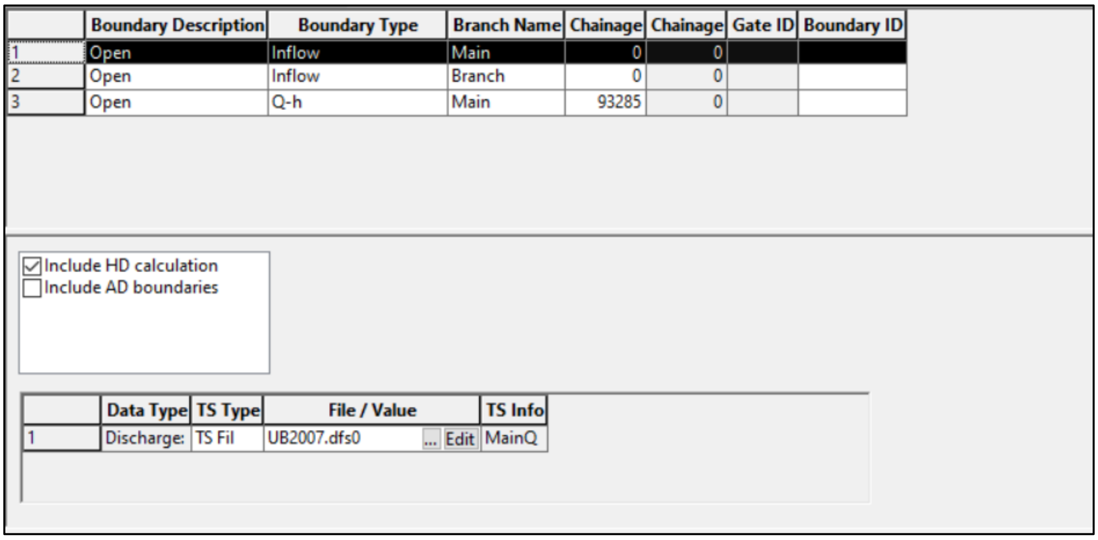


Figure 1.4 Interface window of the boundary file

4. HD parameter file (.HD11)

The HD parameter means the hydrodynamic parameter, and, in this case, the initial conditions and roughness were set while other parameters were ignored. Figure 1.5 present the global values of the water depth, and the discharges were applicable, with 0.2 meters and 0.5 cubic meters per sec respectively, in a way that the initial amount of water depth and discharge is equal everywhere in the river. Additionally, the bed resistance coefficients were defined with 0.025 first, and, then, 0.3 to compare the influence of roughness in the discharge and water levels over time.

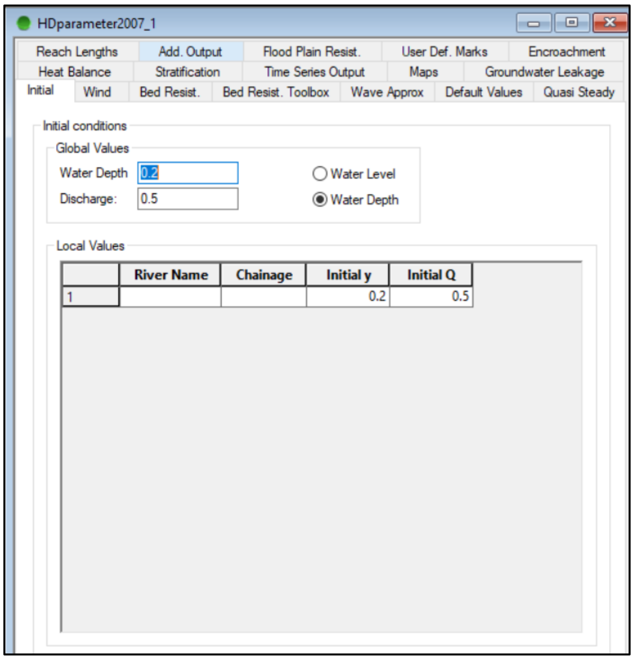


Figure 1.5 Interface window of the HD parameter file

5. Simulation control file (.sim11)

The simulation control file uses to connect other files for running the model and outputting the results. Meanwhile, it can define the interval time of storing data, with 4 hours, in this case, the simulation period from 10 August to 25 September, and the simulation time step, as shown in fig 1.6. Then the Mike 1D button is to click for a running model in “Start” part, and we got the results.

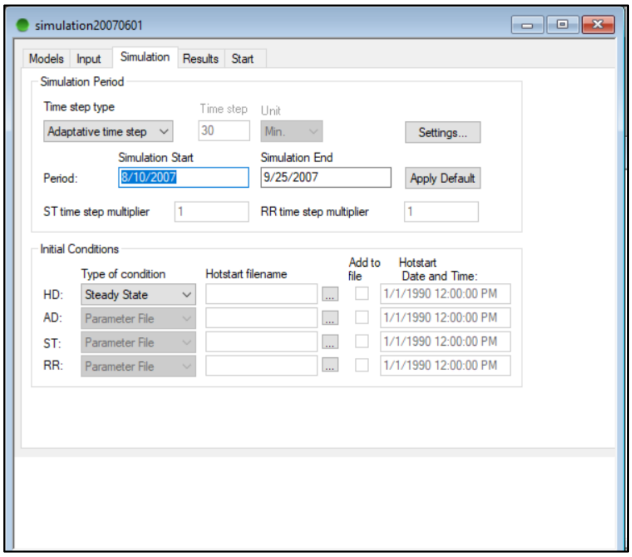


Figure 1.6 Interface window of the simulation control

Finally, the results can be shown visually in 'MIKEView' module in fig. 1.7, which need activating manually in 'Toolbars', 'View' selection.

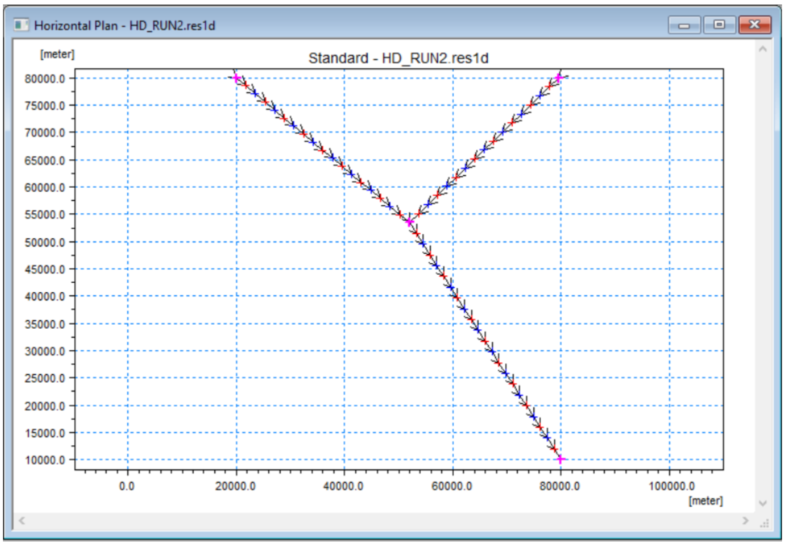


Figure 1.7 Simulation results

1b) Run the model twice with two different global N values specified in the table below and compare simulated discharges and water levels for the two N values at a section specified in the table.

The simulated water levels with different global N values over time in the approximation 10 km downstream of the junction with the tributary is shown in fig. 1.8, and Figure 1.9 shows the discharge with different roughness. Moreover, the Coefficient of Determination (R^2), Nash-Sutcliffe efficiency (NSE) and mean error (Bias) of the water levels and the discharges for comparing the results with different friction coefficients display in table 1.8. Assume that the time-series data of 0.025 in roughness are the observation data.

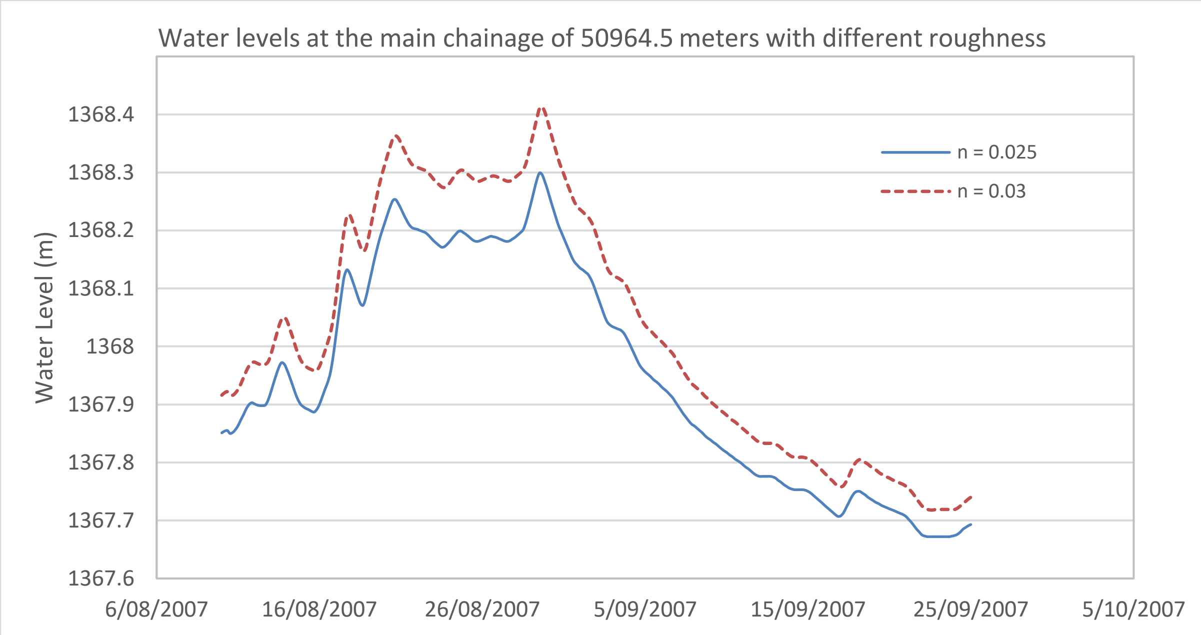


Figure 1.8 Simulation water levels with different global N values

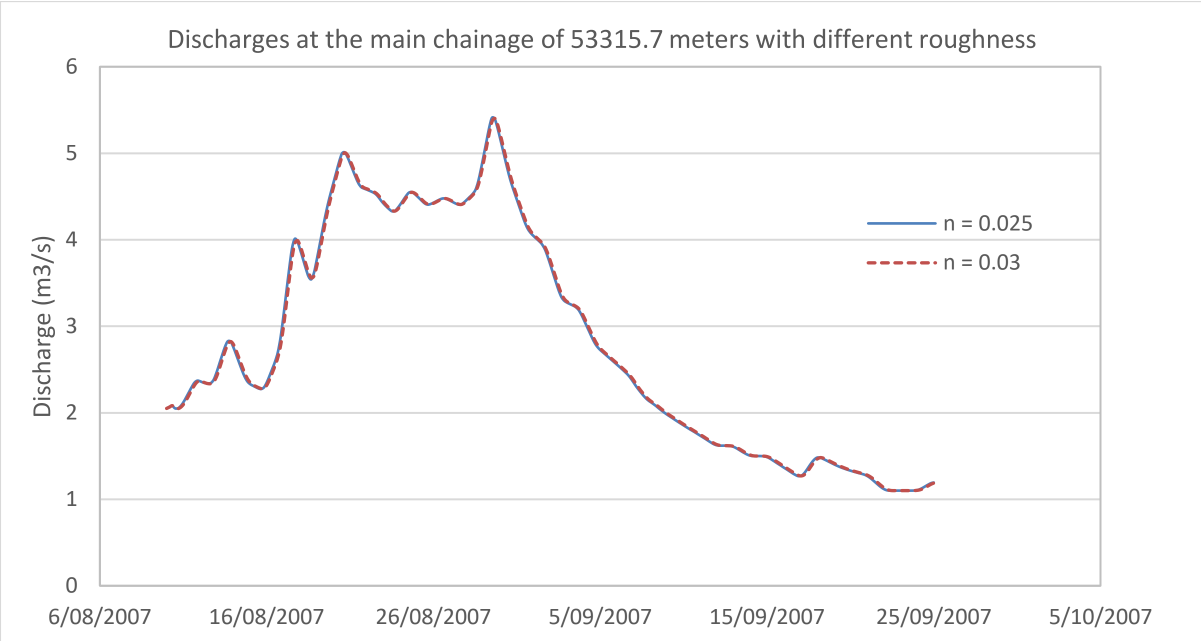


Figure 1.9 Simulation discharges with different global N values

Table 1.1 the parameters for validation in the water levels and discharges

Type	Bias	CoE	R^2
Water Levels	-0.0776	0.8260	0.9995
Discharges	-0.0020	0.9994	0.9994

1c) Describe the effect of changing the *N* value you have observed on the simulated hydrographs both in *Q–t* and *H–t*. Explain why.

Figure 1.8 presents the simulated water level with different bed resistances from 10 August to 25 September. The water levels of 0.025 in the roughness are relatively higher than that of 0.3 in the roughness by about 0.2 meters. Meanwhile, the bias error, the coefficient of efficiency and the coefficient of determination were calculated with -0.0776, 0.8260, 0.9995 respectively, leading to these results have a strong correlation, as shown in table 1.1.

On the other hand, the simulated discharges do not present a noticeable deviation in figure 1.9, but the curve of 0.03 in the friction coefficient is slightly later than that of 0.025 in roughness. It is essential to show that the roughness can impact flow time, which means that the high values of the bed resistance delay discharge. Moreover, the correlation of the discharges between different N values is much stronger than that of the water levels, according to the values of Bias, CoE and R^2, with -0.0020, 0.9994 and 0.9994 respectively.

The reason caused those results is relation with the equation of the mathematical simulation. For the Manning description of Mike 11, the term is(*DHI*, 2003):

$$Q|Q| = \frac{AR^{\frac{4}{3}}}{gn^2} \quad (1.1)$$

, where the value of *n* is typically in the range 0.01 to 0.10; *A* is cross-section area; g is gravity; R is the hydraulic radius and Q is discharge. The equation clearly shows the discharge decreasing, with increasing n value, and the determination of the water levels is used by the Q-h graph. Therefore, there is a difference between those two curves of water levels by about 0.2 meters. As for discharges, the curves of water level are flatter than the discharge one, and the difference between two curves of discharges is not obvious, compared with the variance of the discharge.

2: A simplified model of the Sisaony River (based on Mike 11) is given. An observed hydrograph from the hydrometric station at Ambatofotsy was used as the upstream boundary condition at Chainage 0.000 km. The downstream boundary condition is specified at Chainage 32.760 km as a *Q–h* relationship (rating curve) based on a steady uniform flow assumption. Two observed water level and discharge time series data are also available from the hydrometric station at Ampitatafika (Chainage 21.450 km).

2a) Run the model with the default value of Manning's n and compare the simulated results at Ampitatafika with the observed time series.

What are the most likely reasons for the discrepancies between the observed and simulated hydrographs? Explain.

Figure 2.1 and figure 2.2 present that the comparison of time series of observation and simulated data (e.g. water levels and discharge) of 0.333 in roughness at Ampitatafika. The simulations of the water levels and discharges over time are faster than the observation data, and the first several simulated values are much lower than measured data. Meanwhile, all of the peak flows of discharge in simulated data are higher than the observations, except for the fourth peak flow.

There are many reasons for the discrepancies between the observed and simulated hydrographs. The reason for the difference of the several initial points is the global value of the water depth and discharges in HD parameters file in river model induce the computer calculating water level and discharge, which starts from the global values. However, the river has the base flow, and the value of the started point on 10 August is different for the initial simulated values.

Moreover, the difference between observation and simulation in most parts of the hydrographs is caused by the variance of the roughness and cross-section area. The roughness coefficient in the real river varies by the type of boundary of the river channel, and the model has the constant n value to calculate the river dynamic. Meanwhile, the profiles' shape in the Sisaony River constantly changes, while the model just uses several typical cross-sections to simulate the results. According to equation 1.1, the cross-section area and the roughness coefficient impact on the simulated discharge and water level, which has a big error, compared with the actual values. Thus there have discrepancies between the observed and simulated hydrographs.

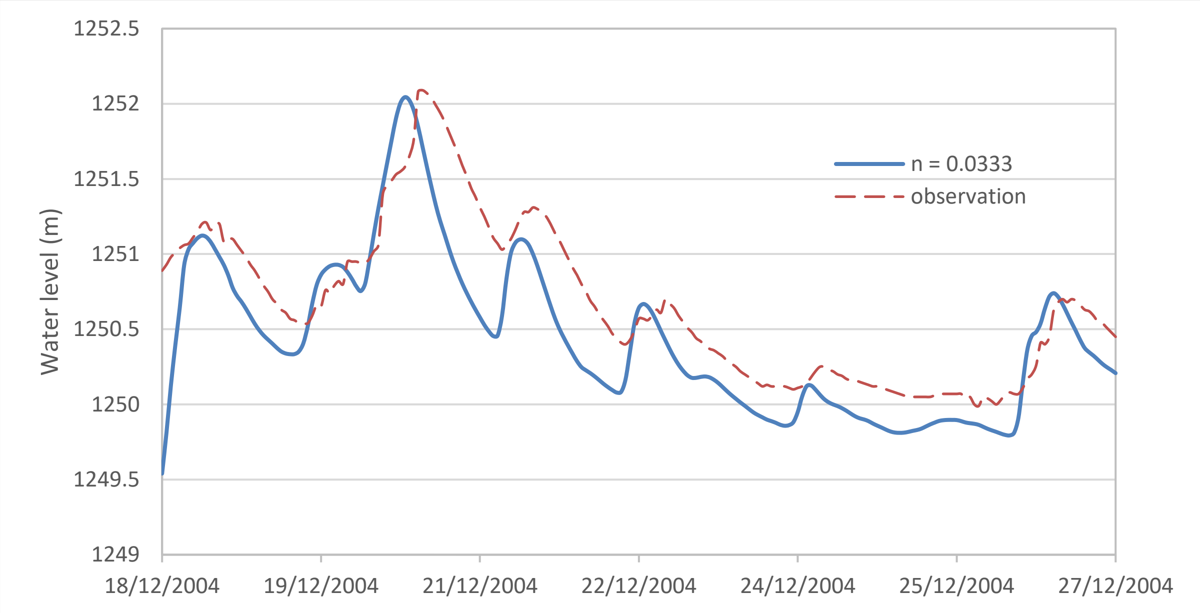


Figure 2.1 Comparison of Simulated water levels and Observation data at Ampitatafika

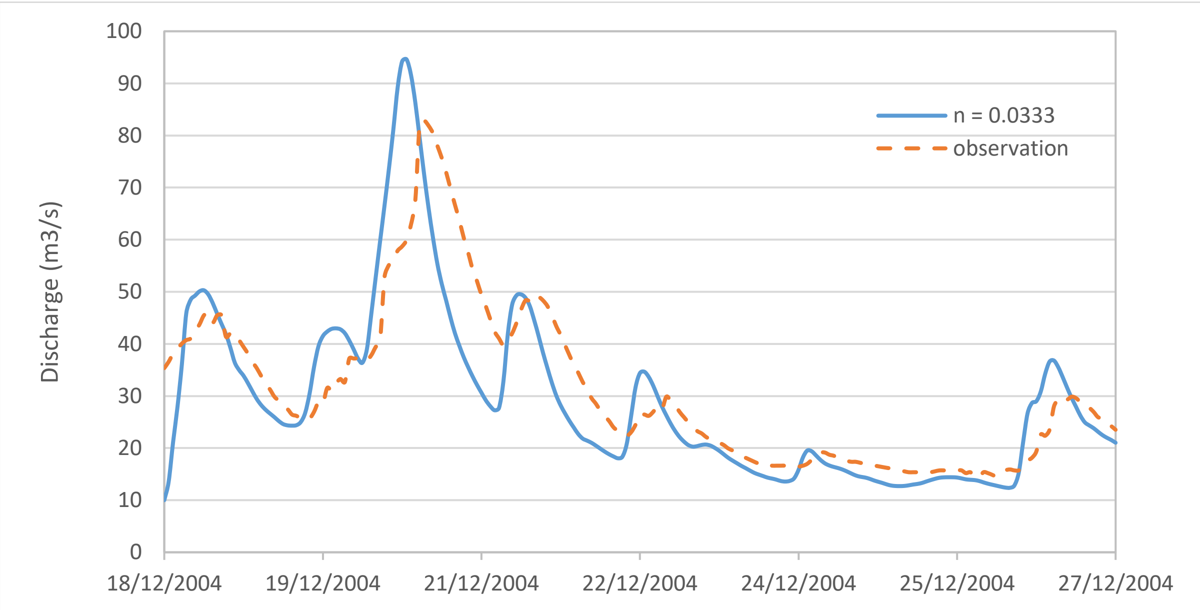


Figure 2.2 Comparison of Simulated discharges and Observation data at Ampitatafika

2b) By changing the empirical parameter Manning's n, can you improve the model result in terms of the peak flow discharge (or water level) and time to peak? Illustrate your result by using three Manning's *N* values and other conditions specified in the table below.

The times series of simulated and observed hydrographs with different Manning' *n* values from 18 December to 27 December are shown in fig.2.3 and 2.4. The figures present that, with increasing value of roughness, the water levels related to the amount of the discharges decline. Meanwhile, the peak flows go-to flat and the time to peak increase. Moreover, the observed water levels are fit better with the simulation of 0.03 in roughness than other curves. The reason for the results impacted by the roughness is that equation 1.1 control the model to simulate the river dynamic. According to the equation, the values of the discharges drop up with rising roughness.

Thus, the friction coefficient can influence the hydrographs in the peak flow discharge and time to peak. And the correlation parameters show that the curve of 0.05 in roughness used to improve the model fit better than the default roughness coefficient both in the water levels and discharge, as shown in table 2.1.

Table 2.1 Correlation Parameters

Type	n	Bias	CoE	R2
Water Level	0.033	0.2324	0.5487	0.7657
	0.15	0.8775	-2.2233	0.6381
	0.03	0.3315	0.3316	0.7473
	0.05	-0.1897	0.5866	0.8054
Discharge	0.033	1.8150	0.6063	0.6847
	0.15	1.5505	0.3833	0.5334
	0.03	1.767512	0.5697	0.6577
	0.05	2.0374	0.7325	0.7836

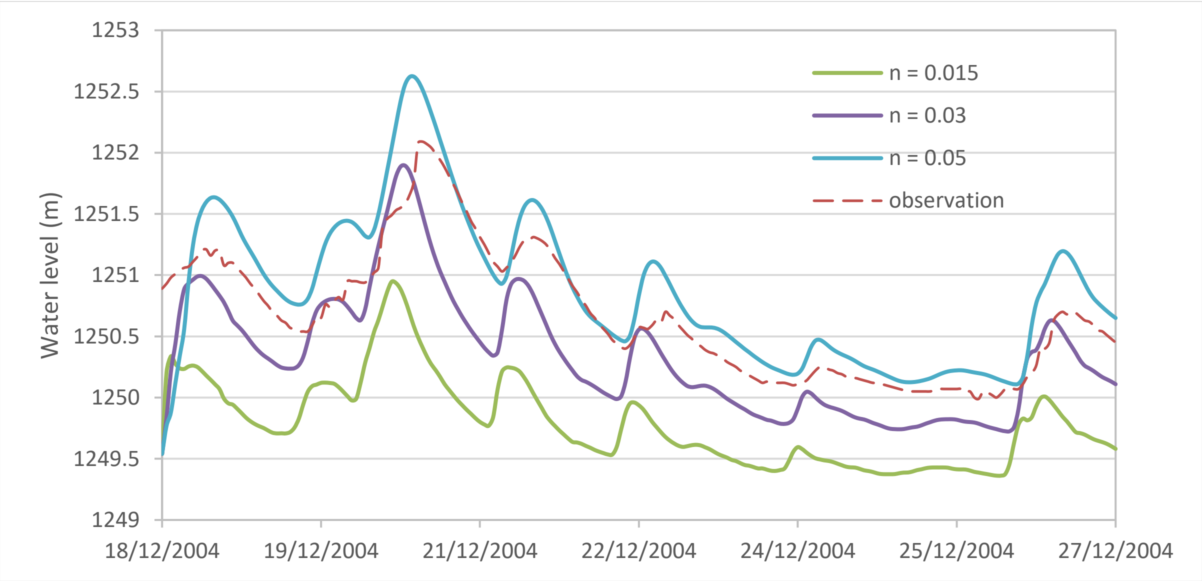


Figure 2.3 Time series of simulated water levels with different roughness and measured data

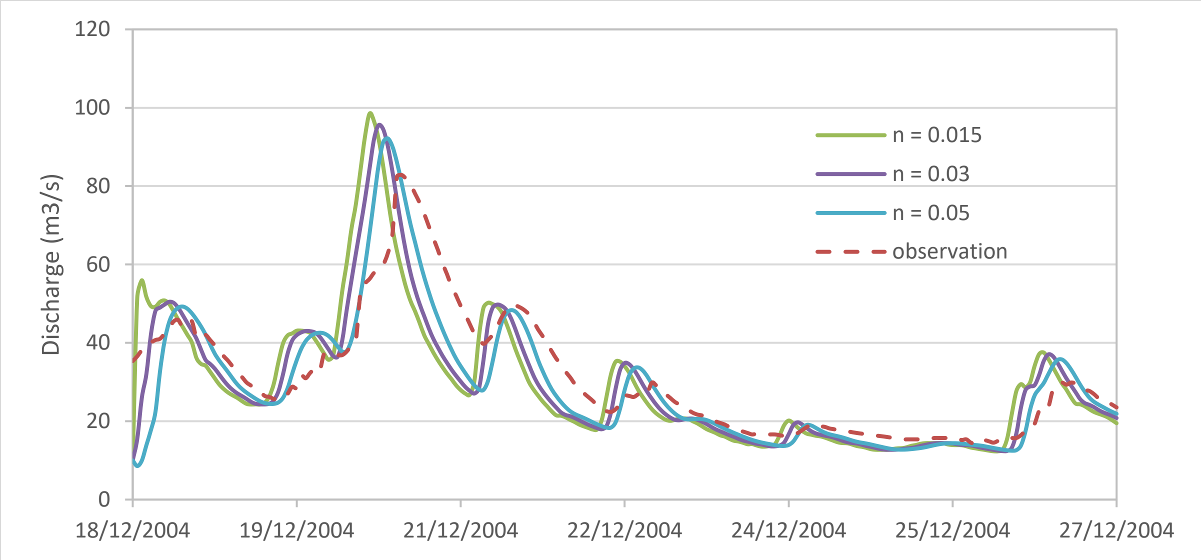


Figure 2.4 Time series of simulated discharges with different roughness and measured data

Assignment 2

- River Water Quality Modelling (MIKE 11 + ECO Lab) -

Zhang Fengbo

Student number: 1068520 Locker: 333

1a) Describe the model setup of the coupled MIKE 11 and ECO Lab that you developed in the class for water quality modelling.

Replace the upstream boundary conditions for the main and the branch with the BOD concentration time series data given in Table 2. For the specified simulation period and other information given in the Table 1, run the model and plot the BOD simulations

The river water quality model is the advanced model based on the previous river model, which was added the 'Advection-Dispersion' and 'MIKE ECO lab' model, as shown in figure 1.1.

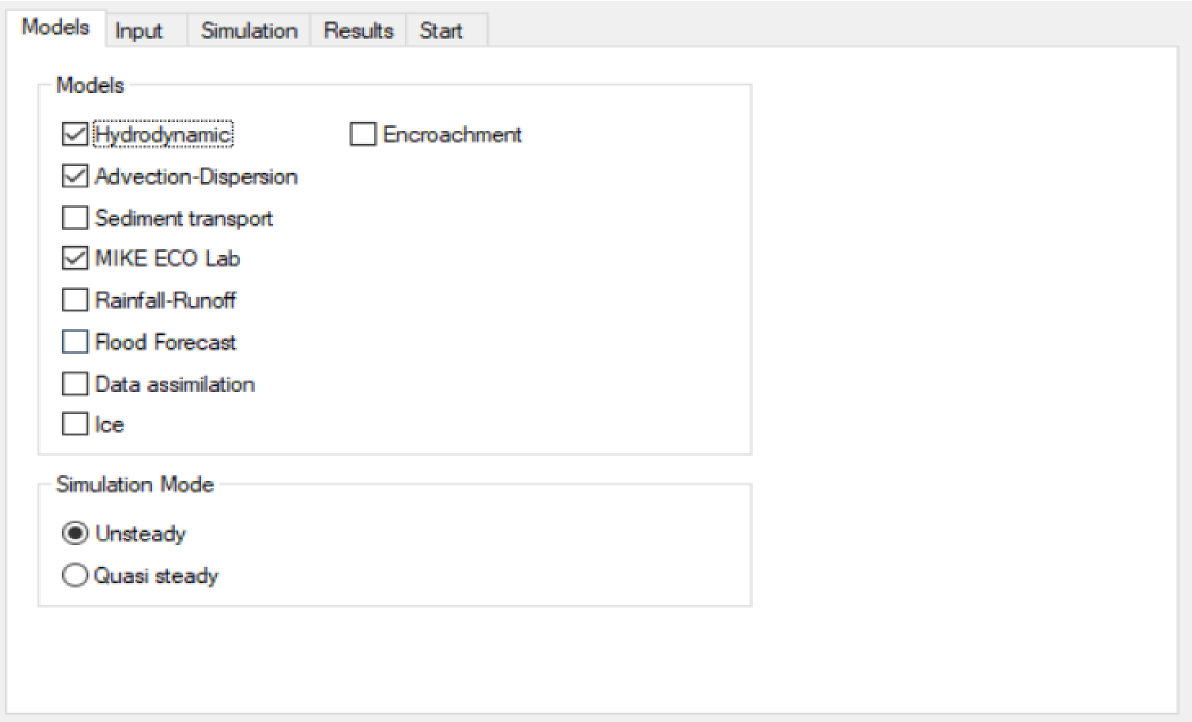


Figure 1.1 Models selection in the simulation file

The Advection-Dispersion model simulated the path of the pollutions, and there are two types of flows. One is the advected flow, and another is the dispersed flow. In this case of study, the dispersion factor, and exponent is determined as the constants with 2 and 0.5, respectively, as shown in figure 1.2. And the dispersion coefficient is calculated by the equation with the velocity of the flow, given as $D = a\,V^b$, where, a is the dispersion factor and b is the exponent. This formula is available in every place of the river.

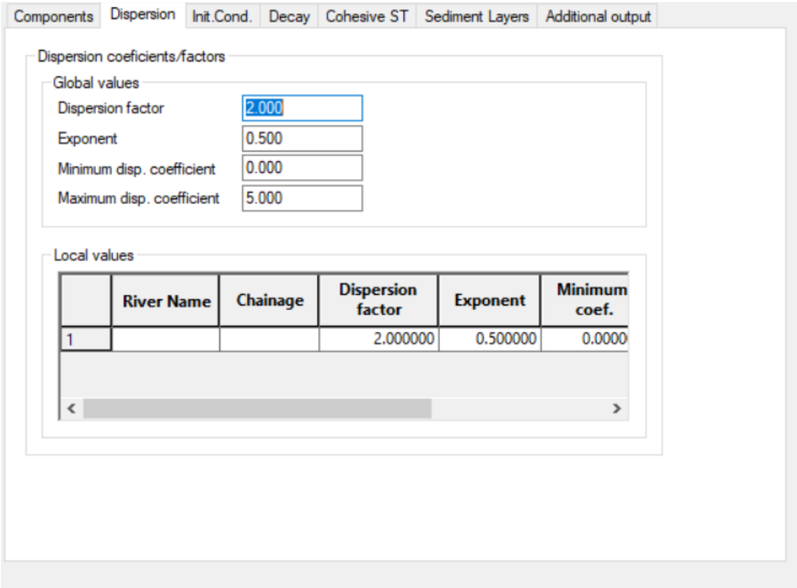


Figure 1.2 Interface of the AD parameter file

The reactions of the contaminations with substance in the river are given by 'MIKE ECO Lab' model. Figure 1.3 presents that the model selected the type of simulation of MIKE 11 WQ Level 3 in this case study. The parameters in this simulation are Dissolved Oxygen, Temperature, Nitrate and BOD, with 10 mg/l, 20 Celsius, 1 mg/l and 1 mg/l in the initial conditions, respectively. Meanwhile, the reaeration is also an important process needed to focus on.

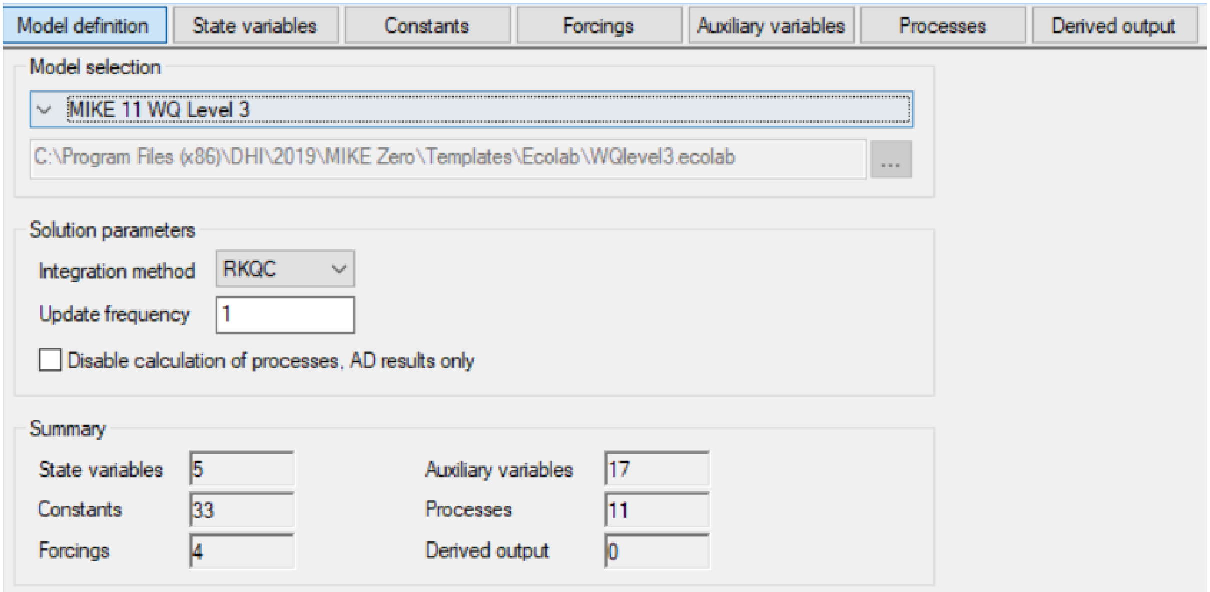
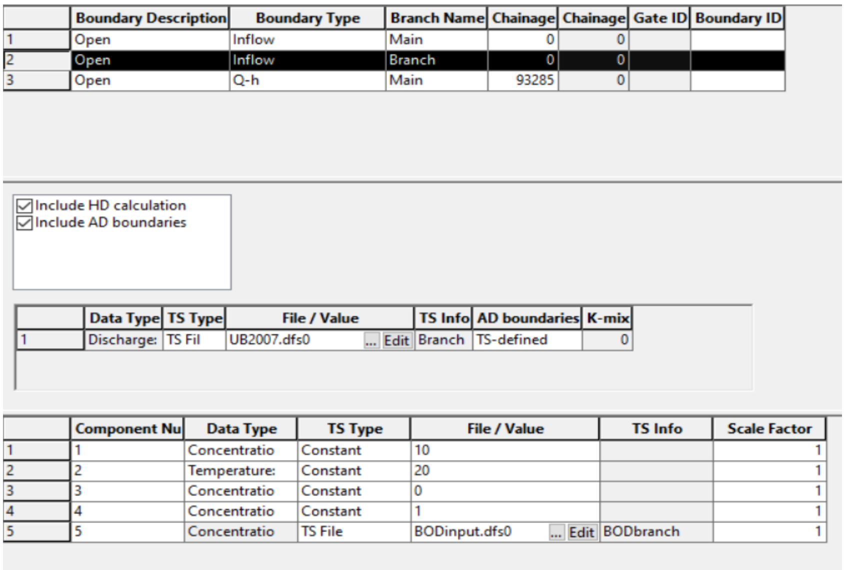


Figure 1.4 Interface window of MIKE ECO Lab model

Importantly, the input data, which is the variation of the BOD concentration over time, are connected with the upstream boundaries of the main and tributary rivers in the boundary file, as shown in figure 1.5. According to the requirement in the assignment, the BOD concentration increase to 6 mg/l in the main river and 10 mg/l in the tributary from 11th day to 15th day, while the concentrations keep constant in the main river and tributary in other time, with 1 mg/l and 2 mg/l respectively.



	Boundary Description	Boundary Type	Branch Name	Chainage	Chainage	Gate ID	Boundary ID
1	Open	Inflow	Main	0	0		
2	Open	Inflow	Branch	0	0		
3	Open	Q-h	Main	93285	0		

☑ Include HD calculation
☑ Include AD boundaries

	Data Type	TS Type	File / Value	TS Info	AD boundaries	K-mix
1	Discharge:	TS Fil	UB2007.dfs0 ... Edit	Branch	TS-defined	0

	Component Nu	Data Type	TS Type	File / Value	TS Info	Scale Factor
1	1	Concentratio	Constant	10		1
2	2	Temperature:	Constant	20		1
3	3	Concentratio	Constant	0		1
4	4	Concentratio	Constant	1		1
5	5	Concentratio	TS File	BODinput.dfs0 ... Edit	BODbranch	1

Figure 1.5 Interface window of the boundary file

Moreover, several other parameters were changed following the requirement of the assignment. There are Global N-value, Simulation period and Timestep for saving model results for comparison, with 0.025, 5 July to 3 August, 4 hours respectively

1b) at the upstream boundary and chainage 15 km on the main river. Explain the differences.

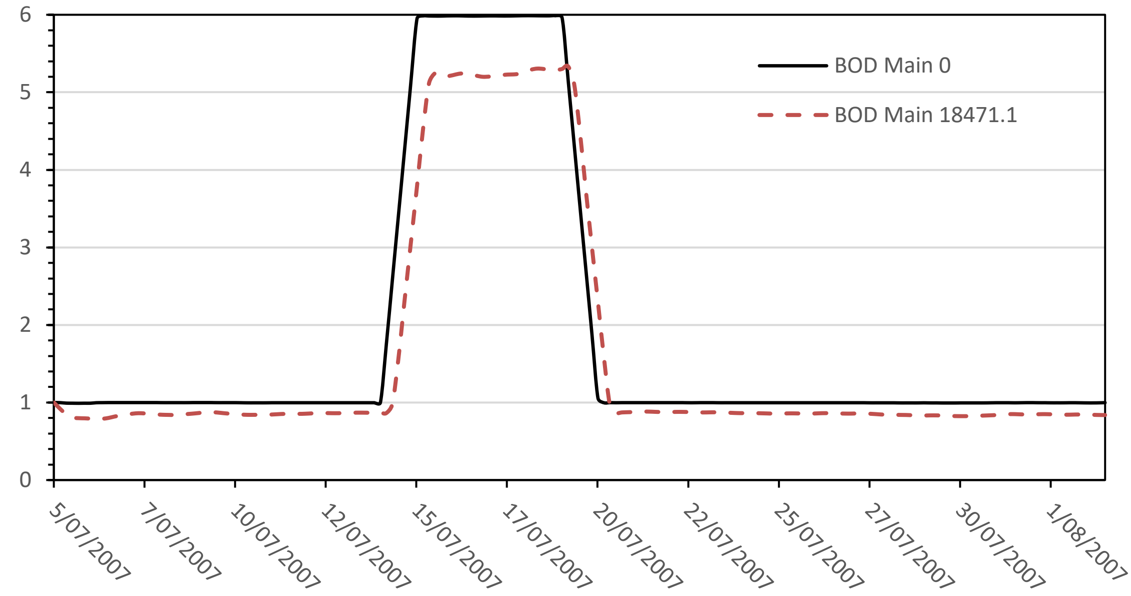


Figure 1.6 Comparison with BOD concentrations at the upstream boundary and chainage 18 km on the main river

Figure 1.6 present the time series of BOD concentrations at the upstream boundary and chainage 18 km on the main river. It means that high BOD concentration for black line in the figure travels into the main river form 11th day to 15th day, and this high concentration pollutions can be detected at the chainage 18 km on the main river. However, there have some discrepancies between those two concentrations. The time to peak values at the chainage 18 km on the main river is larger than that at upstream boundary due to the delay of the contaminations diffusion. In other words, the pollution transport, and reach that place need some time, which makes the time-lag of the BOD concentrations curve between at those two places.

Moreover, there have differences in BOD concentration curves at those places, and the concentration of the pollution at the upstream boundary is bigger, compared with that at the downstream. Especially, the difference between peak values at those place is the largest. Because the aerobic biological organisms break down the contaminations when they transport in the river, which decreases the BOD concentration, and the reduction is shown directly by the profile of the BOD concentration curve with a red dot line in figure 1.7. Meanwhile, with the increase of concentration pollution, the reproduction of bacteria and other microorganisms are easier and the amount of decomposed the pollution rise. Thus, the BOD concentration drops down dramatically, compared with that at other times.

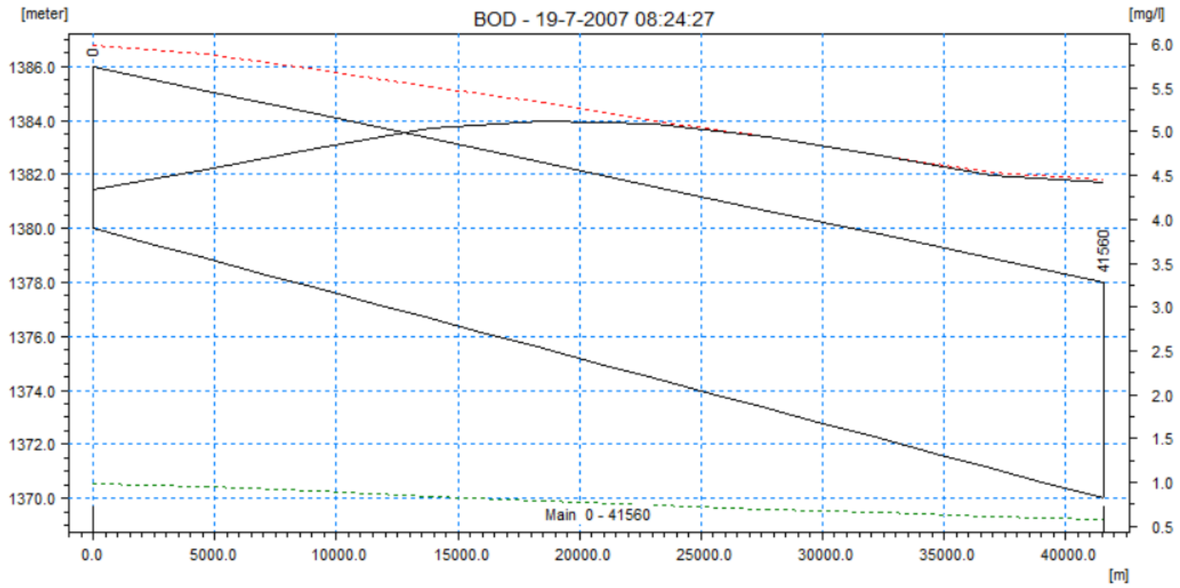


Figure 1.7 Profile of the BOD concentration in the river channel at specific time

1C) at 10 km (approx.) upstream from the confluence on the main and tributary rivers and 10 km (approx.) downstream of the confluence. Explain the differences.

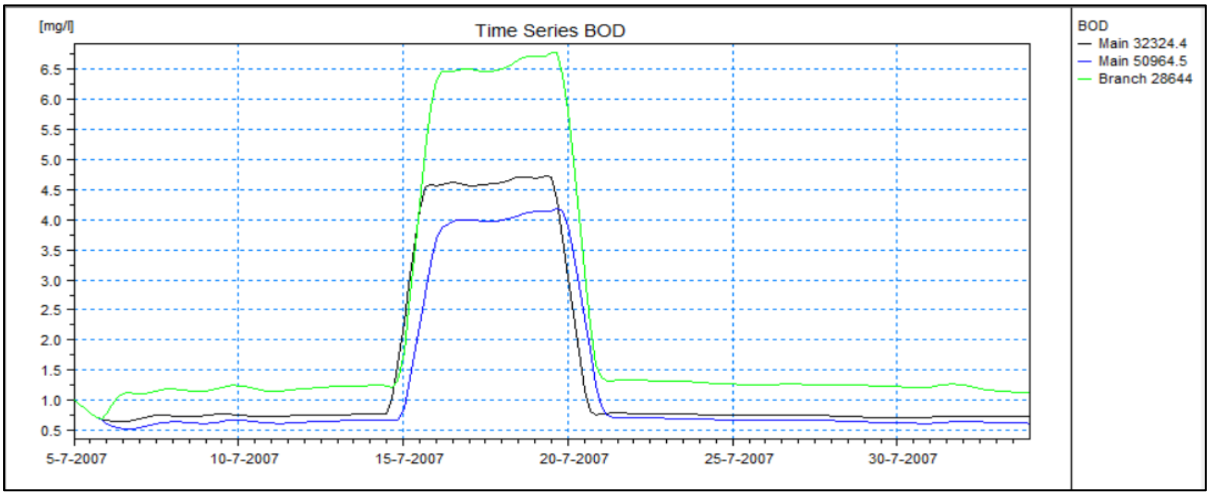


Figure 1.8 Comparison with BOD concentration at 10 km (approx.) upstream from the junction on the main and tributary rivers and 10 km (approx.) downstream from the junction on the main river

The concentrations of BOD changed overtime at 10 km (approx.) upstream from the junction on the main and tributary rivers and 10 km (approx.) downstream from the junction on the main river, which represents the concentration of the pollution, are displayed in figure 1.7. The green line is the time series of BOD concentration at about 10 km upstream from the confluence on the tributary river, which has the highest values, compared with other time series.

Moreover, the peak values of time series of BOD concentration at about 10 km upstream from the junction on the main river with black line in the figure, are higher than that at the about 10 km downstream due to the consumption of the pollutions by aerobic biological organisms, and the time-lag of the BOD concentration between at those two sites appears, because the transport of contaminants takes time.

Interestingly, the concentration of the containments at the downstream is influenced slightly on that from the tributary after the confluence, and the values of concentration are the highest. That is because the discharges of the main and tributary rivers are different, as shown in figure 1.9. In the figure, the discharge in the tributary river with the green line is low, compared with that in the main river, which means that the amount of the pollutions in the tributary river is low, although the concentration is high. Thus, the BOD concentration changes less after the confluence.

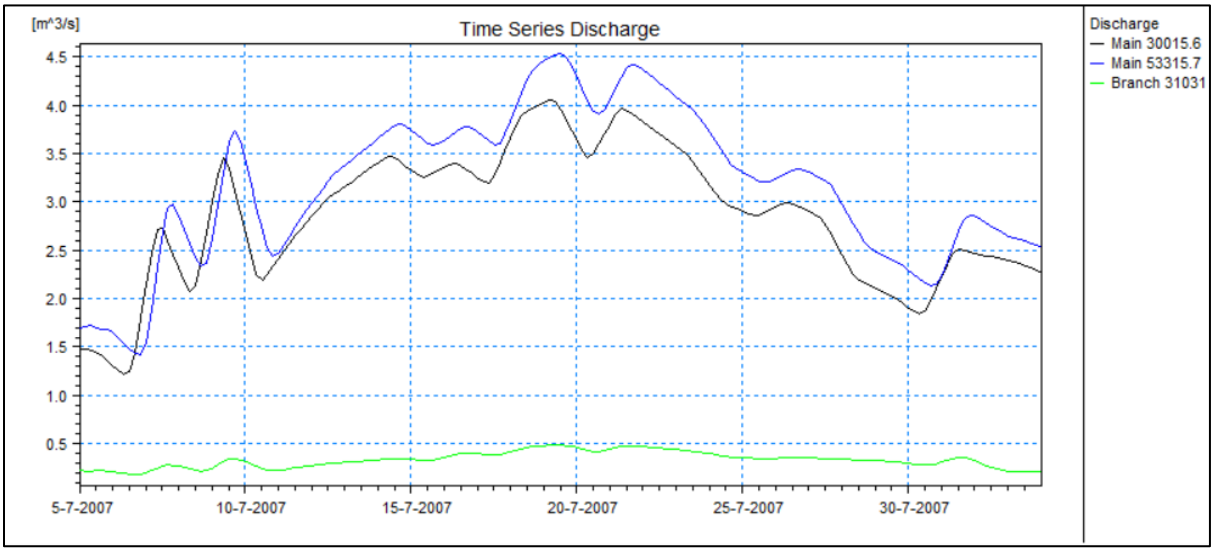


Figure 1.9 Discharges at 10 km (approx.) upstream from the junction on the main and tributary rivers and 10 km (approx.) downstream from the junction on the main river

2) Run the same model as in Assignment 1, but with two different temperature boundary (both constant) for the main river and compare BOD simulations from the two model runs at chainage 15 km (approx.) of the main river. Explain the result. The temperature boundary is specified in Table 1.

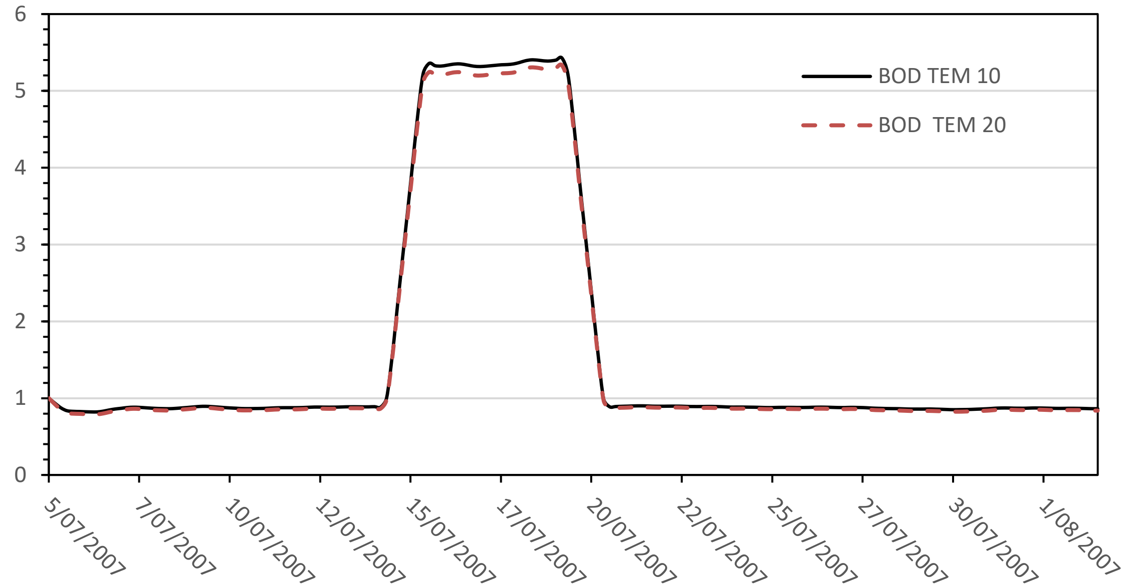


Figure 2 Comparison with the BOD concentration with different temperatures

Figure 2 presents the BOD concentrations at about 18 km downstream on the main river calculated by different temperatures, with 20 and 10 Celsius respectively. The black line is the BOD concentration determined by the temperature of 10 Celsius, which's peak value is higher than that calculated by the temperature of 20 Celsius. The reason, in a mathematical way, is that the temperature corrects the coefficient of the BOD decay following the equation, given as:

$$\mathrm{k}_{1(T)} =: \mathrm{k}_{1(T=20)}\theta^{T-20}$$

, Where the temperature correction factor, θ, is normally taken as 1.047*(DHI, 2005)*. Thus, with the decrease of the temperature, the decomposed containments by the bacteria and other microorganisms reduce. In other words, the biological activities of the aerobic biological organisms are influenced by the temperature, and the higher temperature within a reasonable limit, the lower BOD concentration we have. That is the reason that the peak value of the BOD concentration curve of 10 Celsius in the temperature is high than that of 20 Celsius in the temperature.

Assignment 3

- River Water Quality Modelling (Advection-Dispersion) -

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This model simulates the advection and dispersion of the non- degradable pollution in the river. The water depth depends on the parameters and the Manning equation, given as:

$$Q = \frac{1}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}}$$

. The cross-section of the channels is a rectangle with width B=110m. And then, the discharge formula, $Q = vA$, is calculated for determining the velocity of 18.15 m/s. Meanwhile, according to the requirement of the assignment, the dispersion coefficient is 5 m^2/s. After adjusting the model, the changes in the distance and the time is determined, with 5000 m and 0.05 h respectively. However, Changes in the distance and the time step may be different, according to the questions in the assignment.

1) How much time does it take to reach the peak concentration at 15 km d/s of point 'A'? Plot the time series of the pollution at this point.

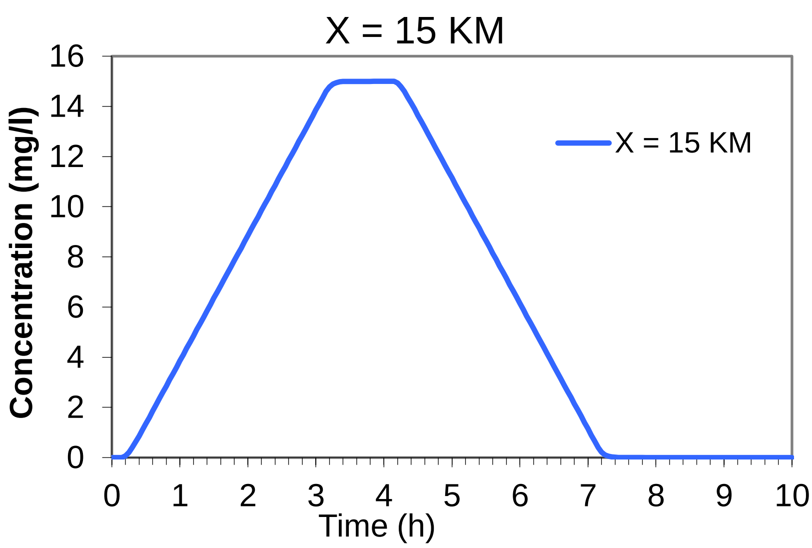

Figure 1 Time series of the pollution at 15 km d/s of point 'A'

The concentration of pollution reaches the peak value of 15 mg/l at 15 Km d/s of point 'A' at the time of 3.4 h later after the accident.

2) Show the concentration level alone the 20 km reach of the river at time 4 hour and 8 hour?

Figure 2 presents the variation of the pollution concentrations along the 20 km reach of the river at different times. The concentration level at 8 hour is higher than that at 4 hours by the difference of 4 mg/l. And the trends of those two concentration levels slightly decrease along the 20 km reach of the river.

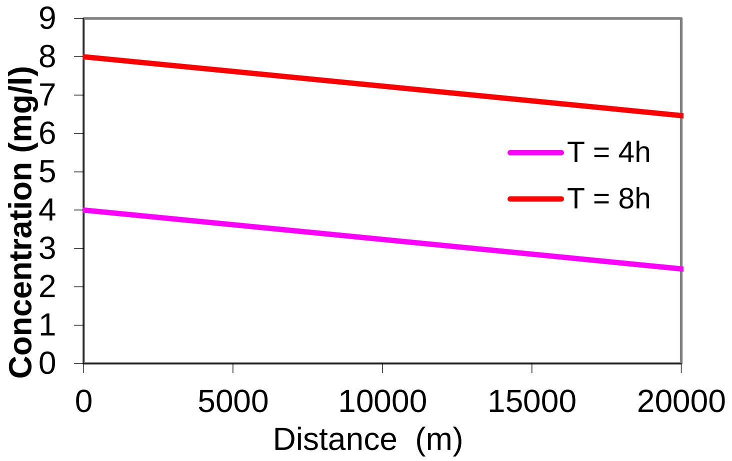

Figure 2 the concentration levels along the 20 km reach of the river at 4 hour and 8 hour

3) There is an intake point in the river for drinking water supplies at 16 km d/s of 'A'. How much time does the authority have to take necessary action in order to prevent the pollution in the drinking water supply? Would your answer be different if you use different time step (within Courant Number ≤ 1)?

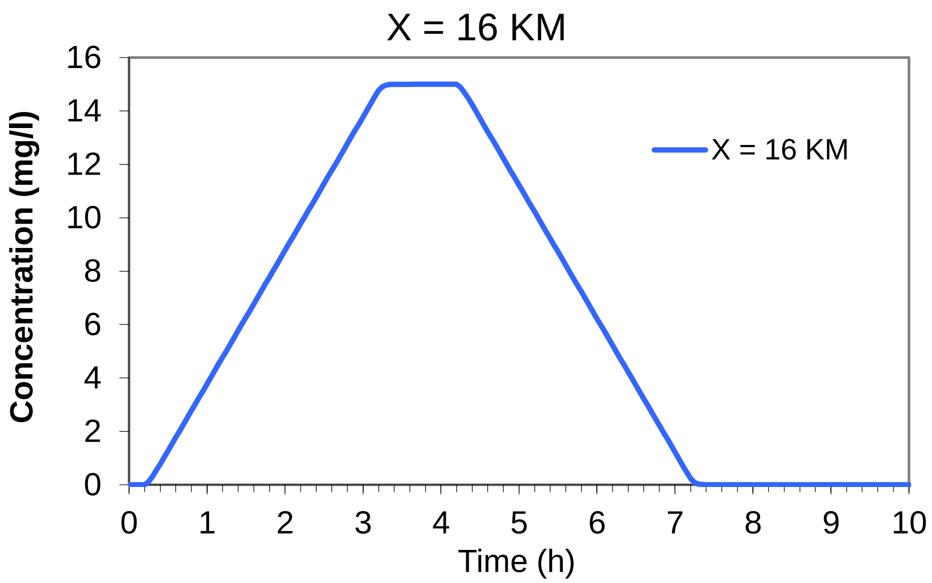

Figure 3.1 Time series of the pollution at 16 km d/s of point 'A'

Figure 3.1 indicates that the necessary action should be taken by authorities at the time of 0.2 hour after the accident to protect the well for the drinking water supplies at 16 km d/s of point 'A'. Because pollution reaches the well after that time.

Interestingly, the accuracy and stability increase, with the decrease of the time step, as shown in figure 3.2. The time series of the pollution concentration of 0.01 hour in a time step with the blue line, present better than other time series with the time steps of 0.05 and 0.1 respectively. Thus, my answer changed for the time of the necessary action is 0.16 hour. However, the smaller time step used, the larger calculation to do, and the time steps, which are smaller than 0.01 hour, have little effect on the results. Therefore, the results should be determined using a properly time step.

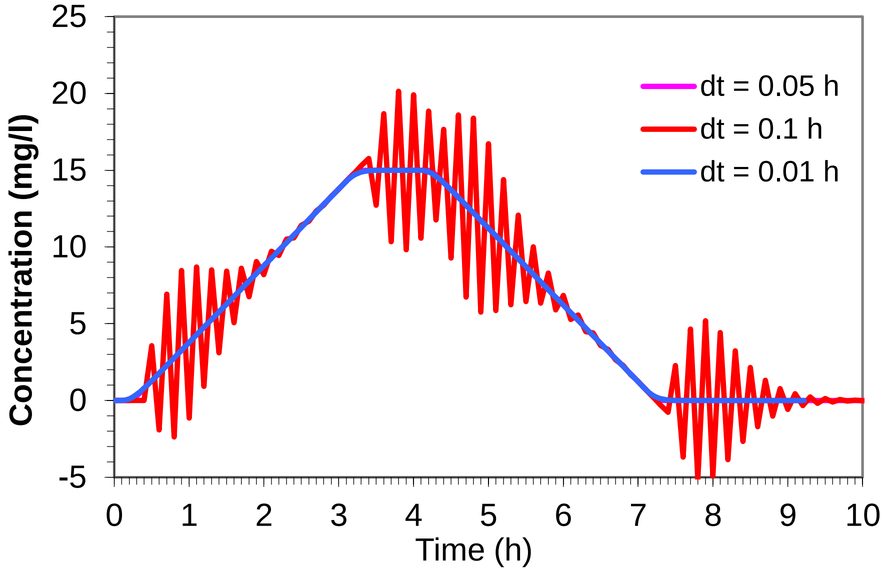

Figure 3.2 the time series of the pollution concentration at the 16 km d/s of point A with different time steps

4) What are the assumptions made when the given AD model is used in this problem?

This AD model in the problem assumes that the discharge is a constant in every place of the river and the rectangle cross-section of the channel is not change, resulting in a constant velocity and a constant water depth, which are calculated by the Manning equation using roughness and slope.

Reference

DHI, D. (2003), Mike-11: a modelling system for rivers and channels, reference manual, *DHI–Water and Development, Horsholm, Denmark*.

DHI (2005), User's Manuals of Mike 11 Water Quality and ECO-Lab modules, *DHI Water and Environment.*