Morpho2D in iRIC

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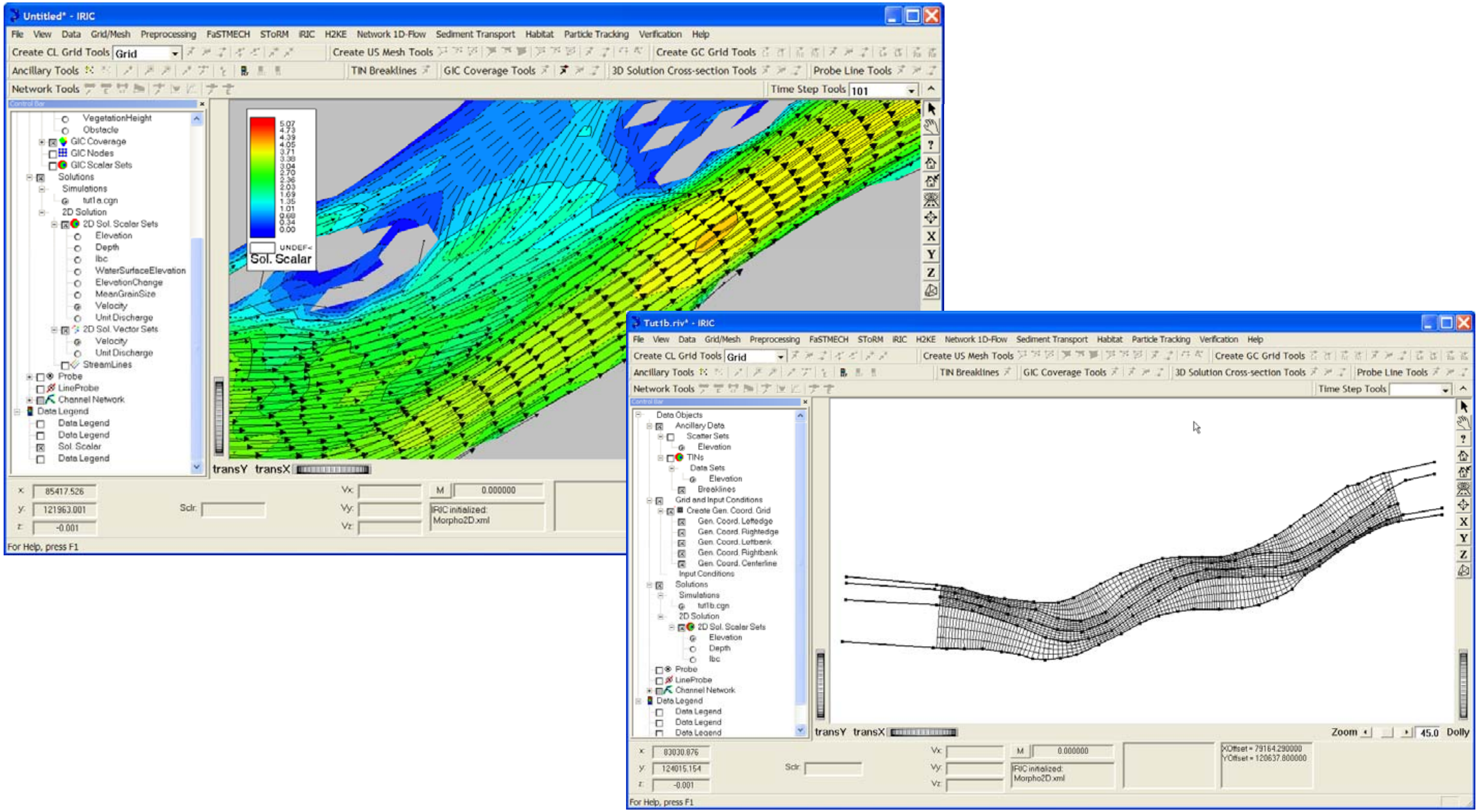
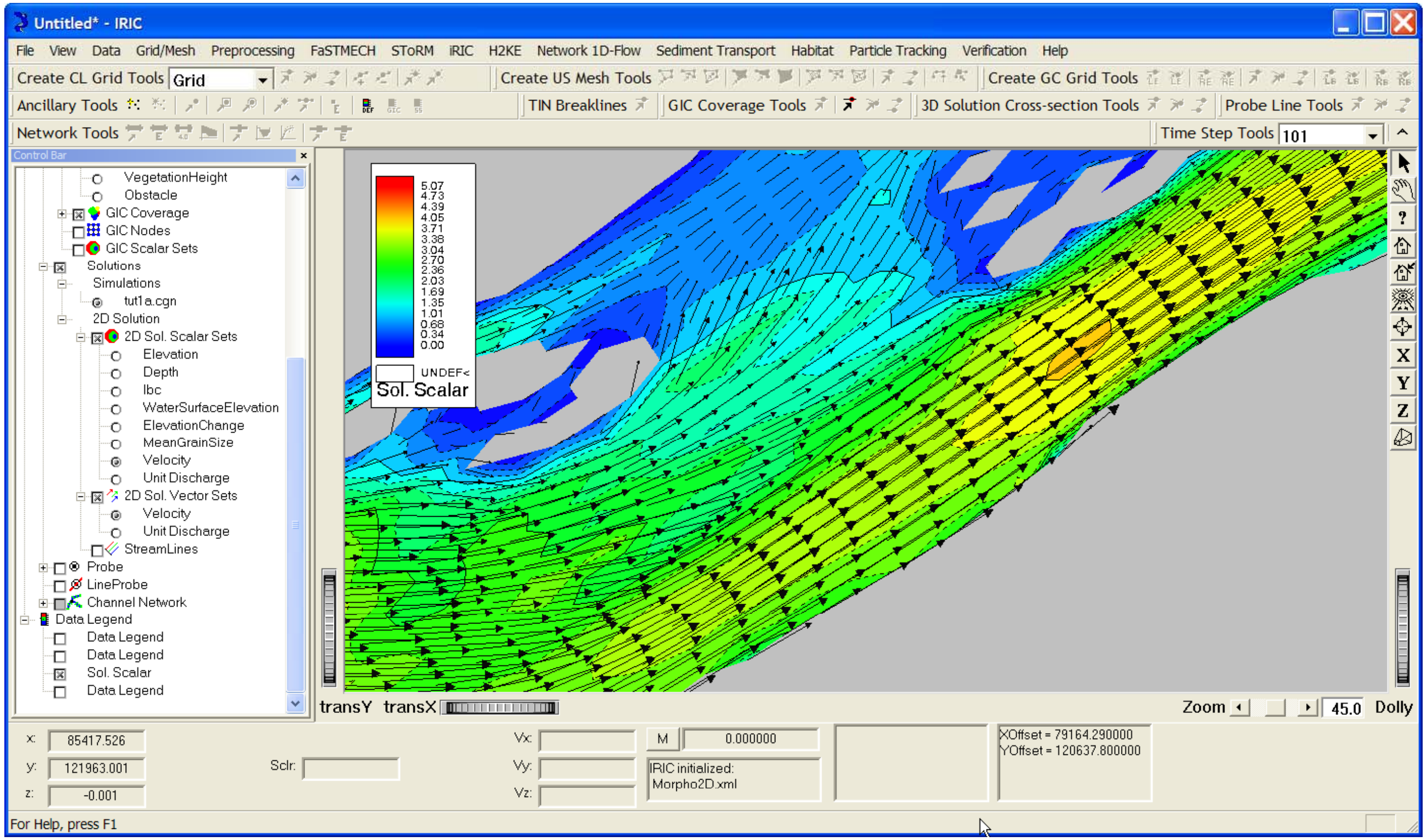


What can we do using Morpho2D?

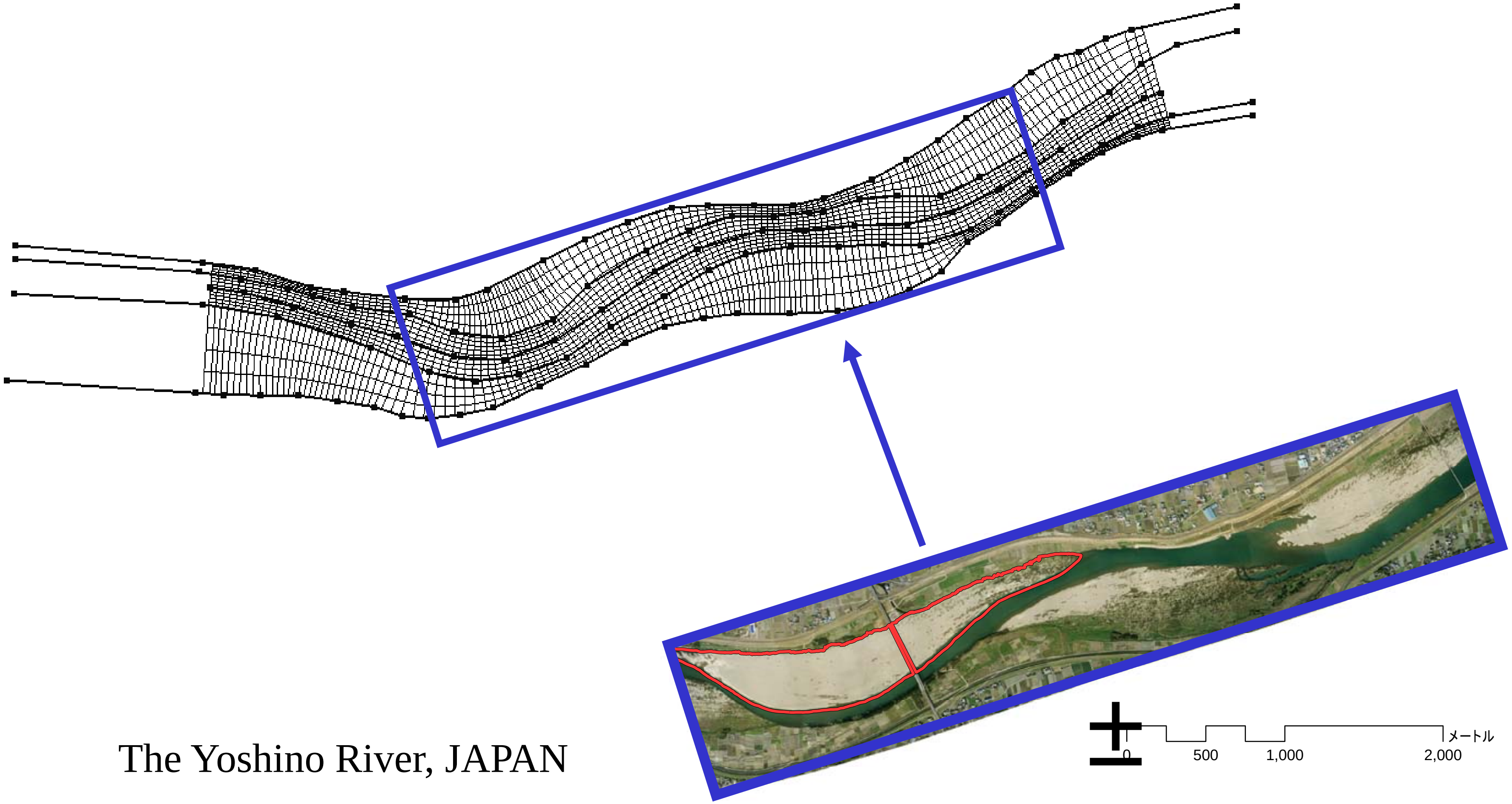
What can we do using Morpho2D?

- Horizontal two dimensional flow and bed deformation analysis



What can we do using Morpho2D?

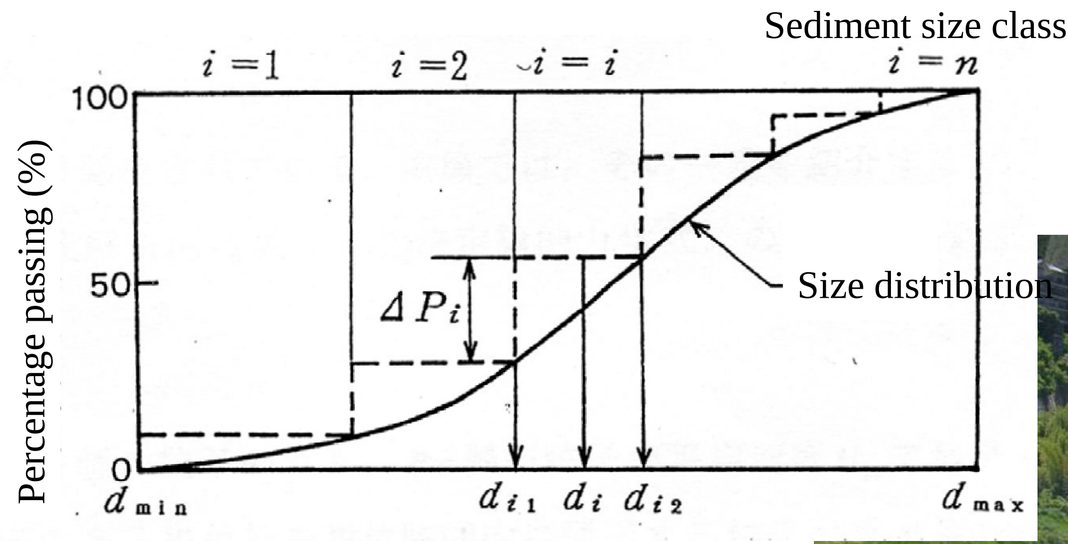
- Boundary fitted structured grids can be used (governing equations are written in general coordinate system



The Yoshino River, JAPAN

What can we do using Morpho2D?

- Non-uniform sediment (graded sediment) can be treated

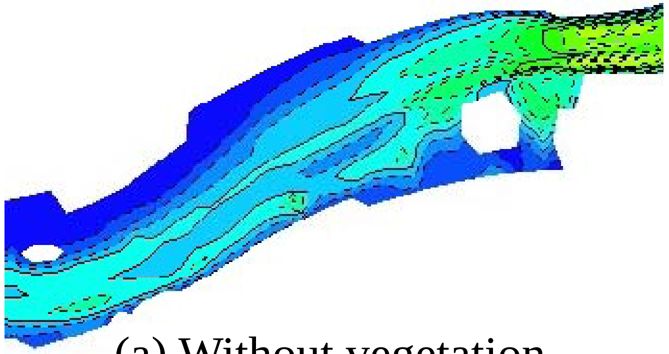


The Kiso River, JAPAN

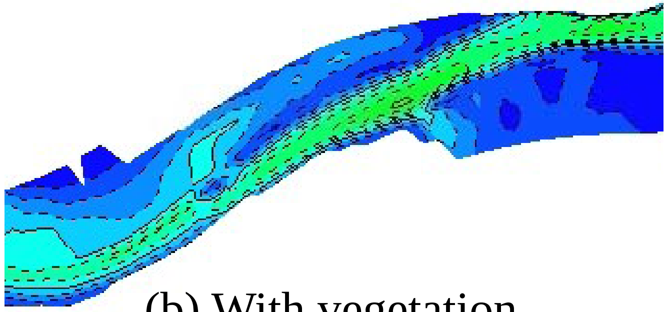
What can we do using Morpho2D?

- Effect of vegetation on flow can be considered

The Yoshino River, JAPAN



(a) Without vegetation

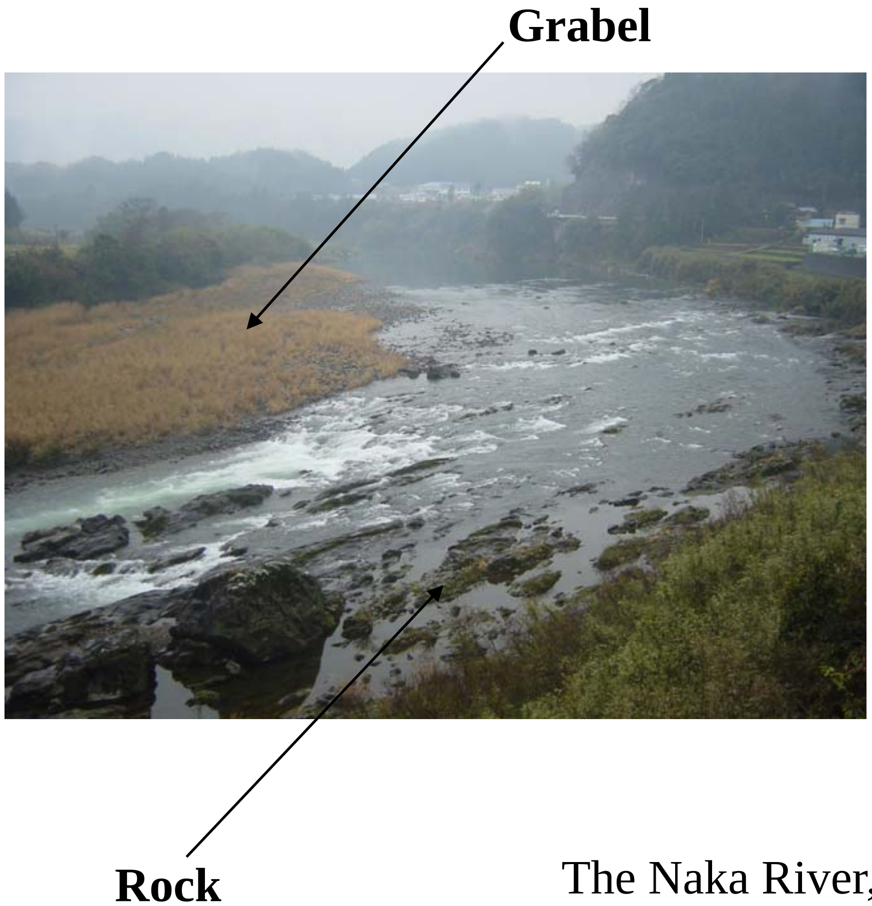


(b) With vegetation

Velocity magnitude

What can we do using Morpho2D?

- Sediment transport on rigid bed (ex. rocks) can be reproduced



The Naka River, JAPAN

Governing equation of Morpho2D in iRIC

Governing equations

Seepage flow

Mass conservation equation of water

$$\Lambda \frac{\partial}{\partial t}\left(\frac{z}{J}\right)+\frac{\partial}{\partial \xi}\left(\frac{hU}{J}\right)+\frac{\partial}{\partial \eta}\left(\frac{hV}{J}\right)+\boxed{\frac{\partial}{\partial \xi}\left(\frac{h_g U_g}{J}\right)+\frac{\partial}{\partial \eta}\left(\frac{h_g V_g}{J}\right)}=0$$

Momentum conservation equation of water in longitudinal direction

Vegetation

$$\begin{aligned}
&\frac{\partial}{\partial t}\left(\frac{hU}{J}\right)+\frac{\partial}{\partial \xi}\left(\frac{hUU}{J}\right)+\frac{\partial}{\partial \eta}\left(\frac{hUV}{J}\right)\\
&-\frac{hu}{J}\left(U\frac{\partial}{\partial \xi}\left(\frac{\partial \xi}{\partial x}\right)+V\frac{\partial}{\partial \eta}\left(\frac{\partial \xi}{\partial x}\right)\right)-\frac{hv}{J}\left(U\frac{\partial}{\partial \xi}\left(\frac{\partial \xi}{\partial y}\right)+V\frac{\partial}{\partial \eta}\left(\frac{\partial \xi}{\partial y}\right)\right)\\
&=-gh\left(\frac{1}{J}\left(\left(\frac{\partial \xi}{\partial x}\right)^2+\left(\frac{\partial \xi}{\partial y}\right)^2\right)\frac{\partial z_s}{\partial \xi}+\frac{1}{J}\left(\frac{\partial \xi}{\partial x}\frac{\partial \eta}{\partial x}+\frac{\partial \xi}{\partial y}\frac{\partial \eta}{\partial y}\right)\frac{\partial z_s}{\partial \eta}\right)-\frac{\tau_{b\xi}}{\rho J}-\frac{F_{v\xi}}{\rho J}\\
&+\frac{1}{J}\left(\frac{\partial \xi}{\partial x}\right)^2\frac{\partial}{\partial \xi}\left(h\sigma_{xx}\right)+\frac{1}{J}\frac{\partial \xi}{\partial x}\frac{\partial \eta}{\partial x}\frac{\partial}{\partial \eta}\left(h\sigma_{xx}\right)+\frac{1}{J}\frac{\partial \xi}{\partial y}\frac{\partial \eta}{\partial x}\frac{\partial}{\partial \eta}\left(h\tau_{yx}\right)+\frac{1}{J}\frac{\partial \xi}{\partial y}\frac{\partial \xi}{\partial x}\frac{\partial}{\partial \xi}\left(h\tau_{yx}\right)\\
&+\frac{1}{J}\frac{\partial \xi}{\partial x}\frac{\partial \eta}{\partial y}\frac{\partial}{\partial \eta}\left(h\tau_{xy}\right)+\frac{1}{J}\frac{\partial \xi}{\partial x}\frac{\partial \xi}{\partial y}\frac{\partial}{\partial \xi}\left(h\tau_{xy}\right)+\frac{1}{J}\left(\frac{\partial \xi}{\partial y}\right)^2\frac{\partial}{\partial \xi}\left(h\sigma_{yy}\right)+\frac{1}{J}\frac{\partial \xi}{\partial y}\frac{\partial \eta}{\partial y}\frac{\partial}{\partial \eta}\left(h\sigma_{yy}\right)
\end{aligned}$$

Vegetation model

Water velocity

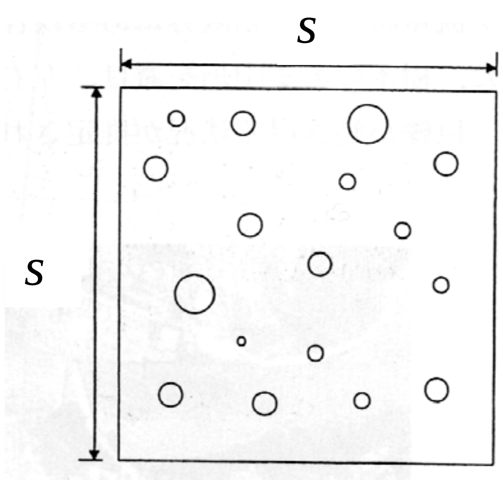
$$\frac{F_v}{\rho} = \frac{1}{2} C_{dv} \lambda_v \left(u^2 + v^2 \right) h_v$$

Drag coefficient

Vegetation Density

Water depth
or Vegetation height

$$\lambda_v = \frac{nd}{s^2}$$

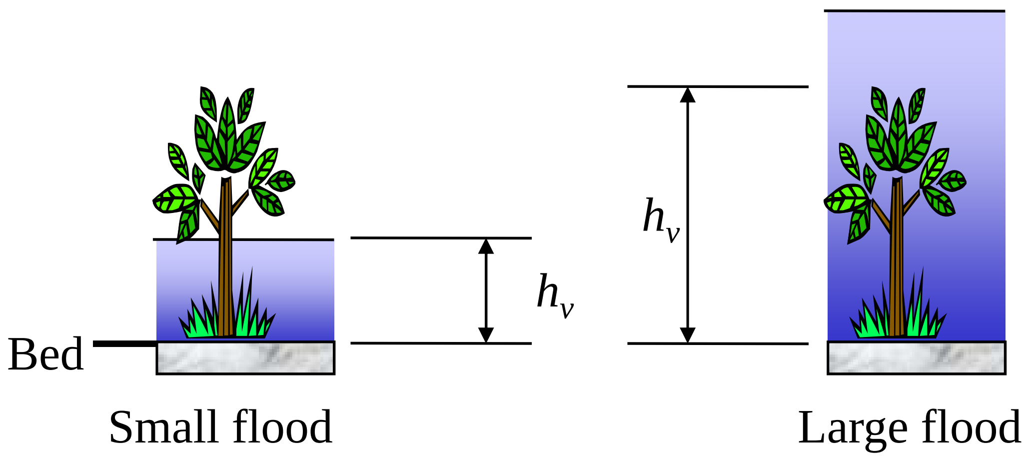


s^2 is the area of grid cell, n is the number of woods in the cell, d is the averaged diameter of wood

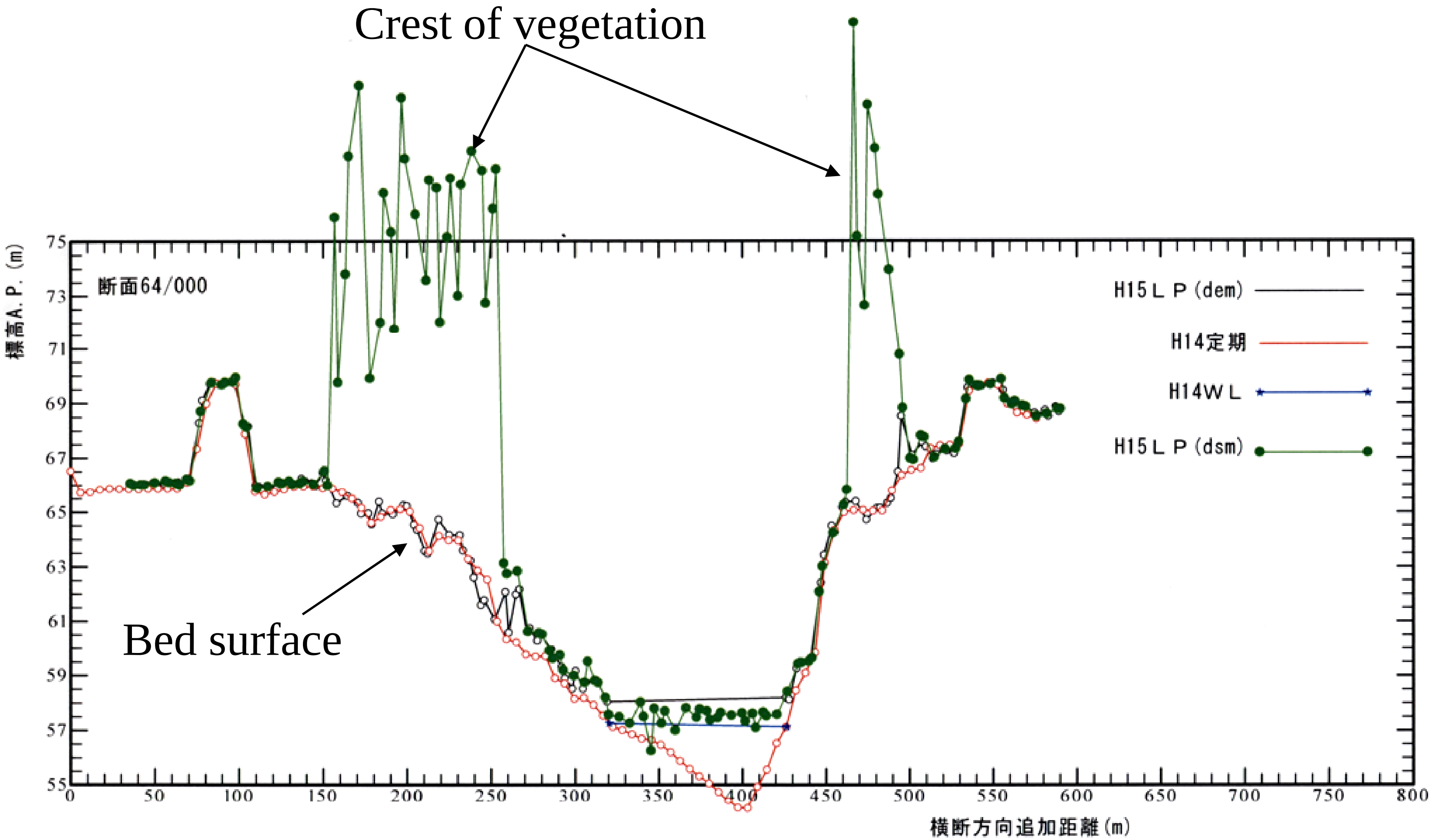
Vegetation model

$$\frac{F_v}{\rho} = \frac{1}{2} C_{dv} \lambda_v \left(u^2 + v^2\right) h_v$$

Water depth or Vegetation height



Vegetation height



Governing equations (for graded sediment)

Non-uniform sediment

Bed elevation equation

$$\frac{\partial}{\partial t}\left(\frac{c_b E_b}{J}\right)+(1-\lambda)\frac{\partial}{\partial t}\left(\frac{z_b}{J}\right)+\left(\frac{\partial}{\partial \xi}\left(\sum_{k=1}^{n}\frac{q_{b\xi k}}{J}\right)+\frac{\partial}{\partial \eta}\left(\sum_{k=1}^{n}\frac{q_{b\eta k}}{J}\right)+\sum_{k=1}^{n}\frac{1}{J}w_k\left(c_{sbek}-c_{sbk}\right)\right)=0$$

Bed load layer model

Mass conservation equation of each sediment size class

for bed load layer

$$\frac{\partial}{\partial t}\left(\frac{c_b E_b f_{bk}}{J}\right)+(1-\lambda)F_{bk}\frac{\partial}{\partial t}\left(\frac{z_b}{J}\right)+\left(\frac{\partial}{\partial \xi}\left(\frac{q_{b\xi k}}{J}\right)+\frac{\partial}{\partial \eta}\left(\frac{q_{b\eta k}}{J}\right)+\frac{1}{J}w_k\left(c_{sbek}-c_{sbk}\right)\right)=0$$

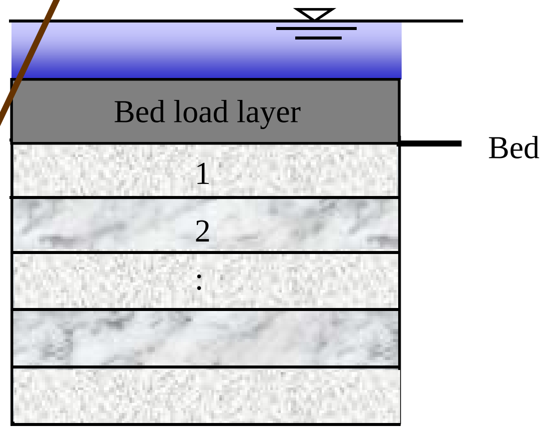
for deposition layer

Stratigraphy

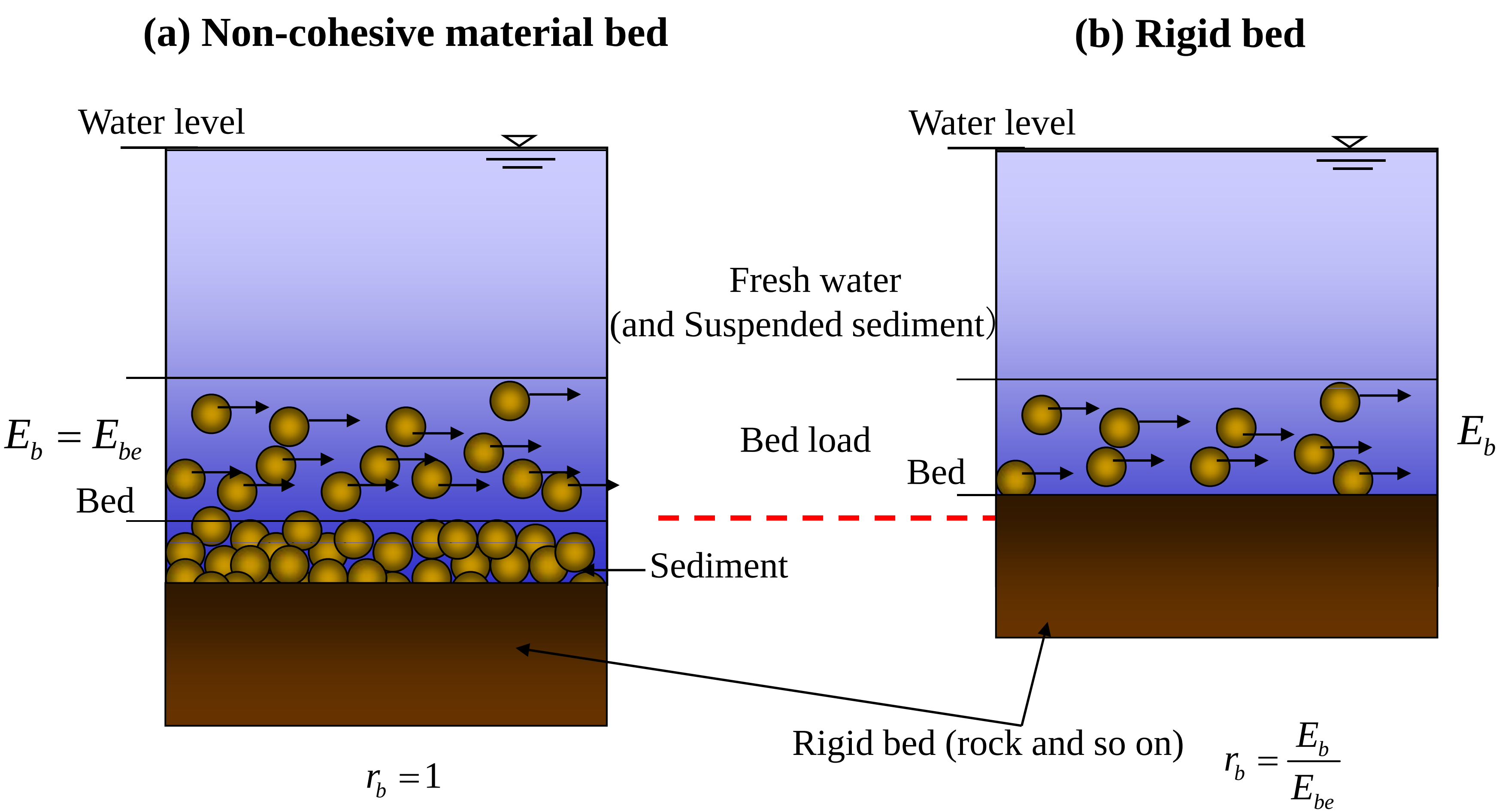
$$\frac{\partial}{\partial t}\left(\frac{E_{d1} f_{d1k}}{J}\right)-F_{dk}\frac{\partial}{\partial t}\left(\frac{E_{d1}}{J}\right)=0$$

Bed load equation (originally from Ashida & Michiue, 1972)

$$q_{bk}=17\frac{\rho u_{*e}^{3}}{(\rho_s-\rho)g}\left(1-\sqrt{K_c}\frac{u_{*ck}}{u_*}\right)\left(1-K_c\frac{u_{*ck}^{2}}{u_*^{2}}\right)f_{bk}r_b$$



Concept of modeling using bed load layer model



$$q_b = 17 \frac{\rho u_{*e}^3}{(\rho_s - \rho) g} \left(1 - \sqrt{K_c \frac{u_{*c}}{u_*}}\right)\left(1 - K_c \frac{u_{*c}^2}{u_*^2}\right) r_b$$

Governing equations (for graded sediment)

Bed load layer model

Equilibrium suspended concentration at reference level (originally from Lane & Kalinske, 1941)

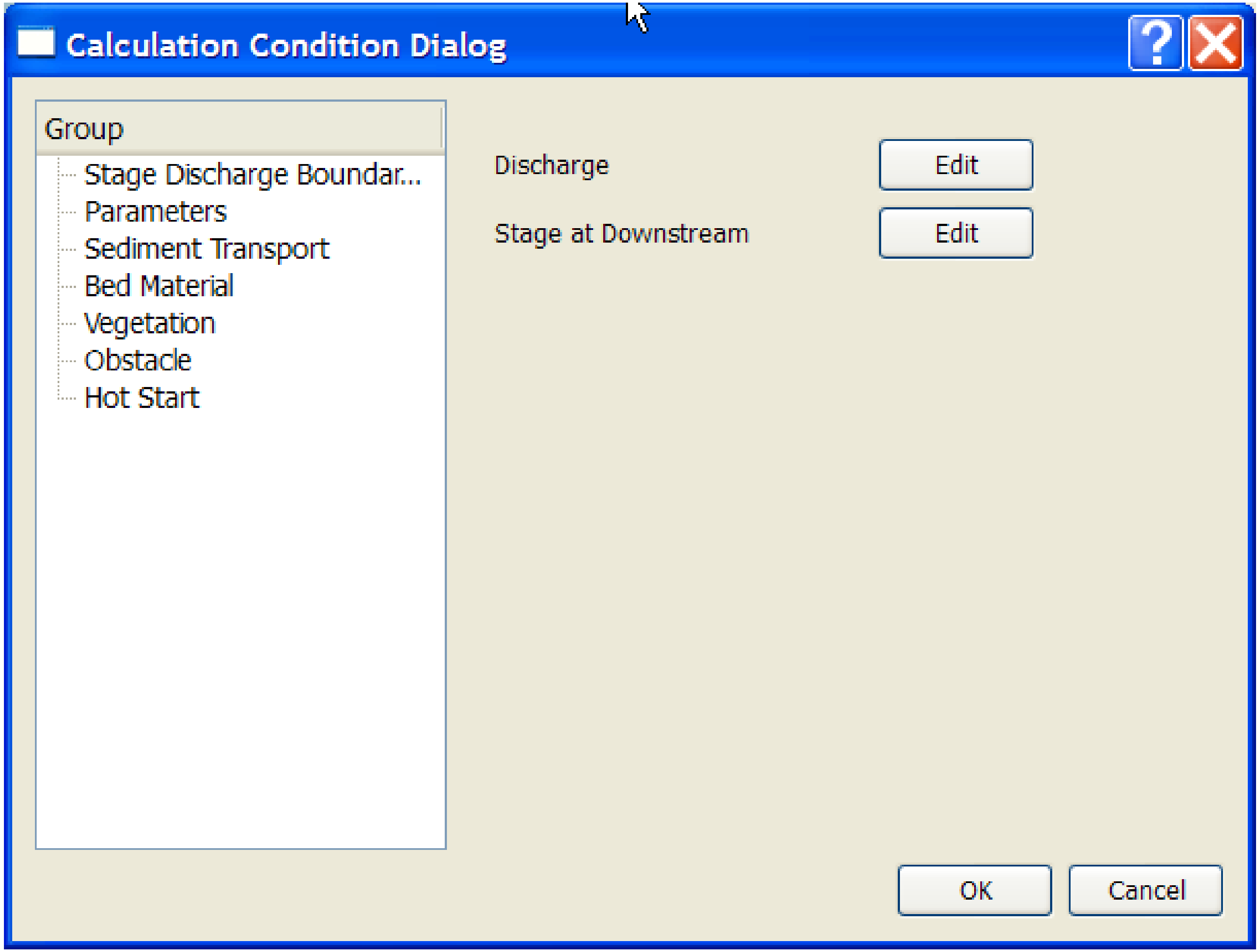
$$c_{sbek} = 5.55\left(\frac{1}{2}\frac{u_*}{w_{fk}}\exp\left(-\frac{w_{fk}}{u_*}\right)\right)^{1.61} f_{bk} r_b$$

Transport equation of depth averaged concentration of suspended load

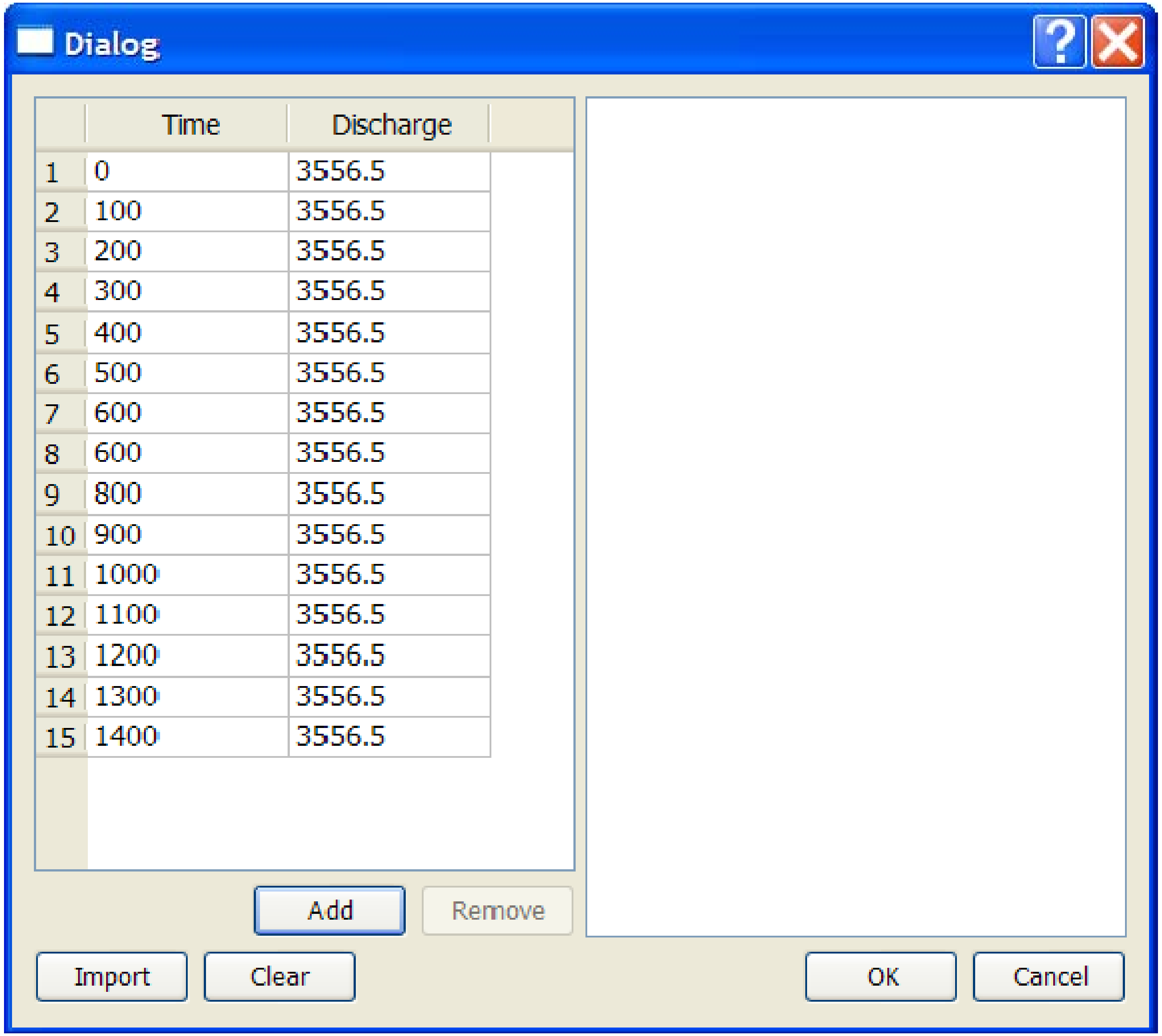
$$\frac{\partial}{\partial t}\left(\frac{hc_{sk}}{J}\right)+\frac{\partial}{\partial \xi}\left(U\frac{hc_{sk}}{J}\right)+\frac{\partial}{\partial \eta}\left(V\frac{hc_{sk}}{J}\right)=\frac{1}{J}w_{fk}\left(c_{sbek}-c_{sbk}\right)$$
$$+\frac{\partial}{\partial \xi}h\left(\frac{1}{J}\left(D_x\left(\frac{\partial \xi}{\partial x}\right)^2+D_y\left(\frac{\partial \xi}{\partial y}\right)^2\right)\frac{\partial c_{sk}}{\partial \xi}+\frac{1}{J}\left(D_x\frac{\partial \xi}{\partial x}\frac{\partial \eta}{\partial x}+D_y\frac{\partial \xi}{\partial y}\frac{\partial \eta}{\partial y}\right)\frac{\partial c_{sk}}{\partial \eta}\right)$$
$$+\frac{\partial}{\partial \eta}h\left(\frac{1}{J}\left(D_x\frac{\partial \xi}{\partial x}\frac{\partial \eta}{\partial x}+D_y\frac{\partial \xi}{\partial y}\frac{\partial \eta}{\partial y}\right)\frac{\partial c_{sk}}{\partial \xi}+\frac{1}{J}\left(D_x\left(\frac{\partial \eta}{\partial x}\right)^2+D_y\left(\frac{\partial \eta}{\partial y}\right)^2\right)\frac{\partial c_{sk}}{\partial \eta}\right)$$

Calculation condition dialog of Morpho2D

Calculation condition dialog of Morpho2D

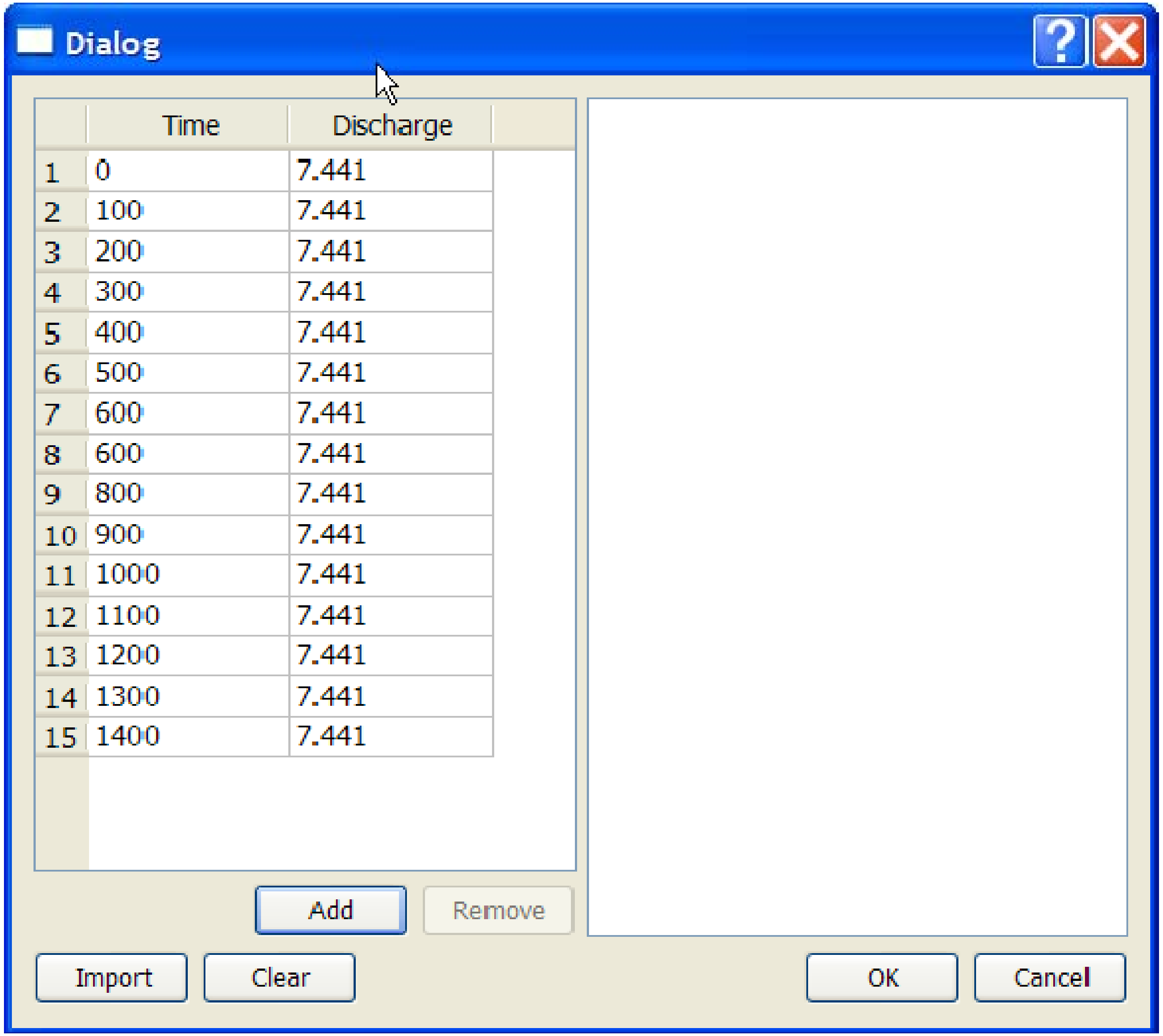


Calculation condition dialog of Morpho2D



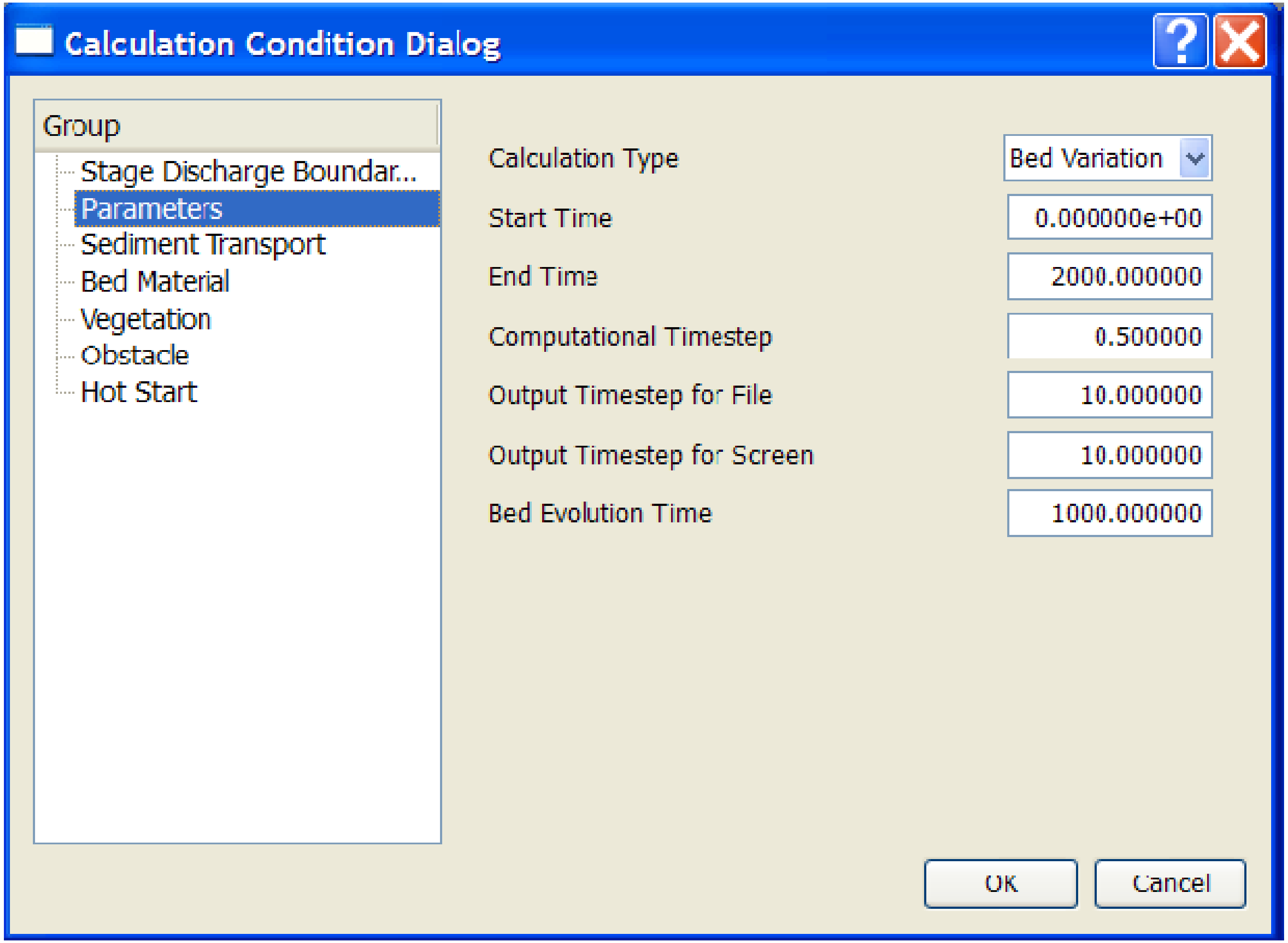
	Time	Discharge
1	0	3556.5
2	100	3556.5
3	200	3556.5
4	300	3556.5
5	400	3556.5
6	500	3556.5
7	600	3556.5
8	600	3556.5
9	800	3556.5
10	900	3556.5
11	1000	3556.5
12	1100	3556.5
13	1200	3556.5
14	1300	3556.5
15	1400	3556.5

Calculation condition dialog of Morpho2D

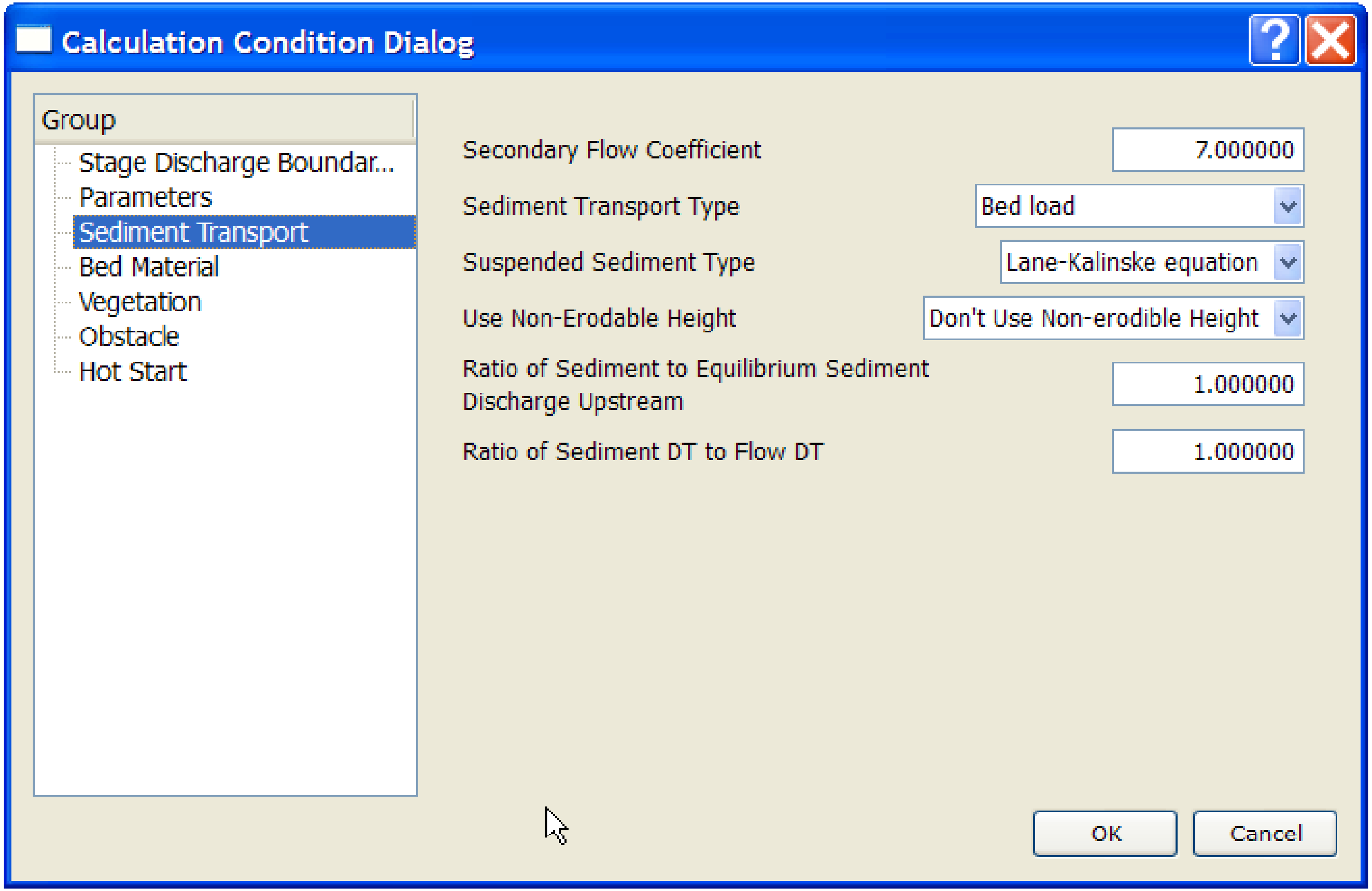


	Time	Discharge
1	0	7.441
2	100	7.441
3	200	7.441
4	300	7.441
5	400	7.441
6	500	7.441
7	600	7.441
8	600	7.441
9	800	7.441
10	900	7.441
11	1000	7.441
12	1100	7.441
13	1200	7.441
14	1300	7.441
15	1400	7.441

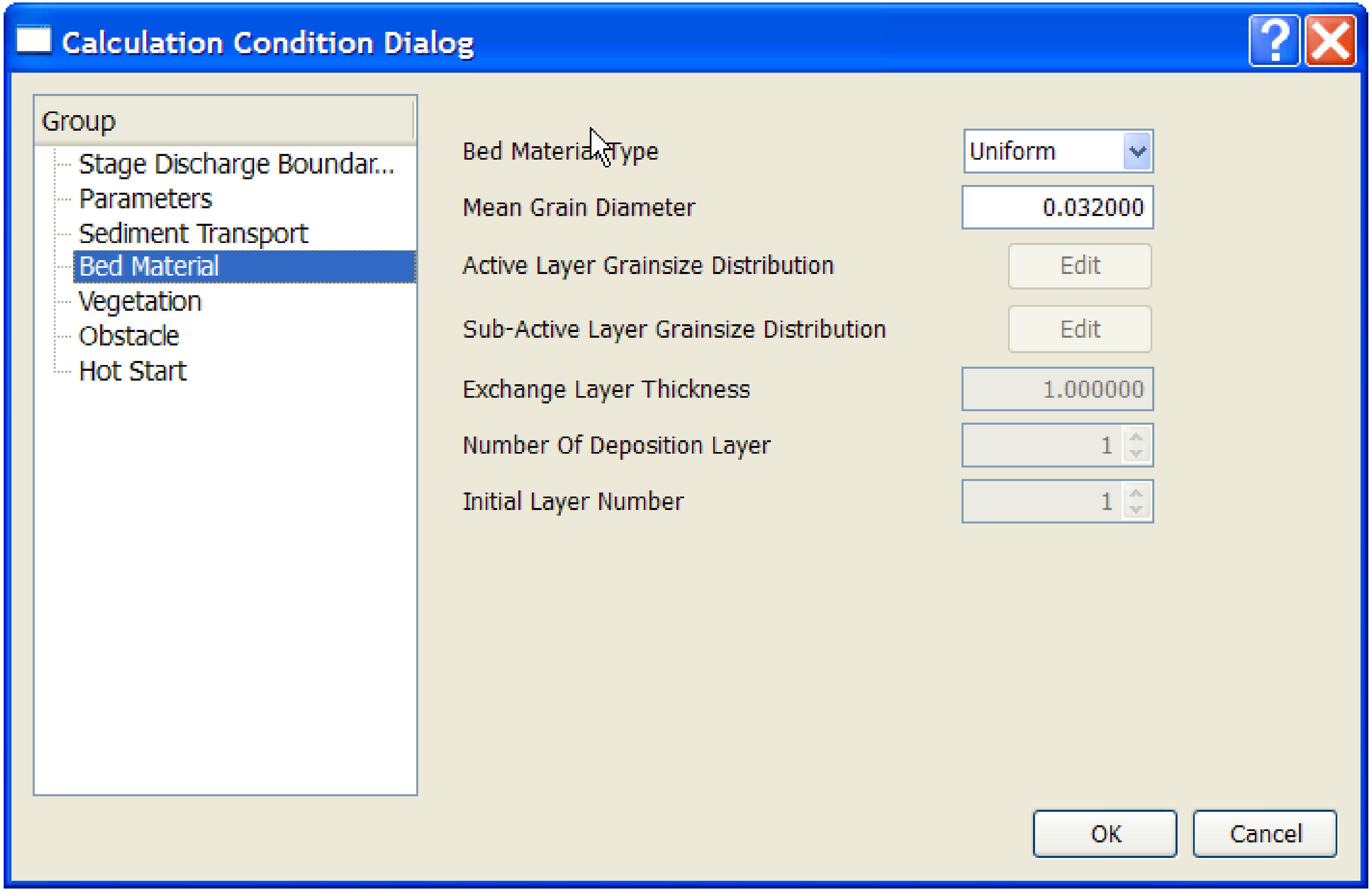
Calculation condition dialog of Morpho2D



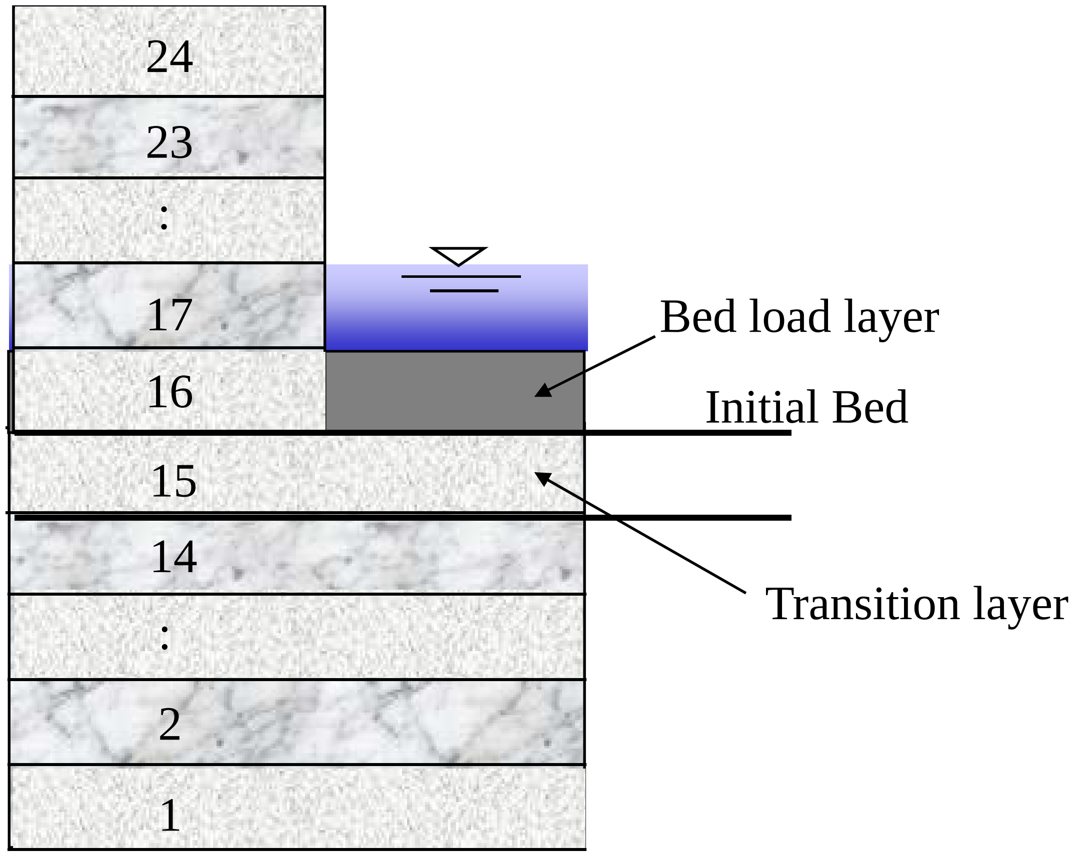
Calculation condition dialog of Morpho2D



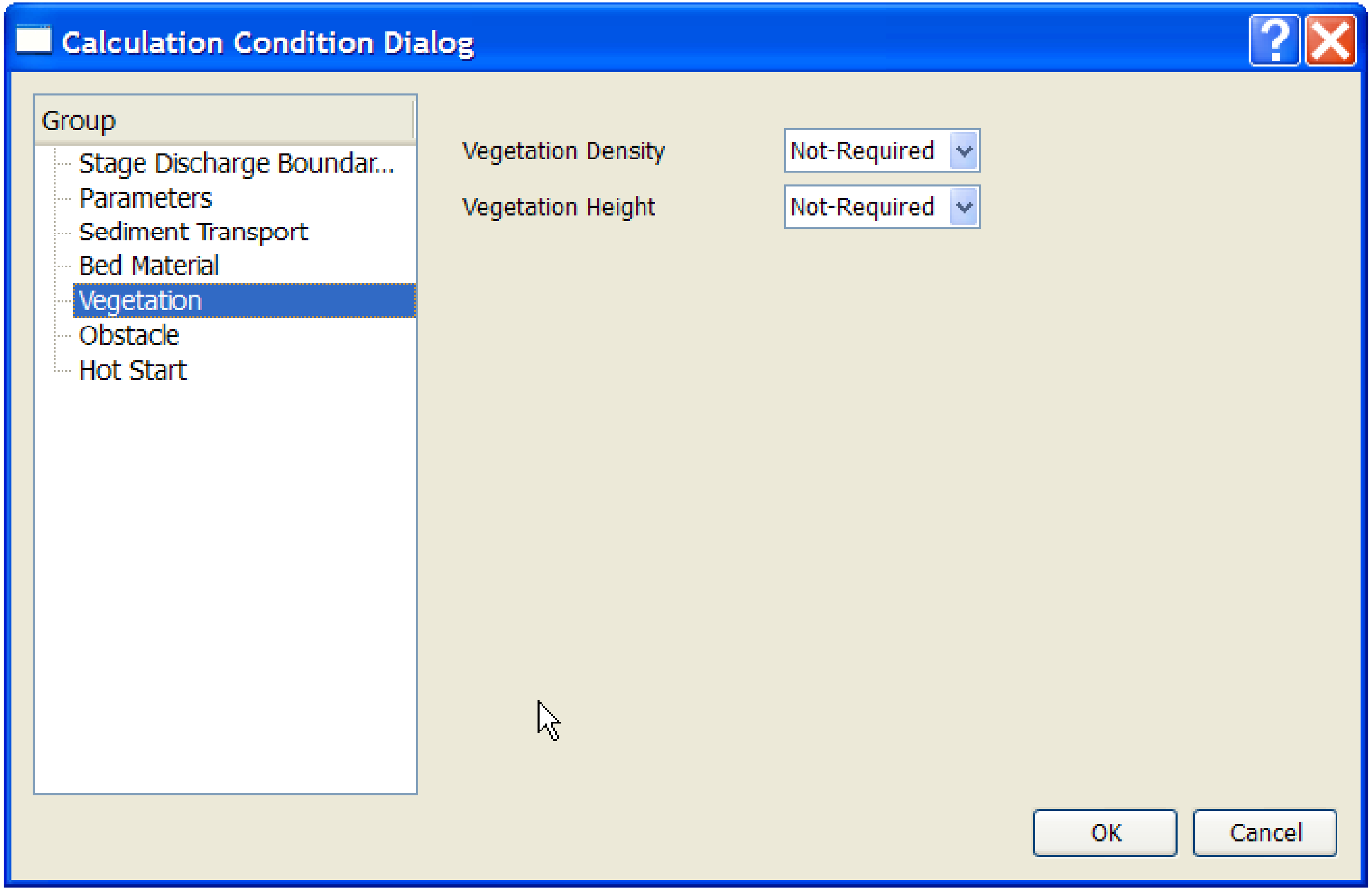
Calculation condition dialog of Morpho2D



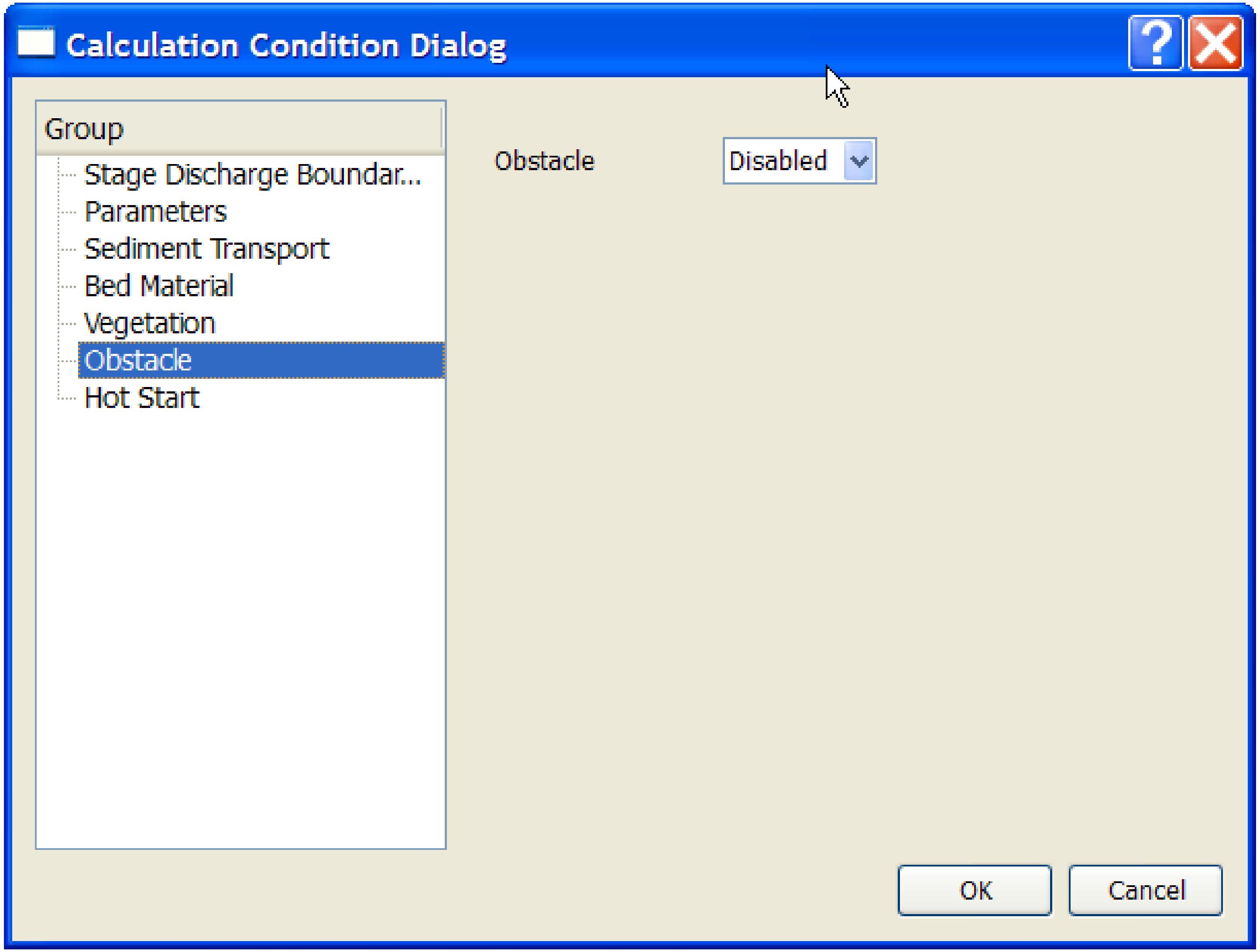
Calculation condition dialog of Morpho2D



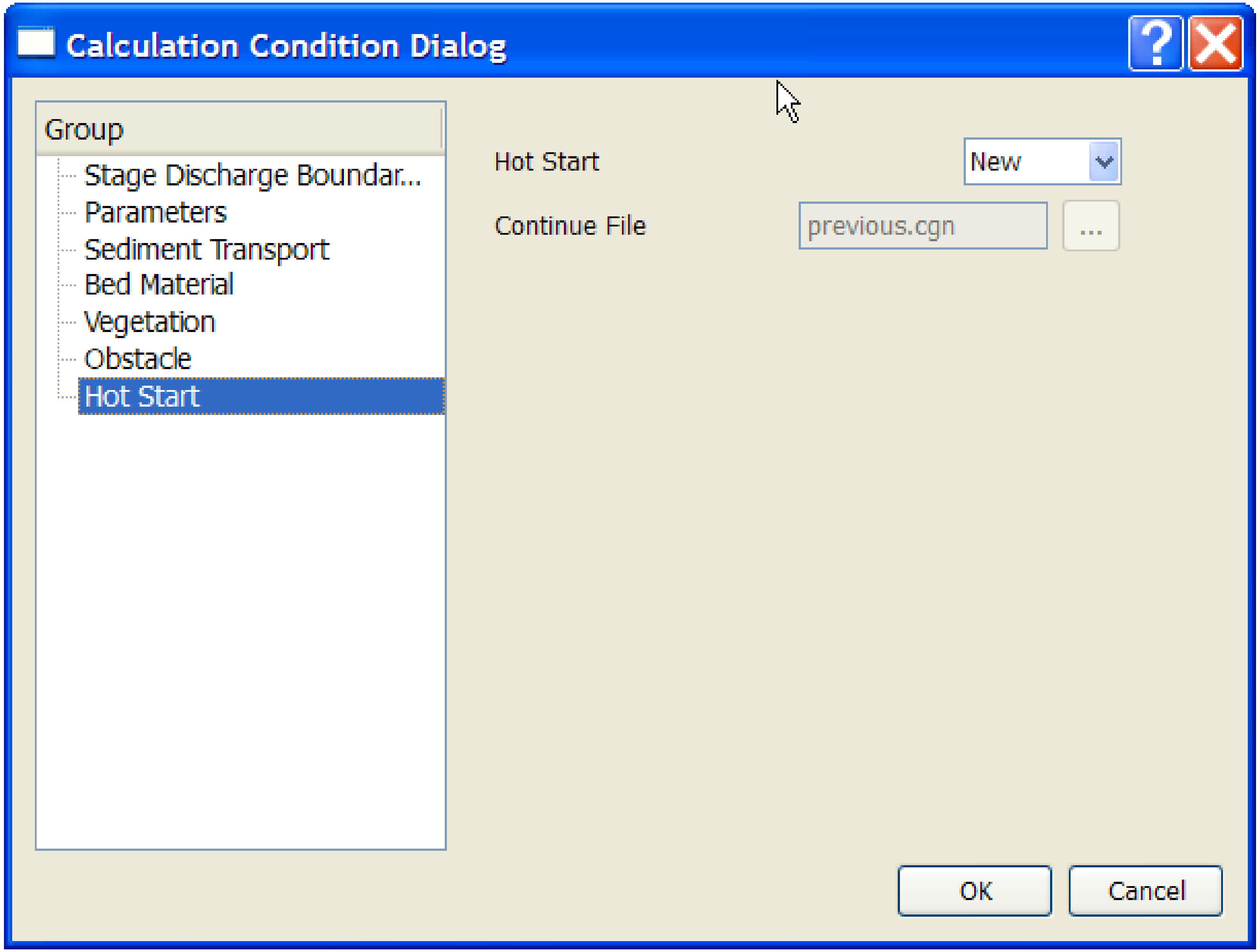
Calculation condition dialog of Morpho2D



Calculation condition dialog of Morpho2D



Calculation condition dialog of Morpho2D



Run !!!

C:\Program Files\USGS\iRIC_0.7.001b\Bin\Takebayashi.exe

```
Non-uniform sediment model Ver.1

Present calculation time                     =       400.0000000 s
Start time of bed deformation                =       100.0000000 s
End time                                     =      1000.0000000 s
Water discharge at upstream end              =      3556.5000000 m3/s
Time step of flow                            =         1.0000000 s
Water level at downstream end                =         7.4159969 m
Initial bed slope                            =         0.0008829
Coefficient for secondary flow               =         7.0000000
Thickness of exchange layer                  =         0.3000000 m
(Supplied)/(Equilibrium sediment discharge)=           1.0000000
(dt of bed deformation)/(dt of flow)         =         1.0000000

Type of calculation: Bed deformation
Type of sediment transport: Bed load only
Bed material: Uniform
Vegetation density data: Not in use
Vegetation height data: Not in use
Rigid bed height data: Not in use
```

Input file format

Input file format

Time (s)

Comma

Water discharge

Water Level

```
0.,3556.500
100.,3556.500
200.,3556.500
300.,3556.500
400.,3556.500
500.,3556.500
600.,3556.500
700.,3556.500
800.,3556.500
900.,3556.500
1000.,3556.500
1100.,3556.500
1200.,3556.500
1300.,3556.500
1400.,3556.500
1500.,3556.500
1600.,3556.500
1700.,3556.500
1800.,3556.500
1900.,3556.500
2000.,3556.500
```

Discharge1.txt

```
0.,7.44100
100.,7.44100
200.,7.44100
300.,7.44100
400.,7.44100
500.,7.44100
600.,7.44100
700.,7.44100
800.,7.44100
900.,7.44100
1000.,7.44100
1100.,7.44100
1200.,7.44100
1300.,7.44100
1400.,7.44100
1500.,7.44100
1600.,7.44100
1700.,7.44100
1800.,7.44100
1900.,7.44100
2000.,7.44100
```

Stage1.txt

Input file format

Diameter of each sediment size class (m)

Comma

Fraction of each sediment size class

SurfaceGS.txt

```
0.000009,0
0.000025,0
0.000056,0
0.000106,0.002
0.000212,0.01098
0.000425,0.051964
0.00085,0.193309
0.0017,0.252182
0.00335,0.240036
0.0067,0.153382
0.0132,0.07142
0.0265,0.021818
0.053,0.002909
```

SubsurfaceGS.txt

```
0.000009,0.060672
0.000025,0.142502
0.000056,0.262502
0.000106,0.243749
0.000212,0.237595
0.000425,0.046769
0.00085,0.006211
0.0017,0
0.00335,0
0.0067,0
0.0132,0
0.0265,0
0.053,0
```

Input file format

```
6258
85976.350059 123229.999951 0.000000
85984.220176 123201.600049 0.000000
85999.959922 123144.600049 0.000000
86009.799766 123109.100049 1.000000
86013.720176 123094.900098 0.672289
86017.640098 123080.699902 0.317446
86021.569785 123066.499951 0.311018
86025.490195 123052.400098 0.000000
86029.410117 123038.199902 0.000000
86033.339805 123023.999951 0.000000
86037.260215 123009.800000 0.000000
86041.180137 122995.600049 0.000000
86045.109824 122981.499951 0.000000
86049.030234 122967.300000 0.000000
86052.950156 122953.100049 0.000000
86056.870078 122938.900098 0.000000
86060.799766 122924.699902 0.000000
86064.720176 122910.600049 0.000000
86068.640098 122896.400098 0.000000
86072.569785 122882.199902 0.000000
```

Total number of data (node)

X coordinate

Ratio of vegetation density

Y coordinate

Vegetation Density.anc

Input file format

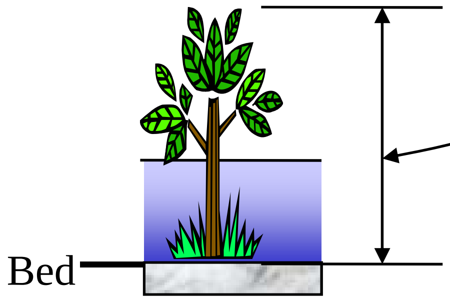
```
6258
85976.350059 123229.999951 0.000000
85984.220176 123201.600049 0.000000
85999.959922 123144.600049 0.000000
86009.799766 123109.100049 8.810417
86013.720176 123094.900098 4.341640
86017.640098 123080.699902 1.959595
86021.569785 123066.499951 1.538606
86025.490195 123052.400098 0.000000
86029.410117 123038.199902 0.000000
86033.339805 123023.999951 0.000000
86037.260215 123009.800000 0.000000
86041.180137 122995.600049 0.000000
86045.109824 122981.499951 0.000000
86049.030234 122967.300000 0.000000
86052.950156 122953.100049 0.000000
86056.870078 122938.900098 0.000000
86060.799766 122924.699902 0.000000
86064.720176 122910.600049 0.000000
86068.640098 122896.400098 0.000000
86072.569785 122882.199902 0.000000
```

Total number of data (node)

X coordinate

Height of vegetation from initial bed (m)

Y coordinate



Vegetation Height.anc

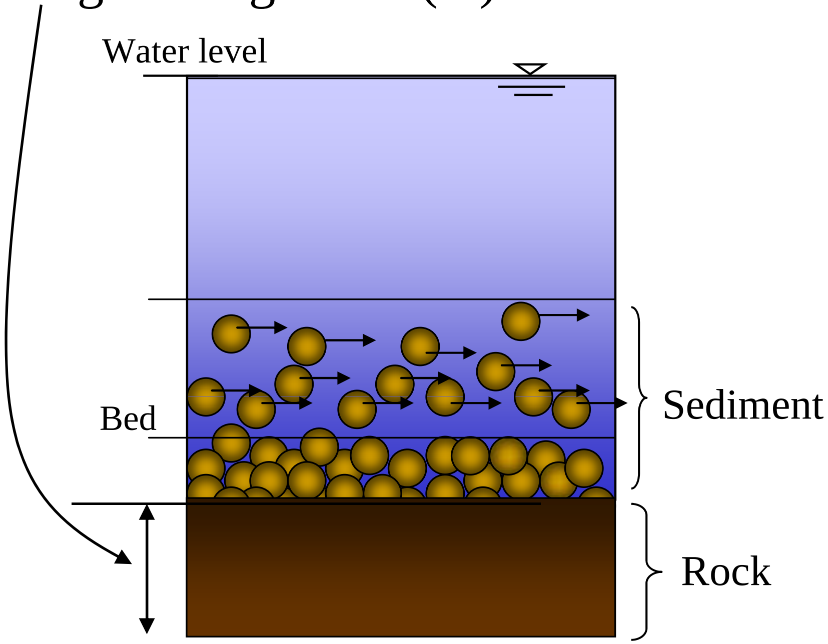
Input file format

```
6259
85976.350059 123229.999951 -4.476000
85984.220176 123201.600049 -4.476000
85999.959922 123144.600049 -4.476000
86009.799766 123109.100049 -4.476000
86013.720176 123094.900098 -4.476000
86017.640098 123080.699902 -4.476000
86021.569785 123066.499951 -4.476000
86025.490195 123052.400098 -4.476000
86029.410117 123038.199902 -4.476000
86033.339805 123023.999951 -4.476000
86037.260215 123009.800000 -4.476000
86041.180137 122995.600049 -4.476000
86045.109824 122981.499951 -4.476000
86049.030234 122967.3[illegible]0000 -4.476000
86052.950156 122953.100049 -4.476000
86056.870078 122938.900098 -4.476000
86060.799766 122924.699902 -4.476000
86064.720176 122910.600049 -4.476000
86068.640098 122896.400098 -4.476000
86072.569785 122882.199902 -4.476000
```

Total number of data (node)

X coordinate

Height of rigid bed (m)

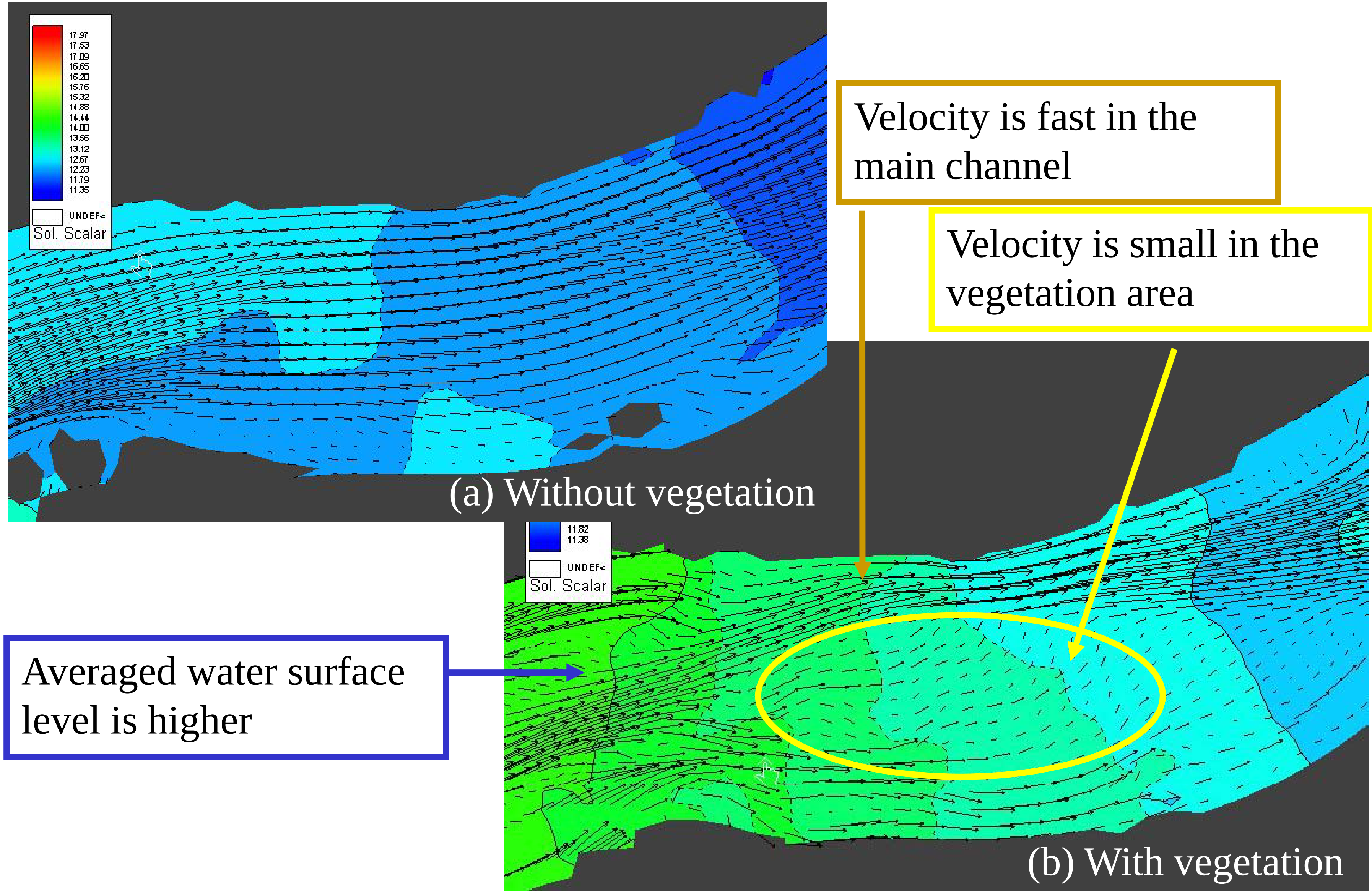


Y coordinate

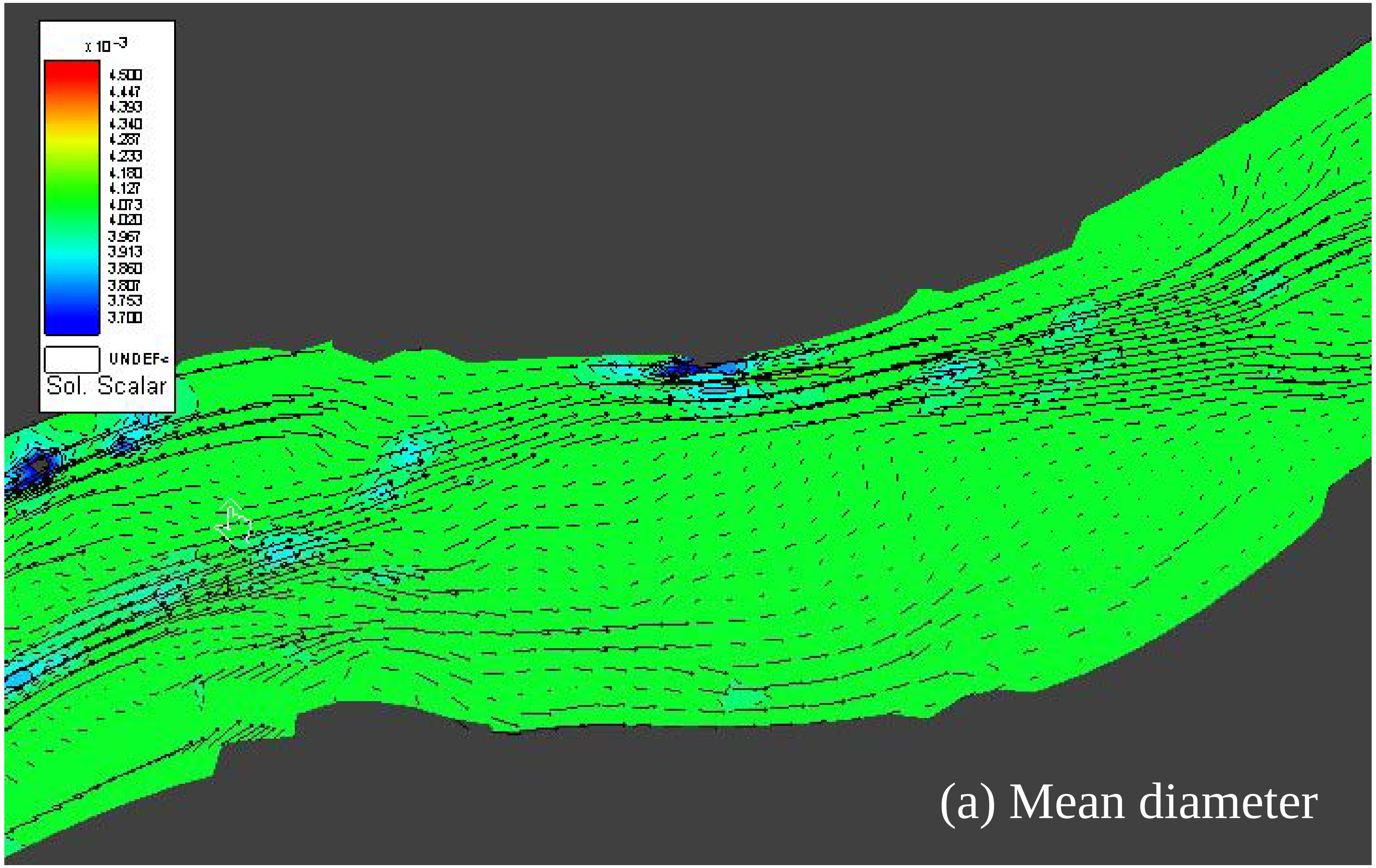
Fixed Bed Elevation.anc

Results of calculations

Effect of vegetation on flow

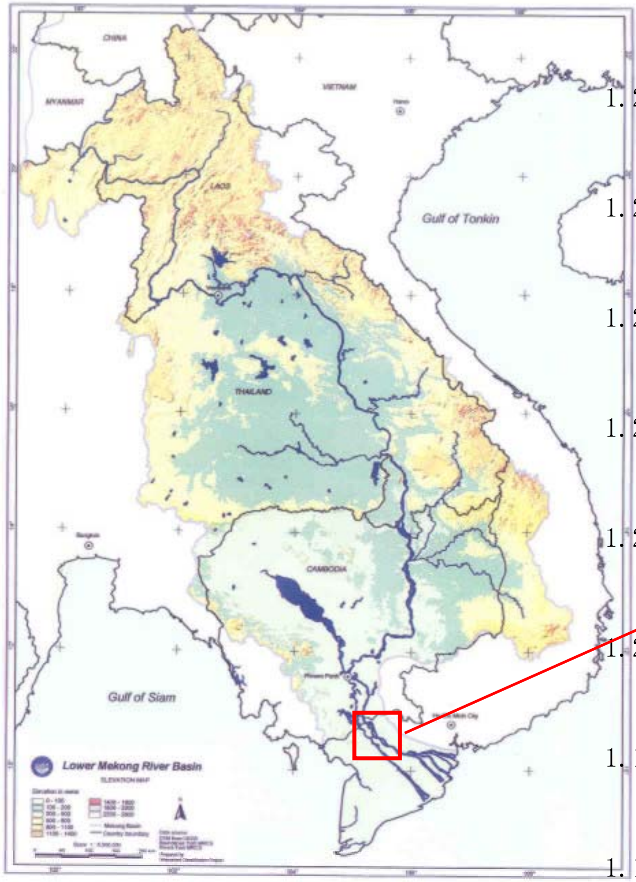


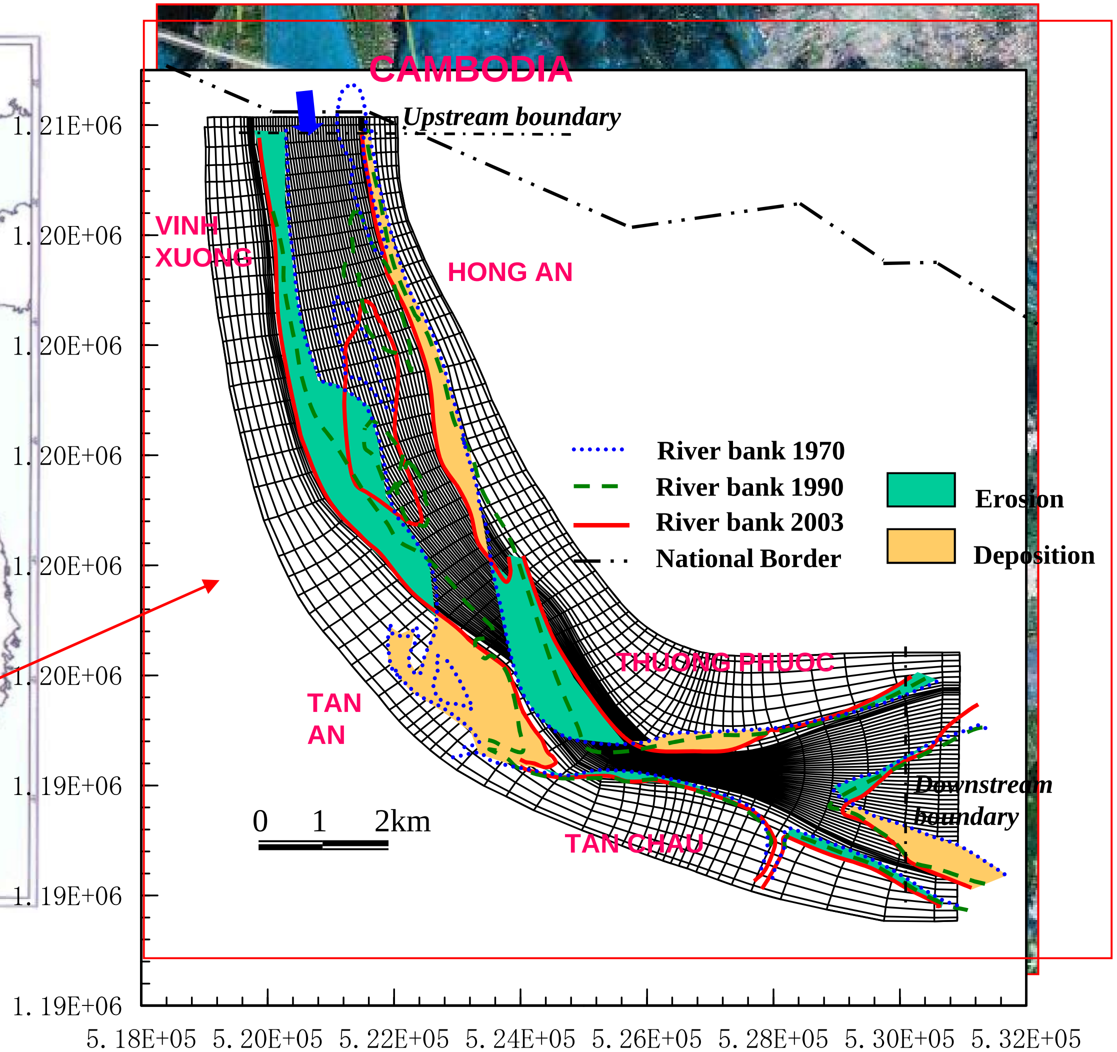
Effect of sediment size distribution on bed deformation



(a) Mean diameter

Morpho2D

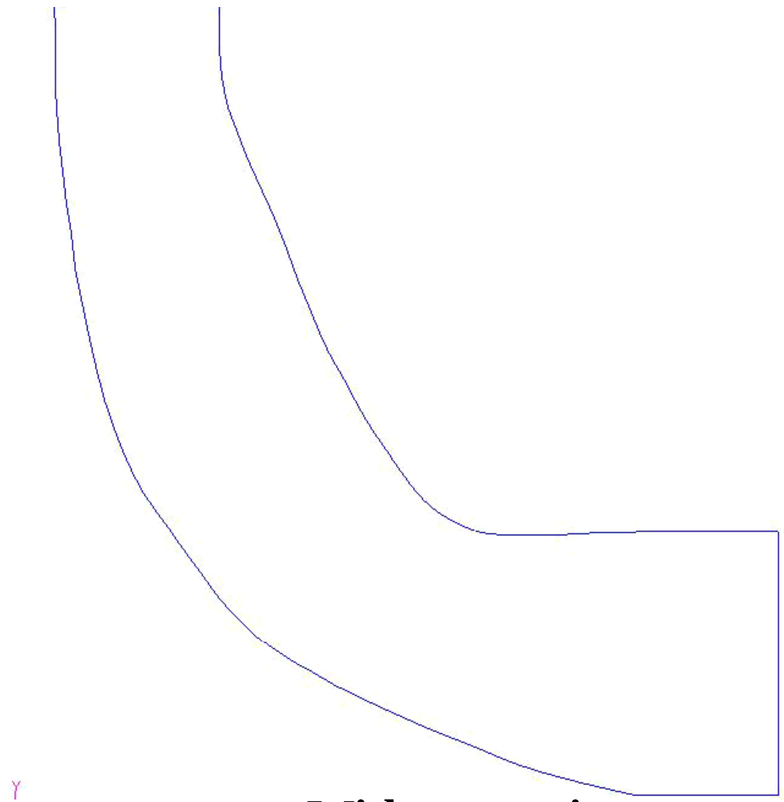




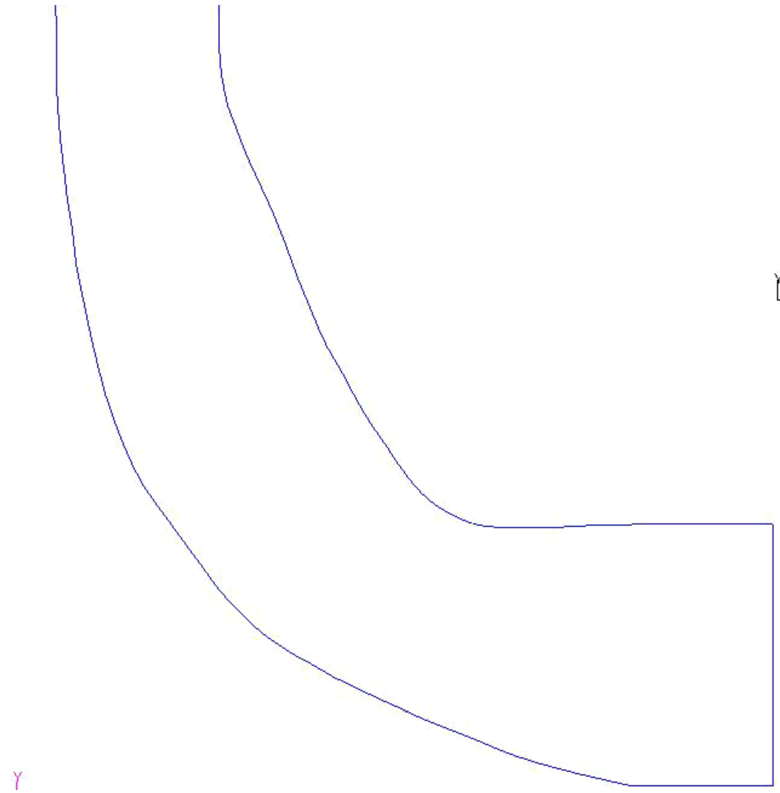
Mekong River near Tan Chau City

One of the most active channel deformation area of the Mekong River !

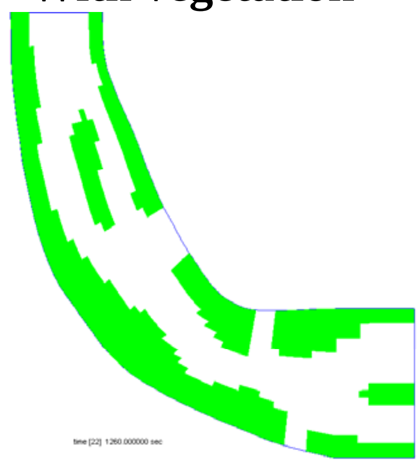
Effect of vegetation
(bed deformation from initial bed)



With vegetation

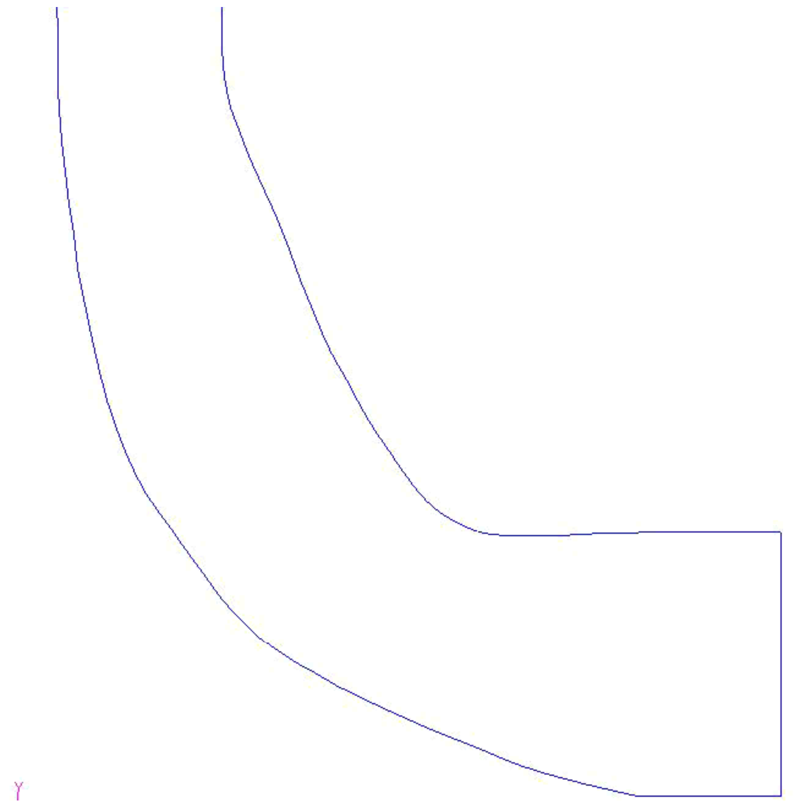


Without vegetation

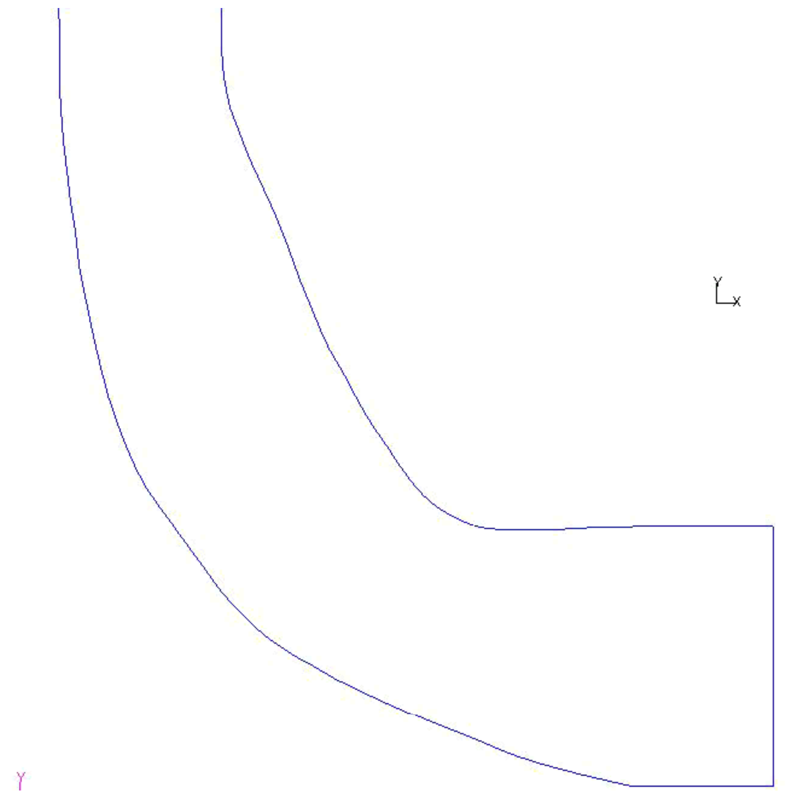


Horizontal distribution of vegetation

Horizontal distribution of mean diameter



Bed deformation from initial bed



Mean diameter of bed matrial

Thank you…