STRUCTURES IN MIKE 21

Flow over sluice gates

For a given geometry of the sluice gate and known water levels upstream and downstream of the structure, the flow rate \( Q \) can be determined through the equations of energy and momentum - see Bo Pedersen, ref. /17/. This approach will be used in the following. Water depths and water levels are specified according to a known reference level, see figure B.1. Moreover \( b_o \) and \( b_n \) denote the width of the channel upstream and downstream of the sluice gate.

![Figure B.1 Sketch of definitions of symbols](image)

For flows up to a given magnitude the flow rate will be determined by the large headloss which occurs right downstream of the sluice gate. In these situations both the equations of energy and momentum should be employed, and the flow rate depends on both upstream and downstream water levels.

Consider two cross-sections: One upstream of the sluice gate and one at the point downstream of the sluice gate, where the flow obtains minimal width. The water level in this cross-section is denoted \( \eta_w \). Because of the short distance and due to the flow not expanding in the considered domain, friction and headloss can be neglected. The equation of energy for the two cross-sections is then

\[
\eta_o + \frac{\alpha_o}{2g} \left( \frac{Q}{b_o (\eta_o + y_o)} \right)^2 = \eta_n + \frac{\alpha_n}{2g} \left( \frac{Q}{b_n (\eta_n + y_n)} \right)^2
\]

From the point with water level \( \eta_w \) to the point downstream of the sluice gate where the flow again is uniformly distributed over the cross-section a large loss of energy occurs due to the expansion of the flow. Thus the equation of momentum is used for calculations in this domain:

\[
\alpha_o \rho \frac{Q^2}{b_w (\eta_w + y_w)} + \frac{1}{2} \rho g b_w (\eta_w + y_w)^2 = \alpha_n \rho \frac{Q^2}{b_n (\eta_n + y_n)} + \frac{1}{2} \rho g b_n (\eta_n + y_n)^2
\]
In the above equations $\alpha_\alpha$ and $\alpha_\alpha$ denote the flow distribution coefficients upstream and downstream of the structure, respectively. A good approximation of these coefficients is 1.0.

With known values of upstream and downstream water levels, $\eta_o$ and $\eta_n$, the equations of energy and momentum constitute a system of two equations with two unknown variables, namely flow rate $Q$ and water level $\eta_w$. (The latter is not of our interest in the actual situation.) As both equations are non-linear they must be solved by iteration. This can easily be done after some simple manipulations.

For strong flows critical flow can occur due to the high flow velocity through the sluice gate. In this situation the upstream water level and the geometry of the sluice gate determine the flow rate and the equation of energy yields:

$$
\eta_o + y_w + \frac{\alpha_\alpha}{2g} \left( \frac{Q}{b_o(\eta_o + y_o)} \right)^2 = \frac{3}{2} (\eta_w + y_w) = \frac{3}{2} \left( \frac{Q^2}{gb_o^2} \right)^{\frac{1}{3}}
$$

This equation exploits that the velocity height in the point where critical flow occurs, exactly equals half of the pressure head. Usually the velocity height upstream can be neglected (last term on the left-hand side); then the equation can be solved explicitly for the critical flow rate. If the velocity height upstream is not omitted the equation must be solved by iteration.

The way of determining which method that should be used in a given situation is the following: Calculate the flow rate by both methods using the given water levels. The method that yields the smallest flow rate is the correct method for the actual situation.

Figure B.2 shows the flow rate versus upstream water level, calculated by the above method. For the calculations the following values were used

<table>
<thead>
<tr>
<th>$\eta_n$</th>
<th>0 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y_o$</td>
<td>-5 m</td>
</tr>
<tr>
<td>$y_n$</td>
<td>-5 m</td>
</tr>
<tr>
<td>$y_w$</td>
<td>-2.27 m</td>
</tr>
<tr>
<td>$b_o$</td>
<td>100 m</td>
</tr>
<tr>
<td>$b_w$</td>
<td>20.3 m</td>
</tr>
<tr>
<td>$b_n$</td>
<td>100 m</td>
</tr>
</tbody>
</table>
For the considered interval of upstream water levels, critical flow through the sluice gate does not occur, thus only the method described at first has been used.
Bprint=true
Include_Structures=true
Nstruct=1
Struct_area(1)=3
Struct_type(1)=1
Struct_jstart(1)=39
Struct_jstop(1)=39
Struct_kstart(1)=24
Struct_kstop(1)=30
Struct_orientation(1)=1

Option for additional print in log file
Turn on the structure option
Number of structures to be read
The structure is placed in area 3
Identifier for structure type:
1. broad-crested weir

Model coordinates for the structure
Must be grid aligned at present
Identifier for structure orientation:
1: parallel to y-axis
2. parallel to x-axis
Loss coefficients for in- and outflow
Number of entries in table

Table values of water levels (surf) and cross-section area (area)

Iteration limit (in metres)
Max iterations
if true: it can be specified that the sluice gates are closed in a part of the simulation period

The sluice gates are closed (1) from timestep 0 to 4, open (0) from 5 to 8 and closed again from timestep 9 to 12960 in the simulation.
[OPTION_PARAMETERS]
  bprint = true
  Include_Structures = true
  nstruct = 1
  struct_area_001 = 2
  struct_type_001 = 1
  struct_jstart_001 = 98
  struct_jstop_001 = 98
  struct_kstart_001 = 54
  struct_kstop_001 = 55
  struct_orientation_001 = 1
  struct_headloss_in_001 = 1
  struct_headloss_out_001 = 2
  struct_table_len_001 = 5
  struct_table_surf_001_001 = -2.2
  struct_table_surf_001_002 = 0.24
  struct_table_surf_001_003 = 0.94
  struct_table_surf_001_004 = 2.73
  struct_table_surf_001_005 = 10
  struct_table_area_001_001 = 0
  struct_table_area_001_002 = 51
  struct_table_area_001_003 = 65
  struct_table_area_001_004 = 179
  struct_table_area_001_005 = 1117
  delhs = 0.05
  itermax = 100
  ...struct_control_001 = true
  struct_control_close_001_000000 = 1
  struct_control_close_001_000180 = 0
  struct_control_close_001_000360 = 1
  struct_control_close_001_000540 = 0
  struct_control_close_001_001200 = 1
EndSect // OPTION_PARAMETERS