Model Predictive Control of a Sewer System

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Group 1030

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Agenda

Implementation

Kontrol

Results

Discussion/Conclusion

Overview

Jacob Naundrup Pedersen

- Implementation
- Kontrol
- Results
- Discussion
- Conclusion

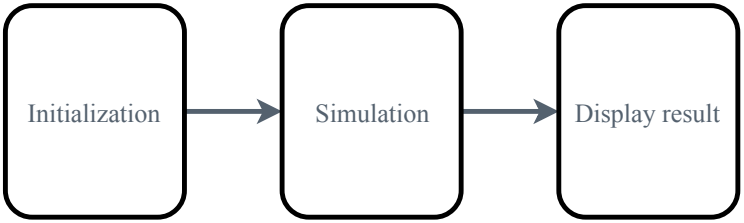


Figure: Chosen structure of simulation environment.

1. Pipe
   - Length [m]
   - Sections (Number of sections the pipe should be split in to)
   - S_b (Slope) [‰]
   - Δx = Length/Sections [m]
   - Diameter [meter]
   - Theta (parameter used in Preissmann scheme)
   - $Q_f [m^3/s]$
   - Side/lateral inflow present
   - Section location in data
2. Tank
   - Size $[m^3]$
   - Height [m]
   - Area = Size / Height $[m^2]$
   - Maximum outflow $[m^3/s]$
   - Section location in data

Table: List of parameters for pipe and tank.

Fields	length	sections	Dx	Sb	d	Theta	Qf	side_inflow	data_location
1	700	35	20	0.0030	0.9000	0.6500	0.9730	0	1
2	303	15	20.2000	0.0030	0.9000	0.6500	0.9730	0	3
3	27	2	13.5000	0.0030	1	0.6500	1.2843	1	4
4	155	8	19.3750	0.0041	1	0.6500	1.5014	0	5
5	295	14	21.0714	0.0122	0.8000	0.6500	1.4386	0	6
6	318	15	21.2000	0.0053	0.9000	0.6500	1.2932	1	7
7	110	5	22	0.0036	0.9000	0.6500	1.0658	1	8
8	38	2	19	0.0024	1	0.6500	1.1487	1	9
9	665	30	22.1667	0.0030	1	0.6500	1.2843	1	10
10	155	7	22.1429	8.0000e-04	1	0.6500	0.6632	0	11
11	955	47	20.3191	0.0029	1.2000	0.6500	2.0415	1	12
12	304	15	20.2667	0.0030	1.2000	0.6500	2.0764	0	13
13	116	5	23.2000	0.0021	1.2000	0.6500	1.7373	1	14
14	283	12	23.5833	0.0017	1.4000	0.6500	2.3463	1	15
15	31	2	15.5000	0.0019	1.4000	0.6500	2.4805	1	16
16	125	6	20.8333	0.0021	1.6000	0.6500	3.7075	0	17
17	94	4	23.5000	0.0013	1.5000	0.6500	2.4609	0	18
18	360	18	20	0.0046	1.6000	0.6500	5.4872	1	19
19	736	38	19.3684	0.0012	1.6000	0.6500	2.8026	0	20

Figure: Setup in MATLAB of pipe specification of the main line in Fredericia.

Field	Value
size	90
height	10
area	9
Q_out_max	0.9730
data_location	2

Figure: Setup in MATLAB of tank specifications.

Fields	type	component	sections
1	'Pipe'	1	35
2	'Tank'	1	1
3	'Pipe'	18	245
4	'Total'	20	281

Figure: Display of structure showing system setup information in MATLAB.

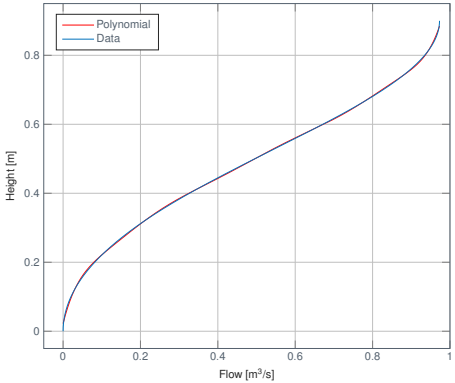
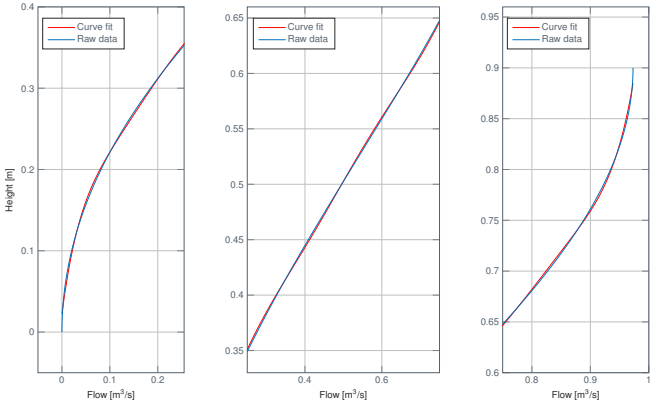


Figure: Comparison between data obtained by equation **??** and the same data curve fitted to a ninth order polynomial.



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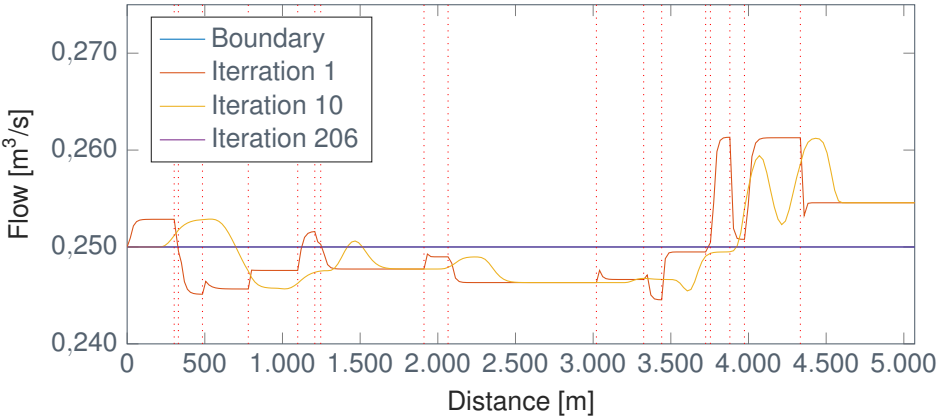


Figure: Height and flow of pipe setup from part of Fredericia where boundary conditions is found by fitted polynomial. Various amount of iterations, with constant flow input of 0,25 m^3/s, is performed. The dotted line indicates pipe intersections.

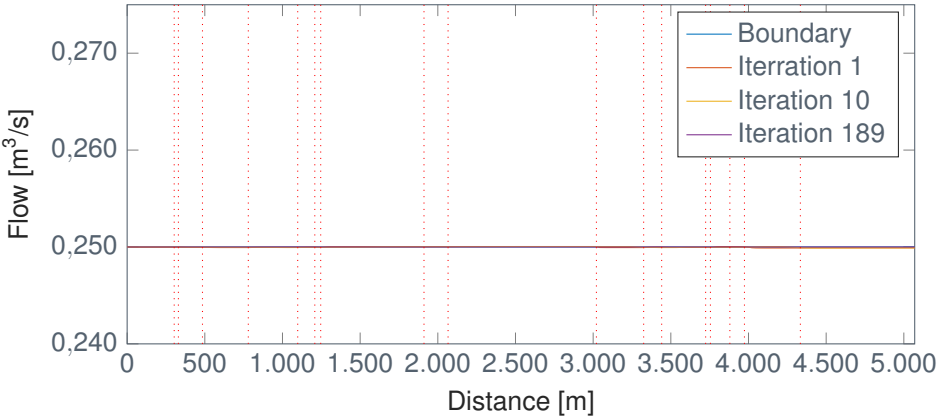
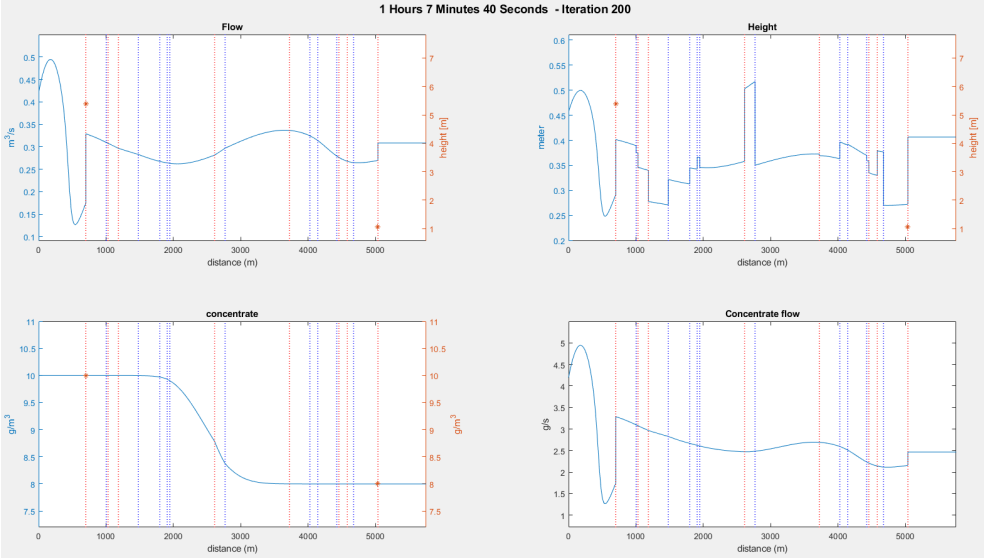


Figure: Height and flow of pipe setup from part of Fredericia where boundary conditions is found by lookup table. Various amount of iterations, with constant flow input of 0,25 m^3/s, is performed. The dotted line indicates pipe intersections.

- Preissmann scheme



Figure

- Linearisering af ulinear model
- Opstilles på state space form

$$\frac{\partial A(x,t)}{\partial t} + \frac{\partial Q(x,t)}{\partial x} = 0 \tag{1}$$

$$\frac{\partial A(h)}{\partial h}\frac{\partial h(x,t)}{\partial t} + \frac{\partial Q(h)}{\partial h}\frac{\partial h(x,t)}{\partial x} = 0 \tag{2}$$

- Priessmann scheme

$$\frac{\partial A(h)}{\partial h}\left(\frac{1}{2}\frac{h_{j+1}^{i+1}-h_{j+1}^{i}}{\Delta t}+\frac{1}{2}\frac{h_{j}^{i+1}-h_{j}^{i}}{\Delta t}\right)+ \frac{\partial Q(h)}{\partial h}\left(\theta\frac{h_{j+1}^{i+1}-h_{j}^{i+1}}{\Delta x}+(1-\theta)\frac{h_{j+1}^{i}-h_{j}^{i}}{\Delta x}\right)=0 \tag{3}$$

$$\underbrace{\begin{bmatrix} 1 & 0 & 0 & \cdots & 0 \\ 0 & b_1 & 0 & \cdots & 0 \\ 0 & a_1 & b_2 & \cdots & \vdots \\ \vdots & \vdots & \ddots & \ddots & 0 \\ 0 & 0 & 0 & a_{m-1} & b_m \end{bmatrix}}_{\xi} \underbrace{\begin{bmatrix} h_0^{i+1} \\ h_1^{i+1} \\ h_2^{i+1} \\ \vdots \\ h_m^{i+1} \end{bmatrix}}_{x(k+1)} = \underbrace{\begin{bmatrix} 0 & 0 & 0 & \cdots & 0 \\ c_0 & d_1 & 0 & \cdots & 0 \\ 0 & c_1 & d_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \ddots & \vdots \\ 0 & 0 & 0 & c_{m-1} & d_m \end{bmatrix}}_{A} \underbrace{\begin{bmatrix} h_0^{i} \\ h_1^{i} \\ h_2^{i} \\ \vdots \\ h_m^{i} \end{bmatrix}}_{x(k)} + \underbrace{\begin{bmatrix} 1 \\ -a_0 \\ 0 \\ \vdots \\ 0 \end{bmatrix}}_{B} h_0^{i+1} + \underbrace{\begin{bmatrix} \frac{dh}{dQ} \\ 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix}}_{B_d} d_0^{i+1} \tag{4}$$

$$\underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & b_{1,1} & 0 & 0 & 0 & 0 & 0 \\ 0 & a_{1,1} & b_{1,2} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & a_{2,1} & b_{2,2} & 0 \\ 0 & 0 & 0 & 0 & 0 & a_{2,2} & b_{2,3} \end{bmatrix}}_{\xi} \underbrace{\begin{bmatrix} h_{1,0}^{i+1} \\ h_{1,1}^{i+1} \\ h_{1,2}^{i+1} \\ h_{tank}^{i+1} \\ h_{2,0}^{i+1} \\ h_{2,1}^{i+1} \\ h_{2,2}^{i+1} \end{bmatrix}}_{x(k+1)}$$

$$= \underbrace{\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ c_{1,0} & d_{1,1} & 0 & 0 & 0 & 0 & 0 \\ 0 & c_{1,1} & d_{1,2} & 0 & 0 & 0 & 0 \\ 0 & 0 & e & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & c_{2,0} & d_{2,1} & 0 \\ 0 & 0 & 0 & 0 & 0 & c_{2,1} & d_{2,2} \end{bmatrix}}_{A} \underbrace{\begin{bmatrix} h_{1,0}^{i} \\ h_{1,1}^{i} \\ h_{1,2}^{i} \\ h_{tank}^{i} \\ h_{2,0}^{i} \\ h_{2,1}^{i} \\ h_{2,2}^{i} \end{bmatrix}}_{x(k)} + \underbrace{\begin{bmatrix} 1 & 0 \\ -a_0 & 0 \\ 0 & 0 \\ 0 & -f \\ 0 & g \\ 0 & 0 \\ 0 & 0 \end{bmatrix}}_{B} \begin{bmatrix} h_0^{i+1} \\ u_{tank} \end{bmatrix} \tag{5}$$

- Sinus input

Type	Components	Sections
Pipe	1	35
Tank	1	1
Pipe	18	227
Total	20	263

Table: System setup.

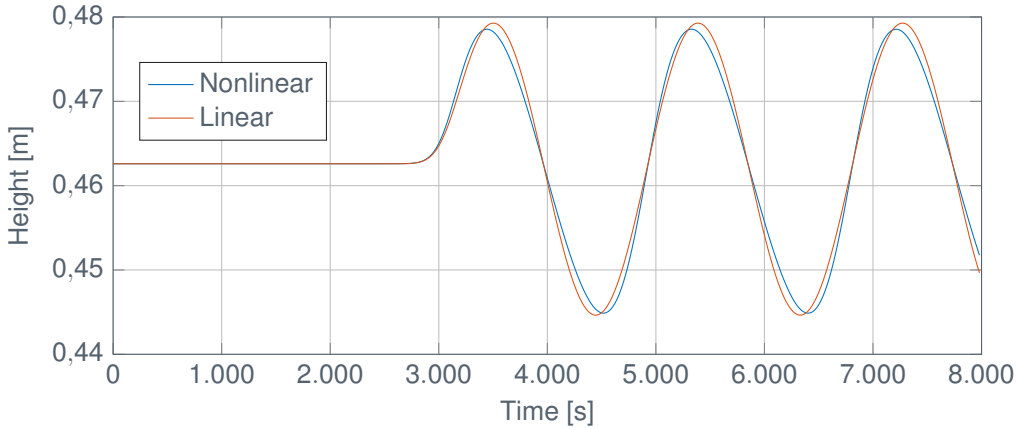


Figure: Comparison of the nonlinear and linear model at the last pipe in the setup.

- Cost function
  - Begrænset til minimiere af output
- Constraints
  - Højde
  - Kontrol input
- Linear model

- Bestemmelse af Prediction horizon
  - Flow profiler
  - Industri
- Begrænsning af Prediction horizon

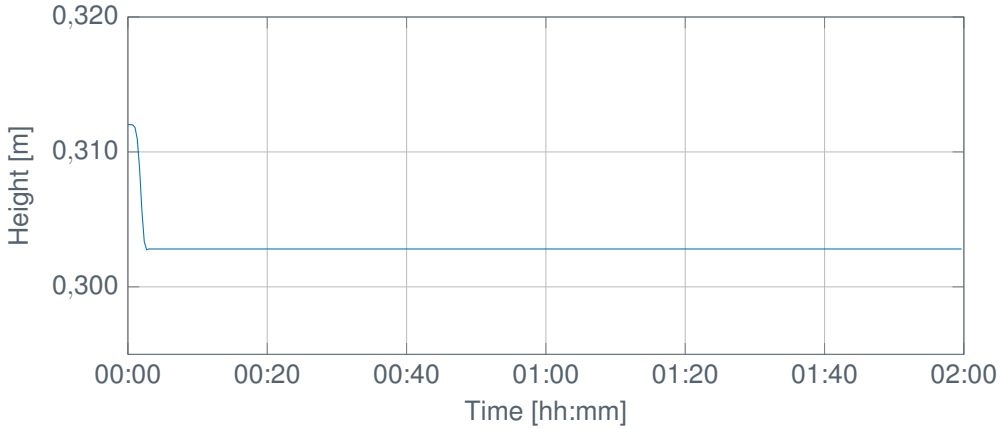


Figure: Output of the last pipe.

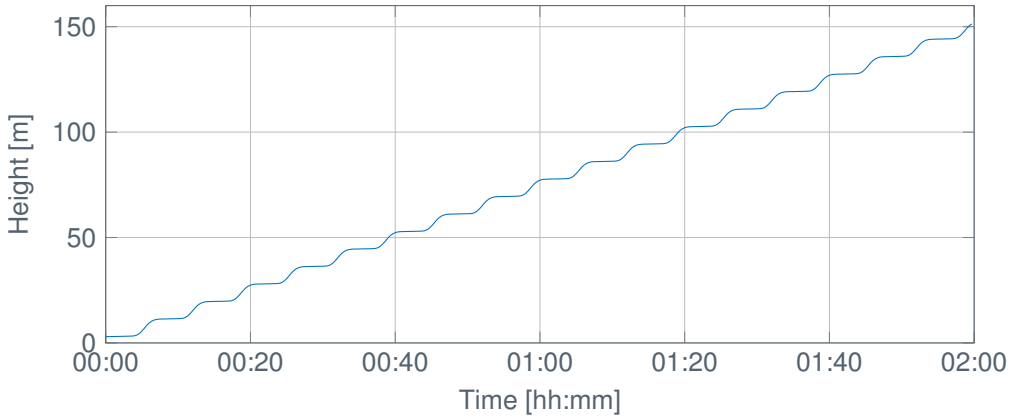


Figure: Height in the tank.

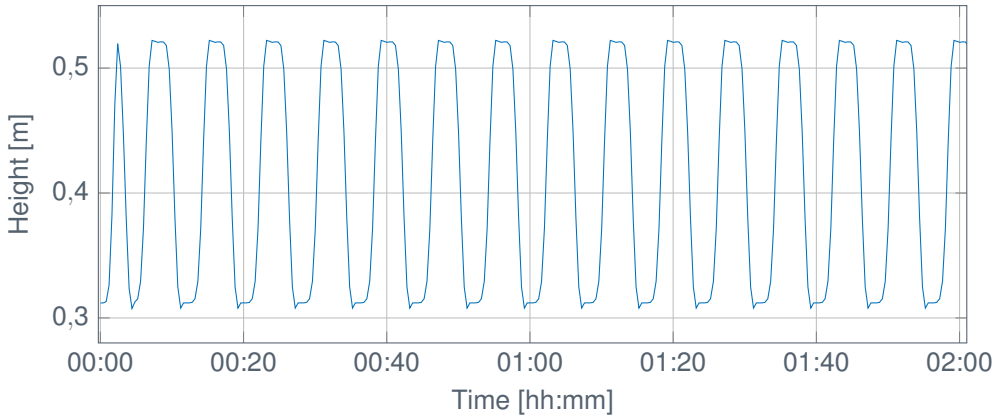


Figure: Output of the last pipe in the second simulation run.

- System setup
- Flow profiles

Type	Component	Sections
Pipe	1	35
Tank	1	1
Pipe	17	207
Tank	1	1
Pipe	1	38
Total	21	282

Table: System setup.

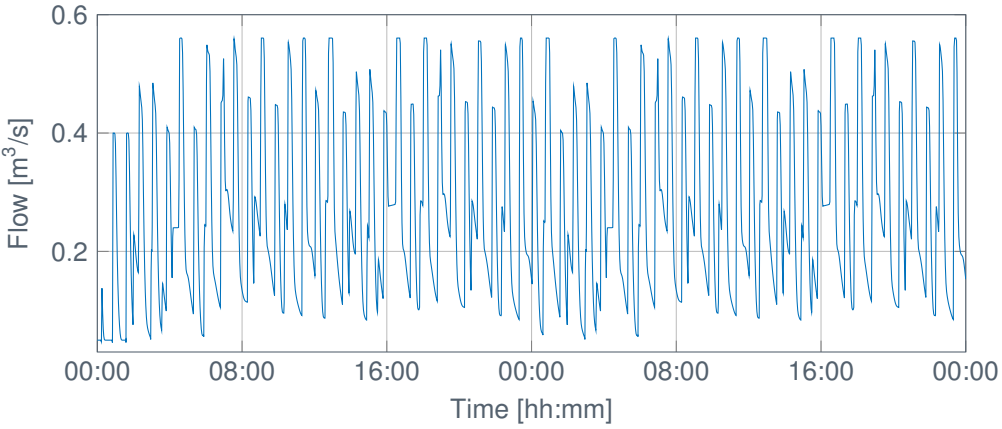


Figure: Output of the last pipe into the WWTP.

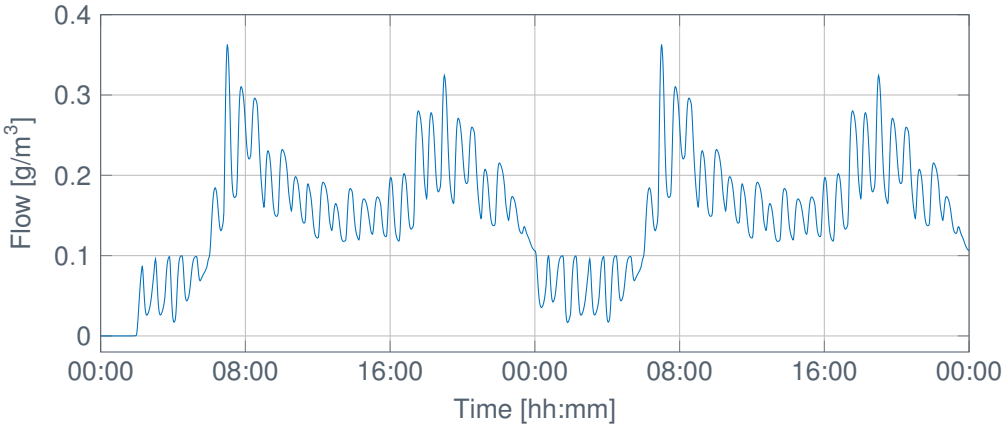


Figure: Simulation of COD output of the last pipe into the WWTP.

Results
Second test

- Over dimensioneret tank
- Konstant output af tank

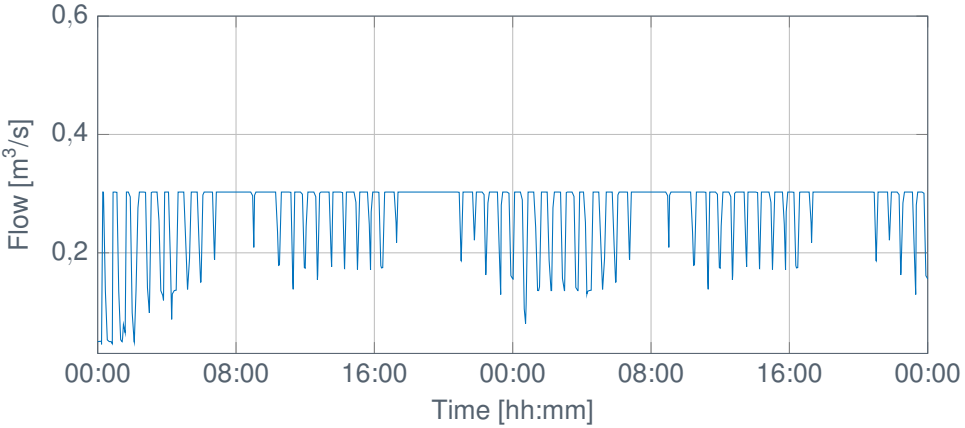


Figure: Output of the last pipe in to the WWTP, where a tank has been placed in front to reduce variation in flow into WWTP.

Discussion

- Courant's number
- Model reduction

Conclusion

- Simulation
- MPC