

Modeliranje turbulencije u pravougaonom kanalu

Softver: iRIC

Solver: NaysCUBE

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Modeliranje turbulencije

Ulazni podaci

Dužina kanala

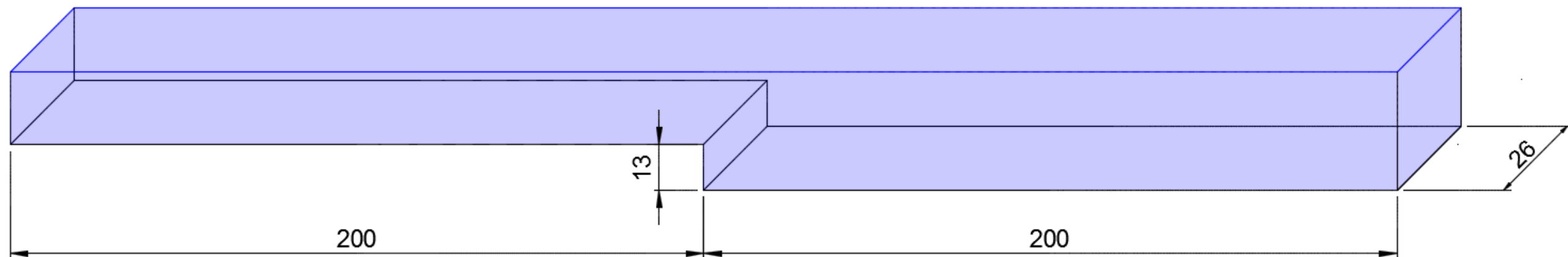
$L = 4,0 \text{ m}$

Širina kanala

$b = 0,26 \text{ m}$

Spuštanje dna

$\Delta = 0,13 \text{ m}$



Modeliranje turbulencije

Ulazni podaci

Protok

$$Q = 20 \text{ L/s}$$

Položaj proširenja poprečnog preseka

$$x_1 = 1 \text{ m}$$

$$x_2 = 2 \text{ m}$$

$$x_3 = 3 \text{ m}$$

Nizvodna dubina

$$h = ?$$

Modeliranje turbulencije

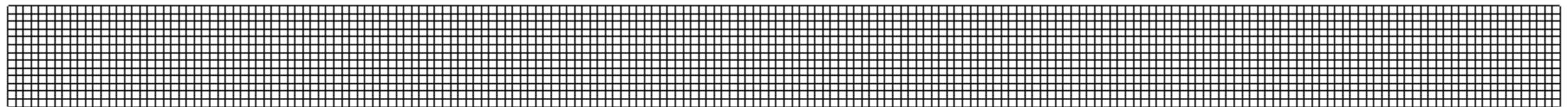
Formiranje proračunske mreže

Multifunction Grid Generator

Wave Length of Meander(m)	<input type="text" value="4"/>
Wave Number	<input type="text" value="1"/>
Meander Angle(degree)	<input type="text" value="0"/>
Number of Grids in One Wave Length	<input type="text" value="200"/>

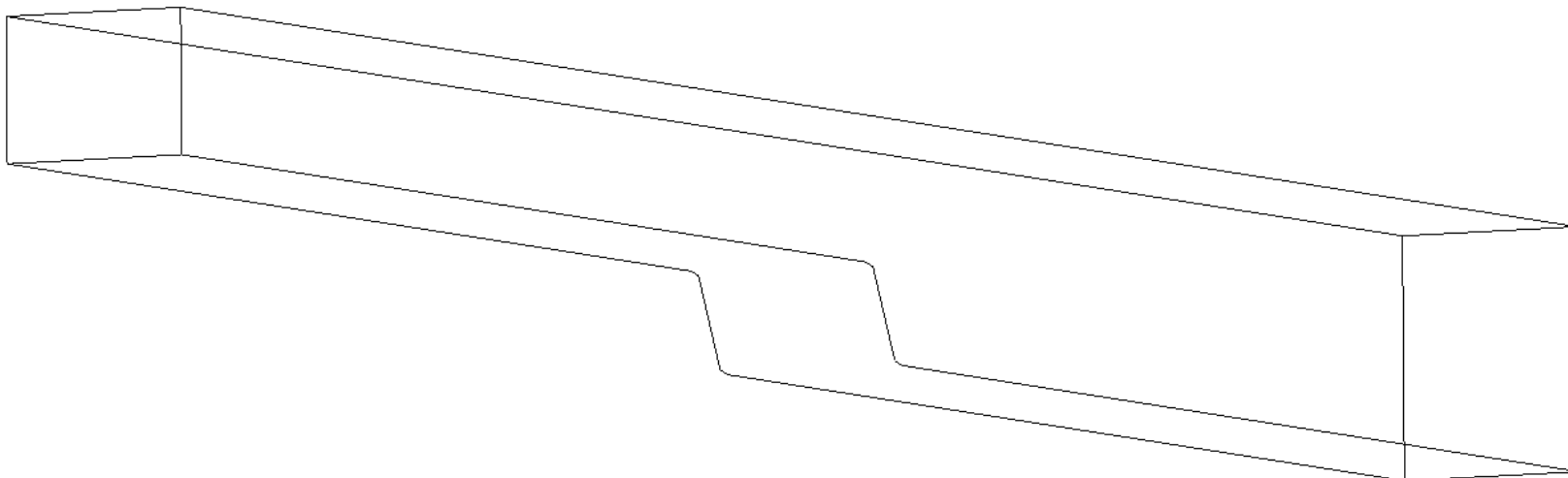
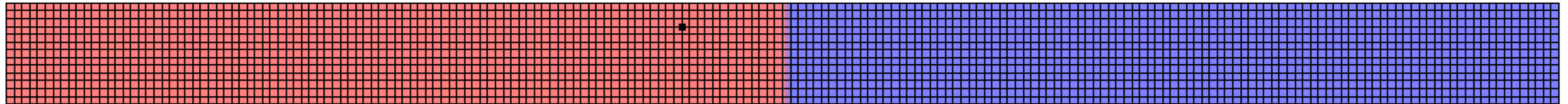
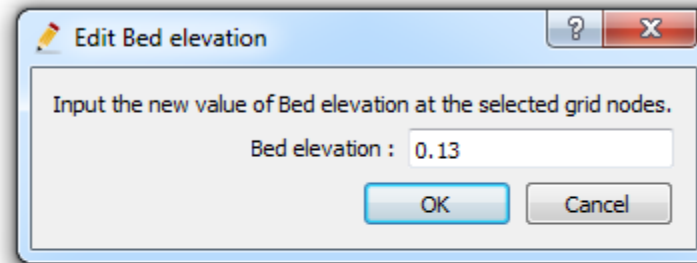
Single Cross Section	
Width(m)	<input type="text" value="0.26"/>
Number of Grid in Lateral Direction	<input type="text" value="13"/>

Veličina ćelija 2 x 2 cm (kvadratna mreža)



Modeliranje turbulencije

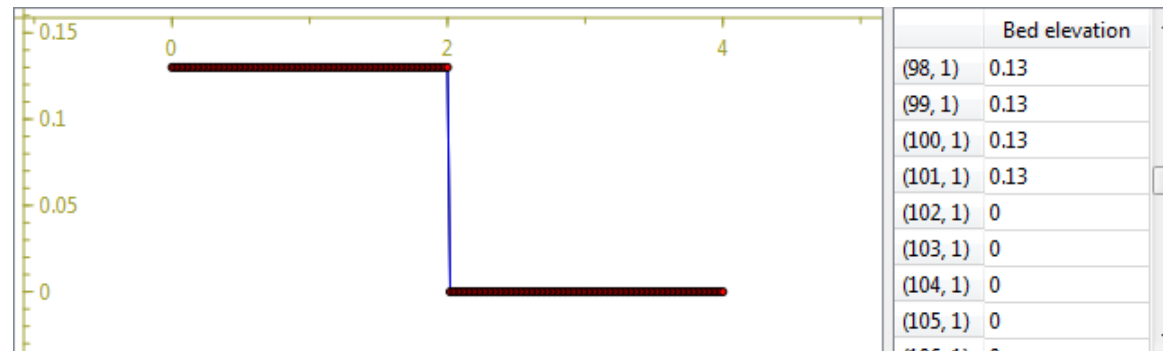
Zadavanje kota dna



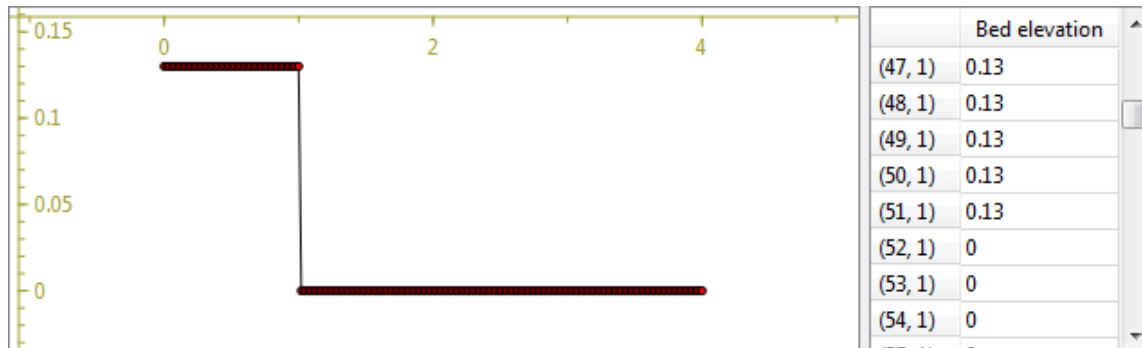
Modeliranje turbulencije

Zadavanje kota dna

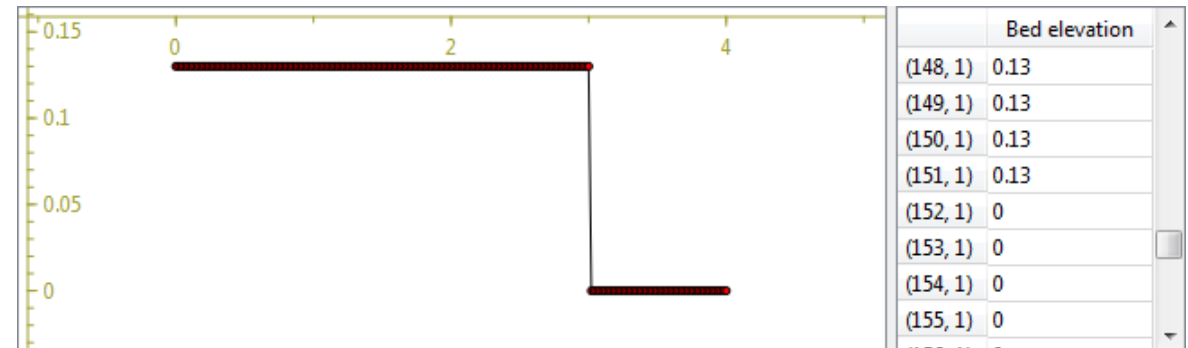
$X_1 = 2 \text{ m}$



$X_2 = 1 \text{ m}$



$X_3 = 3 \text{ m}$



Modeliranje turbulencije

Parametri proračuna

The image displays three overlapping software dialog boxes for configuring turbulence model parameters. A red arrow points to the 'Non-linear k-e model' dropdown in the top-left dialog.

Top-Left Dialog (Basic Parameters):

- Number of Vertical Layers: 10
- Fixed or Movable Bed: Fixed bed
- Turbulence Model: Non-linear k-e model
- Spatial Scheme for Advection Terms: TVD MUSCL

Top-Right Dialog (Time Conditions):

- Start Time[s]: 0
- End Time[s]: 20
- File Output Time[s]: 0.1
- Time Step[s]: 0.005
- Start time of surface move[s]: 0
- Start time of bed move[s]: 2

Bottom Dialog (Flow Conditions):

- Discharge[m³/s]: 0.02
- How to give outlet water level?: uni-flow (Manning eq.)
- Downstream Water Level[m]: 1.5
- Minimum Depth[m]: 0
- How to give initial surface slope?: Given directly
- Initial surface slope: 0.0001
- Q gradual increase: Q given directly
- Initial Q rate: 0.1
- Time for Q slope[s]: 10

Modeliranje turbulencije

Parametri proračuna

Linearni k-ε model

$$-\overline{u^i u^j} = \nu_t S_{ij} - \frac{2}{3} k \delta_{ij}, \quad \nu_t = C_\mu \frac{k^2}{\varepsilon}, \quad S_{ij} = \frac{\partial U^i}{\partial x^j} + \frac{\partial U^j}{\partial x^i}$$

Nelinearni k-ε model

$$-\overline{u_i u_j} = \nu_t S_{ij} - \frac{2}{3} k \delta_{ij} - \frac{k}{\varepsilon} \nu_t \left[\alpha_1 (S_{il} \Omega_{lj} + S_{jl} \Omega_{li}) + \alpha_2 (S_{il} S_{lj} - \frac{1}{3} S_{km} S_{mk} \delta_{ij}) + \alpha_3 (\Omega_{il} \Omega_{lj} - \frac{1}{3} \Omega_{km} \Omega_{mk} \delta_{ij}) \right]$$

$$S_{ij} = \frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{\partial x_i}, \quad \Omega_{ij} = \frac{\partial U_i}{\partial x_j} - \frac{\partial U_j}{\partial x_i}$$

$$\alpha_1 = -0.1325 f_M, \quad \alpha_2 = 0.0675 f_M, \quad \alpha_3 = -0.0675 f_M$$

$$f_M = (1 + m_{\Omega} S^2 + m_{\Omega^2} \Omega^2)^{-1}$$

$$C_\mu = c_{\mu 0} (1 + c_{\mu 2} S^2 + c_{\mu \Omega} \Omega^2) / D_\mu$$

$$D_\mu = 1 + c_{ds} S^2 + c_{d\Omega} \Omega^2 + c_{ds\Omega} S \Omega + c_{ds^4} S^4 + c_{d\Omega^4} \Omega^4 + c_{ds\Omega^2} S^2 \Omega^2$$

$$S = \frac{k}{\varepsilon} \sqrt{\frac{1}{2} S_{ij} S_{ij}}, \quad \Omega = \frac{k}{\varepsilon} \sqrt{\frac{1}{2} \Omega_{ij} \Omega_{ij}}$$

Modeliranje turbulencije

Parametri proračuna

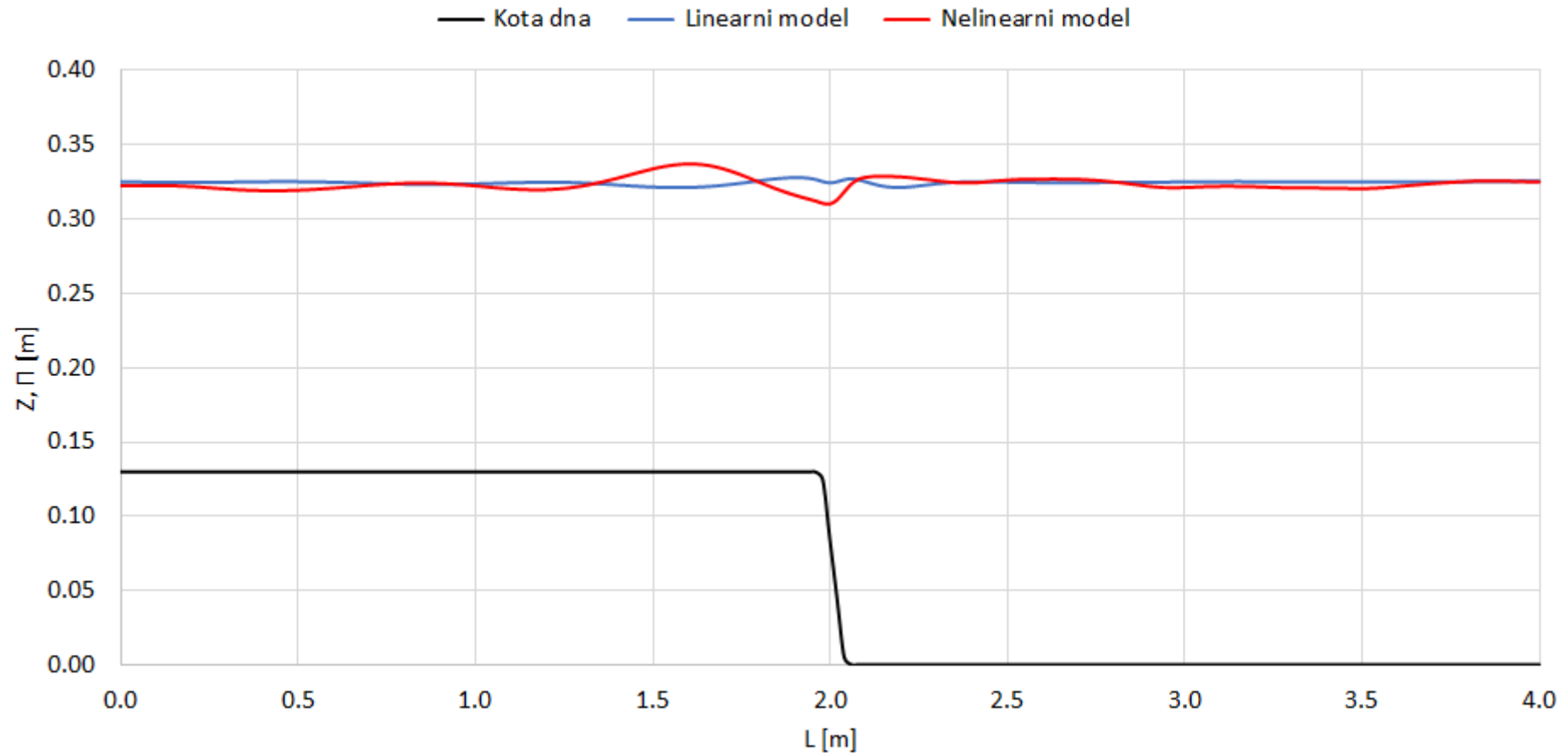
The image displays three overlapping software dialog boxes for configuring turbulence model parameters. The top-left dialog, titled 'Basic Parameters', shows 'Number of Vertical Layers' set to 10, 'Fixed or Movable Bed' set to 'Fixed bed', 'Turbulence Model' set to 'Non-linear k-e model', and 'Spatial Scheme for Advection Terms' set to 'TVD MUSCL'. The top-right dialog, titled 'Time Conditions', shows 'Start Time[s]' set to 0, 'End Time[s]' set to 20, 'File Output Time[s]' set to 0.1, 'Time Step[s]' set to 0.005, 'Start time of surface move[s]' set to 0, and 'Start time of bed move[s]' set to 2. The bottom-center dialog, titled 'Flow Conditions', shows 'Discharge[m3/s]' set to 0.02, 'How to give outlet water level?' set to 'uni-flow (Manning eq.)', 'Downstream Water Level[m]' set to 1.5, 'Minimum Depth[m]' set to 0, 'How to give initial surface slope?' set to 'Given directly', 'Initial surface slope' set to 0.0001, 'Q gradual increase' set to 'Q given directly', 'Initial Q rate' set to 0.1, and 'Time for Q slope[s]' set to 10. Red arrows point to the 'Non-linear k-e model' dropdown, the 'Time Step[s]' input field, and the 'Initial surface slope' input field.

Modeliranje turbulencije

Rezultati proračuna – linija nivoa

$X_2 = 2 \text{ m}$

$t = 18 \text{ s}$

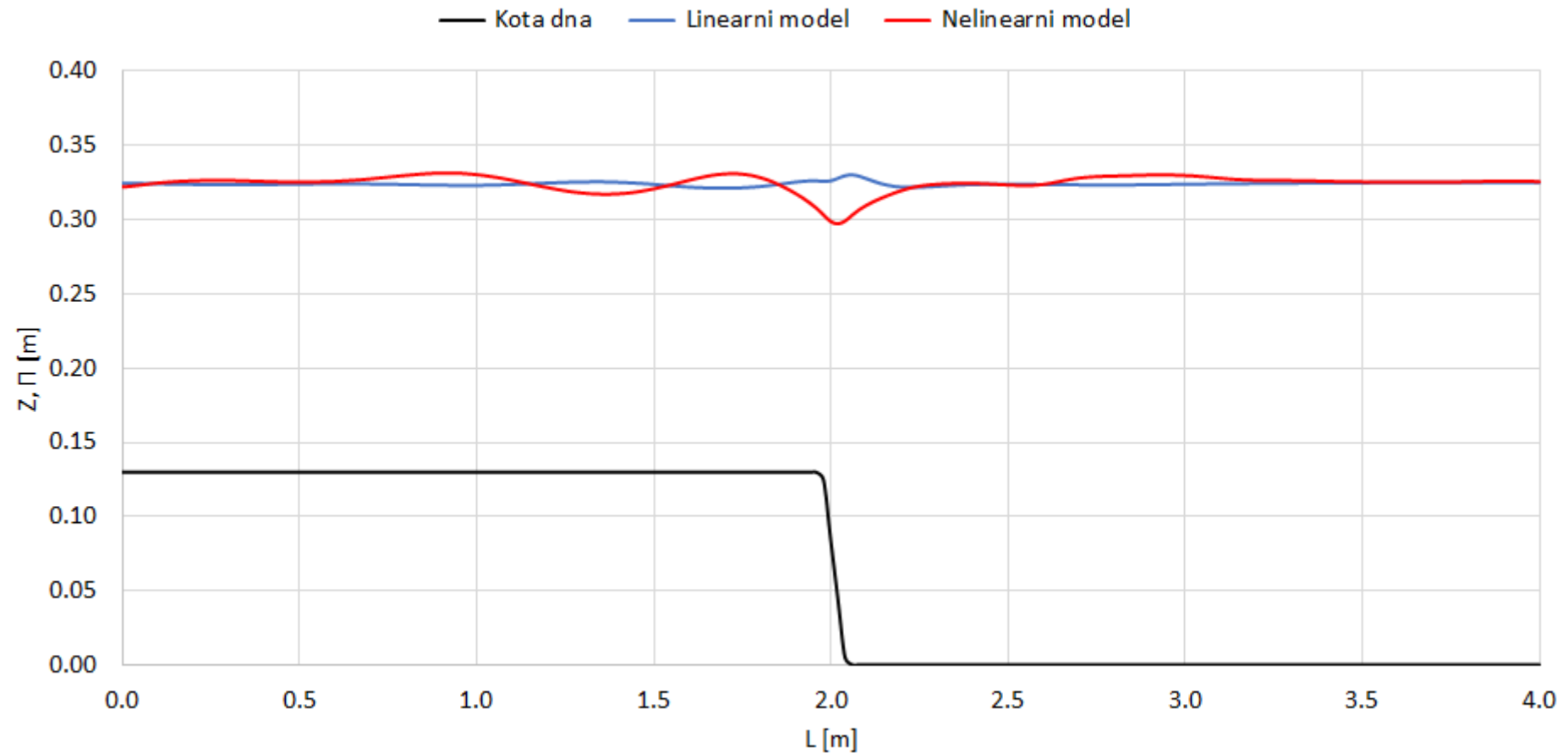


Modeliranje turbulencije

Rezultati proračuna – linija nivoa

$X_2 = 2 \text{ m}$

$t = 19 \text{ s}$

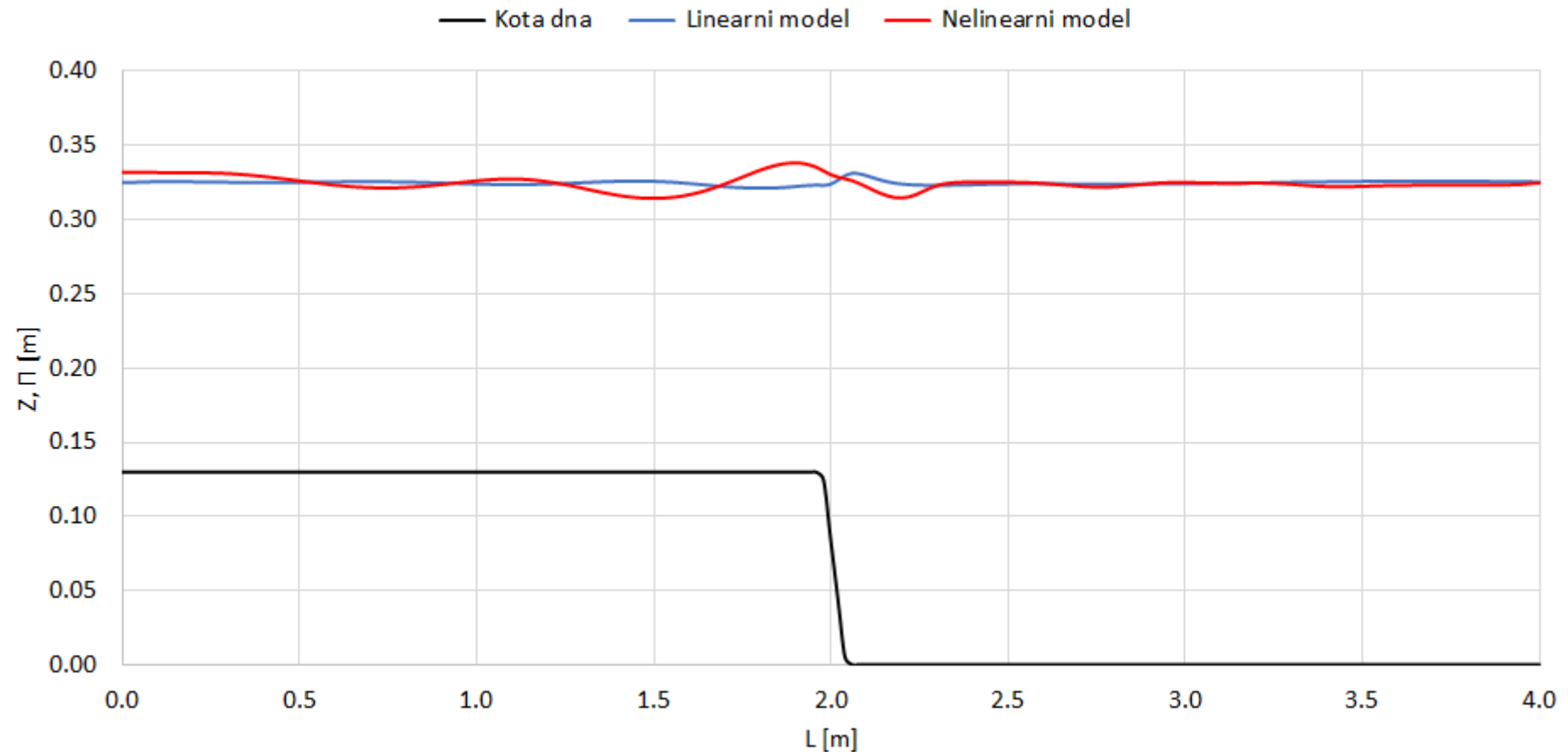


Modeliranje turbulencije

Rezultati proračuna – linija nivoa

$X_2 = 2 \text{ m}$

$t = 20 \text{ s}$

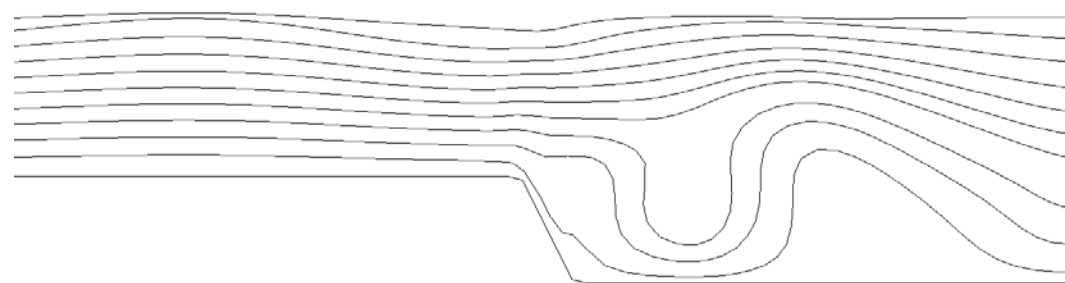
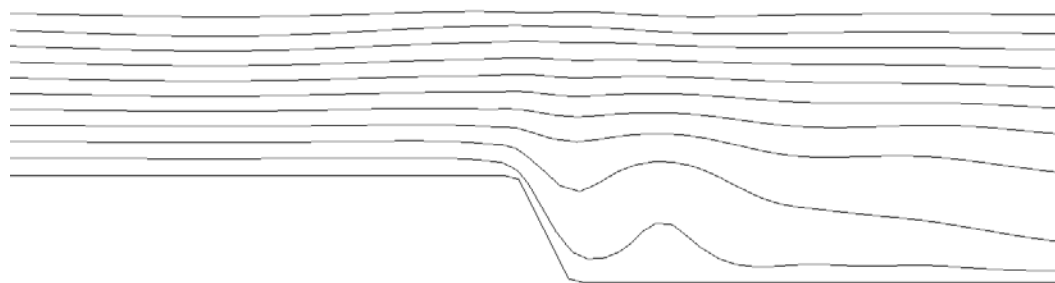


Modeliranje turbulencije

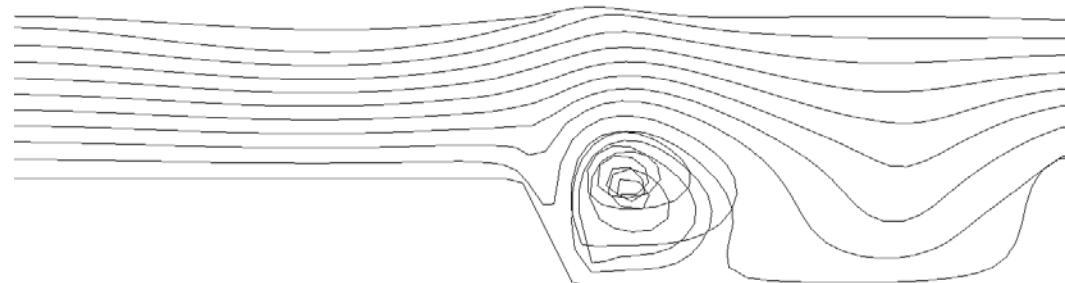
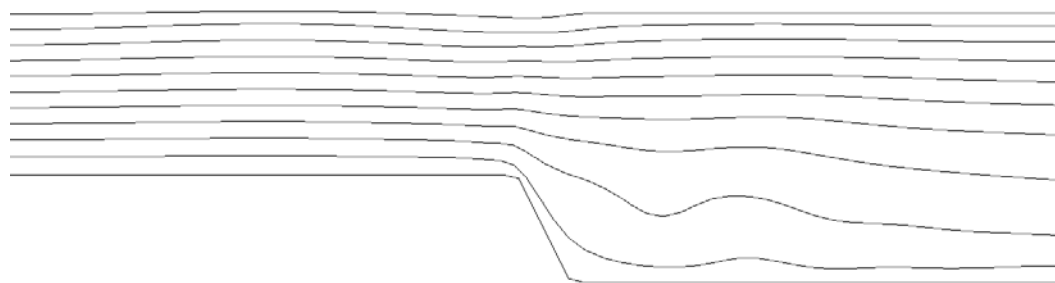
Rezultati proračuna – strujne linije

$X_2 = 2 \text{ m}$

$t = 15,5 \text{ s}$



$t = 19,6 \text{ s}$



Linearni model

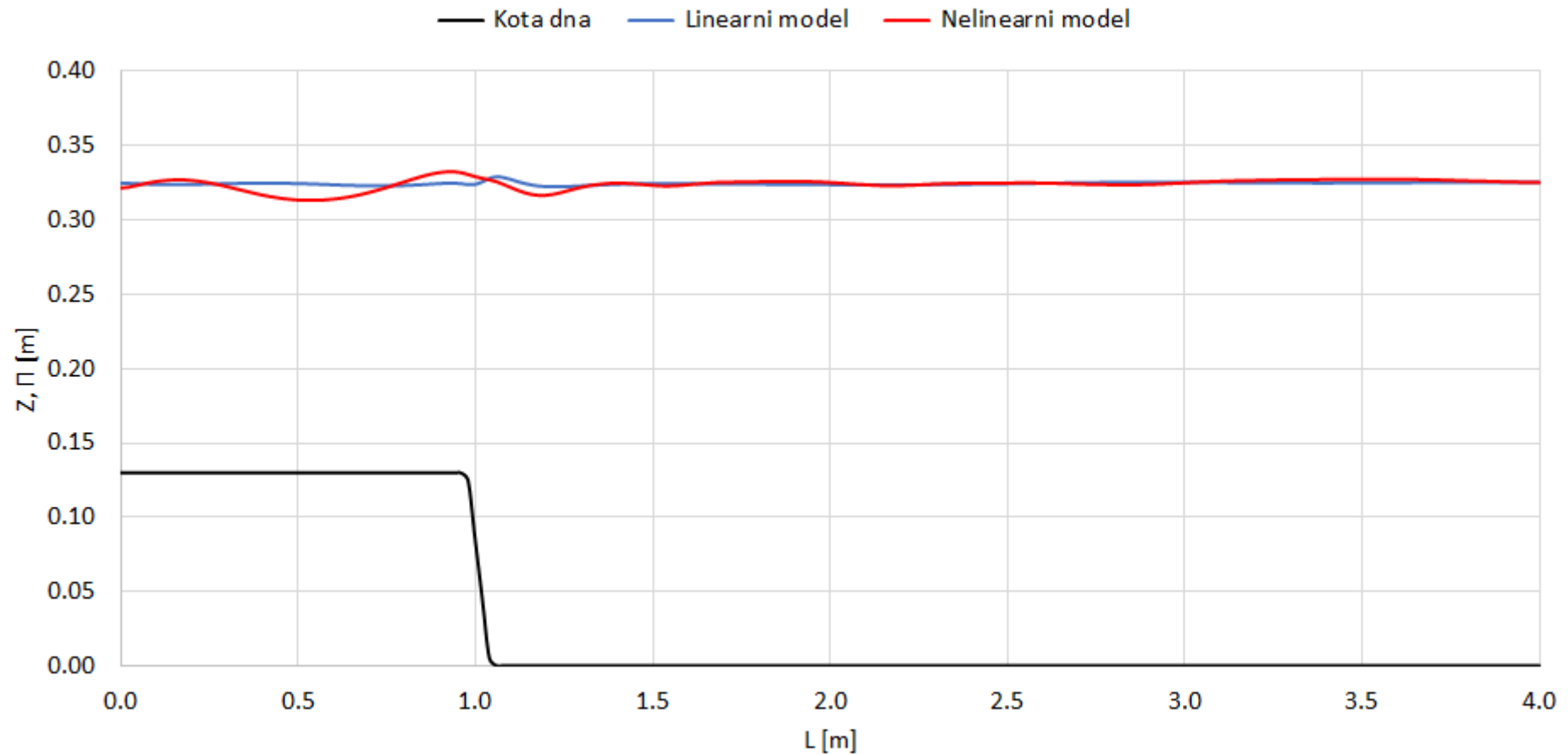
Nelinearni model

Modeliranje turbulencije

Rezultati proračuna - linija nivoa

$X_1 = 1 \text{ m}$

$t = 20 \text{ s}$

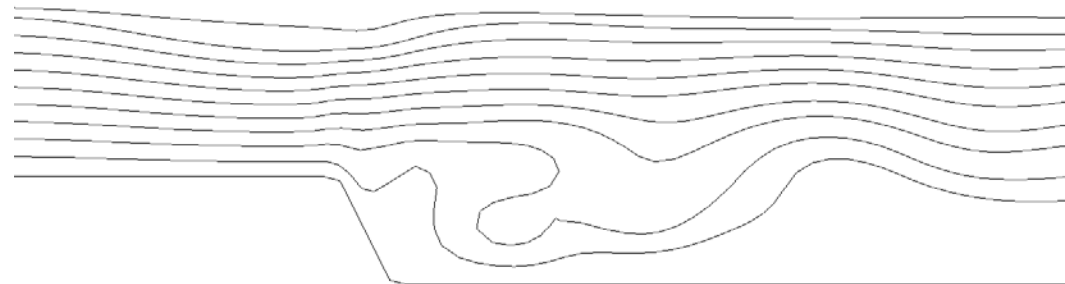
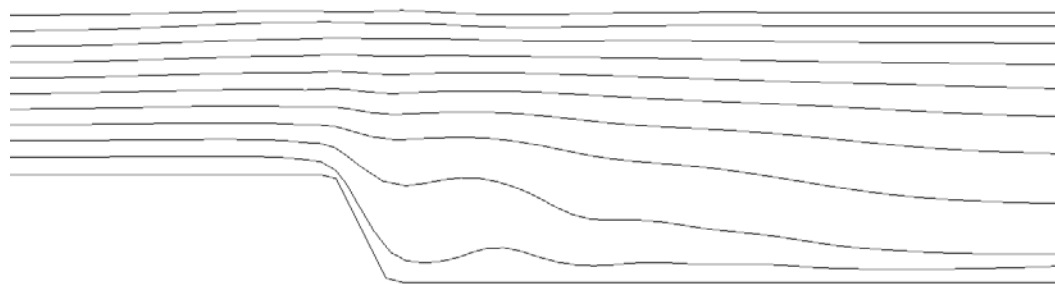


Modeliranje turbulencije

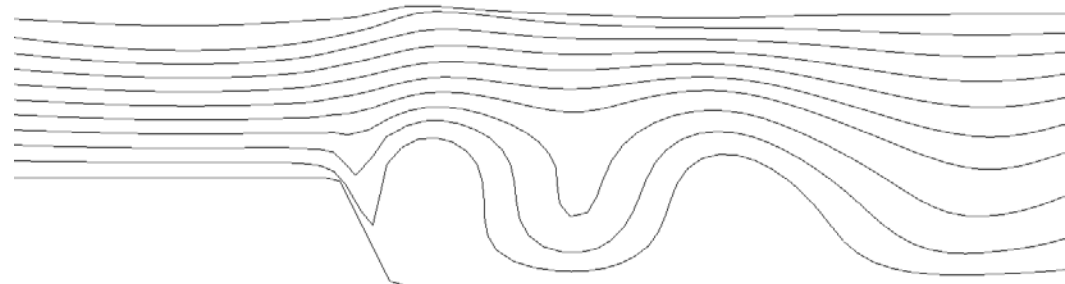
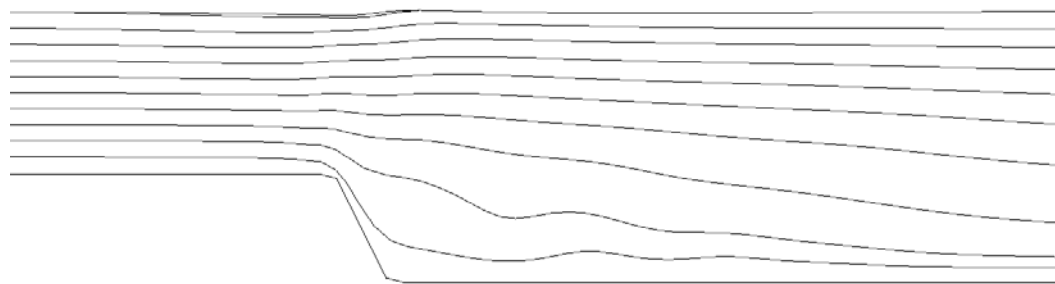
Rezultati proračuna – strujne linije

$X_2 = 2 \text{ m}$

$t = 15,5 \text{ s}$



$t = 19,6 \text{ s}$



Linearni model

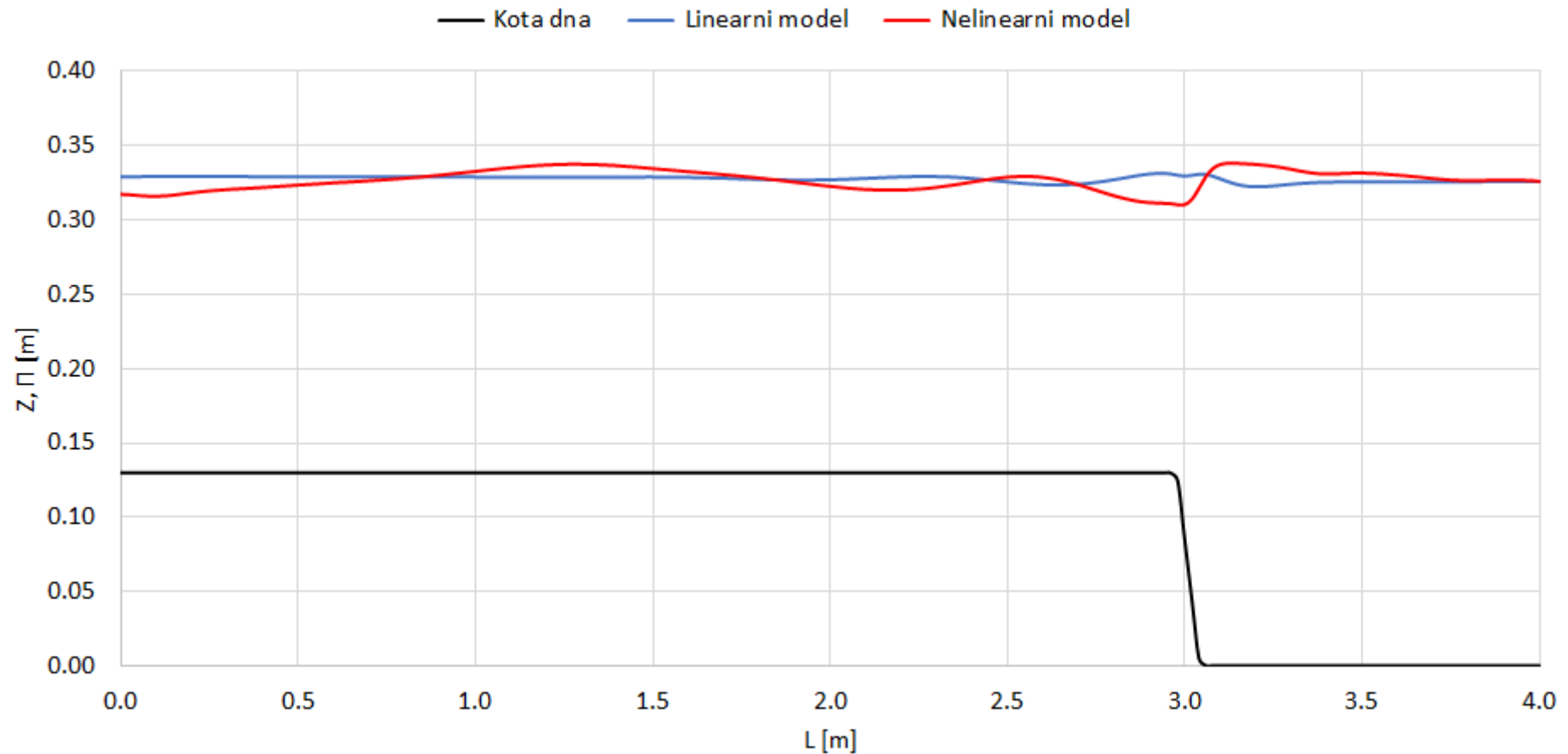
Nelinearni model

Modeliranje turbulencije

Rezultati proračuna – linija nivoa

$X_3 = 3 \text{ m}$

$t = 20 \text{ s}$

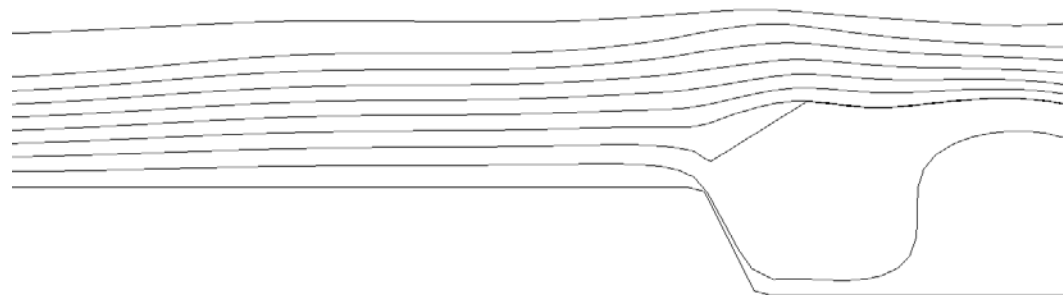
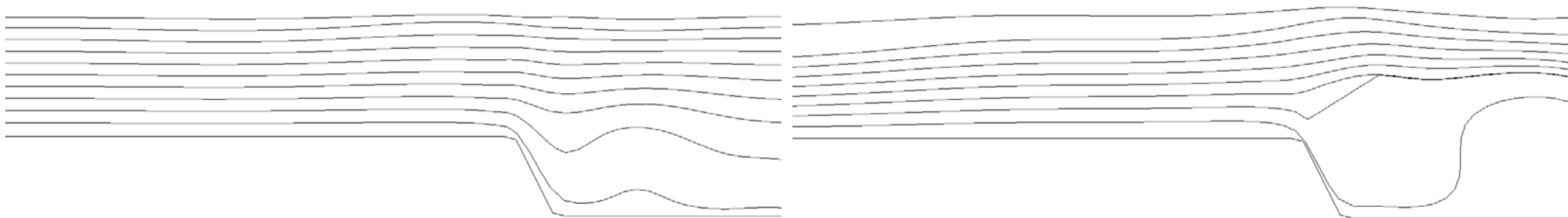


Modeliranje turbulencije

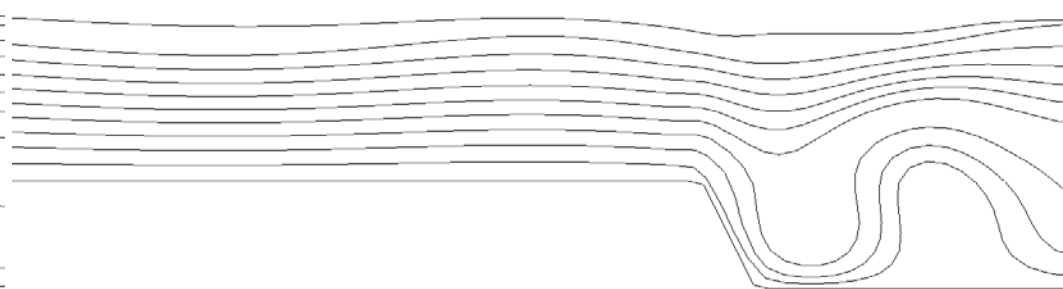
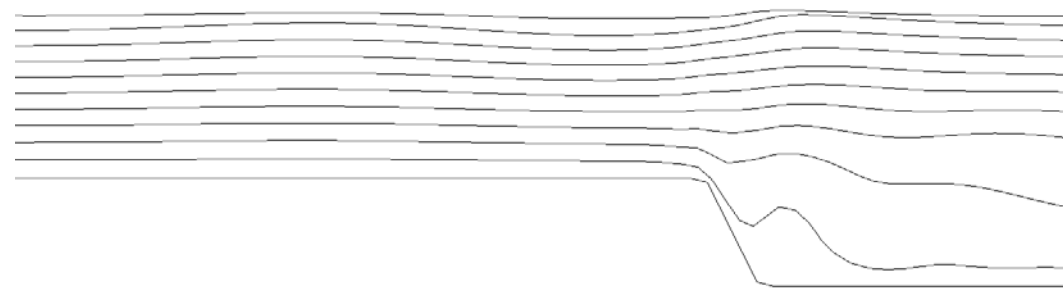
Rezultati proračuna – strujne linije

$X_2 = 2 \text{ m}$

$t = 15,5 \text{ s}$



$t = 19,6 \text{ s}$



Linearni model

Nelinearni model

Modeliranje turbulencije

Rezultati proračuna – Nelinearni model

Promena linije nivoa (u cm)

L [m]	x_1	x_2	x_3
0	31,7 – 33,0	31,9 – 33,2	31,4 – 34,3
1	30,1 – 33,6	31,7 – 33,3	31,7 – 33,6
2	31,9 – 33,0	29,6 – 33,9	31,3 – 33,6
3	32,3 – 32,9	31,7 – 33,0	29,7 – 35,0
4	32,50 – 32,54	32,47 – 32,57	32,45 – 32,61

Modeliranje turbulencije

Rezultati proračuna – Nelinearni model

Brzina (u cm/s)

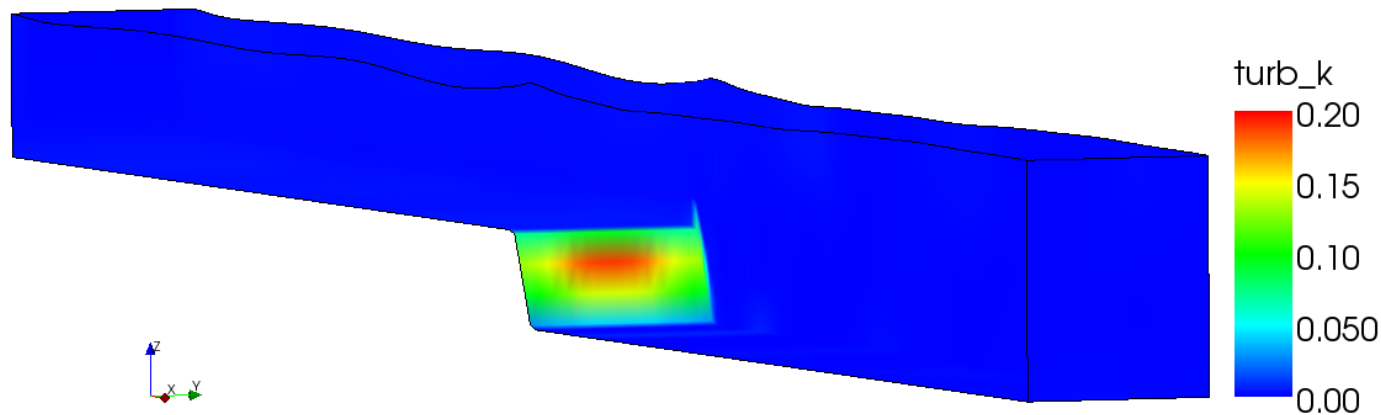
L [m]	x_1	x_2	x_3
0	45,1 – 48,2	44,7 – 47,8	42,3 – 49,0
1	39,5 – 74,1	39,5 – 55,6	35,2 – 57,2
2	26,5 – 54,9	39,4 – 81,5	40,8 – 59,9
3	25,8 – 46,4	26,8 – 55,1	38,4 – 83,2
4	22,6 – 36,3	24,3 – 47,6	24,9 – 59,7

Modeliranje turbulencije

Rezultati proračuna

Maksimalna turbulentna energija (u cm^2/s^2)

L [m]	Linearni m.	Nelinearni m.
x_1	433	1728
x_2	419	1895
x_3	455	2051



Modeliranje turbulencije

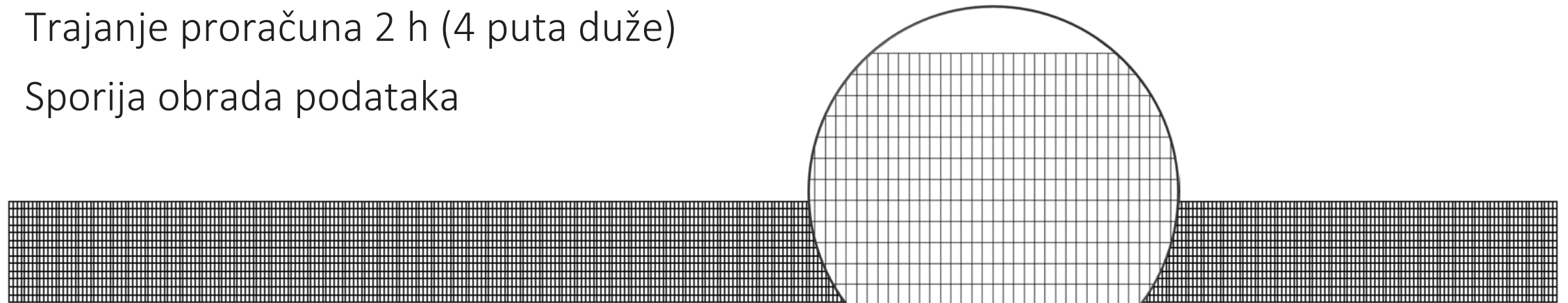
Formiranje proračunske mreže

Veličina ćelija 1 x 2 cm (pravougaona mreža)

Veličina fajla 2,5 Gb (4 puta veći fajl)

Trajanje proračuna 2 h (4 puta duže)

Sporija obrada podataka

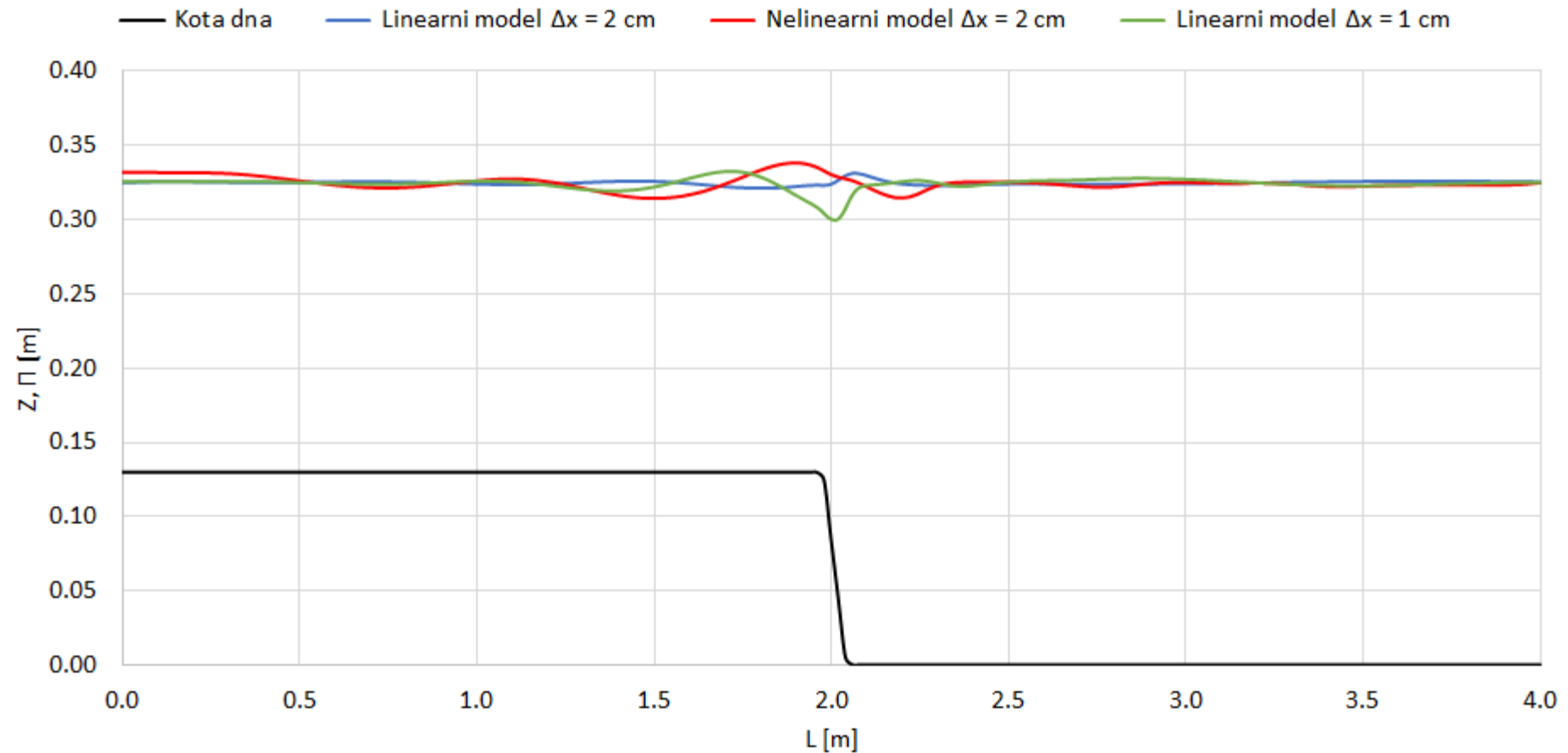


Modeliranje turbulencije

Rezultati proračuna - linija nivoa

$X_2 = 2 \text{ m}$

$t = 20 \text{ s}$



Modeliranje turbulencije

Zaključak

Srednja vrednost nizvodne dubine ne zavisi od položaja proširenja poprečnog preseka kanala, ali je evidentirana (zanemarljiva) promena opsega u kome se kreću vrednosti nizvodne dubine.

Raspon vrednosti brzina tečenja najveći je na mestu proširenja poprečnog preseka. Linearni model daje slične rezultate kao nelinearni model.

Maksimalna vrednost turbulentne kinetičke energije menja se sa promenom položaja proširenja poprečnog preseka kanala (TKE raste sa povećanjem rastojanja proširenja od početka kanala). Linearni model daje značajno manje vrednosti TKE u odnosu na nelinearni model.

Modeliranje turbulencije

Zaključak

Nelinearni model u svim varijantama daje izraženije oscilacije linije nivoa i turbulenciju tokom celog trajanja simulacije.

U linearnom modelu tečenje se ranije umiri.

Linearni model zahteva skraćenje vremenskog koraka radi postizanja stabilnosti proračuna, što vodi do dužih proračuna i većih datoteka koje otežavaju analizu, grafički prikaz i prebacivanje rezultata u drugi program radi dalje obrade.

Smanjenjem veličine mreže u x pravcu postiže se finija diskretizacija proračunskog prostora, ali se ujedno mora smanjiti vremenski korak proračuna. Rezultati linearnog modela u tom slučaju znatno bolje oponašaju rezultate nelinearnog modela, ali je proračun umesto 30 min trajao 4,5 h.

Modeliranje turbulencije u pravougaonom kanalu

Hvala na pažnji