Mehanika fluida – Napredni kurs

Modeliranje turbulencije u pravougaonom kanalu

Softver: iRIC

Solver: NaysCUBE

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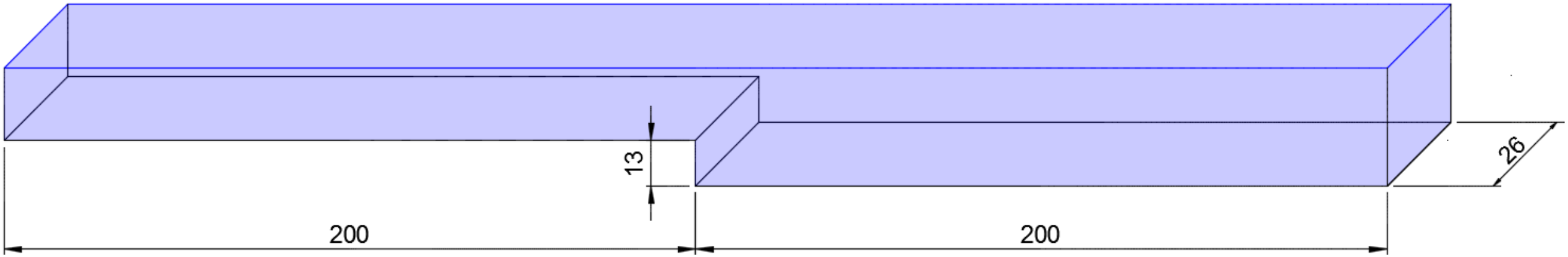
Modeliranje turbulencije

Ulazni podaci

Dužina kanala	L = 4,0 m
Širina kanala	b = 0,26 m
Spuštanje dna	Δ = 0,13 m



Modeliranje turbulencije

Ulazni podaci

Protok	$Q = 20$ L/s
Položaj proširenja poprečnog preseka	$x_1 = 1$ m
	$x_2 = 2$ m
	$x_3 = 3$ m
Nizvodna dubina	$h = ?$

Modeliranje turbulencije

Formiranje proračunske mreže

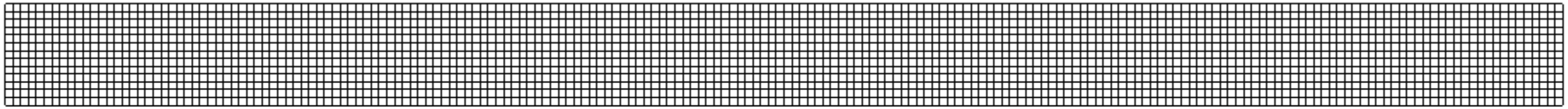
Multifunction Grid Generator

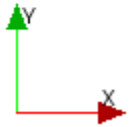
Wave Length of Meander(m)	4
Wave Number	1
Meander Angle(degree)	0
Number of Grids in One Wave Length	200

Single Cross Section

Width(m)	0.26
Number of Grid in Lateral Direction	13

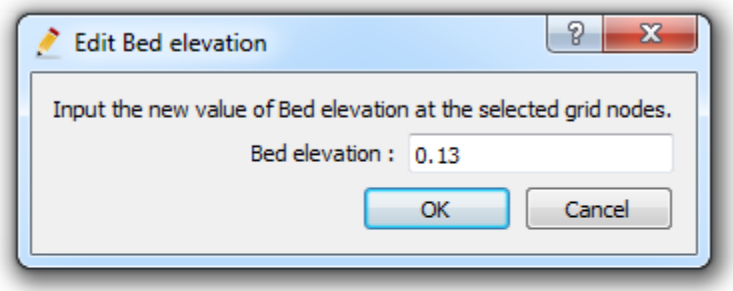
Veličina ćelija 2 x 2 cm (kvadratna mreža)

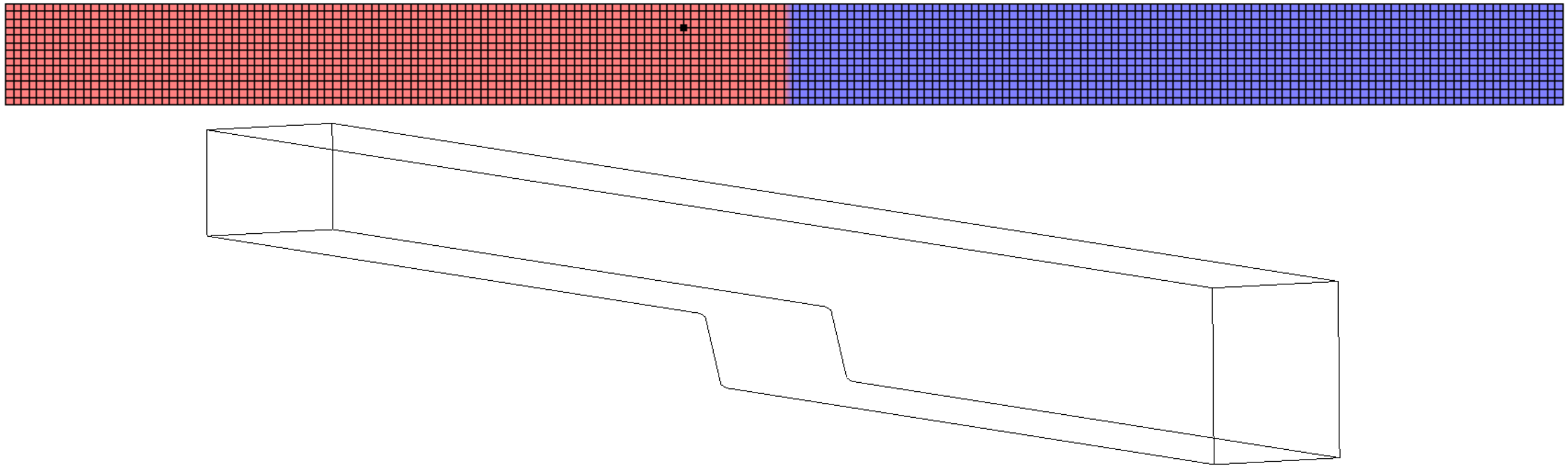




Modeliranje turbulencije

Zadavanje kota dna

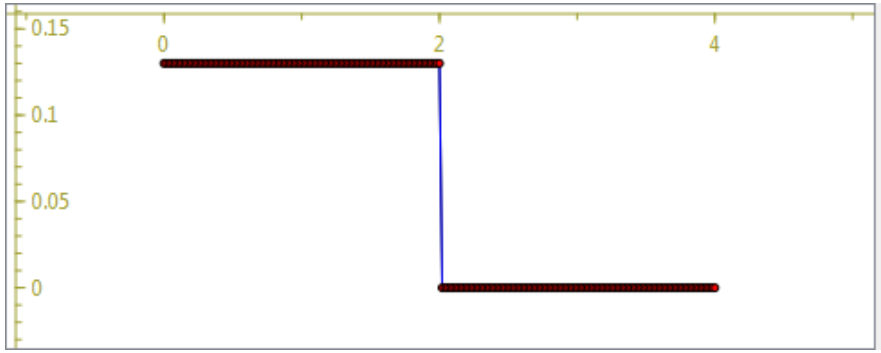




Modeliranje turbulencije

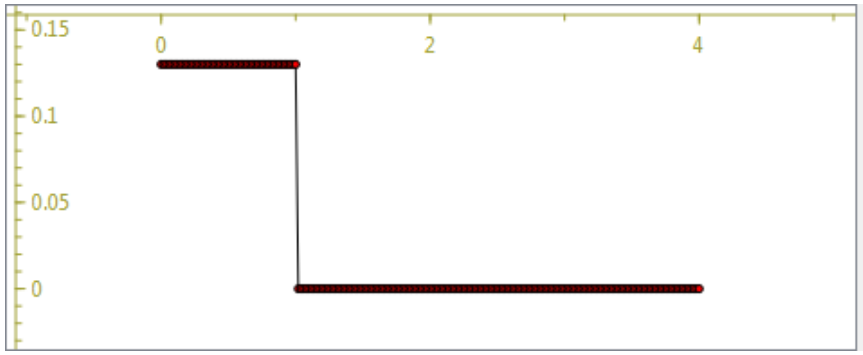
Zadavanje kota dna

X_1 = 2 m



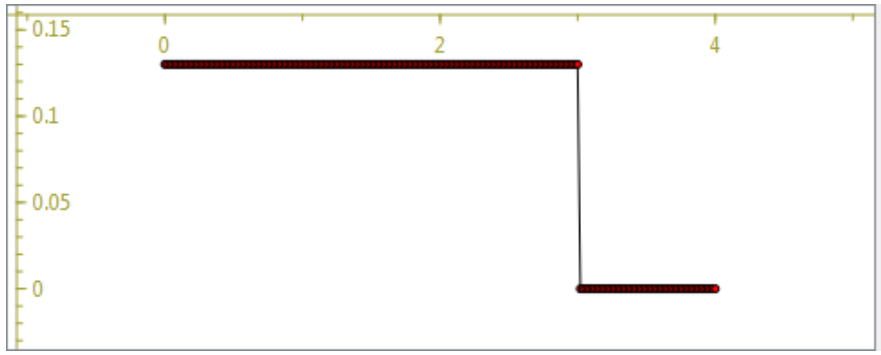
	Bed elevation
(98, 1)	0.13
(99, 1)	0.13
(100, 1)	0.13
(101, 1)	0.13
(102, 1)	0
(103, 1)	0
(104, 1)	0
(105, 1)	0

X_2 = 1 m



	Bed elevation
(47, 1)	0.13
(48, 1)	0.13
(49, 1)	0.13
(50, 1)	0.13
(51, 1)	0.13
(52, 1)	0
(53, 1)	0
(54, 1)	0

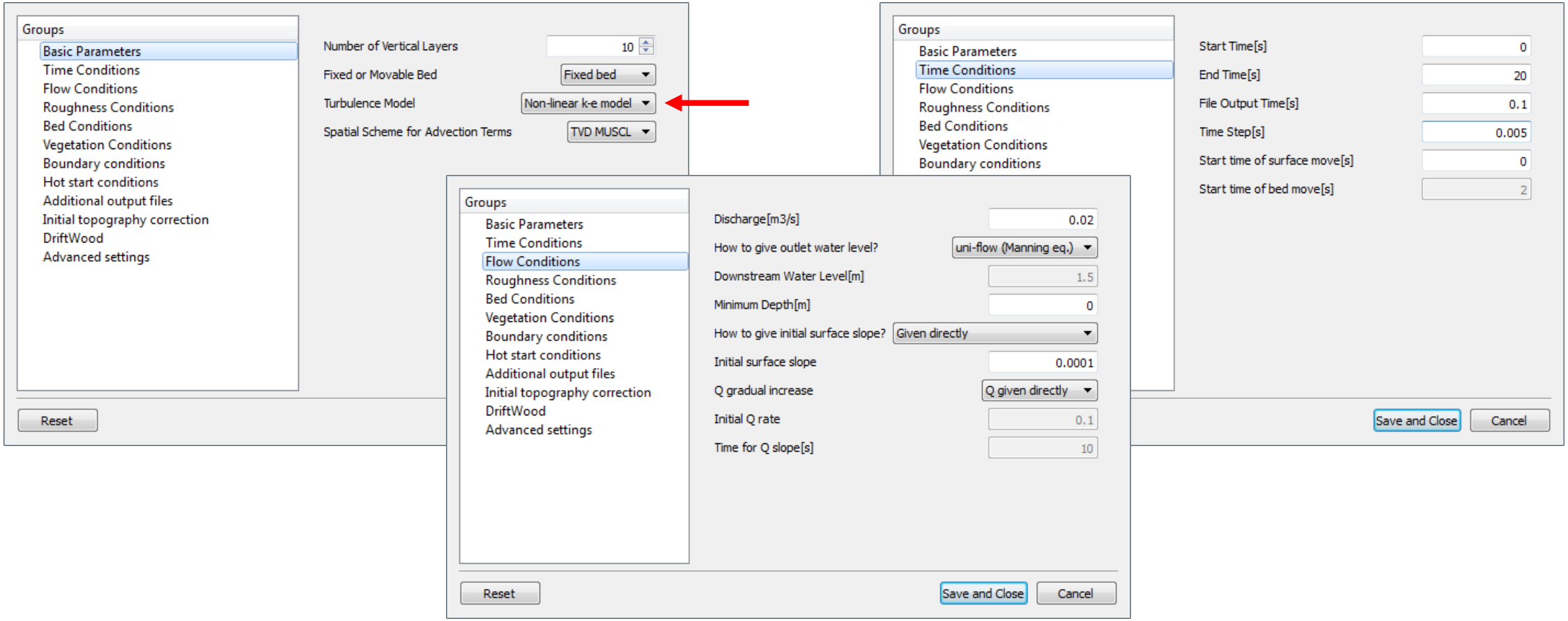
X_3 = 3 m



	Bed elevation
(148, 1)	0.13
(149, 1)	0.13
(150, 1)	0.13
(151, 1)	0.13
(152, 1)	0
(153, 1)	0
(154, 1)	0
(155, 1)	0

Modeliranje turbulencije

Parametri proračuna



Modeliranje turbulencije

Parametri proračuna

Linearni k-ε model

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

Nelinearni k-ε model

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

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

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

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

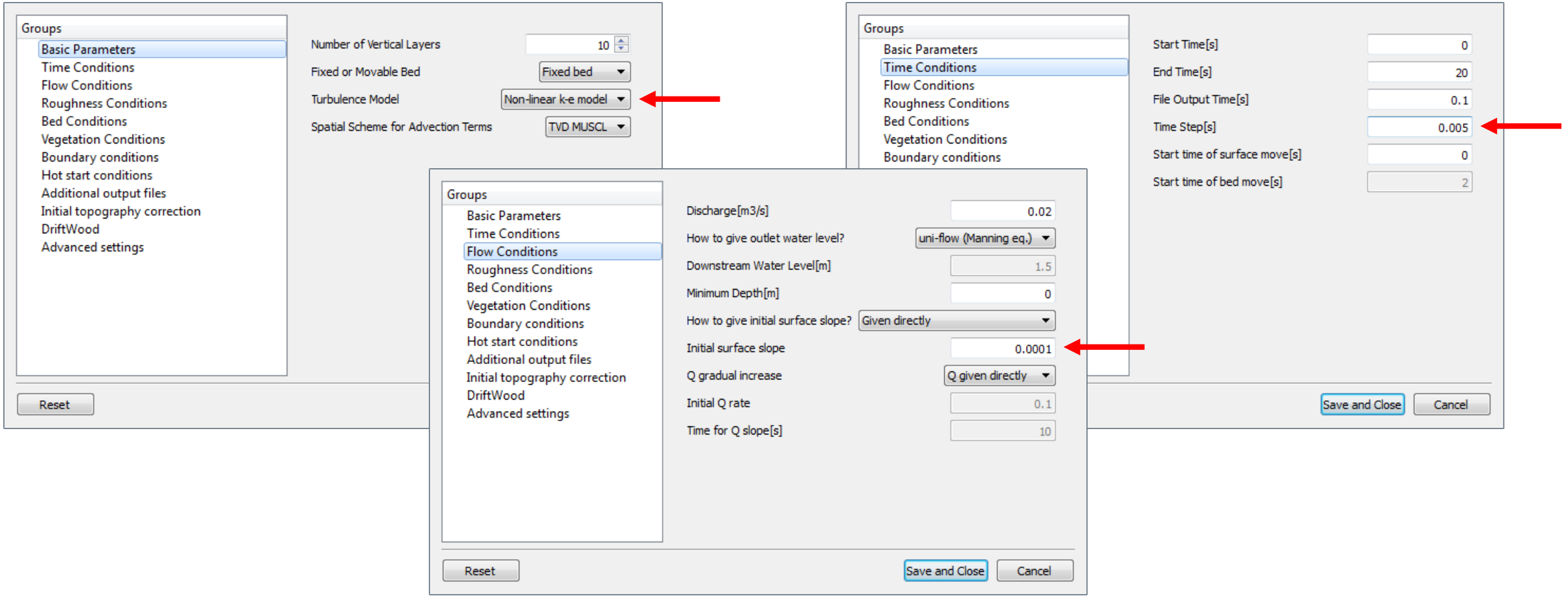
$$C_\mu = c_{\mu o}\ (1 + c_{ns} S^2 + c_{n\Omega}\Omega^2) / D_\mu$$

$$D_\mu = 1 + c_{ds} S^2 + c_{d\Omega}\Omega^2 + c_{ds\Omega} S\Omega + c_{ds1} S^4 + c_{d\Omega 1}\Omega^4 + c_{ds\Omega 1} S^2\Omega^2$$

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

Modeliranje turbulencije

Parametri proračuna

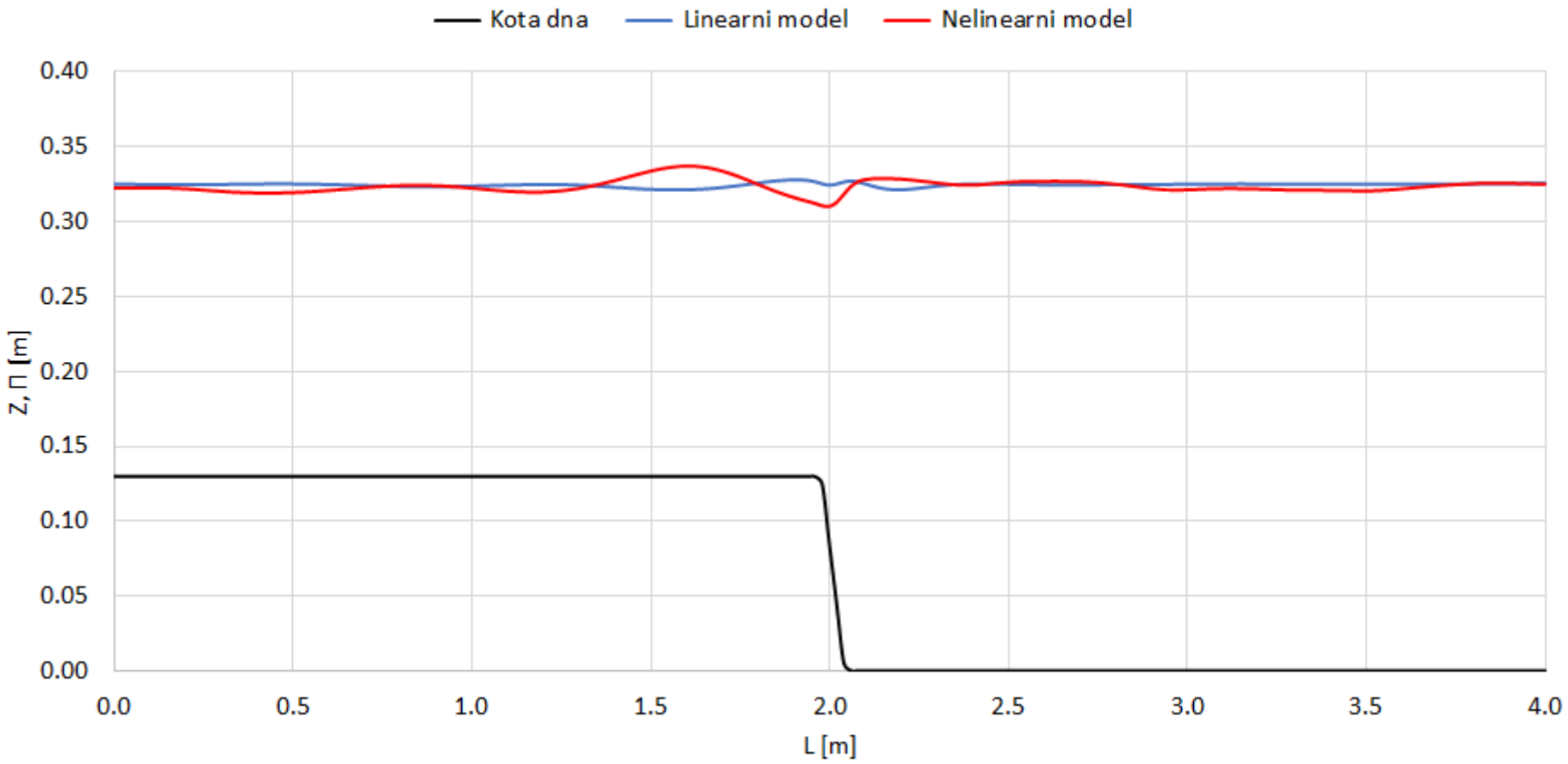


Modeliranje turbulencije

Rezultati proračuna – linija nivoa

X_2 = 2 m

t = 18 s

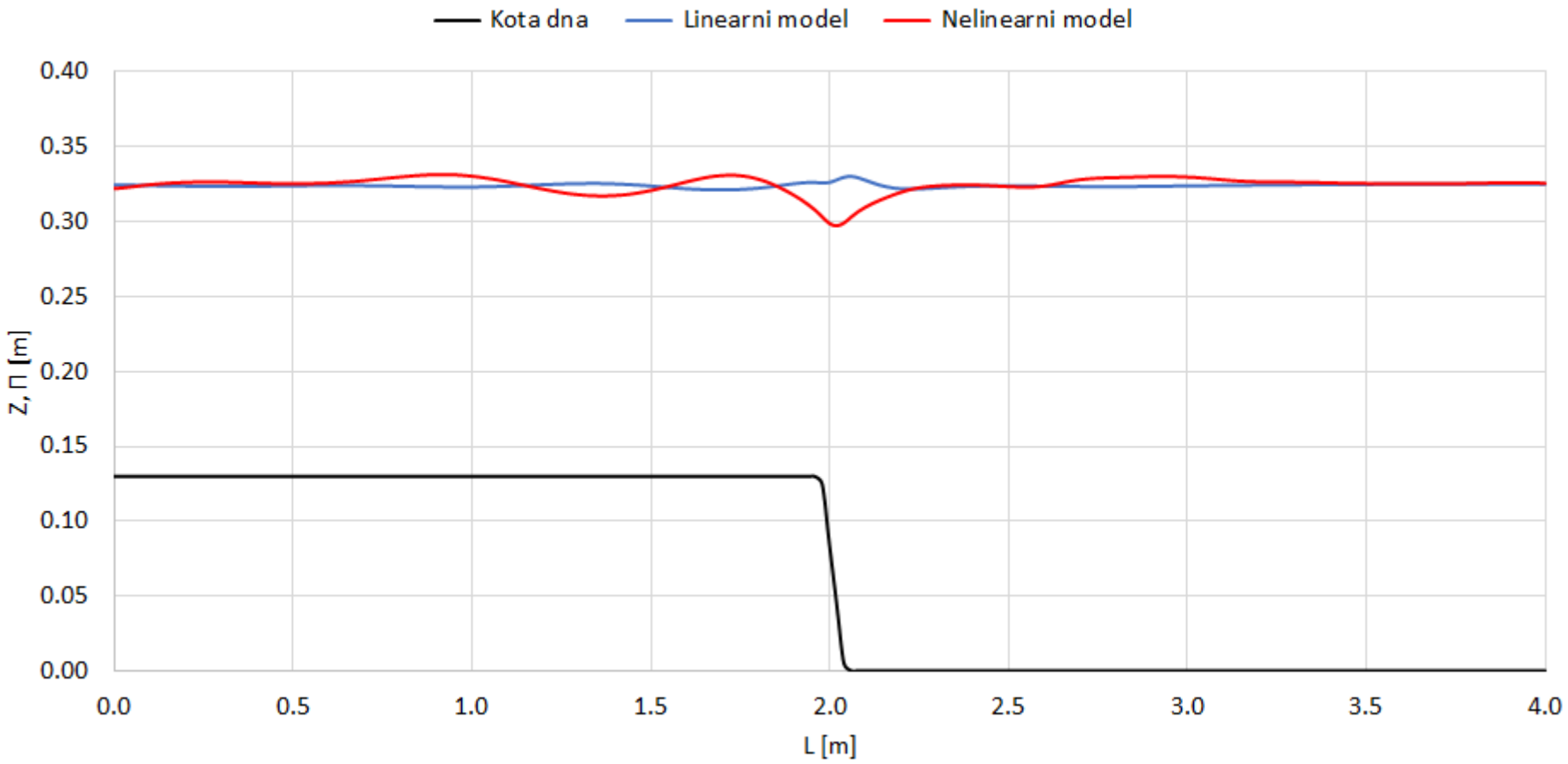


Modeliranje turbulencije

Rezultati proračuna – linija nivoa

X_2 = 2 m

t = 19 s

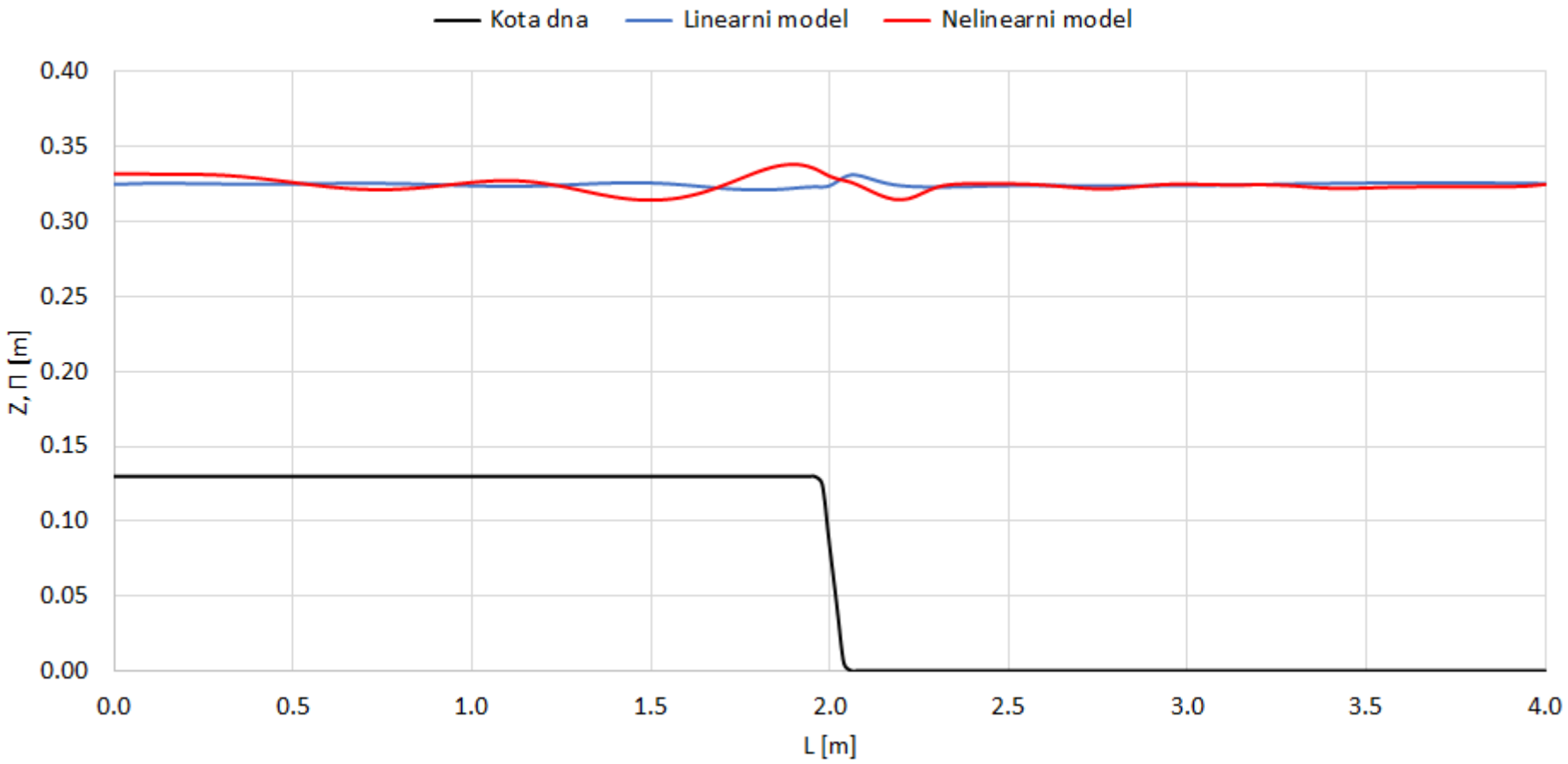


Modeliranje turbulencije

Rezultati proračuna – linija nivoa

X_2 = 2 m

t = 20 s

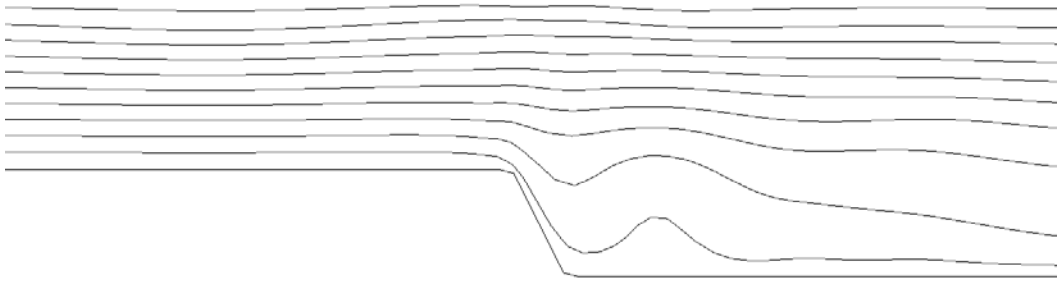


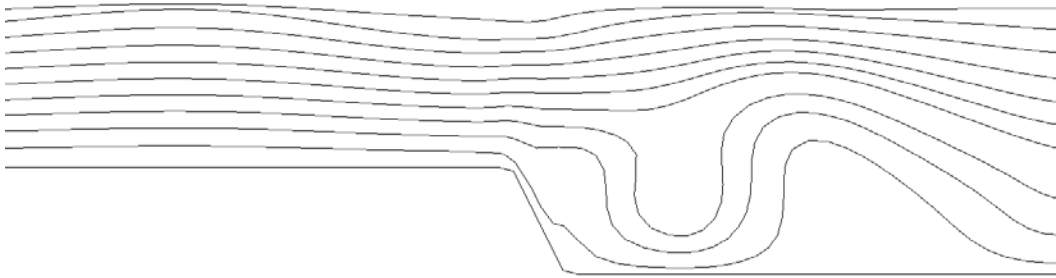
Modeliranje turbulencije

Rezultati proračuna – strujne linije

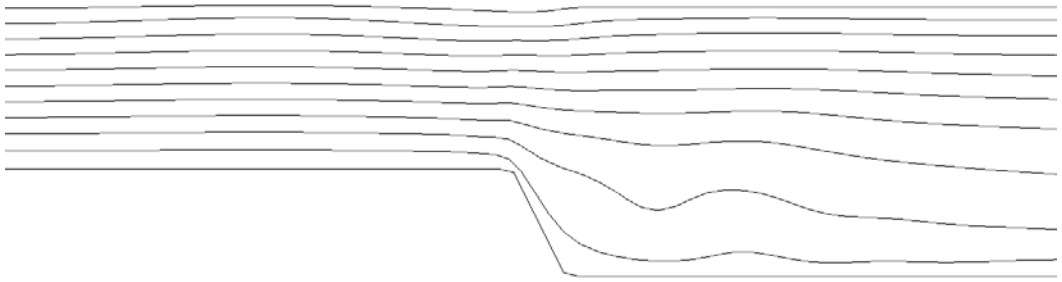
X_2 = 2 m

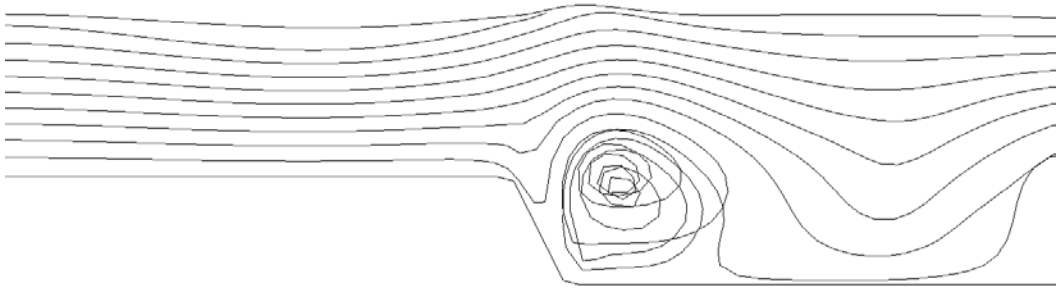
t = 15,5 s





t = 19,6 s





Linearni model

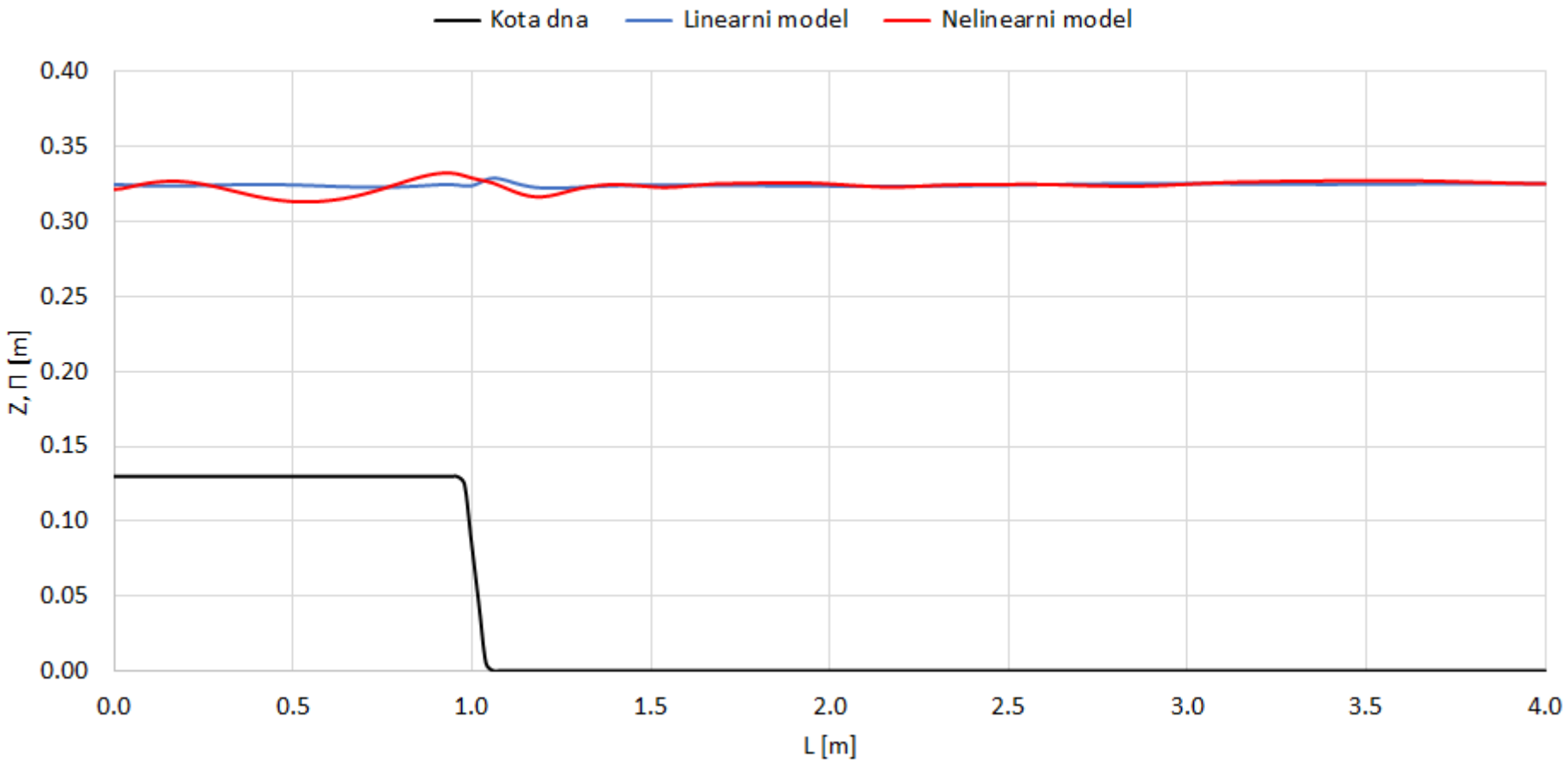
Nelinearni model

Modeliranje turbulencije

Rezultati proračuna - linija nivoa

X_1 = 1 m

t = 20 s

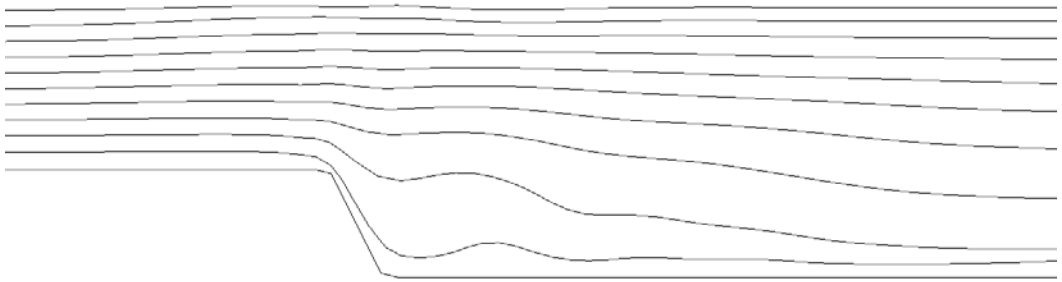


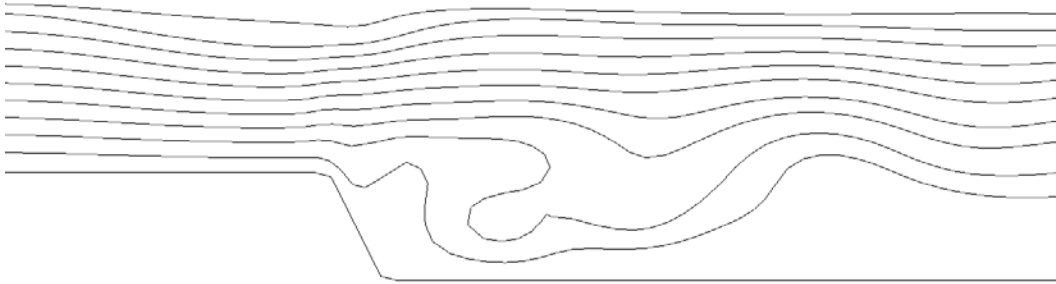
Modeliranje turbulencije

Rezultati proračuna – strujne linije

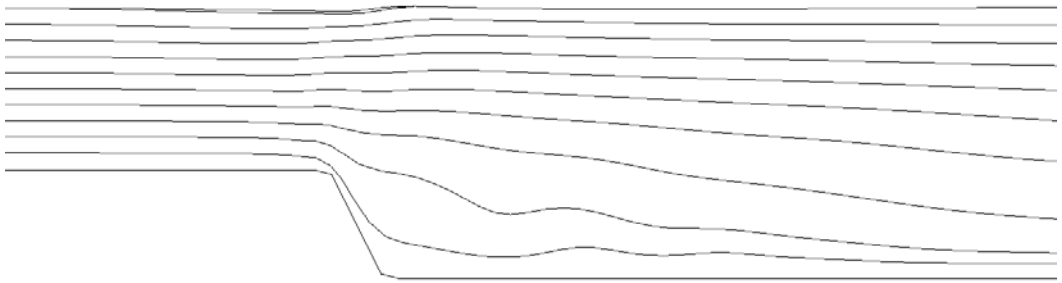
X_2 = 2 m

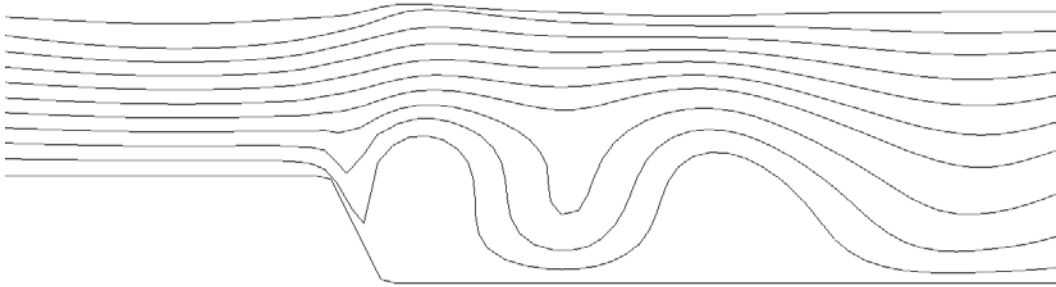
t = 15,5 s





t = 19,6 s





Linearni model

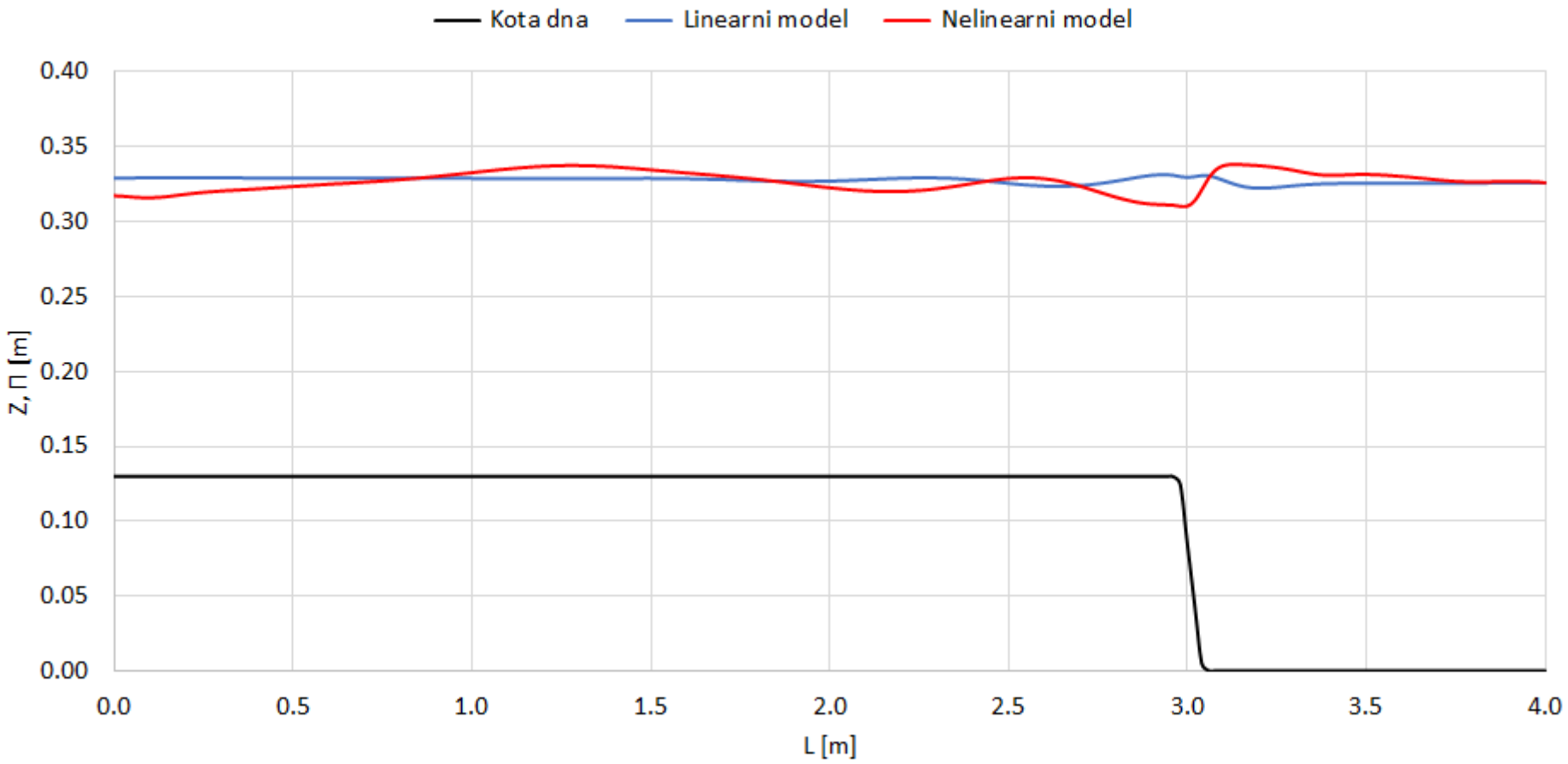
Nelinearni model

Modeliranje turbulencije

Rezultati proračuna – linija nivoa

X_3 = 3 m

t = 20 s

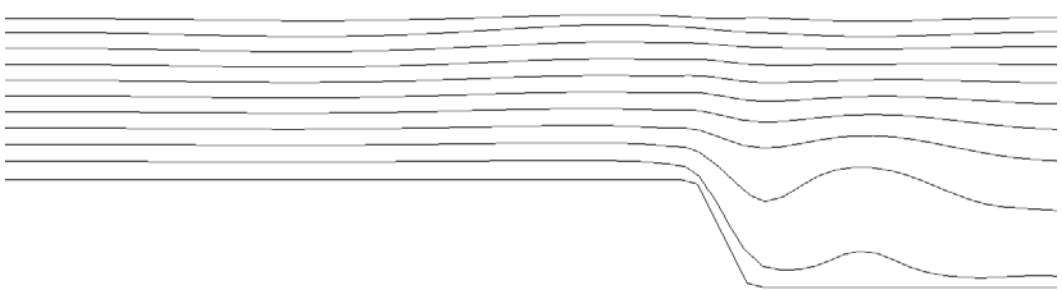


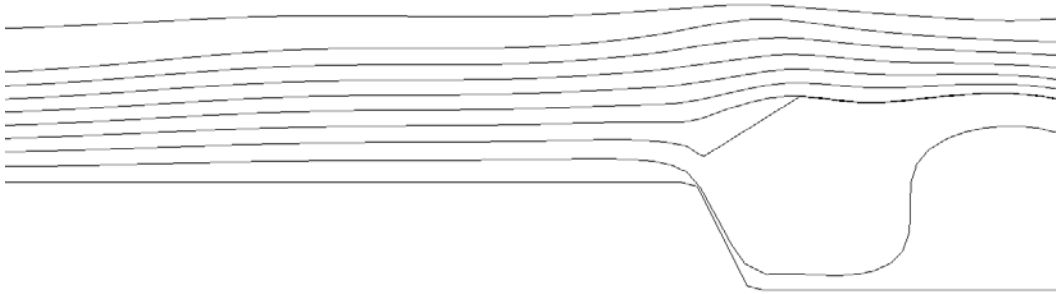
Modeliranje turbulencije

Rezultati proračuna – strujne linije

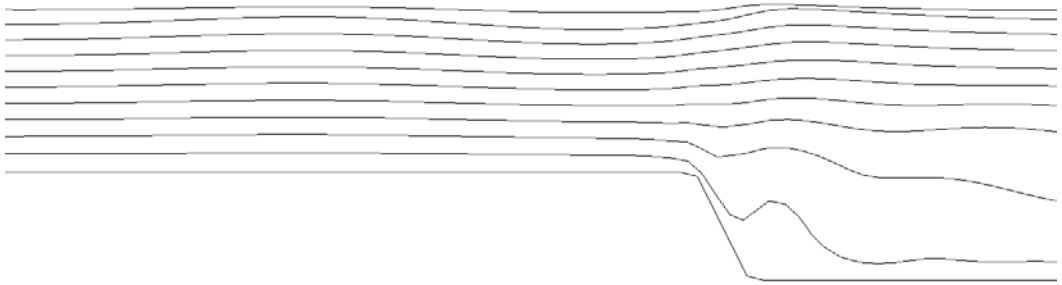
X_2 = 2 m

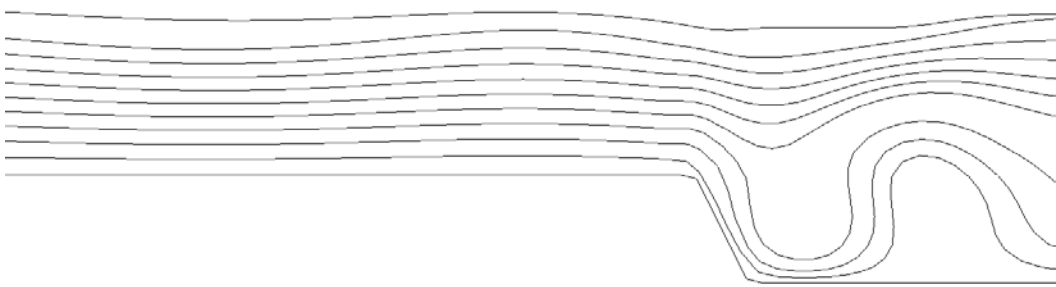
t = 15,5 s





t = 19,6 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)

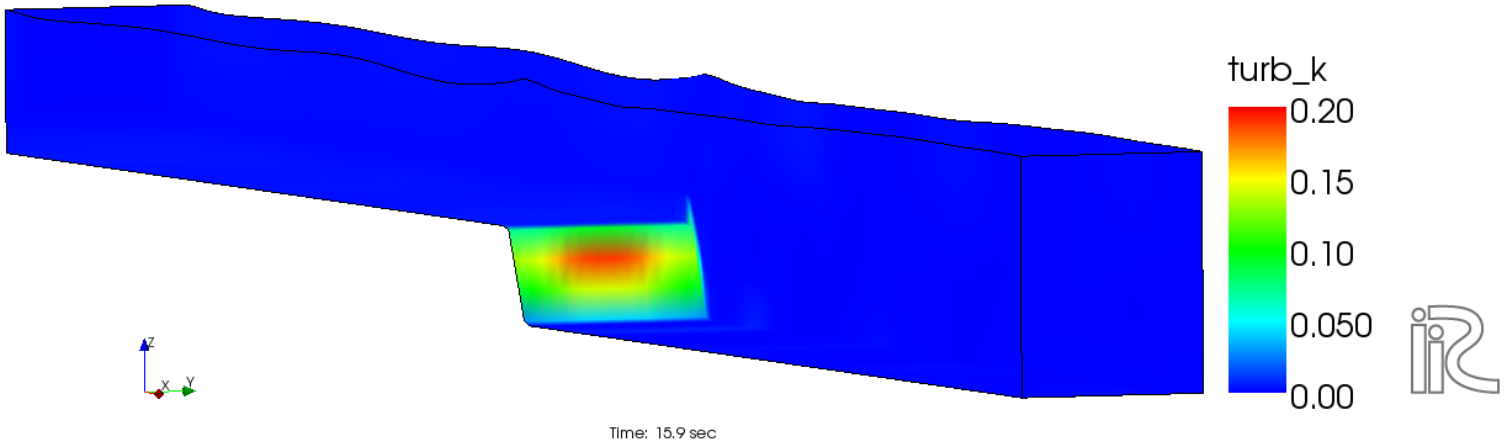
L [m]	x_1	x_2	x_3
0	45,1 – 48,2	44,7 – 47,8	42,3 – 49,0
1	39,5 – 74,1	39,5 – 55,6	35,2 – 57,2
2	26,5 – 54,9	39,4 – 81,5	40,8 – 59,9
3	25,8 – 46,4	26,8 – 55,1	38,4 – 83,2
4	22,6 – 36,3	24,3 – 47,6	24,9 – 59,7

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

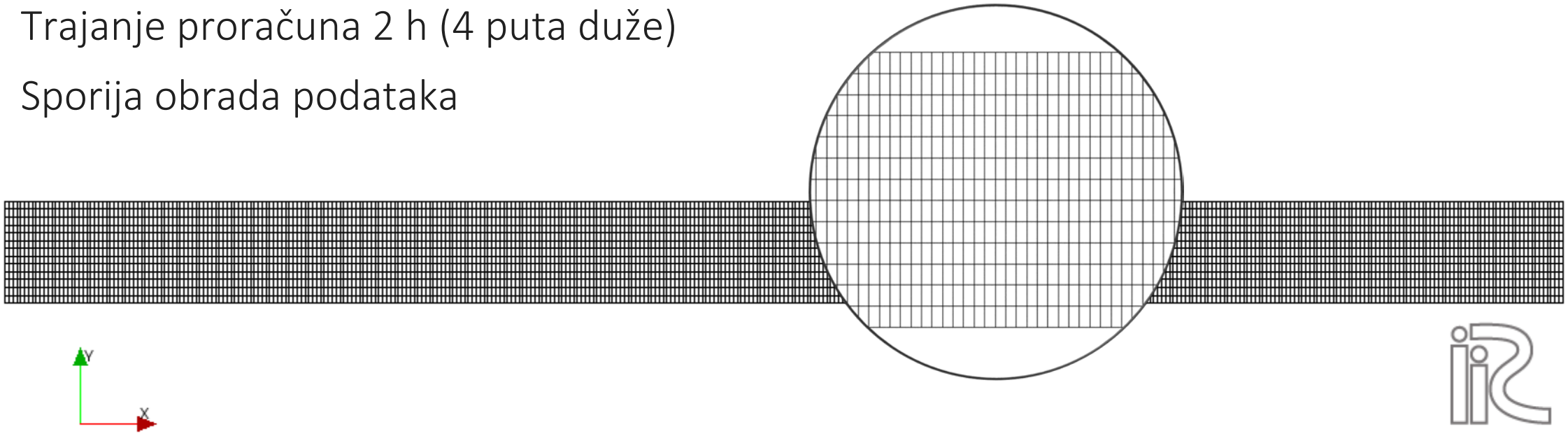
Formiranje proračunske mreže

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

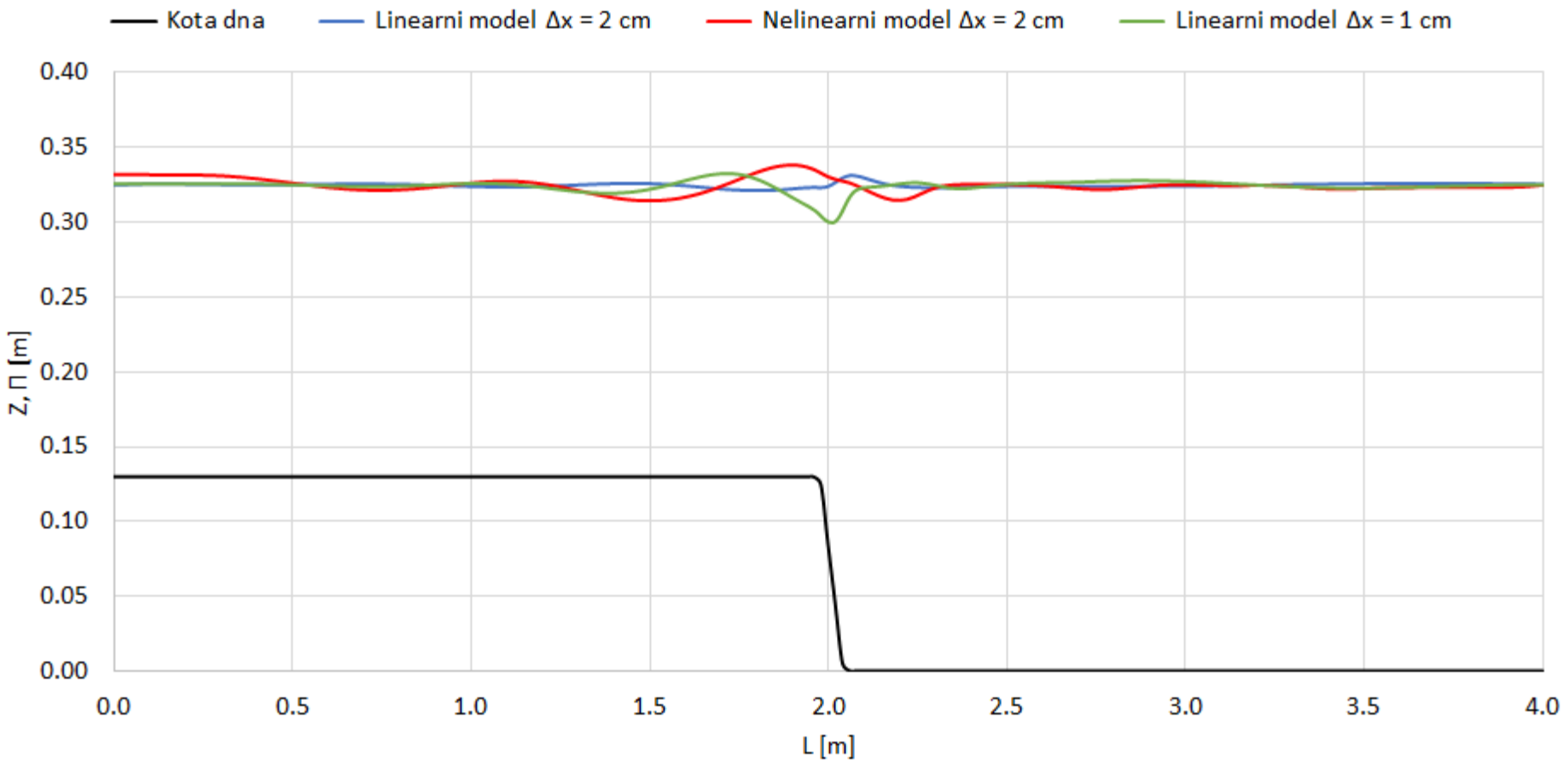


Modeliranje turbulencije

Rezultati proračuna - linija nivoa

X_2 = 2 m

t = 20 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