พฤติกรรมทางชลศาสตร์และแนวทางการออกแบบเขื่อนกันตลิ่ง

HYDRAULICS BEHAVIOR AND DESIGN CONCEPTUAL OF SPUR DIKE

สนิท วงษา

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Outlines

- Introduction
- Governing Equations
- CIP Method
- Results
- Design Conceptual

Ushitsu River, Shikoku, Japan

Introduction

Snow Festival, 2004

Spur Dike

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Spur Dike

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Governing Equation

Snow Festival, 2004

Cartesian coordinate system

Continuity eq.

$$\frac{\partial h}{\partial t}+\frac{\partial\left(hu\right)}{\partial x}+\frac{\partial\left(hv\right)}{\partial y}=0$$

Momentum eq.

$$\frac{\partial\left(hu\right)}{\partial t}+\frac{\partial\left(hu^{2}\right)}{\partial x}+\frac{\partial\left(huv\right)}{\partial y}=-gh\frac{\partial H}{\partial x}-\frac{\tau_{bx}}{\rho}+\frac{\partial}{\partial x}\left[\nu\frac{\partial\left(hu\right)}{\partial x}\right]+\frac{\partial}{\partial y}\left[\nu\frac{\partial\left(hu\right)}{\partial y}\right]$$

$$\frac{\partial\left(hv\right)}{\partial t}+\frac{\partial\left(huv\right)}{\partial x}+\frac{\partial\left(hv^{2}\right)}{\partial y}=-gh\frac{\partial H}{\partial y}-\frac{\tau_{by}}{\rho}+\frac{\partial}{\partial x}\left[\nu\frac{\partial\left(hv\right)}{\partial x}\right]+\frac{\partial}{\partial y}\left[\nu\frac{\partial\left(hv\right)}{\partial y}\right]$$

where h= water depth, u, v= average velocity, τ_b=shear stress, ρ=water density, H= water surface elevation (=z_b+h), z_b=bed elevation, ν= eddy viscosity, t=time, and x, y= spatial coordinate in Cartesian coordinate system.

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Cartesian coordinate system

Bed shear stress

$$\tau_{bx} = \rho C_f u \sqrt{u^2 + v^2} \qquad \tau_{by} = \rho C_f v \sqrt{u^2 + v^2}$$

Eddy viscosity

$$\nu = \frac{\kappa}{6} u_* h$$

Shear velocity

$$u_* = C_f \sqrt{u^2 + v^2}$$

where C_f=bed friction coefficient, κ=Karman's constant, u_*=shear velocity

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Cartesian coordinate system

Bedload eq.

Kavacs&Parker eq.

$$q_{bx} = \frac{17}{\cos\theta_b} \tau_*^{3/2} \left(1 - \frac{\tau_{*c}}{\tau_*}\right) \left[1 - \sqrt{\frac{2\tau_{*c} \cos\theta_b}{\tau_*}}\right] + 2\left(\tan\theta_b - \frac{\partial z_b}{\partial s}\right)\sqrt{sgd^3}$$

Hasegawa eq.

$$\frac{q_{by}}{\sqrt{sgd^3}} = q_{bx}\left(\frac{v}{u} - N_* \frac{h}{r_*} - \sqrt{\frac{\tau_{*c}}{\nu_s \nu_k \tau_*}} \frac{\partial z_b}{\partial y}\right)$$

where τ_*=non-dimensional shear stress, τ_c=critical shear stress, τ_{*c}=critical non-dimension shear stress, θ_b=bed slope, ρ_s=sediment density, s=(ρ_s/ρ-1), N_*=Engelund's constant, and r_*=radius of curvature.

$$\frac{1}{r_*} = \frac{1}{\left(u^2 + v^2\right)^{3/2}} \left\{ u\left(u\frac{\partial v}{\partial x} - v\frac{\partial u}{\partial x}\right) + v\left(u\frac{\partial v}{\partial y} - v\frac{\partial u}{\partial y}\right) \right\}$$

Cartesian coordinate system

Sediment transport eq.

$$\frac{\partial z_b}{\partial t} + \frac{1}{1-\lambda}\left[\frac{\partial q_{bx}}{\partial x} + \frac{\partial q_{by}}{\partial y}\right] = 0$$

where z_b**=bed elevation,** λ**=porosity of bed material.**

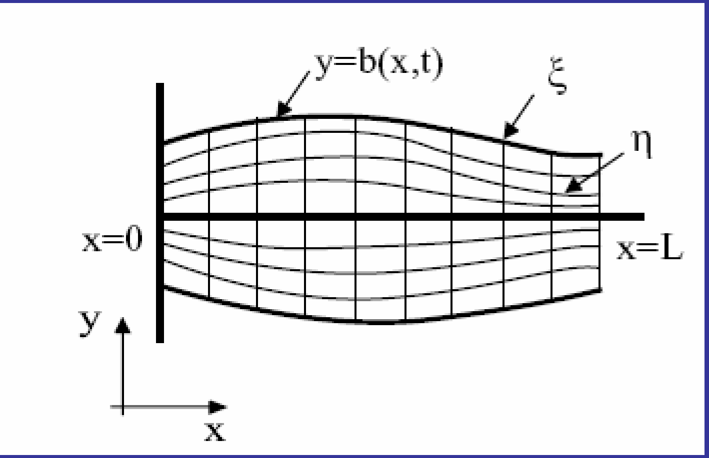
Moving boundary-fitted system

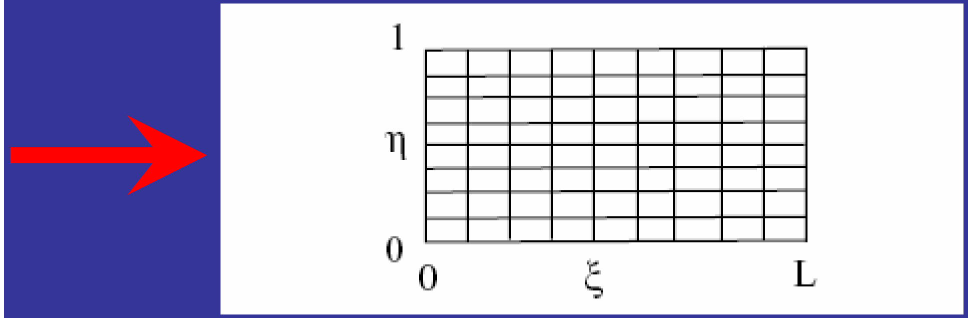
Transformed rule

$$\begin{pmatrix} \frac{\partial}{\partial t} \\ \frac{\partial}{\partial x} \\ \frac{\partial}{\partial y} \end{pmatrix} = \begin{pmatrix} \tau_t & \xi_t & \eta_t \\ \tau_x & \xi_x & \eta_x \\ \tau_y & \xi_y & \eta_y \end{pmatrix} \begin{pmatrix} \frac{\partial}{\partial \tau} \\ \frac{\partial}{\partial \xi} \\ \frac{\partial}{\partial \eta} \end{pmatrix}$$

$$\begin{pmatrix} u \\ v \end{pmatrix} = \frac{1}{J} \begin{pmatrix} \eta_y & -\xi_y \\ -\eta_x & \xi_x \end{pmatrix} \begin{pmatrix} u^{\xi} \\ v^{\eta} \end{pmatrix}$$

where u^{ξ}, v^{η}=average velocity components in the of ξ, η direction, τ=time, and J=Jacobian of coordinate transformed.





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Moving boundary-fitted system

Continuity eq.

$$\frac{\partial}{\partial \tau}\left(\frac{h}{J}\right)+\frac{\partial}{\partial \xi}\left[\left(\xi_t+u^{\xi}\right)\frac{h}{J}\right]+\frac{\partial}{\partial \eta}\left[\left(\eta_t+u^{\eta}\right)\frac{h}{J}\right]=0$$

Momentum eq.

$$\frac{\partial u^{\xi}}{\partial \tau}+\left(\xi_t+u^{\xi}\right)\frac{\partial u^{\xi}}{\partial \xi}+\left(\eta_t+u^{\eta}\right)\frac{\partial u^{\xi}}{\partial \eta}+\alpha_1 u^{\xi}u^{\xi}+\alpha_2 u^{\xi}u^{\eta}+\alpha_3 u^{\eta}u^{\eta}-D_{\xi}$$

$$=-g\left[\left(\xi_x^2+\xi_y^2\right)\frac{\partial H}{\partial \xi}\left(\xi_x\eta_x+\xi_y\eta_y\right)\frac{\partial H}{\partial \eta}\right]-\frac{C_f u^{\xi}}{hJ}\sqrt{\left(\eta_y u^{\xi}+\xi_y u^{\eta}\right)^2+\left(-\eta_x u^{\xi}-\xi_x u^{\eta}\right)^2}$$

$$\frac{\partial u^{\eta}}{\partial \tau}+\left(\xi_t+u^{\xi}\right)\frac{\partial u^{\eta}}{\partial \xi}+\left(\eta_t+u^{\eta}\right)\frac{\partial u^{\eta}}{\partial \eta}+\alpha_4 u^{\xi}u^{\xi}+\alpha_5 u^{\xi}u^{\eta}+\alpha_6 u^{\eta}u^{\eta}-D_{\eta}$$

$$=-g\left[\left(\eta_x^2+\eta_y^2\right)\frac{\partial H}{\partial \eta}\left(\xi_x\eta_x+\xi_y\eta_y\right)\frac{\partial H}{\partial \xi}\right]-\frac{C_f u^{\eta}}{hJ}\sqrt{\left(\eta_y u^{\xi}+\xi_y u^{\eta}\right)^2+\left(-\eta_x u^{\xi}-\xi_x u^{\eta}\right)^2}$$

Moving boundary-fitted system

Sediment transport eq.

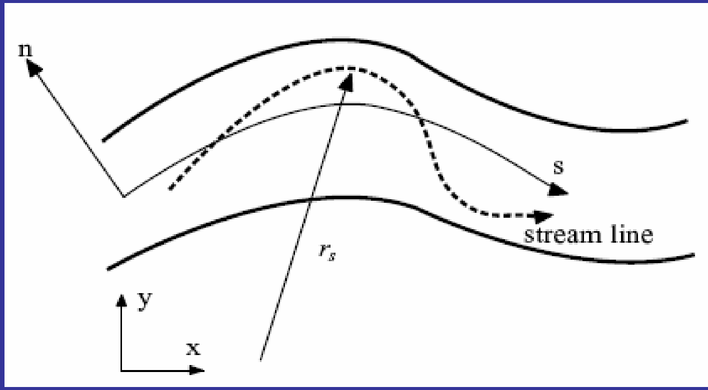
$$\frac{\partial z_b}{\partial t}+\frac{1}{1-\lambda}\left[\frac{\partial q_{bx}}{\partial x}+\frac{\partial q_{by}}{\partial y}\right]=0$$

$$\frac{\partial}{\partial \tau}\left(\frac{z_b}{J}\right)+\frac{1}{1-\lambda}\left[\frac{\partial}{\partial \xi}\left(\frac{q^{\xi}}{J}\right)+\frac{\partial}{\partial \eta}\left(\frac{q^{\eta}}{J}\right)\right]=0$$

where q^{ξ}, q^{η}=sediment transport rate components in the ξ, η direction, respectively.

$$q^{\xi}=\left(\xi_x\frac{\partial x}{\partial s}+\xi_y\frac{\partial y}{\partial s}\right)q^s+\left(\xi_x\frac{\partial x}{\partial n}+\xi_y\frac{\partial y}{\partial n}\right)q^n$$

$$q^{\eta}=\left(\eta_x\frac{\partial x}{\partial s}+\eta_y\frac{\partial y}{\partial s}\right)q^s+\left(\eta_x\frac{\partial x}{\partial n}+\eta_y\frac{\partial y}{\partial n}\right)q^n$$



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Bank erosion mechanisms

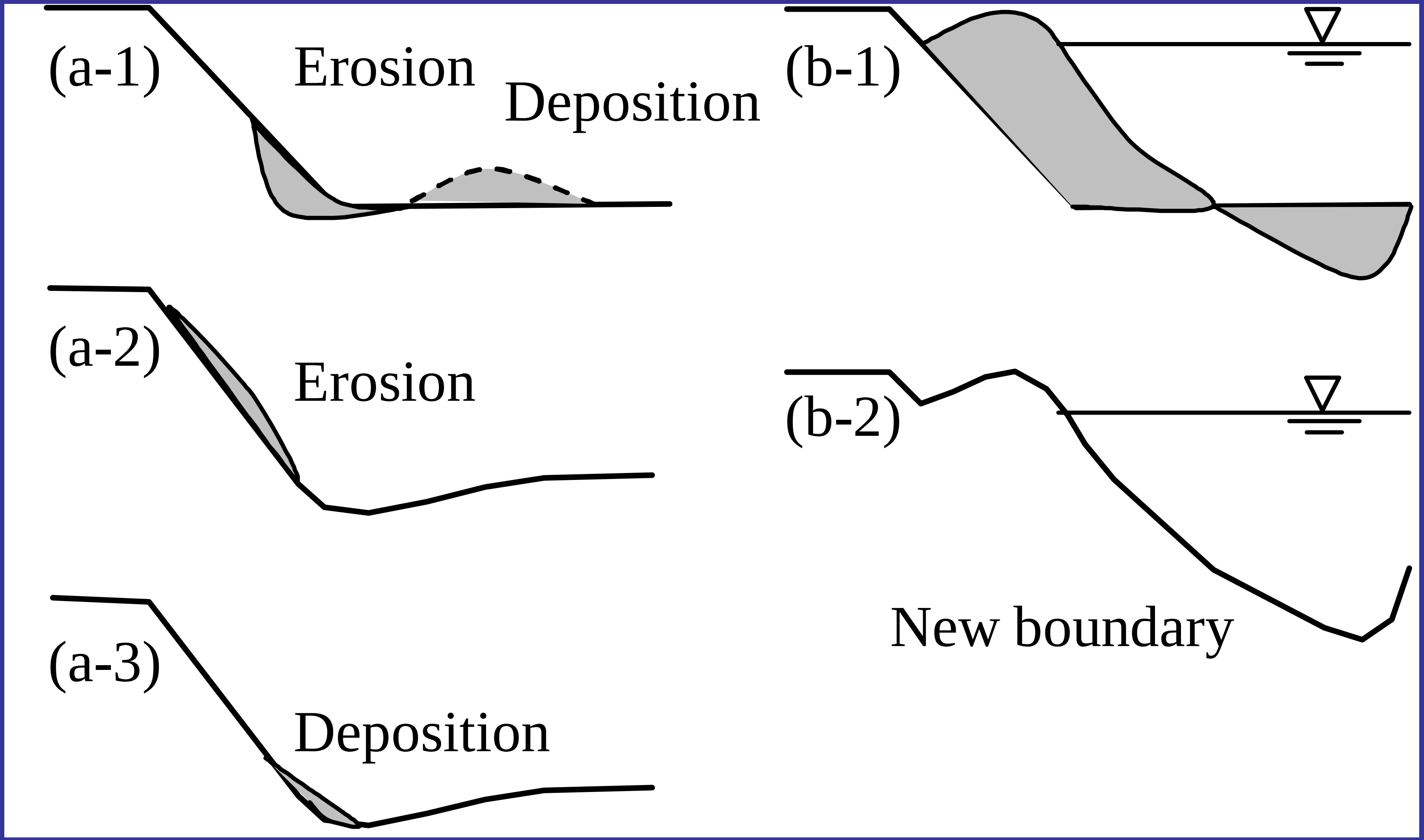

Fig. (a) bank erosion and migration, (b) bed aggradation and bank deposition.

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Bank deformation

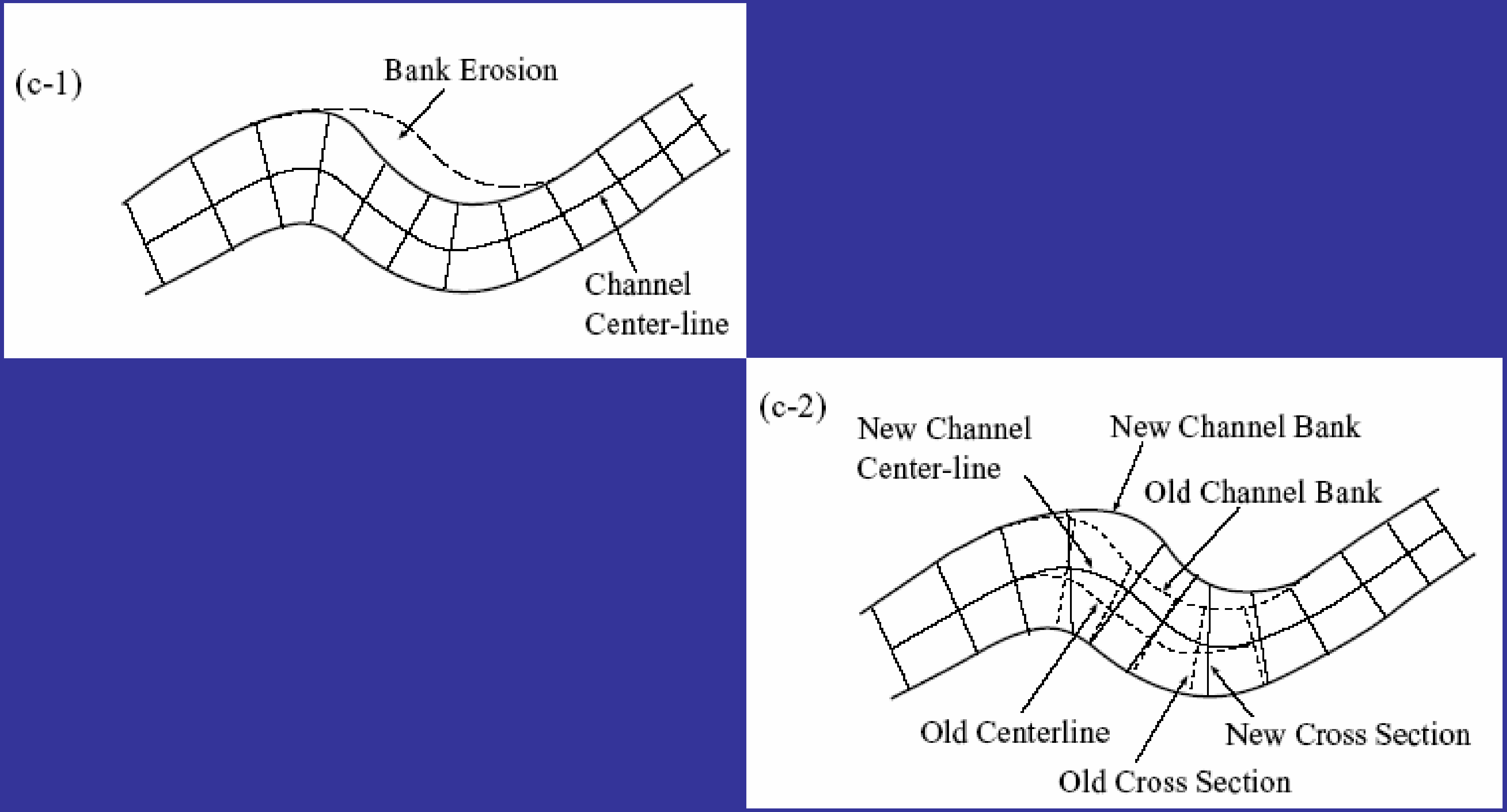

Fig. (c) bank deformation and renewal of the computational grid.

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CIP Method

Snow Festival, 2004

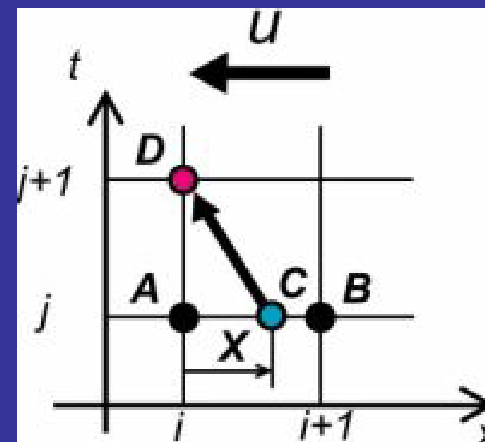
CIP method (Yabe et al., 1990)

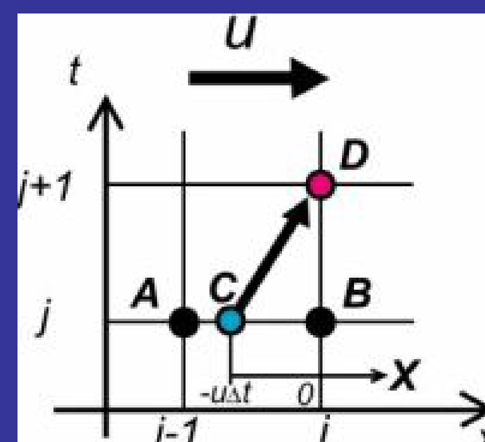
C=Cubic, I=Interpolated, P=Psuedoparticle

$$\frac{\partial h}{\partial t} + u\frac{\partial f}{\partial x} = G$$

Advection phase: $$\frac{\partial h}{\partial t} + u\frac{\partial f}{\partial x} = 0$$

Diffusion phase: $$\frac{\partial h}{\partial t} = G$$





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Results

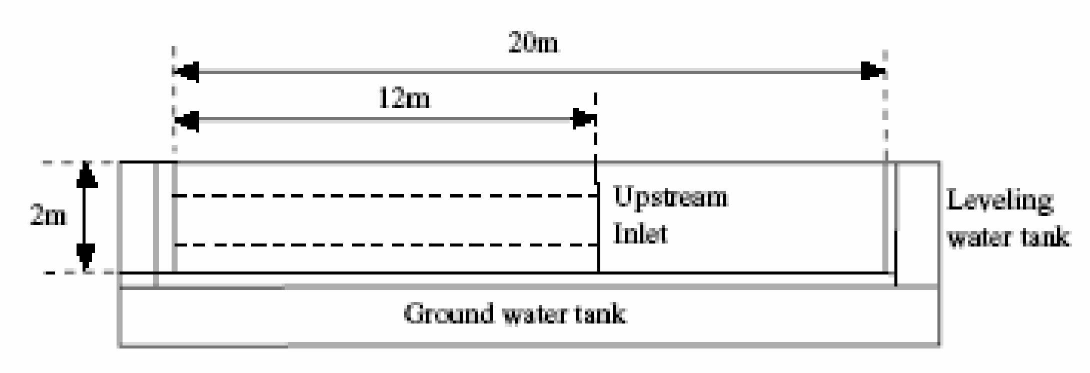
Snow Festival, 2004

Jang&Shimizu, 2003

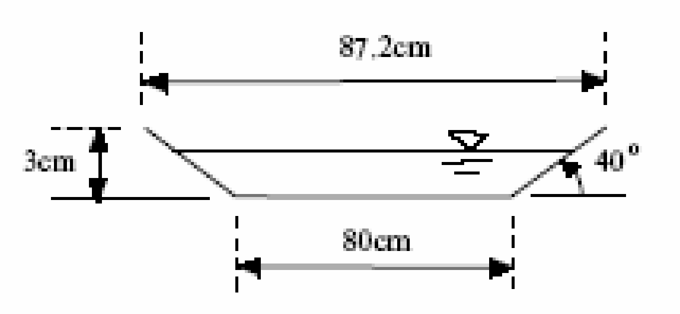
Conditions

L = 12.0 m, b = 0.80 m, q = 4.50 l/s, i = 1.0%, $\theta = 40^o$

d = 1.25 mm



Experiment



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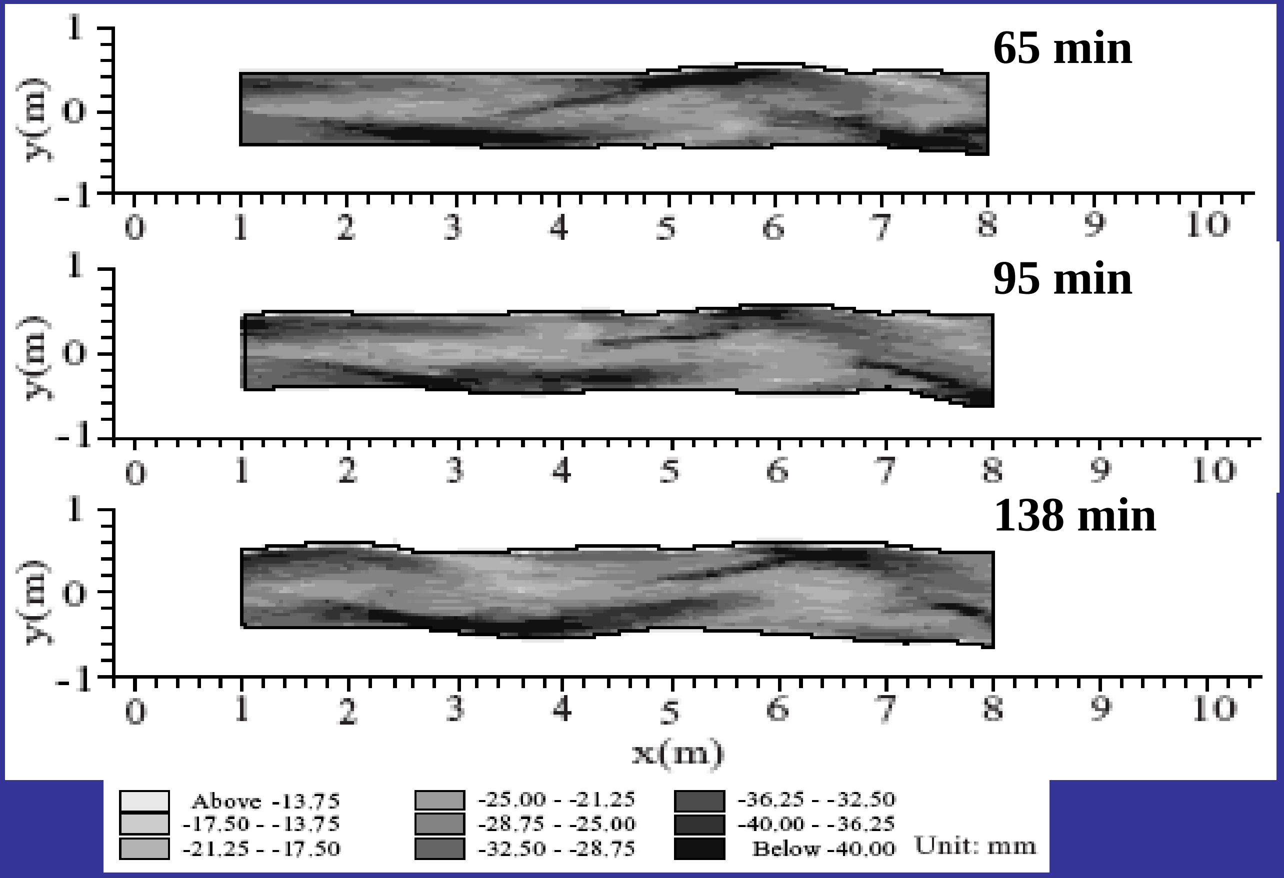
Jang&Shimizu, 2003

Experiment Results



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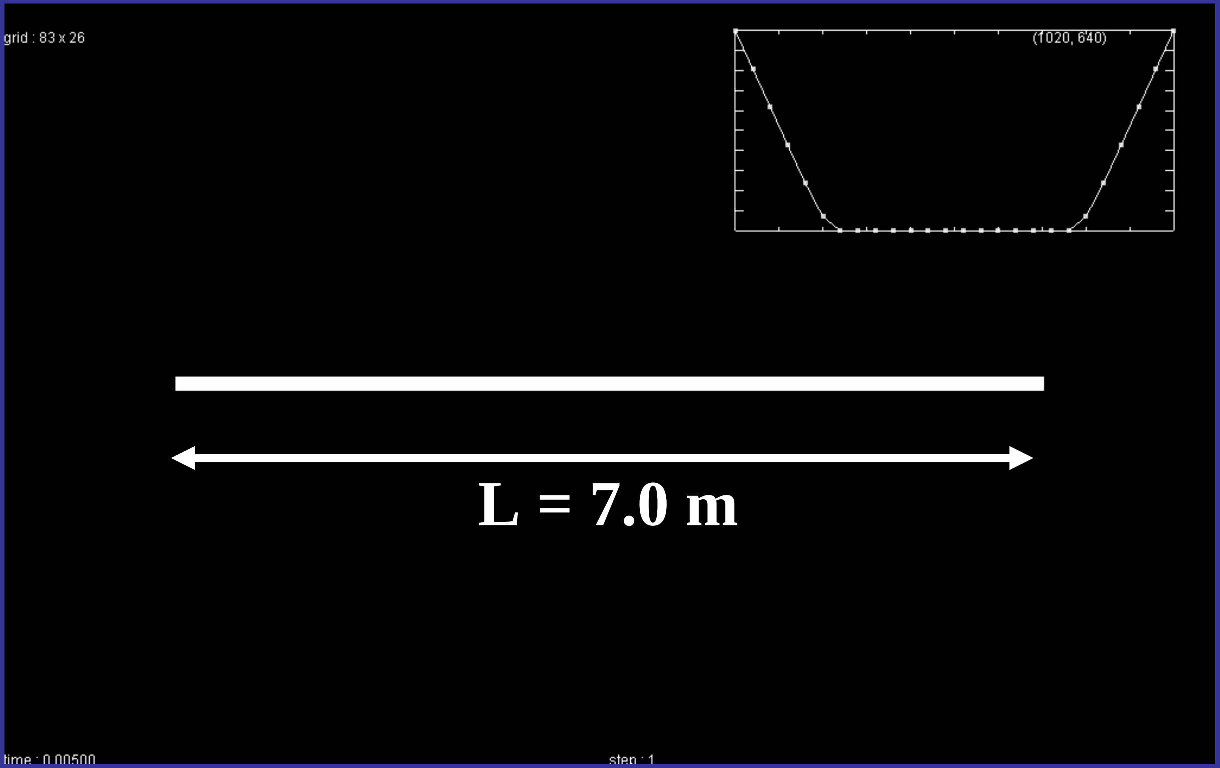
Jang&Shimizu, 2003

Conditions

L = 12.0 m, b = 0.80 m, q = 4.50 l/s, i = 1.0%

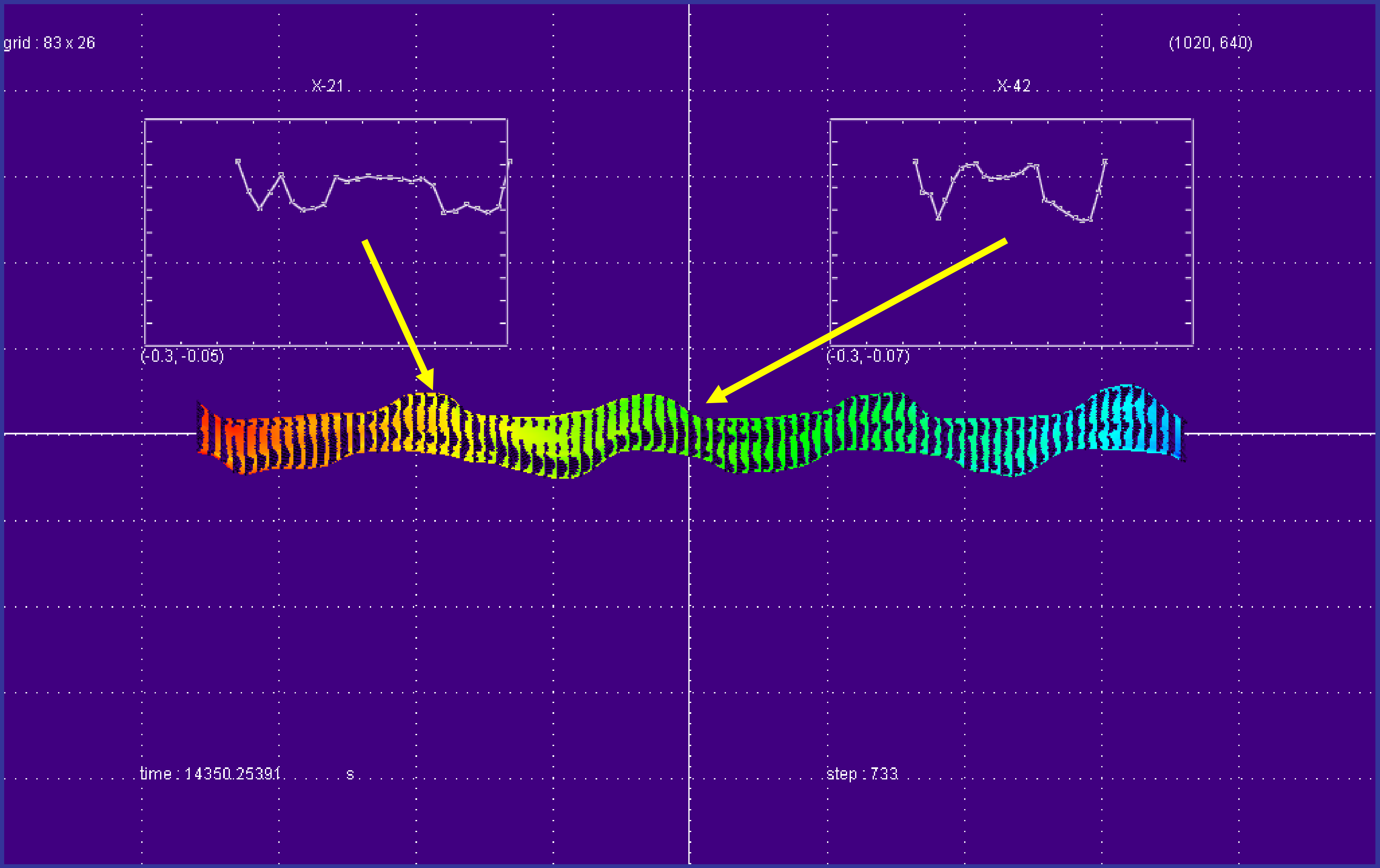
nx = 83, ny = 26, Δx = 0.1463 m, Δy = 0.0038 m, Δt = 0.005 s,

d = 1.25 mm



Initial grid

Flow vector and bank deformation

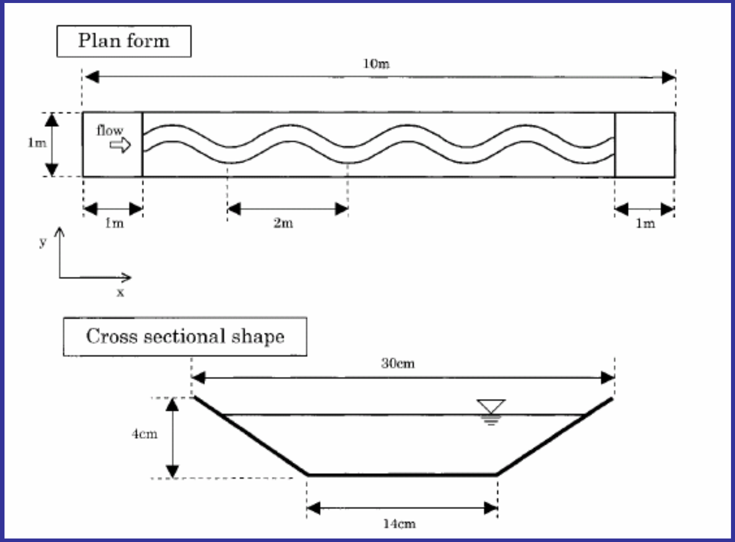


Run3- Nagata et al., 2000

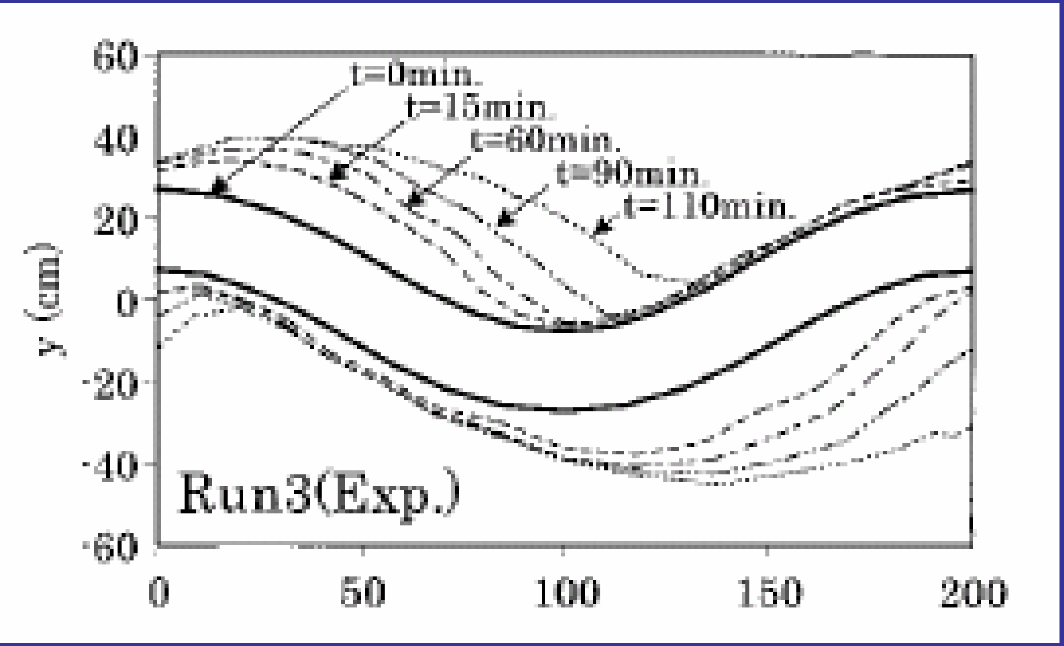
Conditions

L = 10.0 m, *B* = 0.30 m, *q* = 1.98 l/s, *i* = 1.0%

d = 1.42 mm



Experiment



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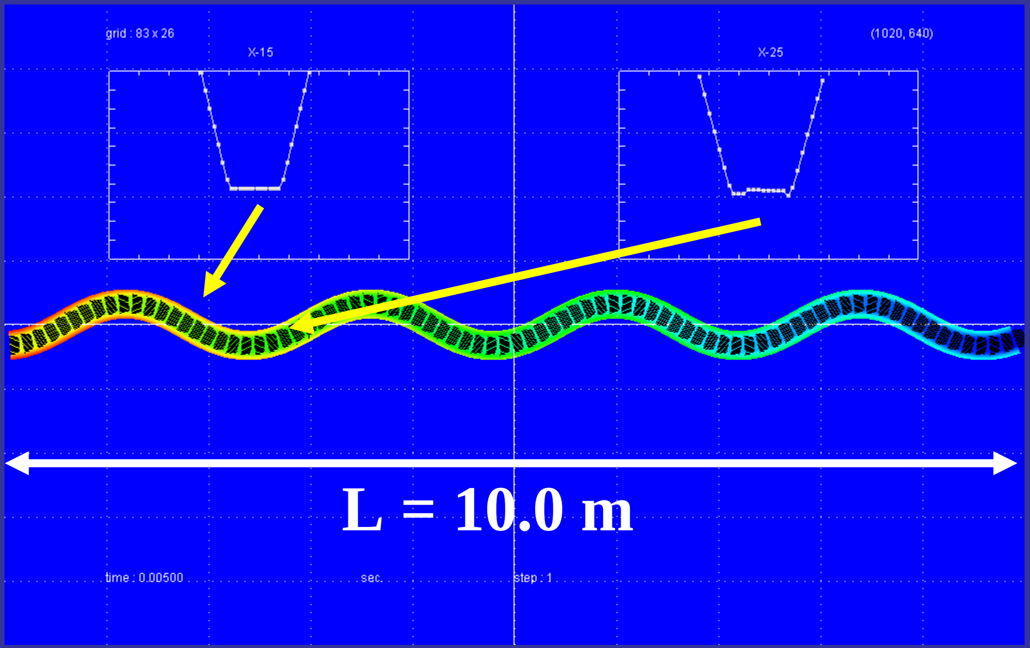
Run3- Nagata et al., 2000

Conditions

L = 10.0 m, B = 0.30 m, q = 1.98 l/s, i = 1.0%

nx = 83, ny = 26, Δx = 0.128 m, Δy = 0.0054 m, Δt = 0.005 s,

d = 1.42 mm



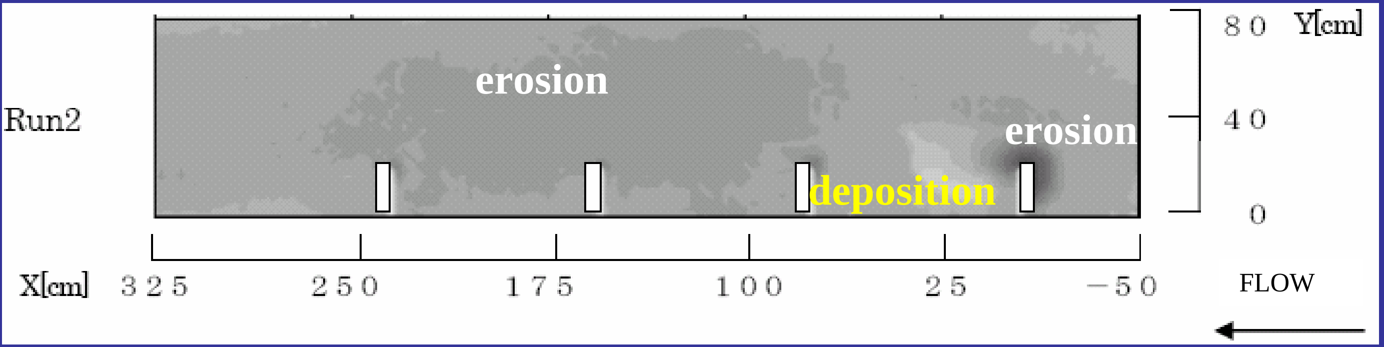
Initial grid

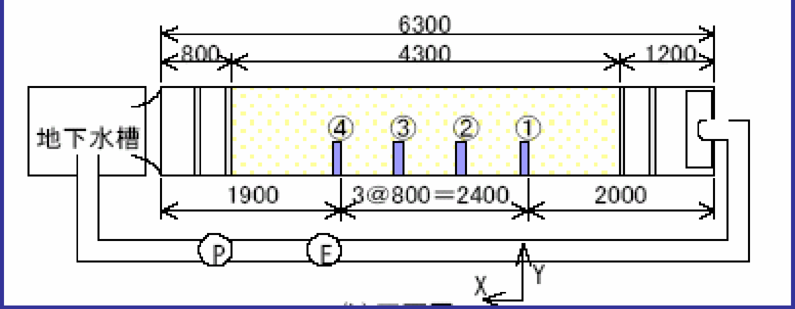
Run2- Morita et al., 2005

Conditions

L = 6.30 m, *B* = 0.80 m, *q* = 8.25 l/s, *i* = 1/2000

d = 0.88 mm





Experiment

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Run2- Morita et al., 2005

Conditions

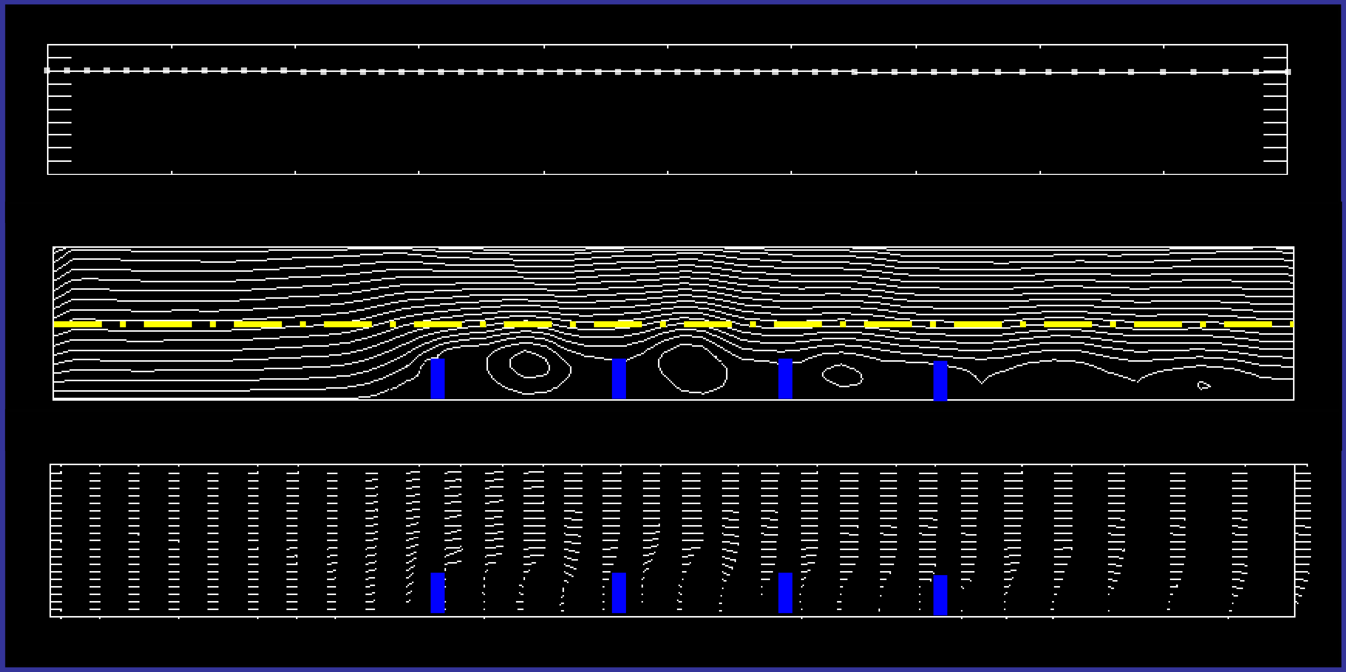
L = 6.30 m, B = 0.80 m, q = 8.25 l/s, i = 1/2000

nx = 50, ny = 20, Δx = 0.126 m, Δy = 0.04 m, Δt = 0.002 s,

Bed elevation

Streamline

Velocity vector



Initial condition

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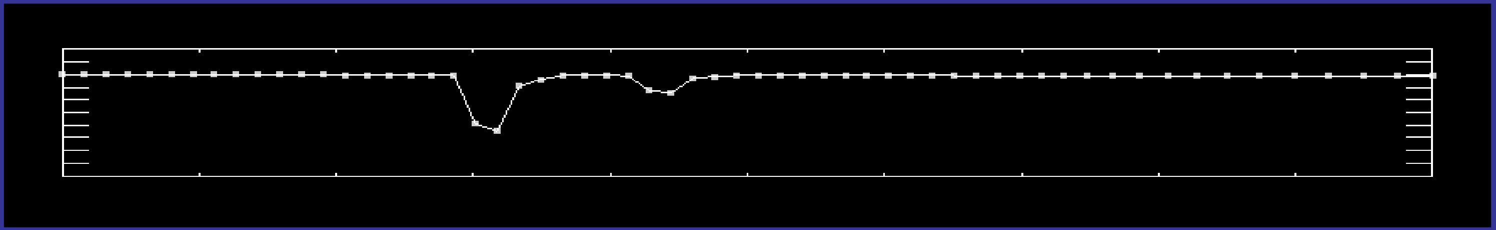
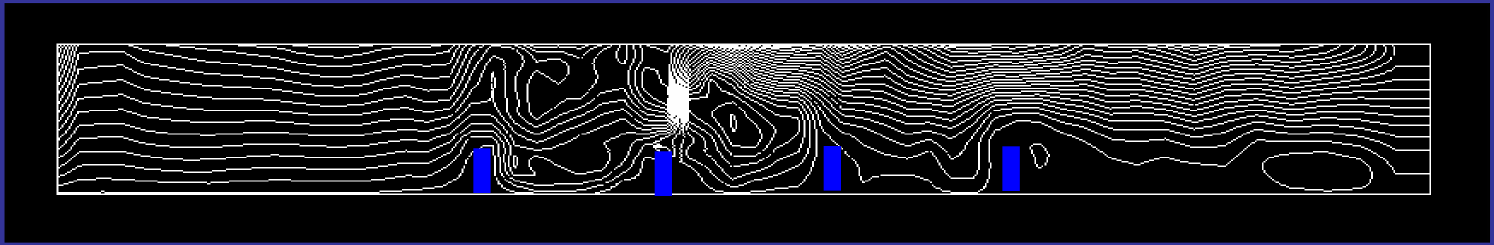
Run2- Morita et al., 2005

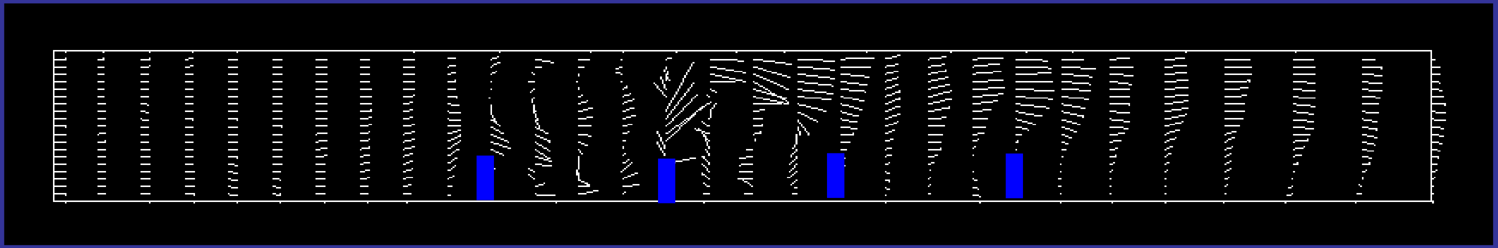
Bed elevation



Streamline



Velocity vector



t = 120 min.

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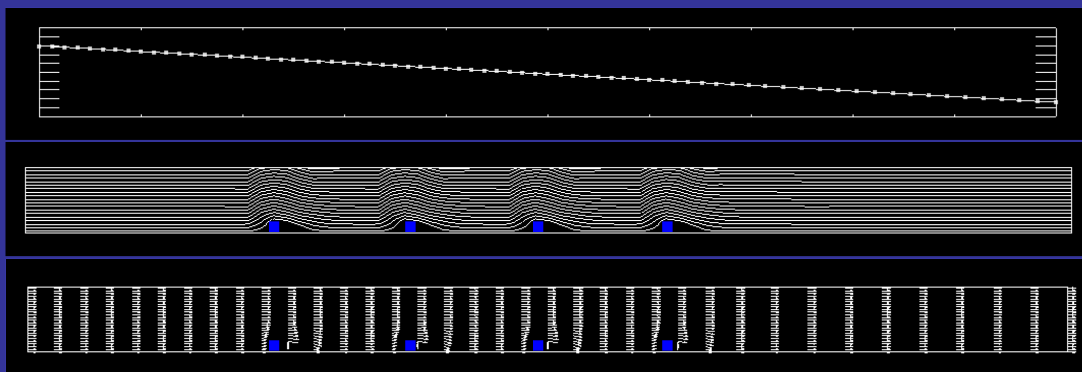
Application 1

Conditions

L **= 80.0 m,** ***B*** **= 10.0 m,** ***q*** **= 50 m³/s,** ***i*** **= 1/2000,** ***d*** **= 1.45 mm**

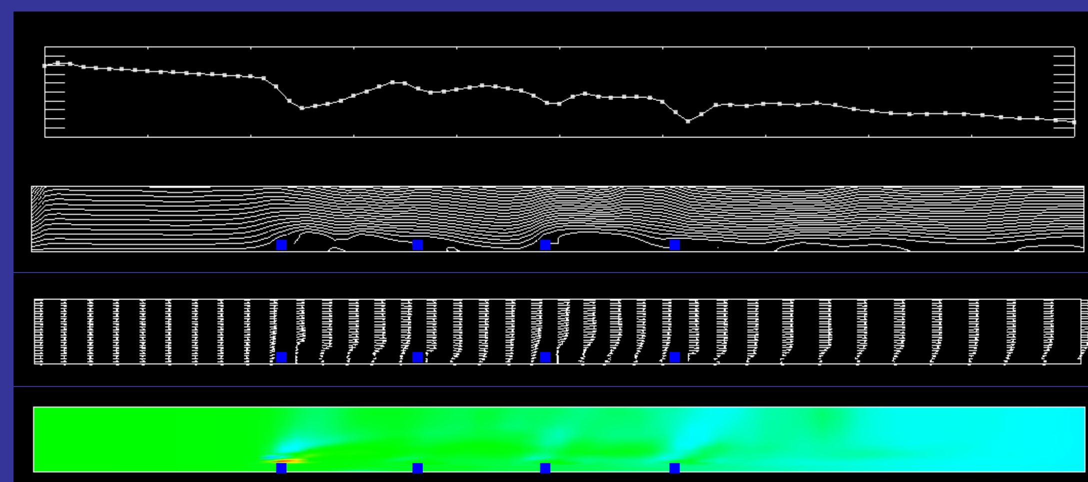


Bed elevation

Streamline

Velocity vector

t = 0 min.



Equilibrium

กรณีมีเขื่อนกันตลิ่งขนาดกว้าง 2.0 เมตร x หนา 0.3 เมตร โดยวางไว้ห่างเท่าๆ กัน 20.0 เมตร

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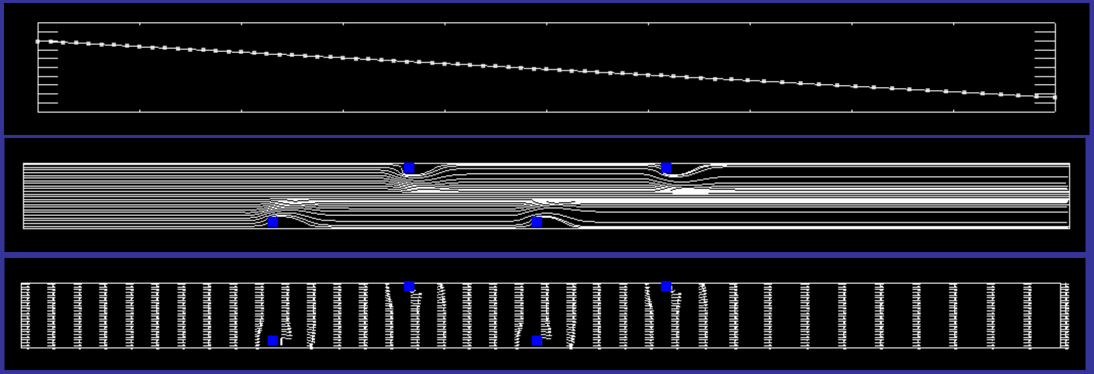
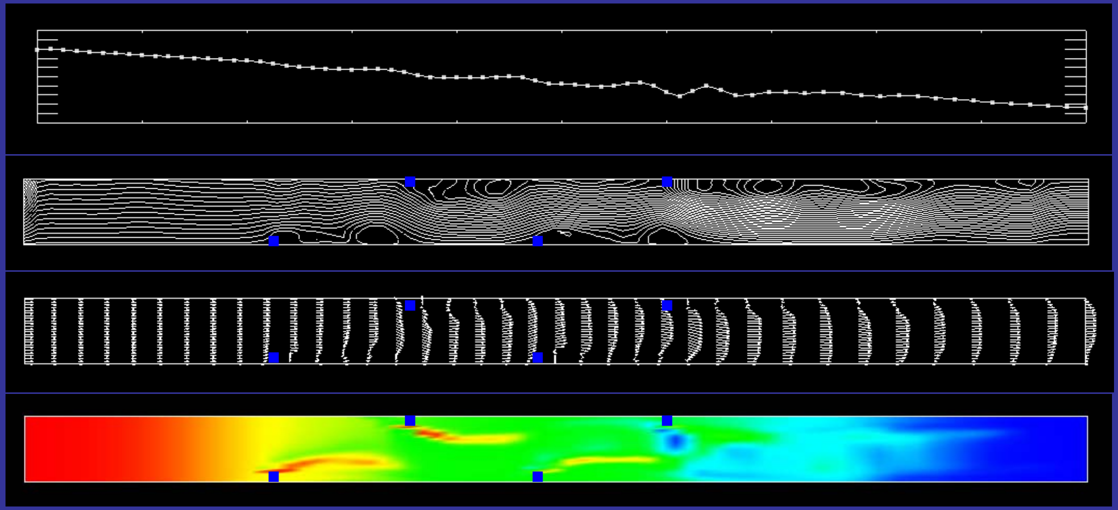
Application 2

Conditions

L = 80.0 m, B = 10.0 m, q = 50 m^3/s, i = 1/2000, d = 1.45 mm



t = 0 min.



Equilibrium

กรณีมีเขื่อนกันตลิ่งขนาดกว้าง 2.0 เมตร x หนา 0.3 เมตร โดยวางสลับด้านห่างเท่าๆ กัน 20.0 เมตร

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New Conceptual Design
of
Spur Dike
Snow Festival, 2004

Spur Dike

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Natural Diversities River Methods

Hokkaido, Japan

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Natural Diversities River Methods

Before

After

Before

After

Hokkaido, Japan

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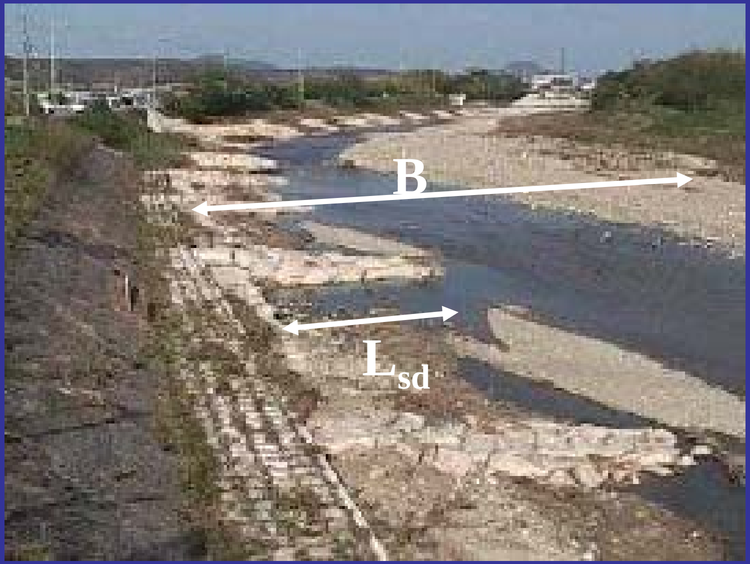
Spur Dike Design



Straight Channel Section

Length	0.10B
Height	$0.2\text{-}0.3H_{Wmax}$
Distance	$2\text{-}4L_{sd}$, $10\text{-}30H_{sd}$
Side Slope	1/20-1/100

Bend Channel Section

Length	0.10B
Height	$0.5\text{-}1.0H_{Waver}$
Distance	$>2L_{sd}$
Side Slope	1/20-1/100

B	Channel width
L_{sd}	Length of spur dike
H_{Waver}	Average water depth
H_{Wmax}	Maximum water depth
H_{sd}	Height of spur dike

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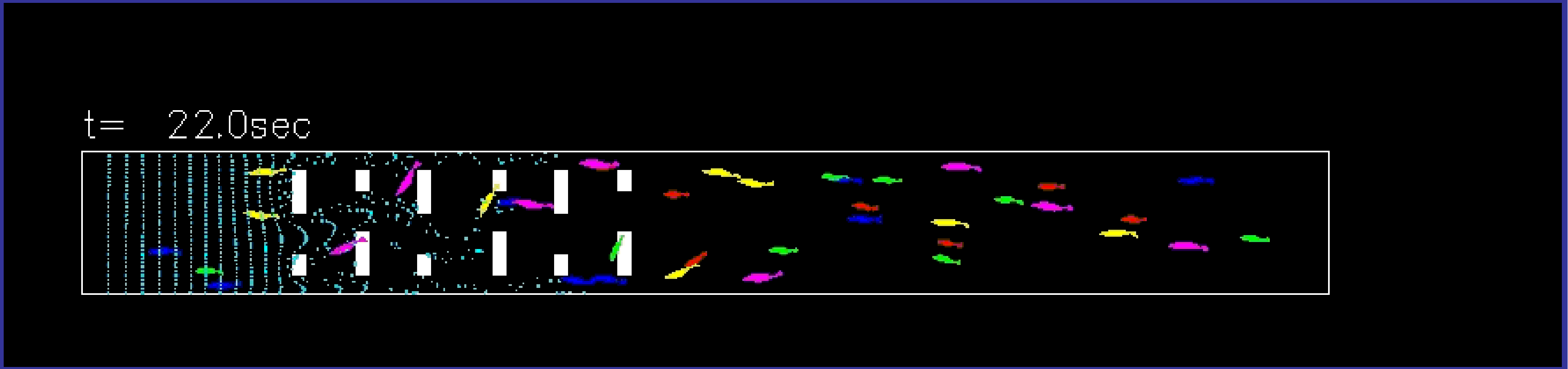
THE END



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