Flow, loads

Chapter 2

ct4310 Bed, Bank and Shoreline protection

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Faculty of Civil Engineering and Geosciences
Section Hydraulic Engineering

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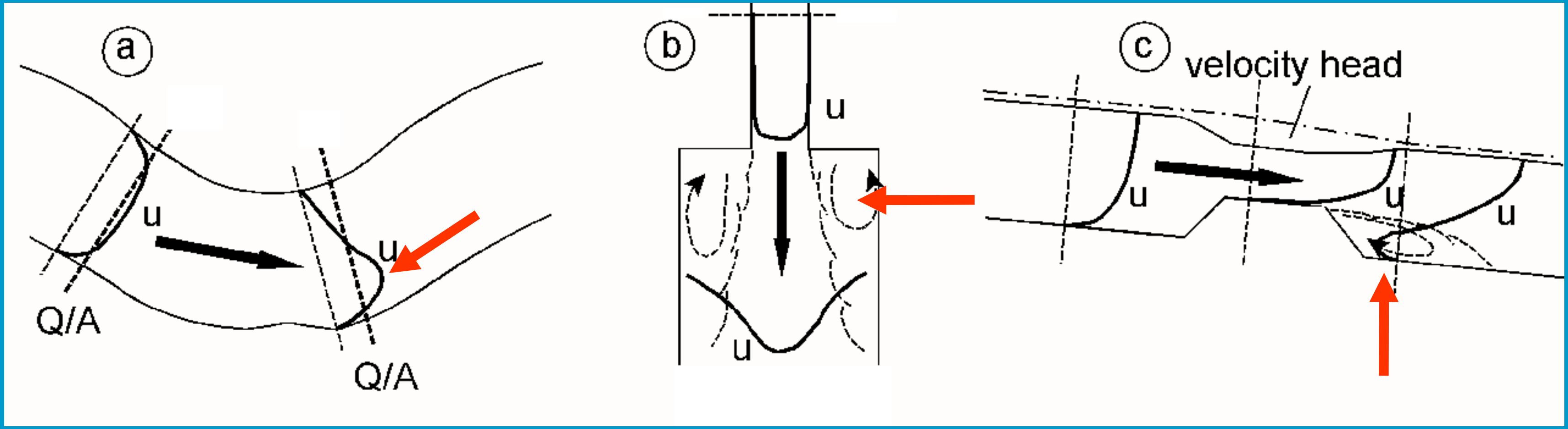
Introduction

- we have forces on protection elements
- forces are caused by flow
- flow can be regular and fluctuating
- fluctuations can be in the order of:
  - hours tide
  - seconds short waves
  - milliseconds turbulence

velocity fields in various situations



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Demonstration Reynolds number

Flume with uniform flow velocity is approx. 0.5 m/s

turbulent in case Re > 2000

$$Re = \frac{uh}{\nu} = \frac{0.5 \cdot 0.2}{10^{6}} = 10^{5}$$

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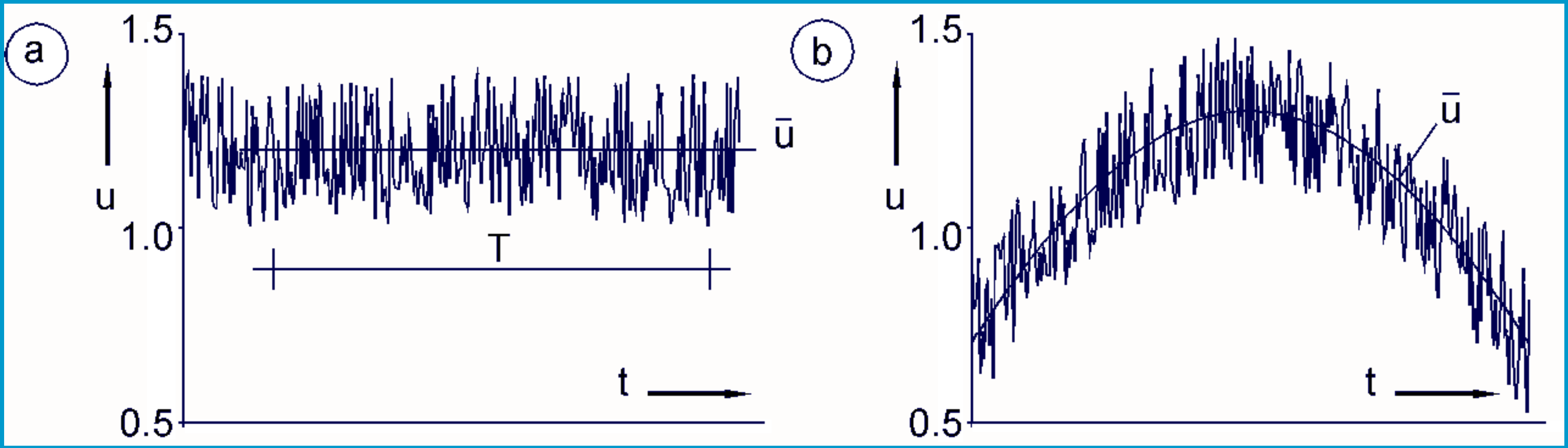
velocity

m * a = F

$$\rho\left(\frac{\partial \overline{u}}{\partial t}+\overline{u}\frac{\partial \overline{u}}{\partial x}+\overline{w}\frac{\partial \overline{u}}{\partial z}\right)=-\frac{\partial \overline{p}}{\partial x}+\mu\frac{\partial^2 \overline{u}}{\partial z^2}$$

inertia press. visc.

velocity registration in turbulent flow



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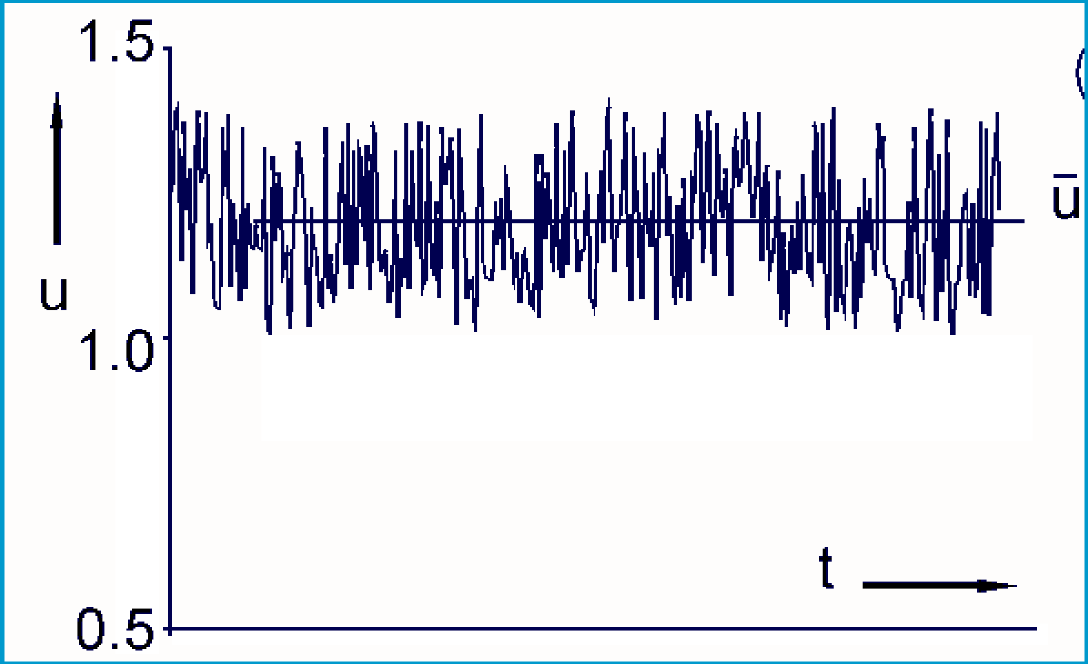
turbulent variations

$$u = \overline{u} + u'$$

$$v = \overline{v} + v'$$

$$w = \overline{w} + w'$$

$$p = \overline{p} + p'$$



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how to express turbulence ?

$$k = \frac{1}{2}\left(\overline{u'^2} + \overline{v'^2} + \overline{w'^2}\right)$$

k is the total kinetic energy in turbulent flow

$$r_u = \frac{\sqrt{\overline{u'^2}}}{\overline{u}}, r_v = \frac{\sqrt{\overline{v'^2}}}{\overline{u}}, r_w = \frac{\sqrt{\overline{w'^2}}}{\overline{u}}$$

r is relative fluctuation intensity in turbulent flow

Reynolds stresses

m * a = F

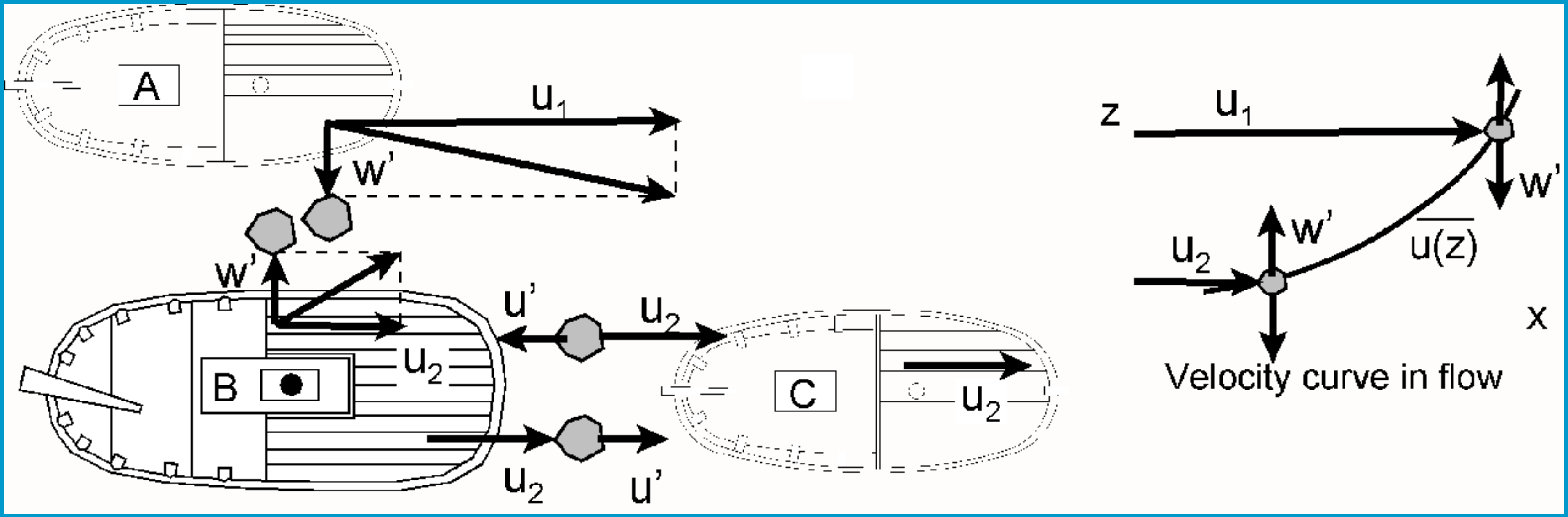
$$\rho\left(\frac{\partial \overline{u}}{\partial t}+\overline{u}\frac{\partial \overline{u}}{\partial x}+\overline{w}\frac{\partial \overline{u}}{\partial z}\right)=-\frac{\partial \overline{p}}{\partial x}+\mu\frac{\partial^2 \overline{u}}{\partial z^2}-\rho\left(\frac{\partial \overline{u'^2}}{\partial x}+\frac{\partial \overline{u'w'}}{\partial z}\right)$$

inertia — press. — visc. — Reynolds stresses

|– –| |– – – – – – – – – – –|

mean values — turb. fluctuations

exchange of momentum



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Flow resistance

$$\tau = c_f \rho u^2$$

In turbulent flow quadratic terms become dominant and relation between τ an u becomes quadratic

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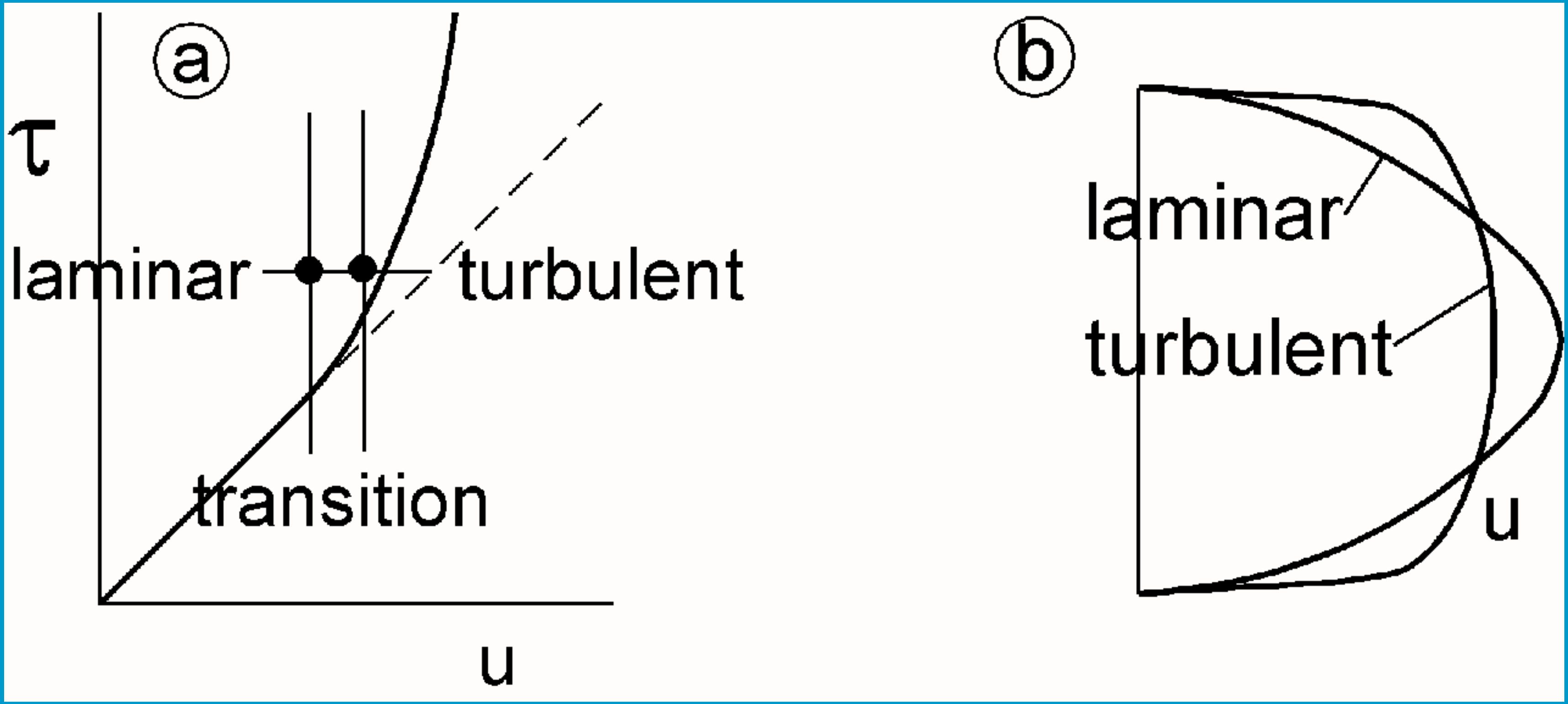
resistance in laminar and turbulent flow



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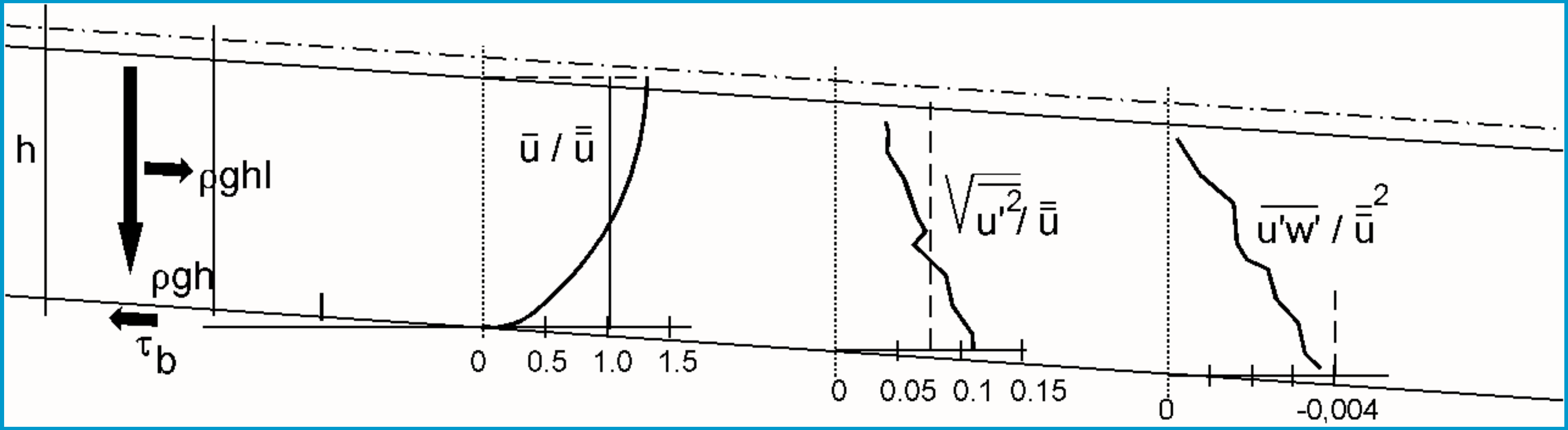
uniform wall flow



wall flow

$$\tau_b = \rho\, g\, h I = c_f\, \rho\, \overline{\overline{u}}^2 \;(= \rho\, u_*^2 = \rho\, \overline{u_b' w_b'}) \quad \Rightarrow \quad \overline{\overline{u}} = \frac{1}{\sqrt{c_f}} \sqrt{g h I}$$

u_* is the shear "velocity"

Chezy: $\overline{\overline{u}} = C\sqrt{R\,I}$ with: $C = \sqrt{\frac{g}{c_f}}$

Manning: $\overline{\overline{u}} = \frac{1}{n} R^{2/3} \sqrt{I}$ with: $n = R^{1/6} \sqrt{\frac{c_f}{g}}$

Nikuradse-Colebrook roughness:

$$C = \frac{\sqrt{g}}{\kappa} \ln \frac{12\,R}{k_r} \approx 18 \log \frac{12\,R}{k_r} \qquad (k_r \text{ is equivalent roughness})$$

$$u_* = \overline{\overline{u}}\,\sqrt{g}\,/\,C$$

Cress
Coastal and River Engineering Support System

- Simple program to solve hydraulic engineering equations
- Downloadable from:
  http://www.cress.nl
  - English, Spanish and Dutch
  - extended help
  - focus on dikes and related structures
- Requires Administrator rights for installation
- Also available on citg-network (?)

Cress download page - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://www.kennisbank-waterbouw.nl/cress/ | kaliumpermanganaat

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CRESS

Coastal and River Engineering Support System

A cooperation project of the Netherlands Ministry of Public Works (Rijkswaterstaat), IHE-Delft and TU-Delft

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UNESCO-IHE Institute for Water Education

Introduction

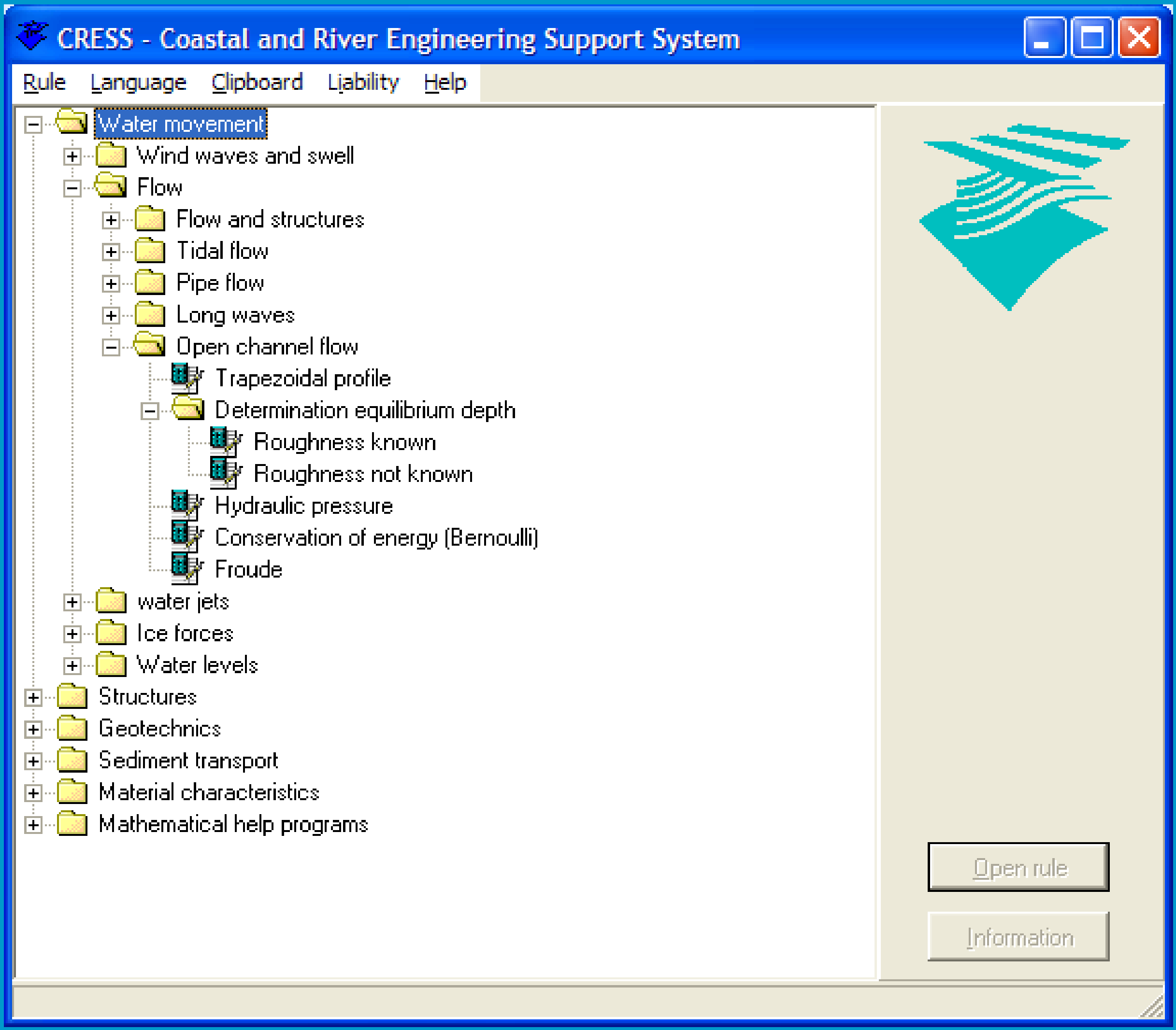
This program is intended as a support for design and planning of coastal and river projects and is not intended to replace the judgement of a qualified engineer on a particular project. The contents of CRESS are not to be used for advertising, publication or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products. The issuing partners do not accept liability for interpretations or implementations made by users of this program.

	Latest Cress version (RWS-Cress), (version 4.0.5) in English, Dutch, French and Spanish. This version contains extensive help. For installation administrator rights are required (installation includes a registration procedure of the dll's in the registry of your computer). The French version is only available as test version. To activate the French version, download menu.zip and replace the files in your directory .../cress/menu by the files from this zipfile.
	Seperate link to helpfiles of Cress (RWS-Cress)
	Download IHE-version of Cress (old version, does not require writing in the registry of your computer) Remark: Help in program does not work any more. Download separate helpfiles.
	Chinese version of Cress (IHE-Cress)
	DOS-version of Cress
	DOS-verson of Cress in Bahassa Indonesia
	Older versions of Cress (windows): • Cress 2007 • Cress 2005 • Cress 2004

In case of problems, you may consult the faq-list.

Cress is not able to compute the shallow water wave parameters $T_{m-1,0}$ and $H_{2\%}$, because then you need to enter depth profile information. These parameters can be calculated with Swan. The full Swan code can be downloaded from the Swan-homepage. However, also a practical Graphical User Interface, SwanOne is available free of charge. With the use of SwanOne you may calculate $T_{m-1,0}$ and $H_{2\%}$ without detailed knowledge of the Swan computational system.

Cress (3)


CRESS - Coastal and River Engineering Support System
Rule Language Clipboard Liability Help
Water movement
Wind waves and swell
Flow
Flow and structures
Tidal flow
Pipe flow
Long waves
Open channel flow
Trapezoidal profile
Determination equilibrium depth
Roughness known
Roughness not known
Hydraulic pressure
Conservation of energy (Bernoulli)
Froude
water jets
Ice forces
Water levels
Structures
Geotechnics
Sediment transport
Material characteristics
Mathematical help programs
Open rule
Information

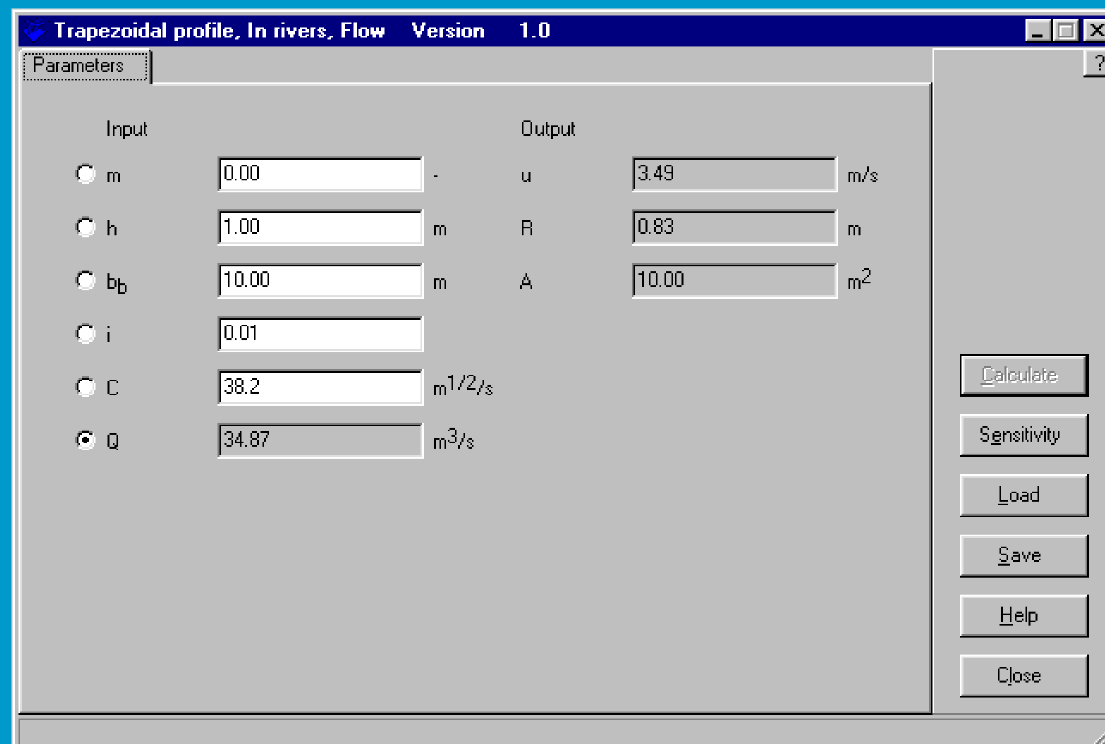
example

Cress

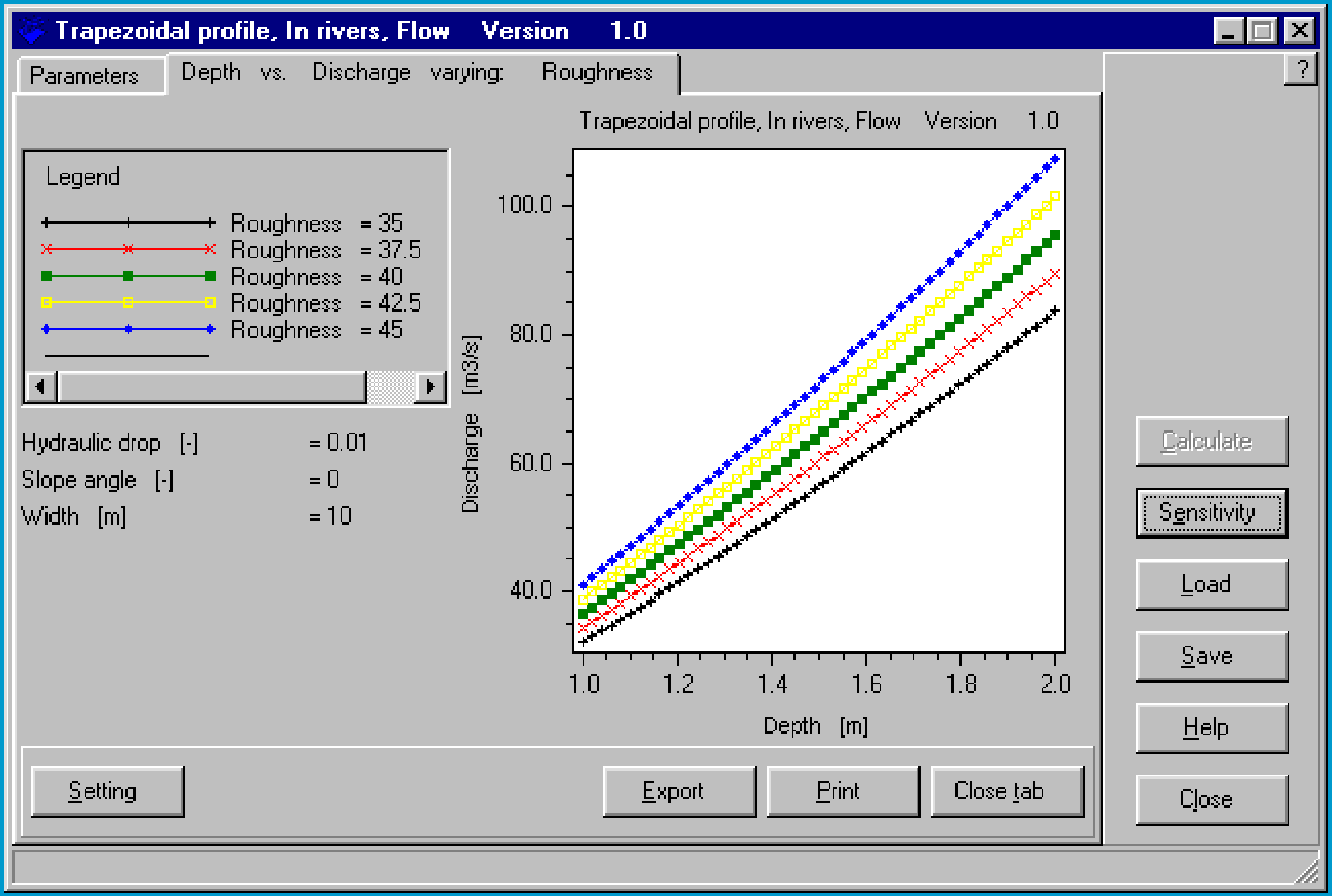
Given: discharge q=20 m³/s
bed slope i=1/1000
channel width b_b 10 m
roughness 0.2 m
side slope vertical m=0

calculate h and u

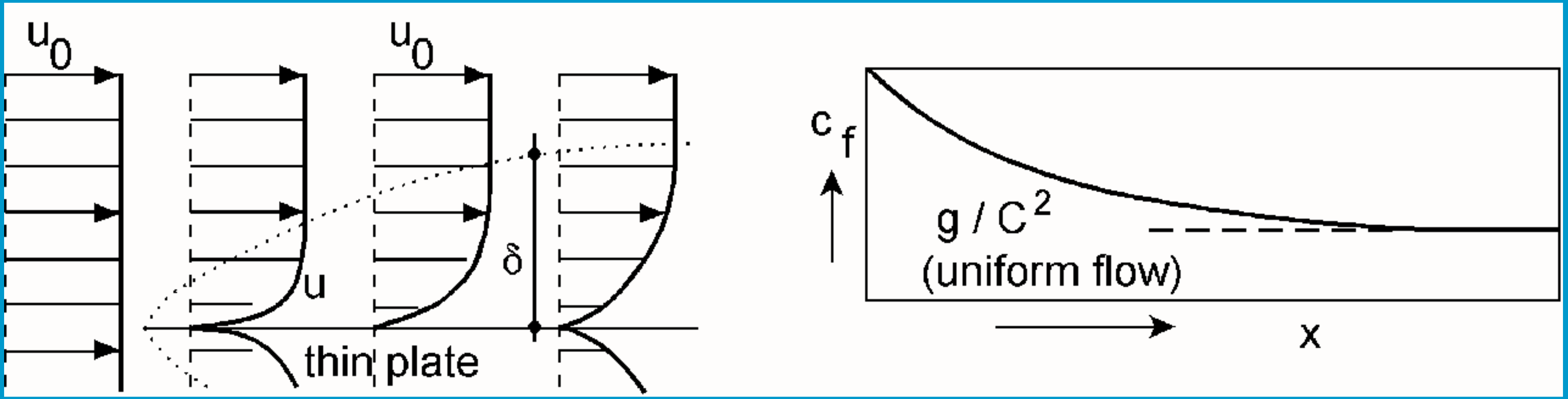
assume h=1
R= bh/(b+2h)=0.83
C=18log(12*0.83/0.2)
= 30.6
Q = bh C⌧Ri
= 10*1*30*√0.3*.001
=8.83 m³/s
⇒ too low, increase d



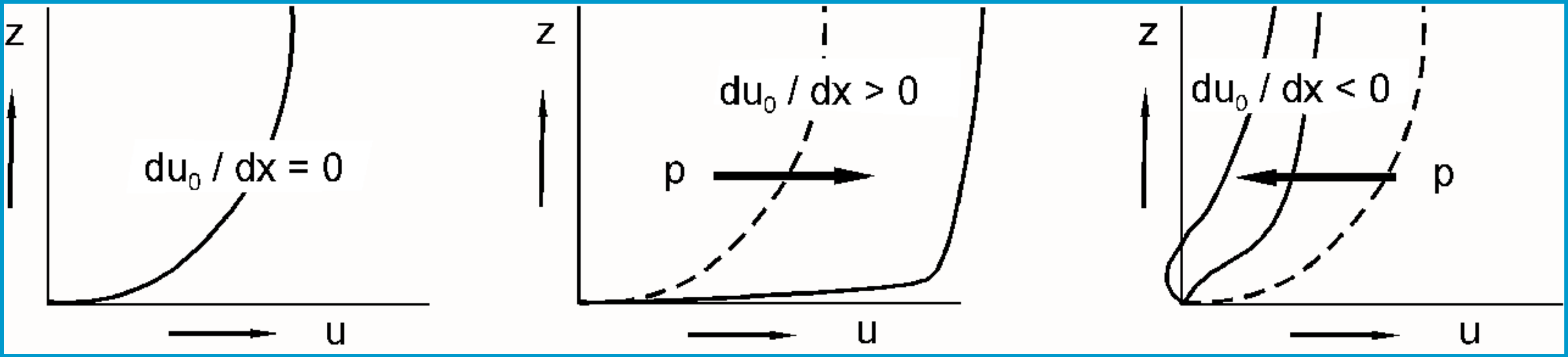
output of program



growth of boundary layer



influence of pressure gradient on velocity profile



uniform **accelerated** **decelerated**

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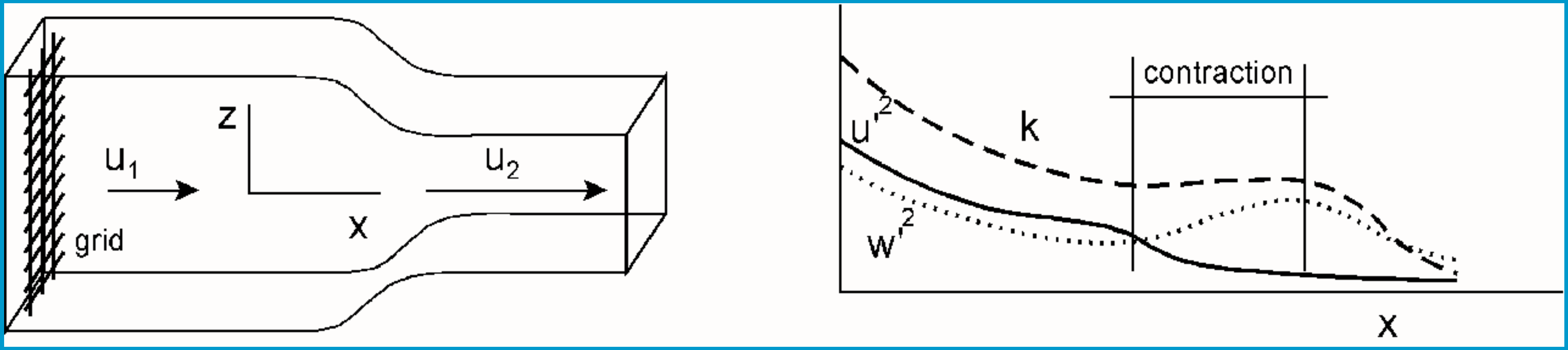
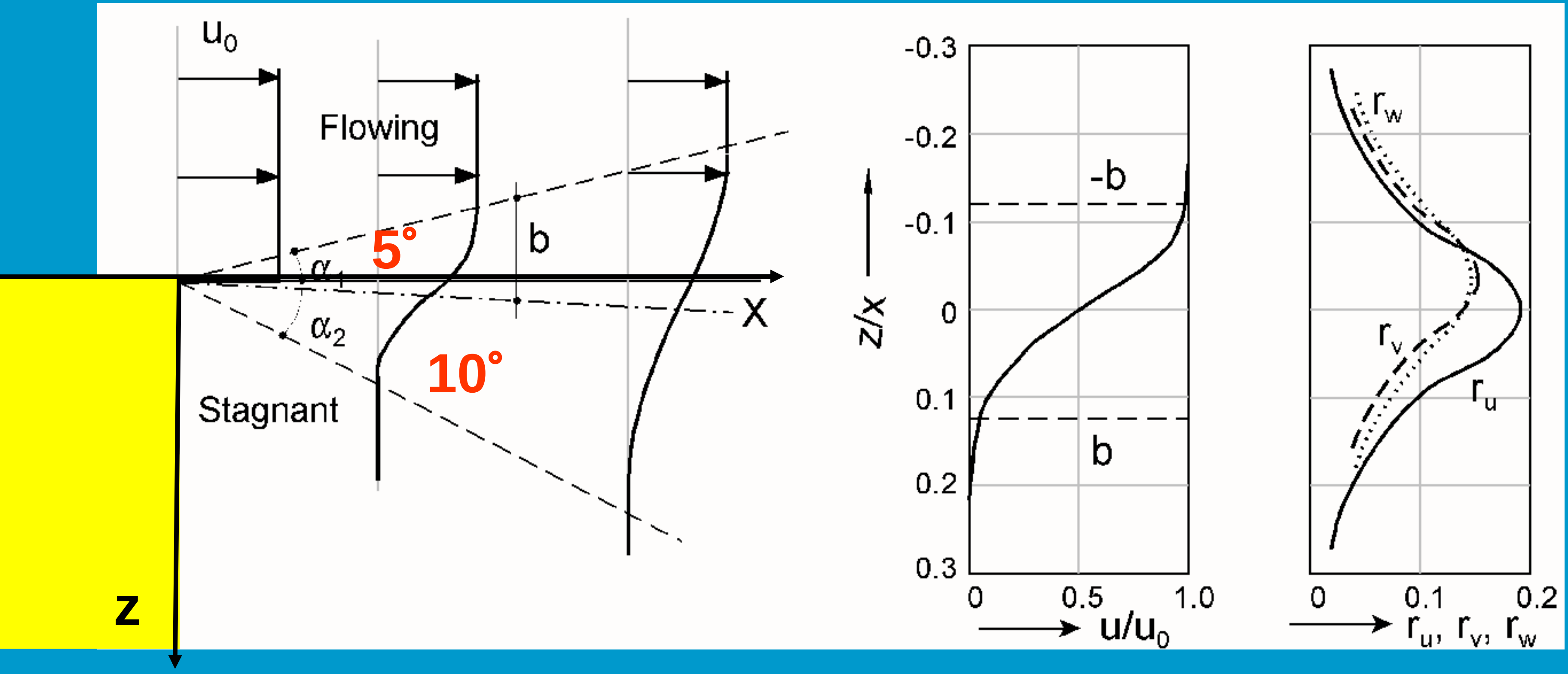
turbulence in windtunnel contraction



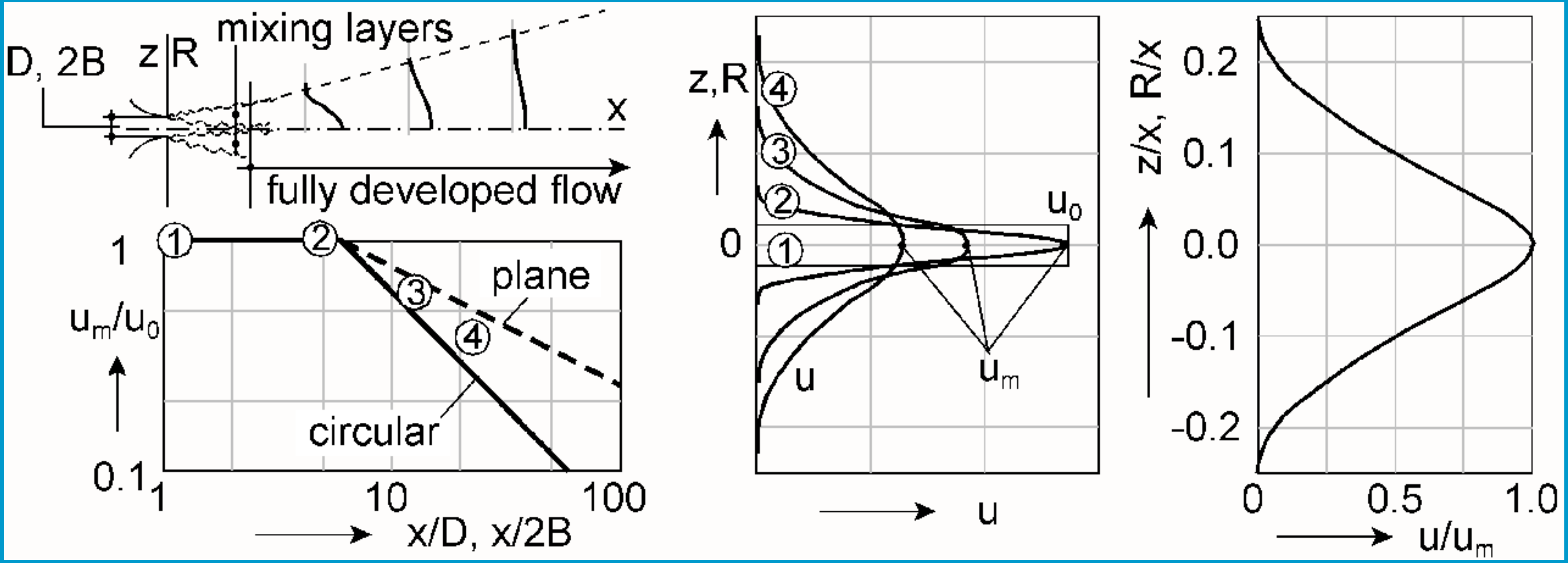
the fluctuations in x-direction decrease due to acceleration

flow, velocities and turbulence in mixing layer



ct4310/01overzichtstroming
BB: 4310V2-MixingZone

flow and velocities in jets

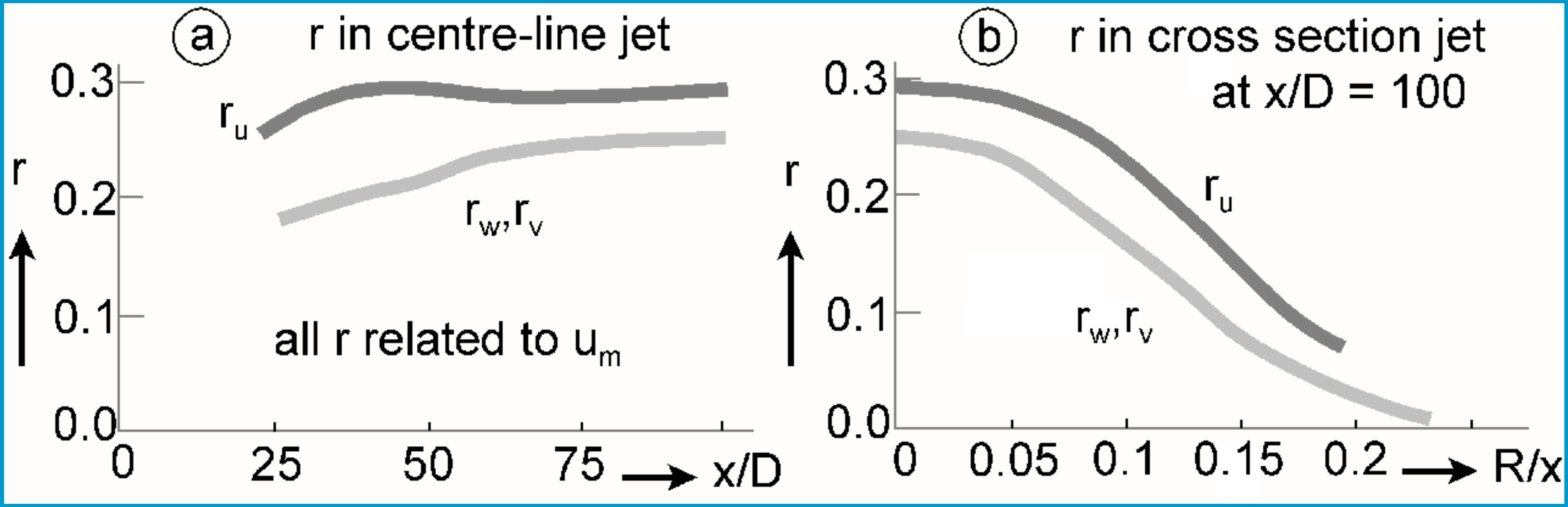


jet equations

$$Plane\ jets: u_m = \frac{3.5\, u_0}{\sqrt{x/B}} \quad b = 0.1x \quad u = u_m\, e^{\left(-0.693\left(\frac{z}{b}\right)^2\right)}$$

$$Circular\ jets: \ u_m = \frac{6.3\, u_0}{x/D} \quad b = 0.1x \quad u = u_m\, e^{\left(-0.693\left(\frac{R}{b}\right)^2\right)}$$

turbulent fluctuations in circular jet



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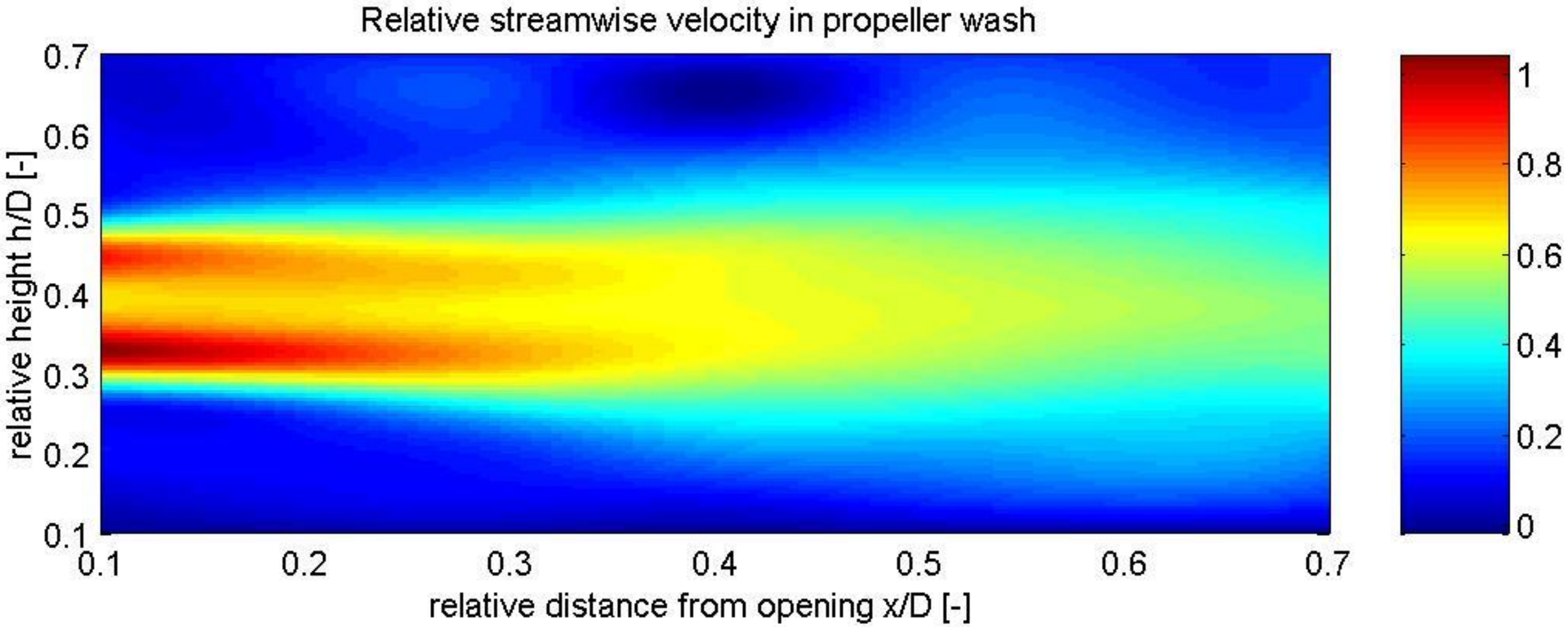
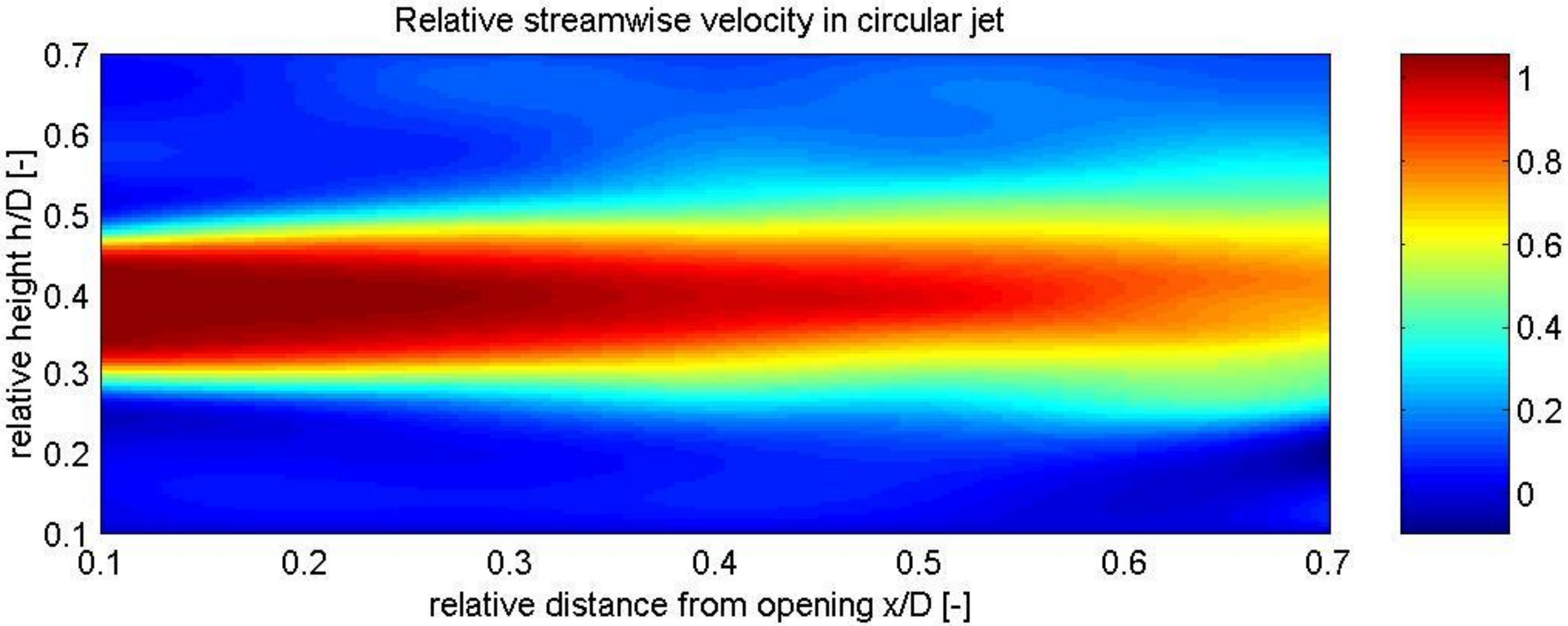
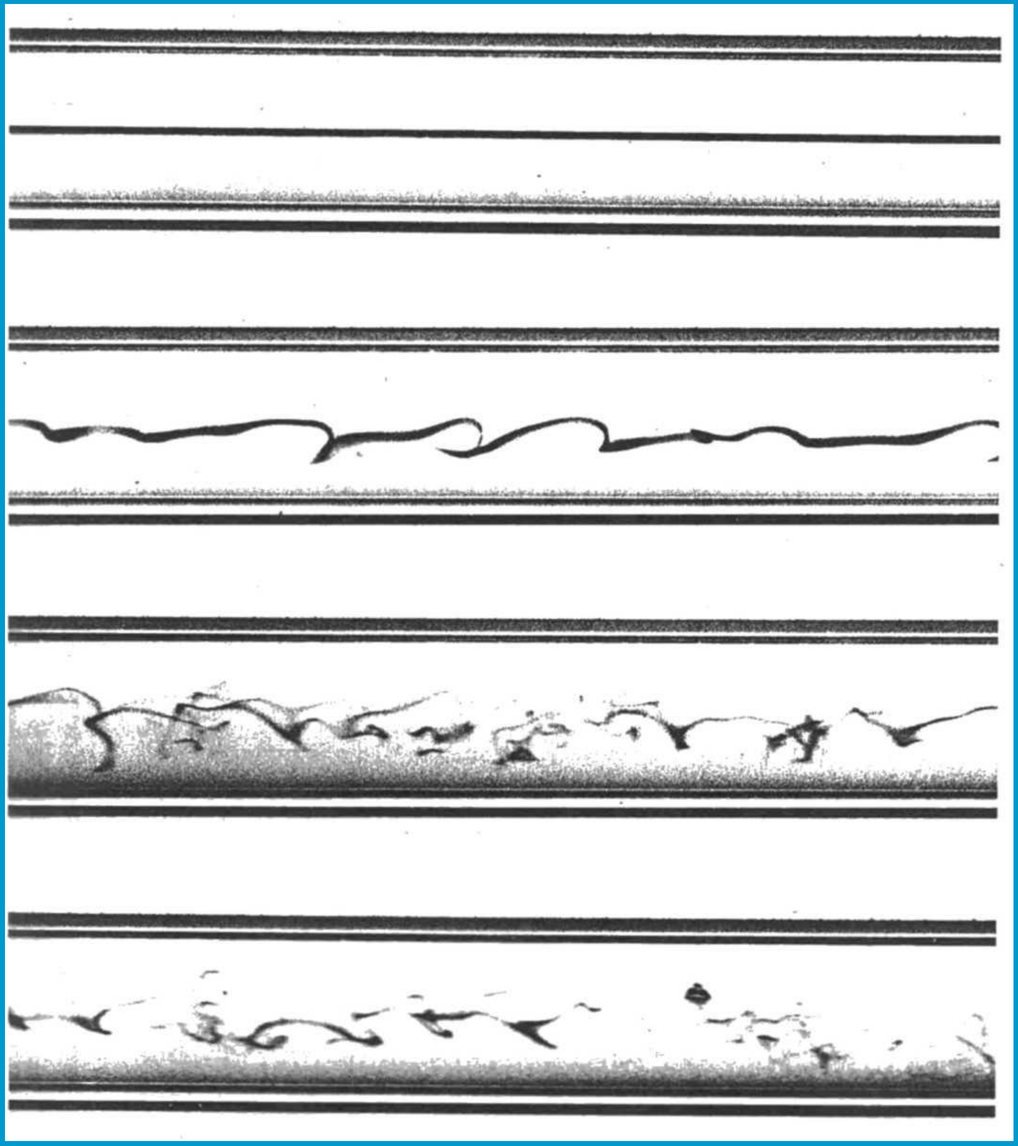




data from Victor van Veldhoven 2002

Reynolds dye experiment



Video on Turbulence

- Presented by Robert W Stuart
  University of British Columbia
- Produced by the national committee for fluid mechanics films, national science foundations
- Downloadable from: http://web.mit.edu/fluids/www/Shapiro/ncfmf.html

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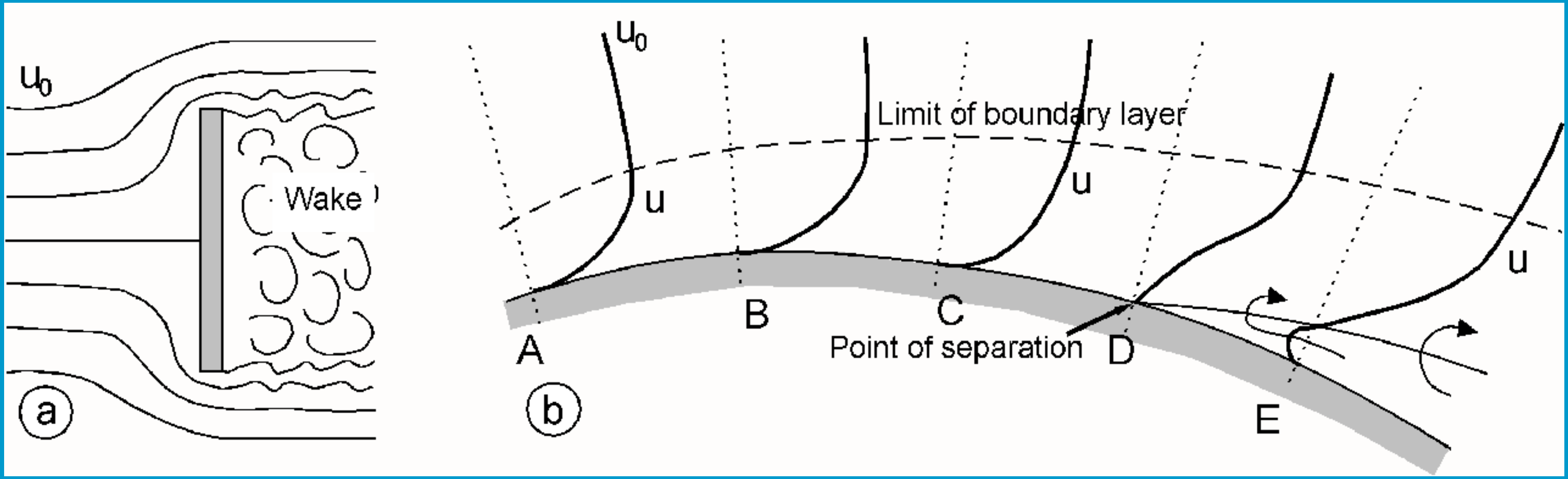
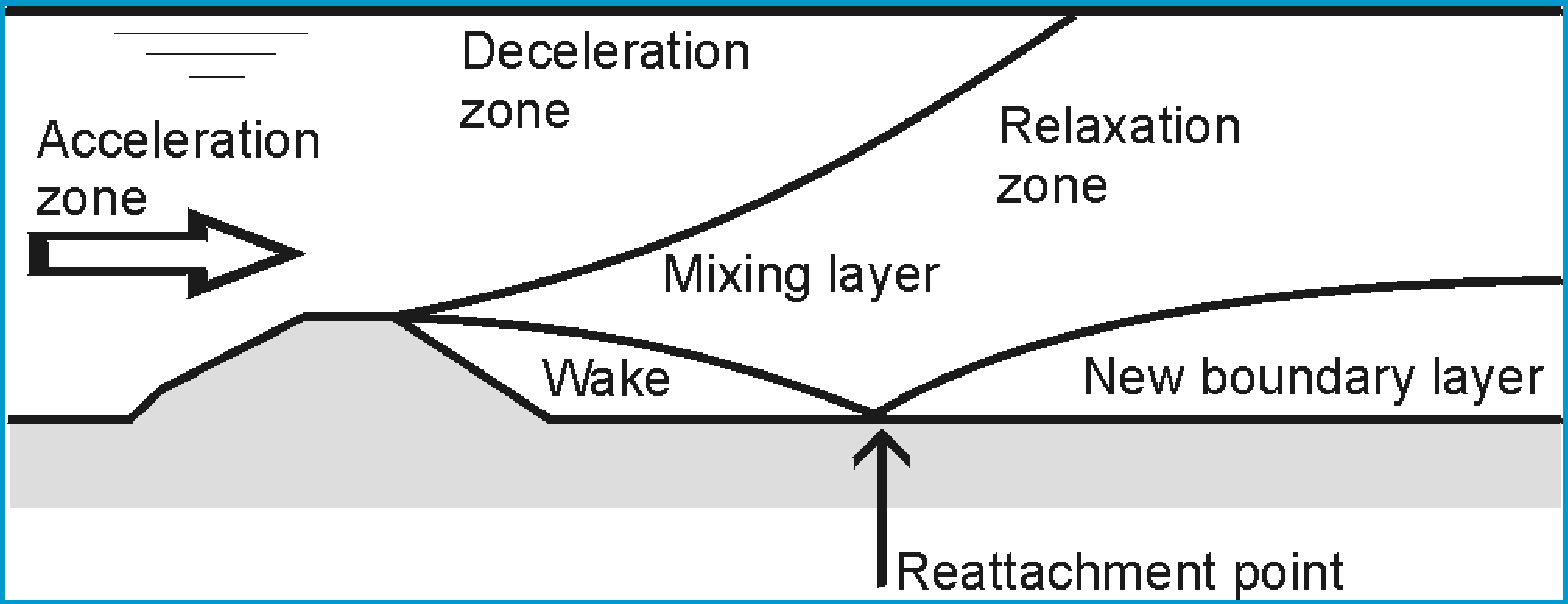
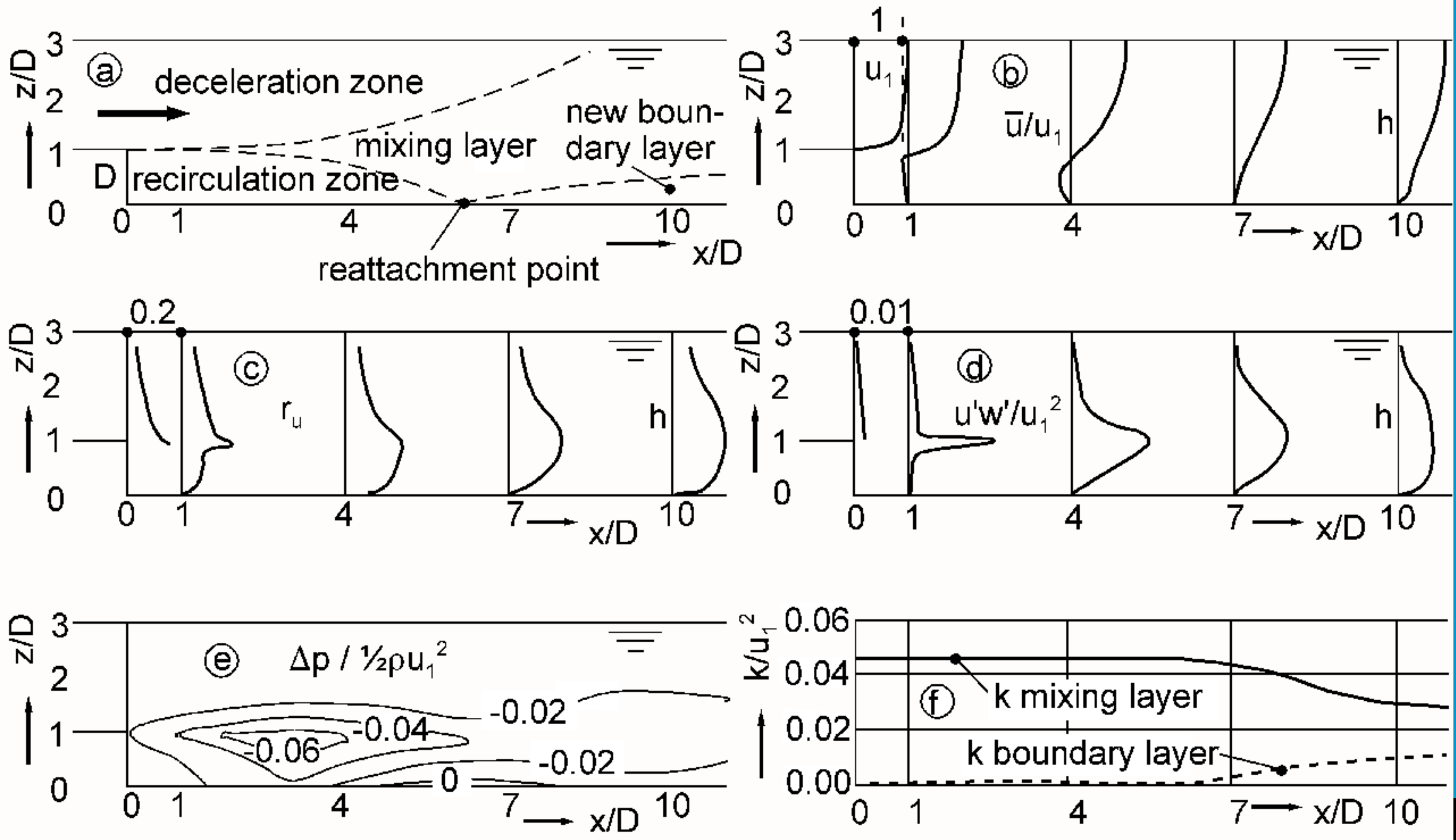
flow separation around blunt and round body



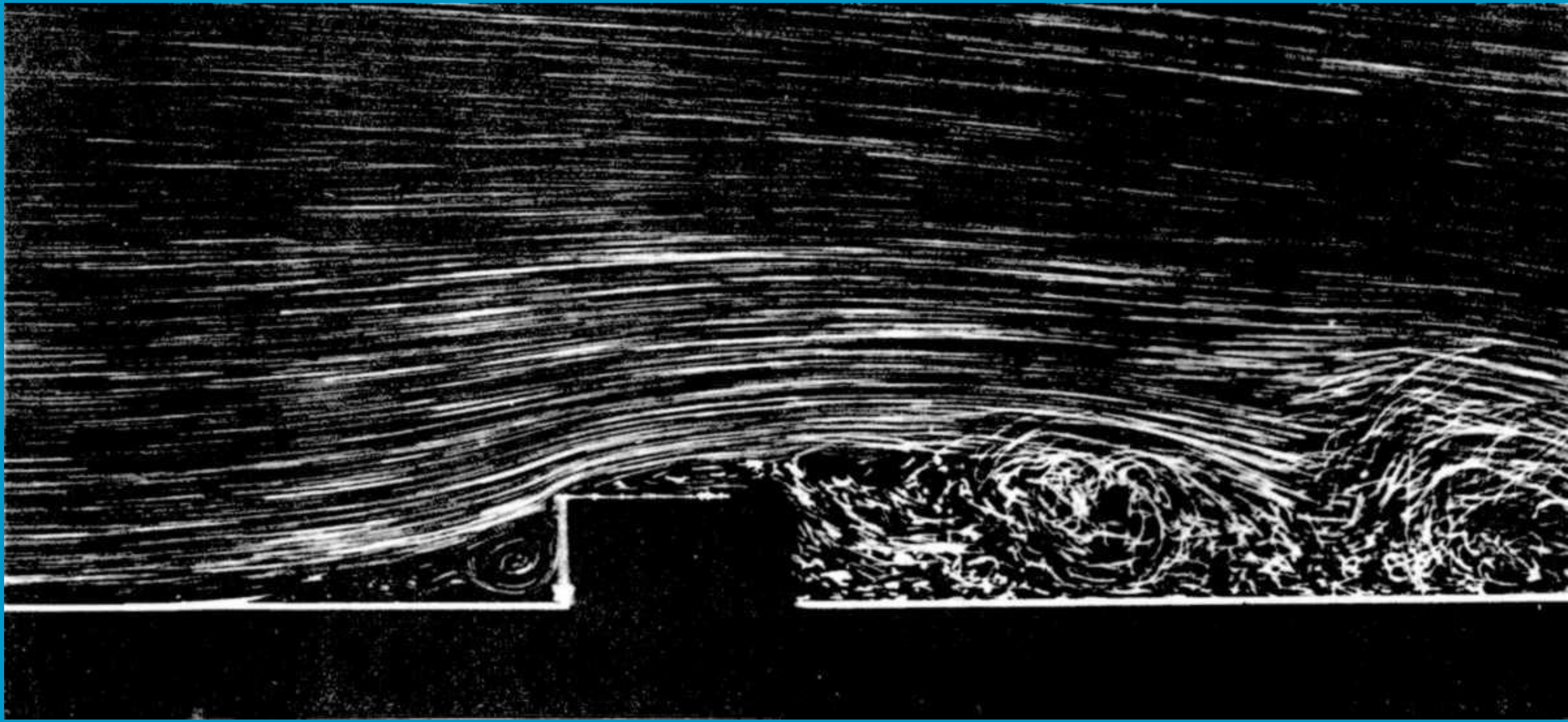
flow phenomena in backwater-facing step (1)



flow phenomena in backwater-facing step (2)



turbulent separation over a rectangular block



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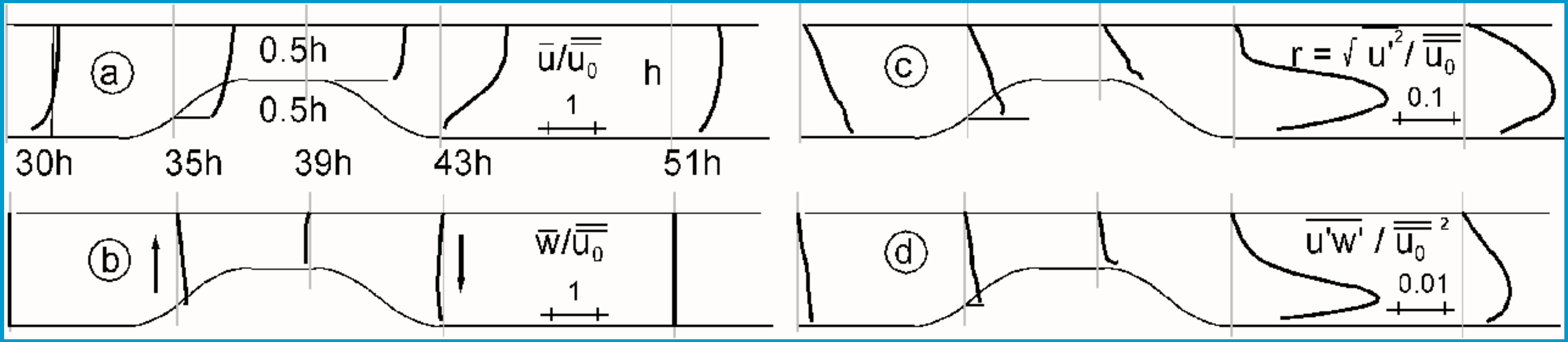
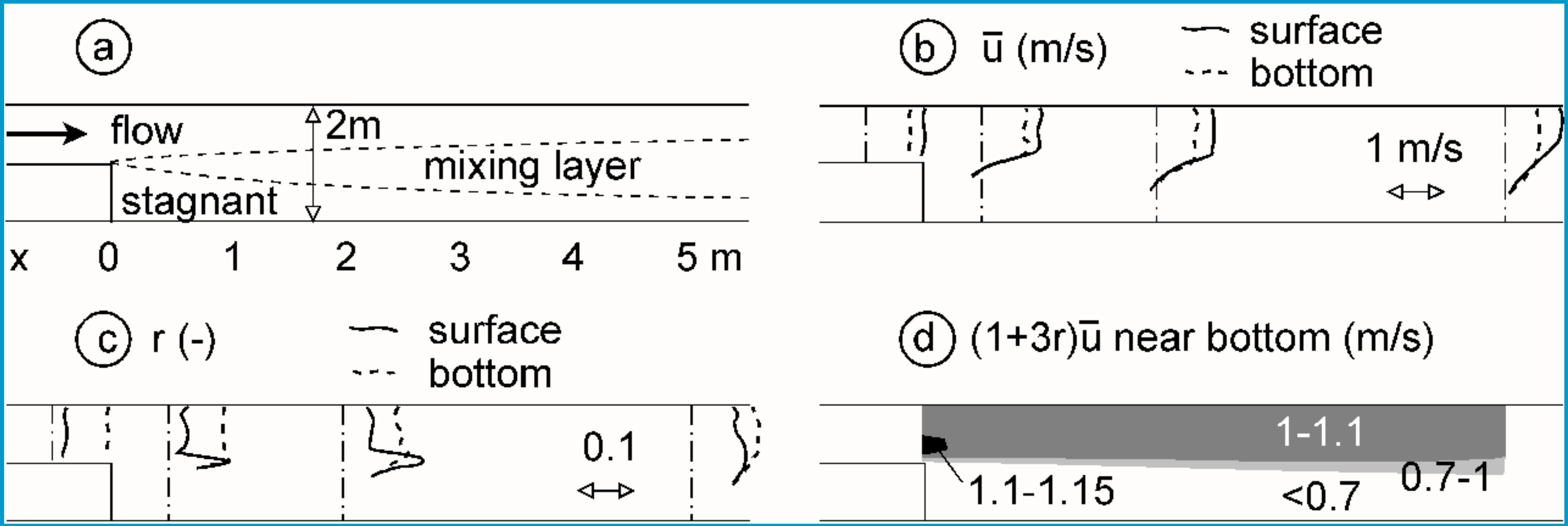
flow characteristics around a sill



flow characteristics in a horizontal expansion



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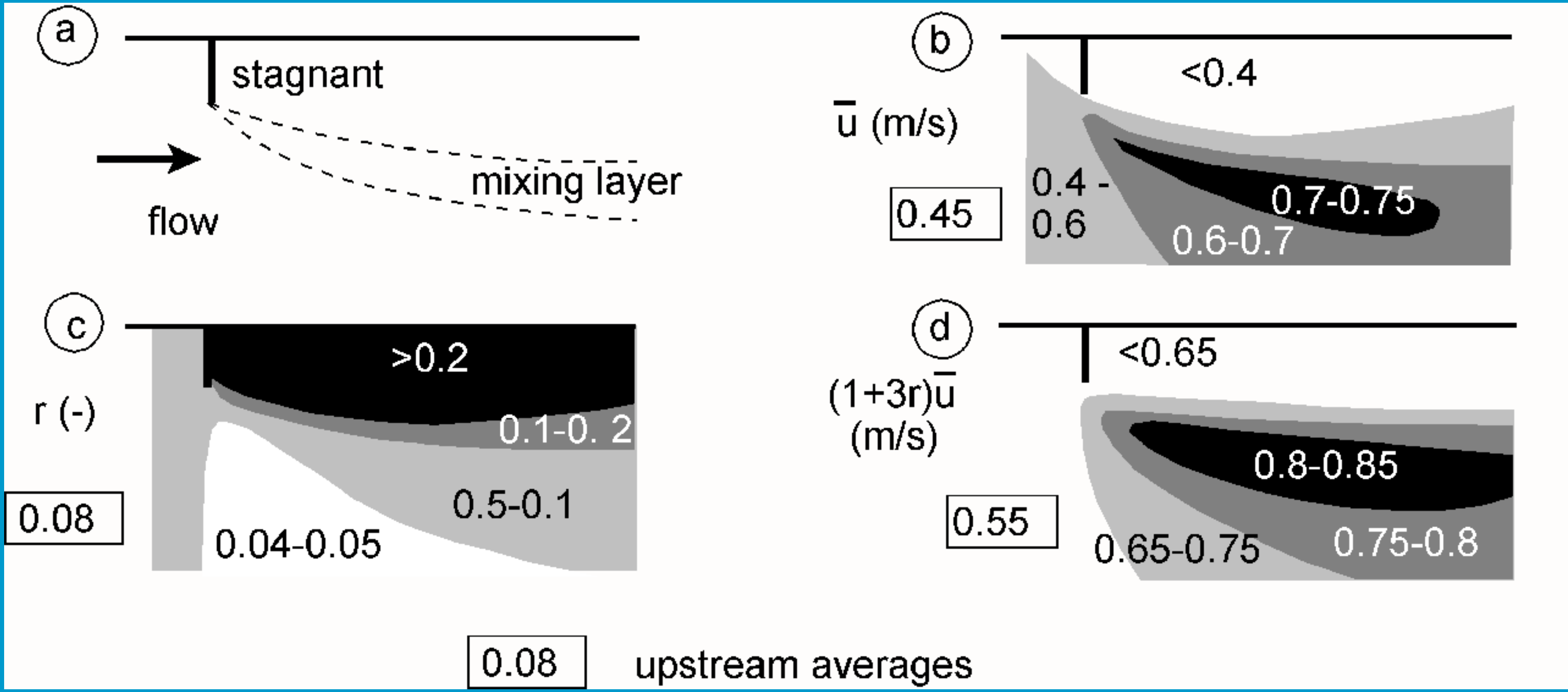
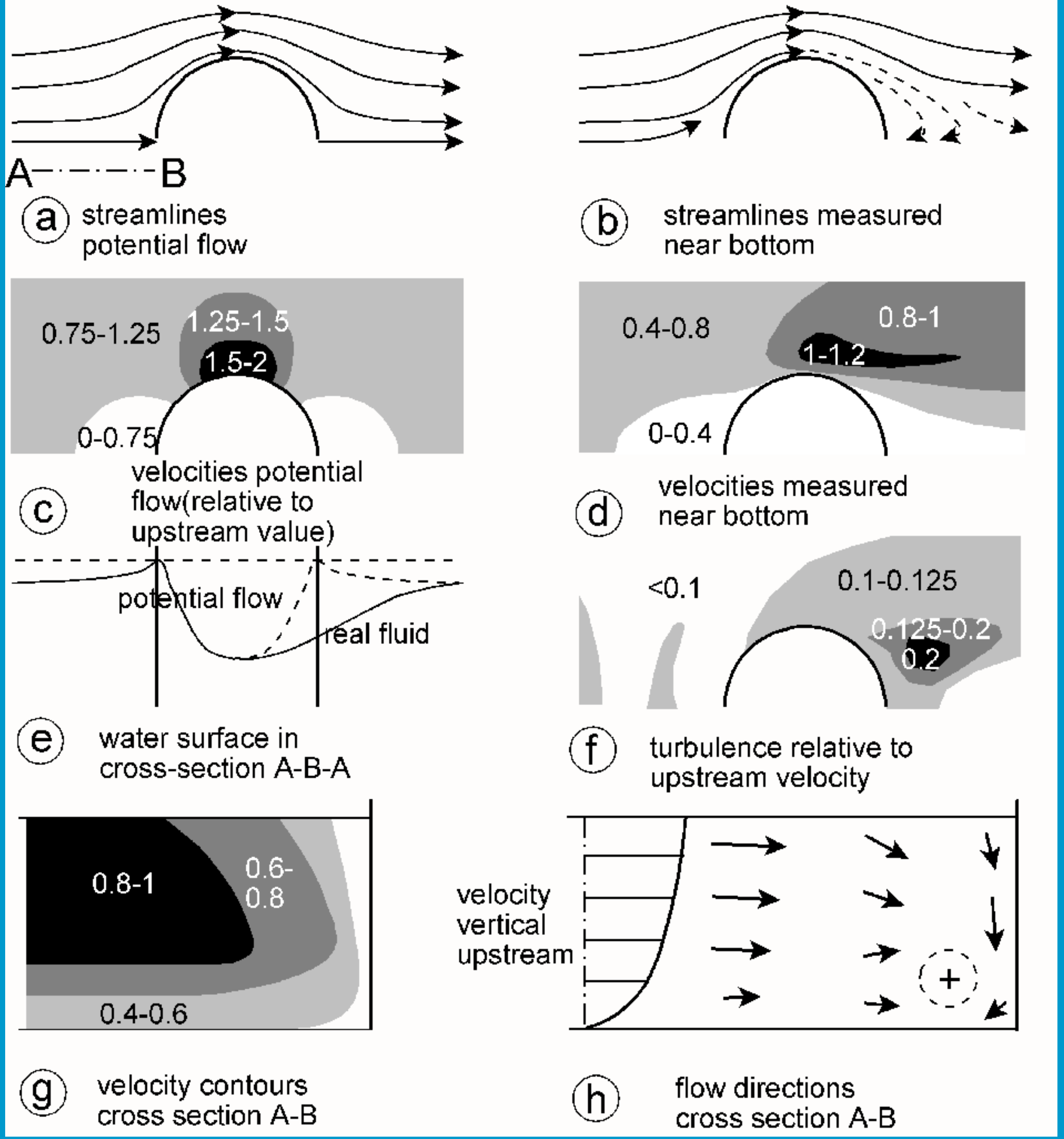
flow characteristics for a horizontal constriction



flow around cylinder



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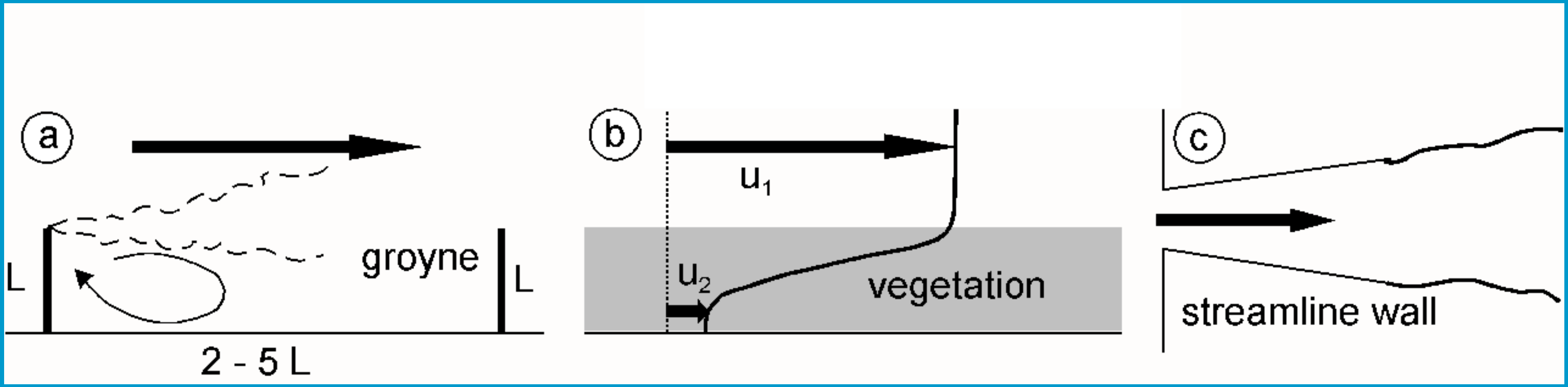
possible load reduction of flow induced loads



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appendix
basic equations
turbulence

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basic equations

$$F_x = - \frac{\partial p}{\partial x} dx\,(dy\,dz) + \frac{\partial \tau}{\partial z} dz\,(dx\,dy) + Fe(x)$$

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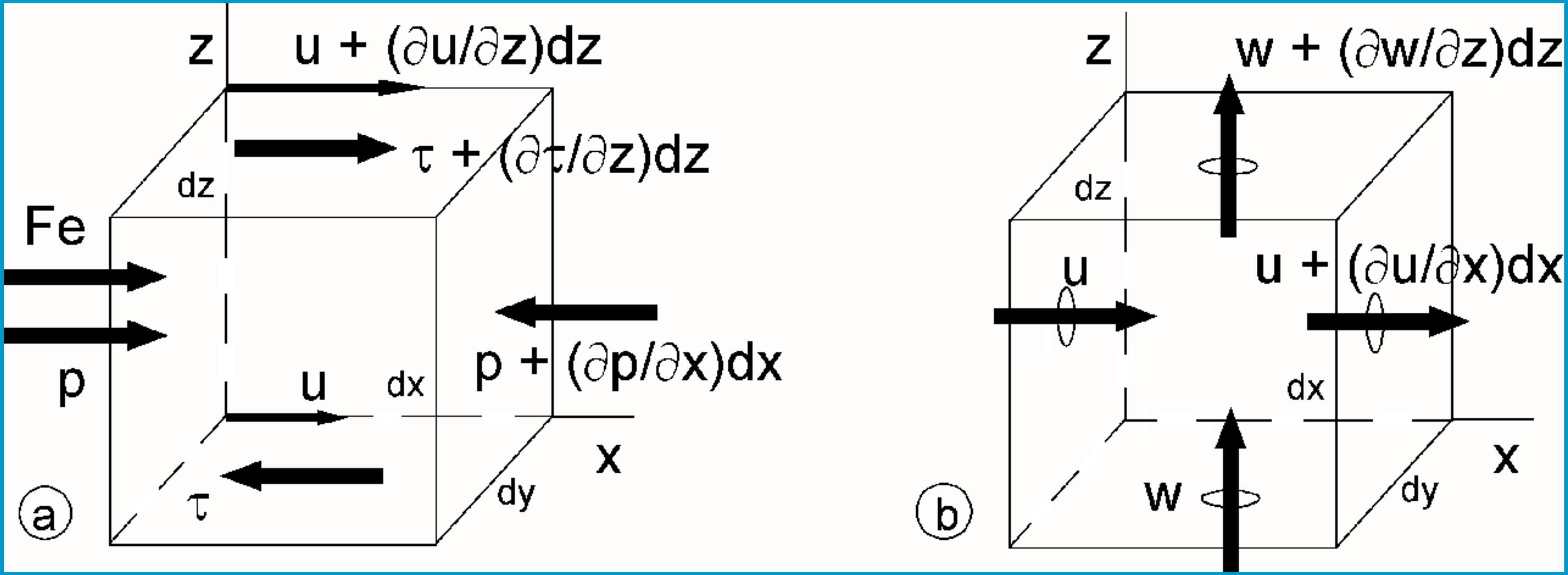
forces and flow with regards to dxdydz



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simplified Navier-Stokes equation

$$\rho\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+w\frac{\partial u}{\partial z}\right)=-\frac{\partial p}{\partial x}+\mu\frac{\partial^2 u}{\partial z^2}$$

local inertia	convective inertia	pressure gradient	viscous shear

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continuity equation

$$\frac{\partial u}{\partial x} + \frac{\partial w}{\partial z} = 0$$

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after some mathematics...

$$\rho\left(\frac{\partial\overline{u}}{\partial t}+\overline{u}\,\frac{\partial\overline{u}}{\partial x}+\overline{w}\,\frac{\partial\overline{u}}{\partial z}+\overline{u'\,\frac{\partial u'}{\partial x}}+\overline{w'\,\frac{\partial u'}{\partial z}}\right)=-\frac{\partial\overline{p}}{\partial x}+\mu\,\frac{\partial^2\overline{u}}{\partial z^2}$$

local inertia	conv. inertia by mean vel.	conv. inertia by fluct. vel.	press. grad.	visc. shear

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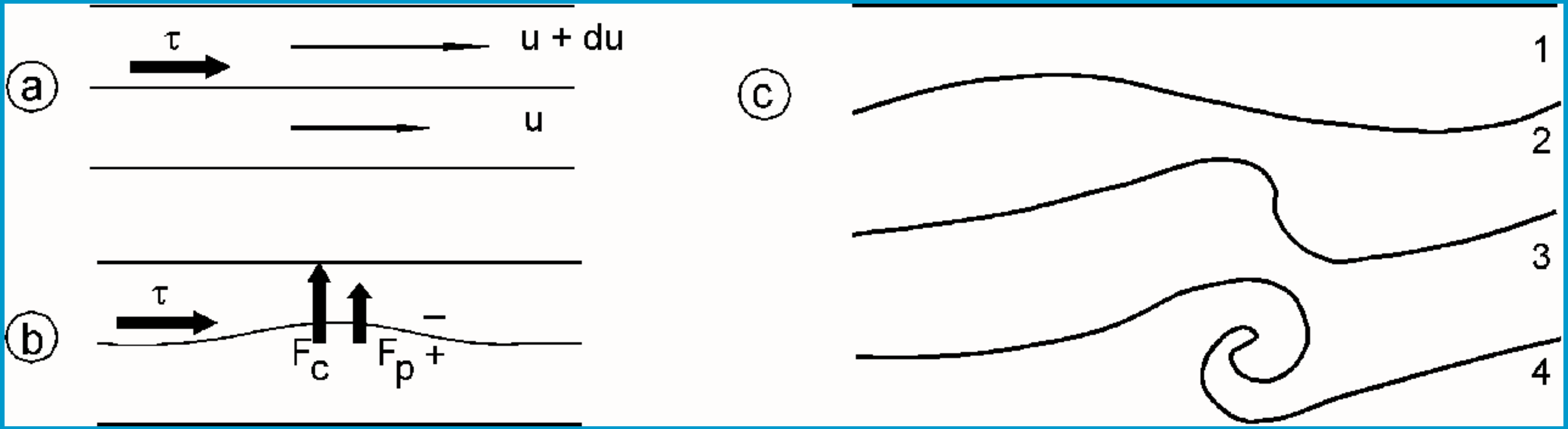
Reynolds equation

$$\underbrace{\rho\left(\frac{\partial \overline{u}}{\partial t}+\overline{u}\frac{\partial \overline{u}}{\partial x}+\overline{w}\frac{\partial \overline{u}}{\partial z}\right)}_{inertia}=\underbrace{-\frac{\partial \overline{p}}{\partial x}}_{press.}+\underbrace{\mu\frac{\partial^2 \overline{u}}{\partial z^2}}_{visc.}\underbrace{-\rho\left(\frac{\partial \overline{u'^2}}{\partial x}+\frac{\partial \overline{u'w'}}{\partial z}\right)}_{Reynolds-stresses}$$

mean values (inertia, press., visc.) — *turb. fluct.* (Reynolds-stresses)

(in)stability of laminar flow



The Reynolds number

$$Re = \frac{\rho \cdot U^2 / L}{\mu \cdot U / L^2} = \frac{U \cdot L}{\upsilon}$$

transition from laminar to turbulent flow:
Re ≈ 1000 - 2000

μ = dynamic viscosity
ν = kinematic viscosity (ν = μ/ρ)

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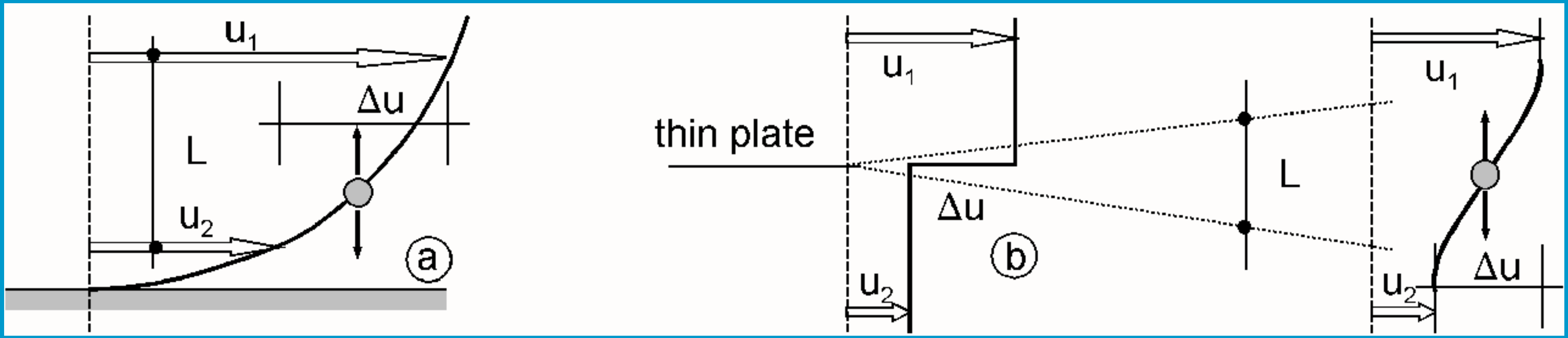
wall turbulence and free turbulence



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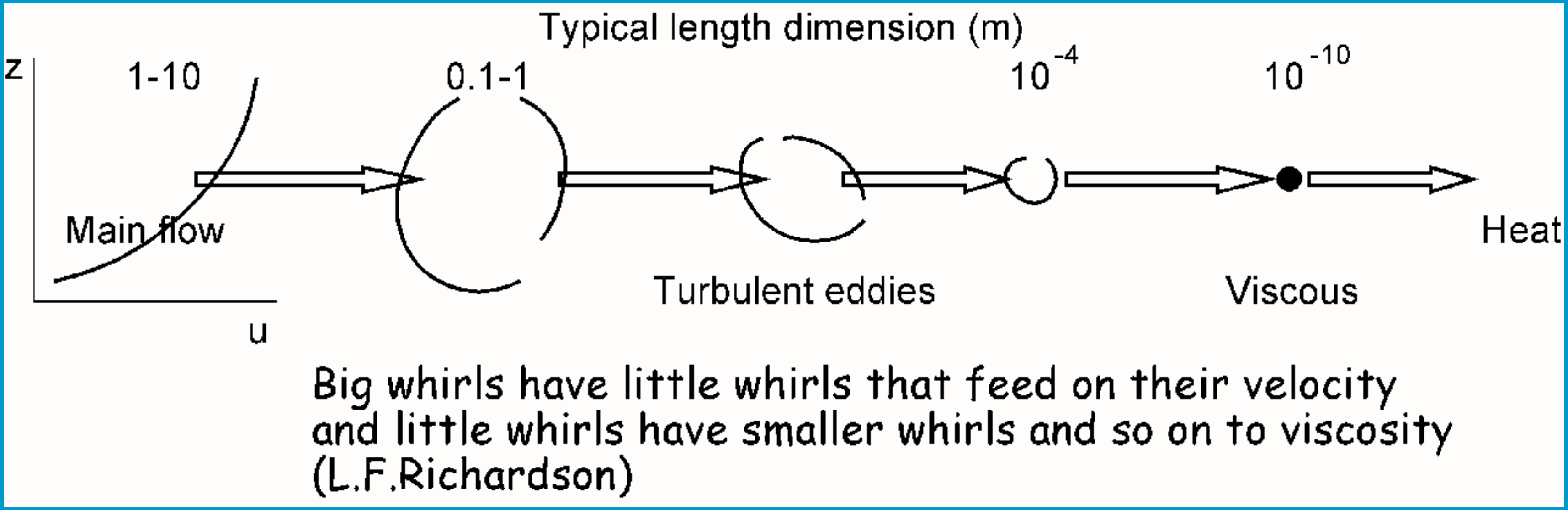
energy cascade in turbulent motion



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flow and turbulence in hydraulic jump