LULEÅ TEKNISKA UNIVERSITET

Air-water interaction in bottom outlets

An ambition within SVC – the Swedish Hydropower Centre

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(partly in Swedish)

Skandinaviens nordligaste tekniska universitet

Forskning & utbildning i världsklass

Svenskt Vattenkraftscentrum

- Vattenturbiner och generatorer
- Vattenbyggnad

  Vattenbyggnadshydraulik:

  - 2 miljöer: KTH och LTU, samarbete med CTH prioriterat
  - Miljö = Seniorforskare + 3-4 doktorander
  - Etableras 2009-2012
  - Fokus på bottenutskov initialt
  - Probleminventering: SWECO 2007-12-19

Bottenutskov – tvåfasfokus

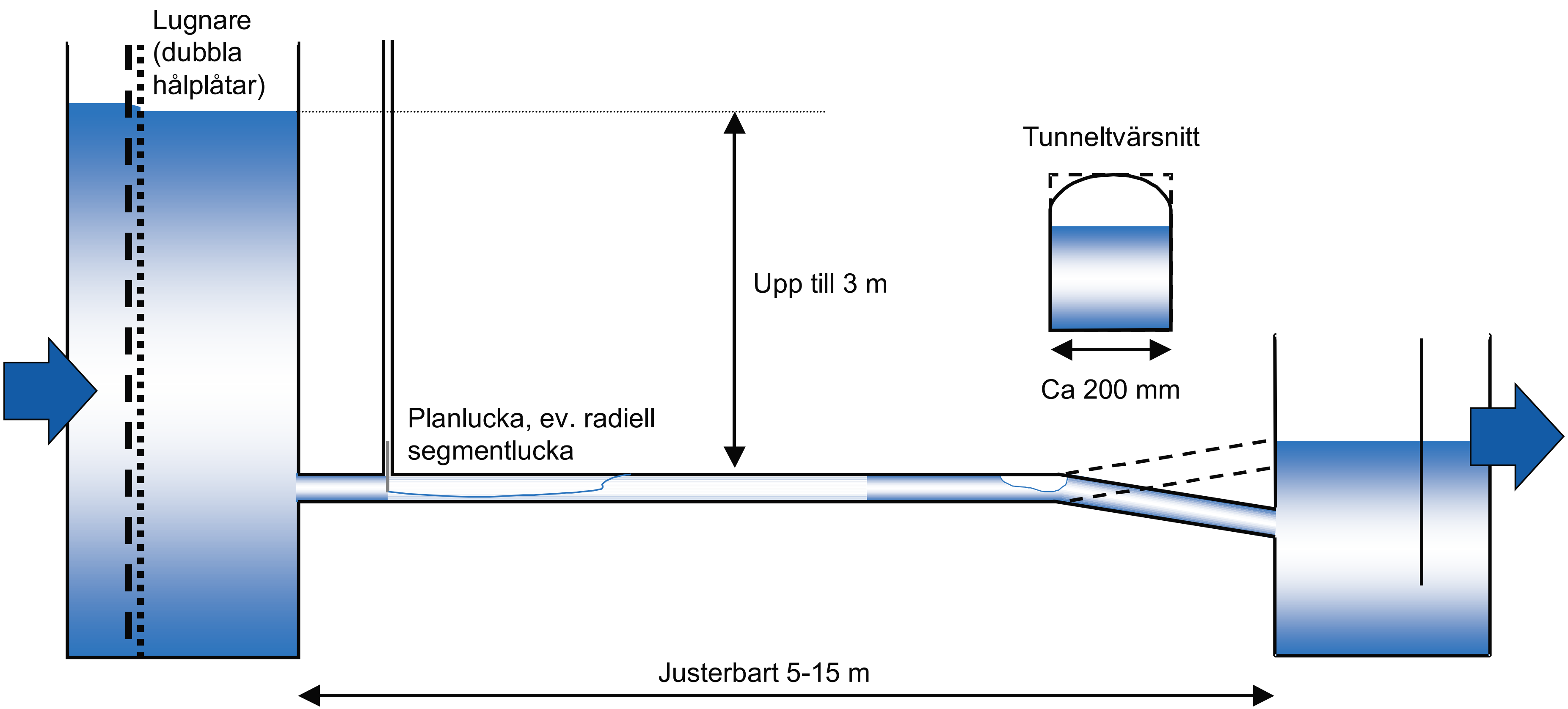
Praktiska frågeställningar:

- Luftmedrivning
- Luftblåsning
- Modelleringsverktyg för frivattenströmning och luftinblandning

Fokus LTU (OBS prel. tankar):

- Luftinblandning och avluftning
  - Tvåfas: modellering av fri vattenyta, bubbeldynamik, val av tvåfasansats
  - Fokus/mål på ingenjörsmodellering, d.v.s. subgridmodeller för RANS – I första hand tillämpning och validering, ej modellutveckling
  - Möjlig fördjupning: modellering av fri v.y. i regimer från “weak” till “strong turbulence”
  - Fokus vattensprång
  - Skaleffekter
  - Samverkan med KTH och CTH
- Modellering av luftblåsning
  - Kräver validering i utskovsrigg

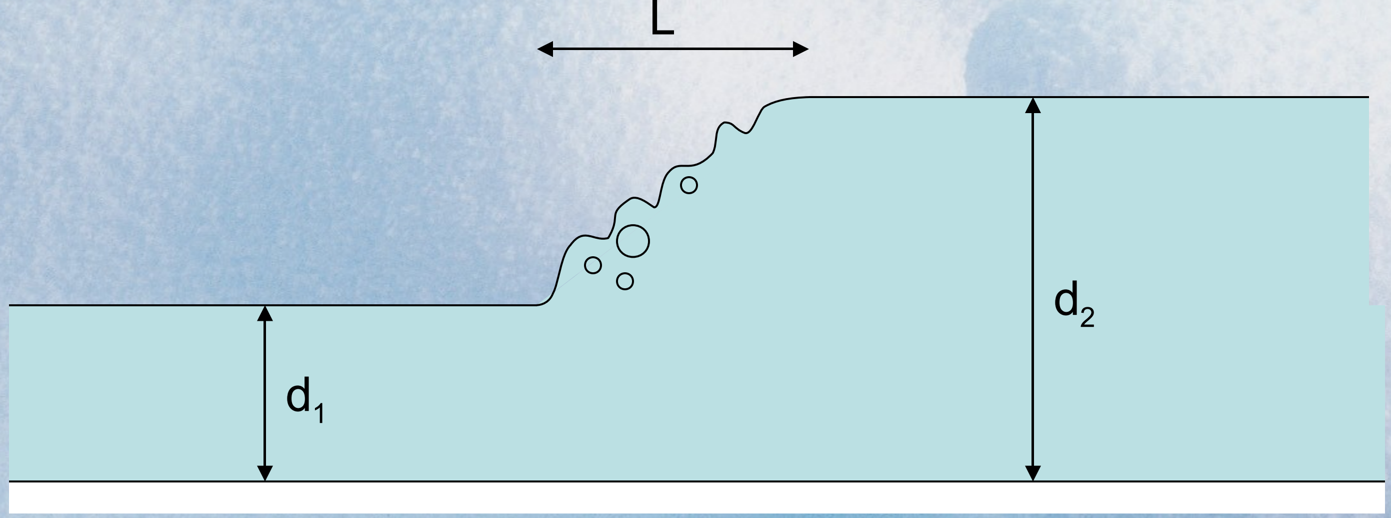
Avbörningsrigg: skiss med modell av tunnel/kulvertutskov



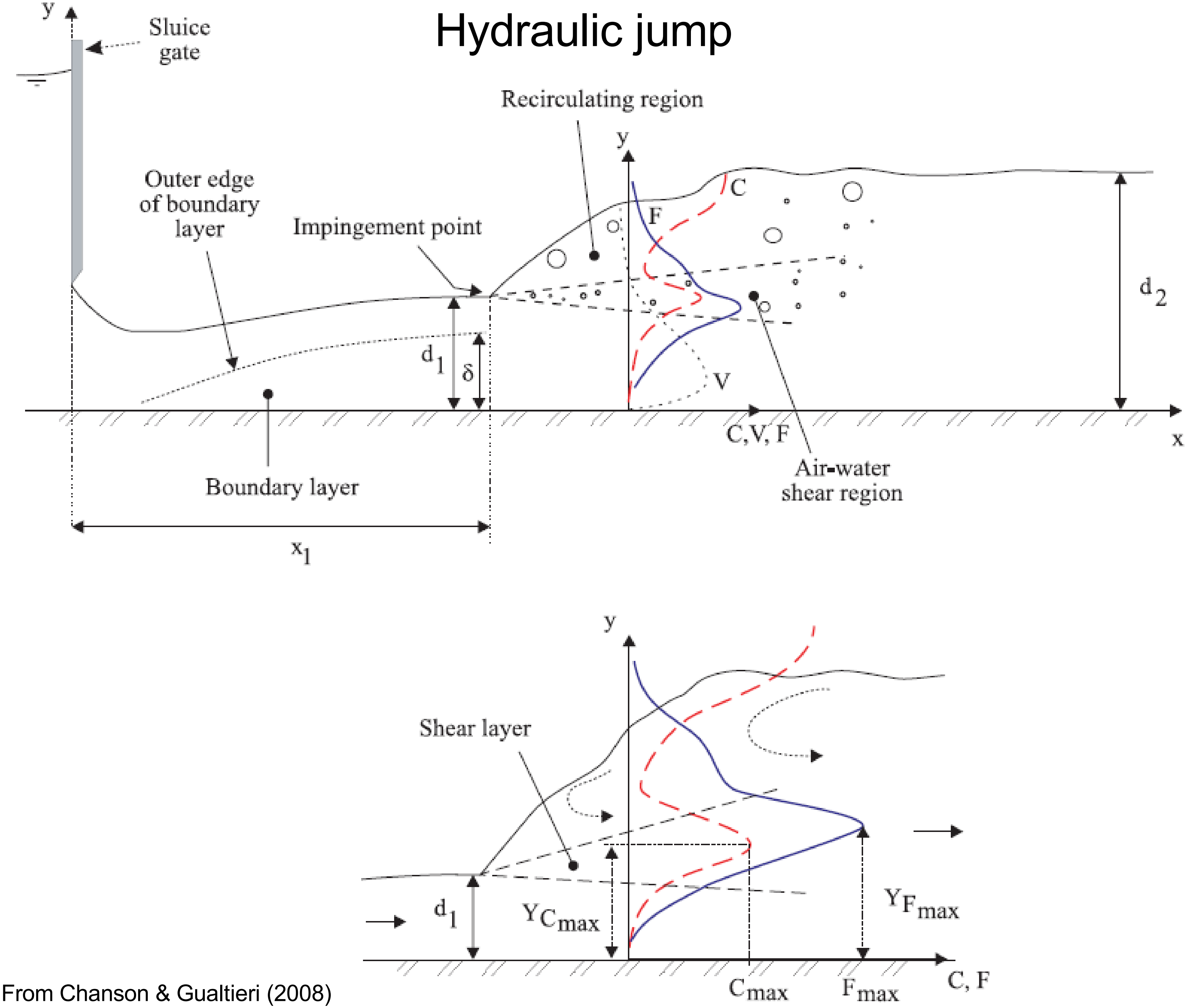
VATTENFALL

Hydraulic jump

- Fr > 1 to Fr < 1
- Substantial energy dissipation
- Role in hydro: dissipate kinetic energy from spillways
- Why: Control - safety, erosion, cavitation
- Classical Civil Engineering: Momentum & Continuity, empirical relations
- Present design-tool: Physical modelling (trust in results)



Hydraulic jump



From Chanson & Gualtieri (2008)

Physical hydraulic models

→ Froude scaling: gravity forces are scaled correctly

$\lambda = L_p/L_m$, Typically $\lambda = 50$

$U_m = \lambda^{-1/2} U_p$

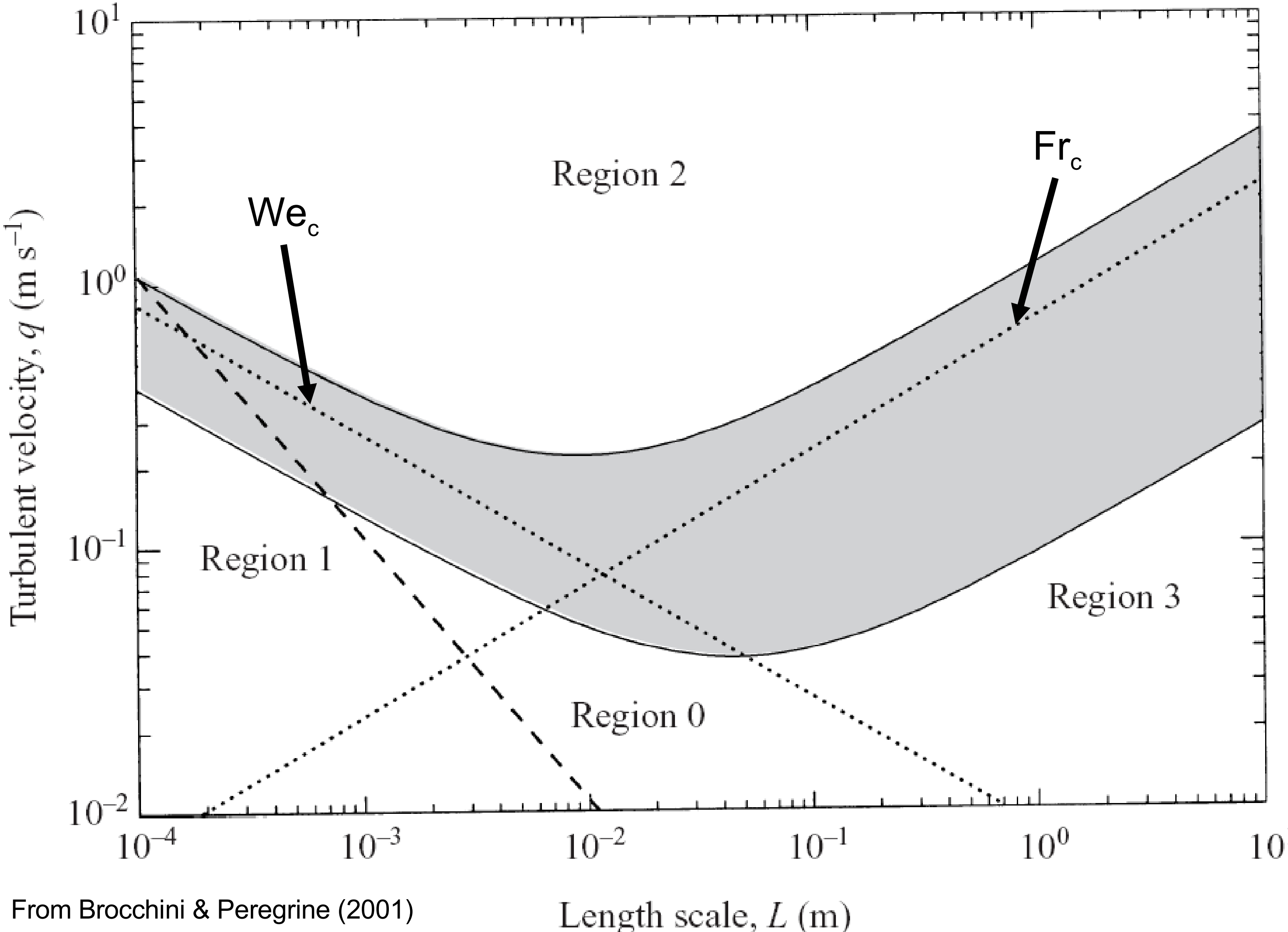
$Re_m = \lambda^{-3/2} Re_p$

$We_m = \lambda^{-2} We_p$

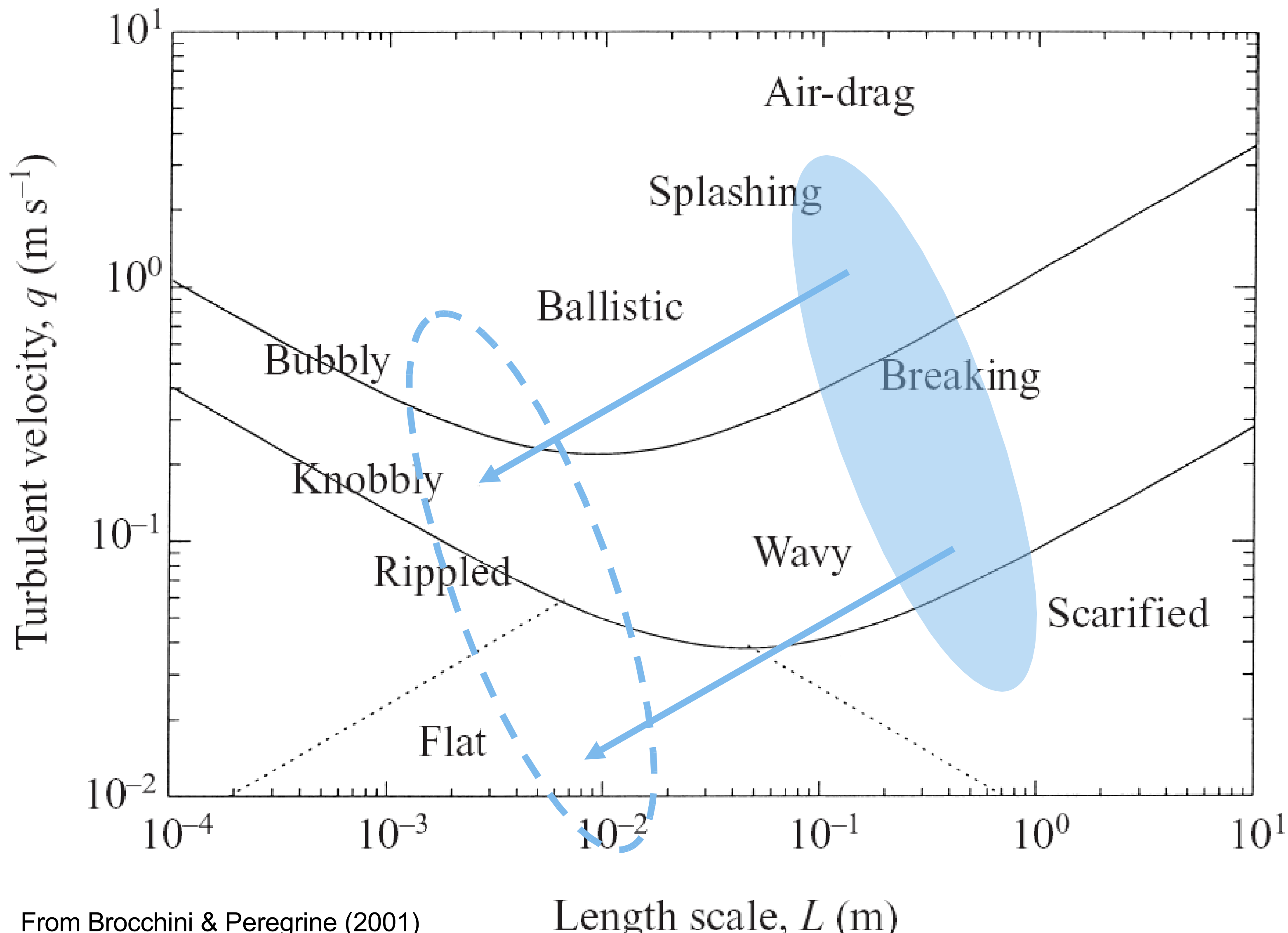
Re number and We significantly reduced:

- Re-effects small (remains essentially fully turbulent rough)
- We-effects substantial (surface tension forces inhibits destabilisation by inertial forces)

From Gualtieri & Chanson (2007)



From Brocchini & Peregrine (2001)



From Brocchini & Peregrine (2001)

More reading:

SVC – Swedish Hydropower Centre: http://www.svc.nu/

Bottom outlets – review of problems in Sweden:

- Dath, J. and M. Mathiesen, 2007, "Förstudie hydraulisk design – Inventering och översiktlig utvärdering av bottenutskov i svenska dammanläggningar", Slutrapport, Stockholm 2007-12-19, Uppdragsnr. 2165545, Sweco VBB AB.

Hydraulic jumps:

- Murzyn, F. and H. Chanson, 2008, "Experimental assessment of scale effects affecting two-phase flow properties in hydraulic jumps", Experiments in Fluids, v. 45, pp. 513-521.
- Chanson, H. and T. Brattberg, 2000, "Experimental study of the air-water shear flow in a hydraulic jump", International Journal of Multiphase Flow, v. 26, pp. 583-607.
- Murzyn, F. *et al.*, 2007, "Air–water interface dynamic and free surface features in hydraulic jumps", Journal of Hydraulic Research v. 45(5), pp. 679–685.
- Chanson, H. and C. Gualtieri, 2008, "Similitude and scale effects of air entrainment in hydraulic jumps", Journal of Hydraulic Research v. 46(1), pp. 35–44.

Surface conditions at "strong" turbulence:

- Brocchini, M. and D. H. Peregrine, 2001, "The dynamics of strong turbulence at free surfaces. Part 1. Description", Journal of Fluid Mechanics, v. 449, pp. 225-254.
- Brocchini, M. and D. H. Peregrine, 2001, "The dynamics of strong turbulence at free surfaces. Part 1. Free-surface boundary conditions", Journal of Fluid Mechanics, v. 449, pp. 255-290.
- Smolentsev, S. and R. Miraghaie, 2005, "Study of a free surface in open-channel water flows in the regime from "weak" to "strong" turbulence", International Journal of Multiphase Flow, v. 31, pp. 921-939.