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Working with water

Concepts and principles in hydraulics

Darren Lumbroso, HR Wallingford

What is hydraulics?

> Study of how water moves

> Deterministic based on mass conservation and force balance

> Uses principles of momentum and energy transfer

> Provides water levels, velocities, flow rates

Links to other areas

Water resources -

> What are water levels for different flows in different seasons

River morphology -

> sediment carrying capacity

Water quality -

> velocities associated with flows and channel shapes and sizes

Conservation -

> velocity distributions, water levels

Fisheries -

> velocities, water depths

Open channel principles

Energy and Momentum

Uniform Flow

- > Channel conveyance
- > Resistance equations

States of flow

Water surface profiles

Energy and momentum

Energy is the “capacity” to do “work”

- > Kinetic energy (from speed)
- > Potential energy (from position)
- > Also heat, sound etc
- > Each type has a magnitude (value) only
- > Energy “balance” on streamlines
- > Total energy is conserved

Energy “losses” arise because some energy types are ignored in analysis

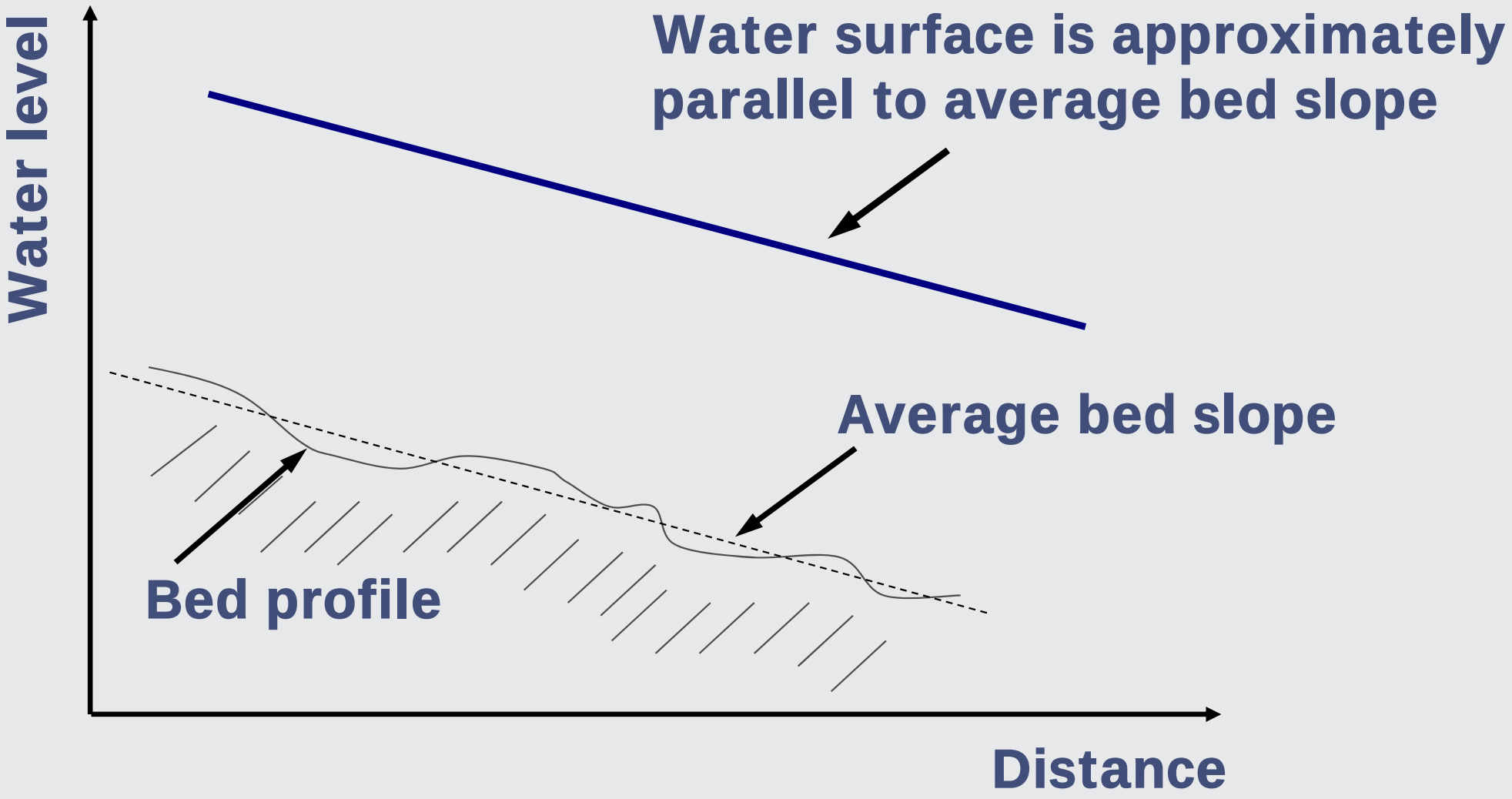
Energy and momentum

Momentum is mass x velocity

- > Changed by forces and impulses
- > Use Newton's second law
- > Has magnitude and direction
- > Used to calculate forces on structures
- > Can be applied where energy "losses" are large

Scope for confusion!

Uniform flow profile



Uniform flow

> Central to understanding of open channel hydraulics

> Energy “line”, water surface slope and channel bed are all parallel

> The depth is called “Normal Depth”

> Several assumptions in the analysis

> Rarely occurs in practice!

Calculating uniform flow

Assumptions are:

- steady flow
- regular shape of cross-section
- no change of velocity, depth or slope with distance along channel
- rate of “loss” of potential energy balances work done against flow resistance - but ...

What is really happening?

Uniform flow equation

Equation relating slope, channel dimensions and velocity

$$Q = K\, s^{1/2}$$

- Q is discharge [m^3/s]
- K is conveyance [m^3/s]
- s is water surface slope

Conveyance represents the flow capacity of the channel

What is conveyance?

Links channel dimensions, shape and roughness - many formulae available

Manning's equation:

$$K = \frac{A\,R^{2/3}}{n}$$

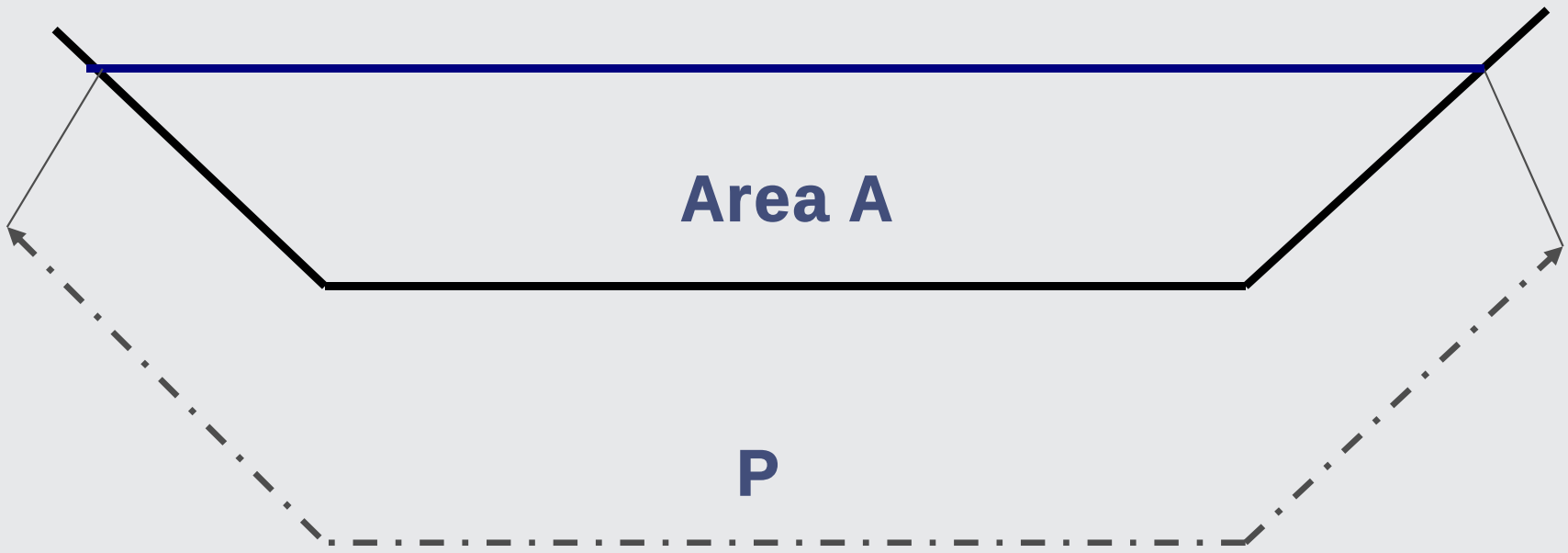
- K is conveyance
- A is area
- R is hydraulic radius
- n is Manning's roughness coefficient

Hydraulic Radius

Represents the shape of the cross section

Ratio of Area, A to Wetted Perimeter, P

$$R = \frac{A}{P}$$



Putting things together

$Q = K\, s^{1/2}$

$K = A\, R^{2/3} / n$

$R = A / P$

$Q = A\, R^{2/3} (s^{1/2} / n)$

Given a section shape, we can calculate A and P

With information on slope and roughness we can calculate discharge

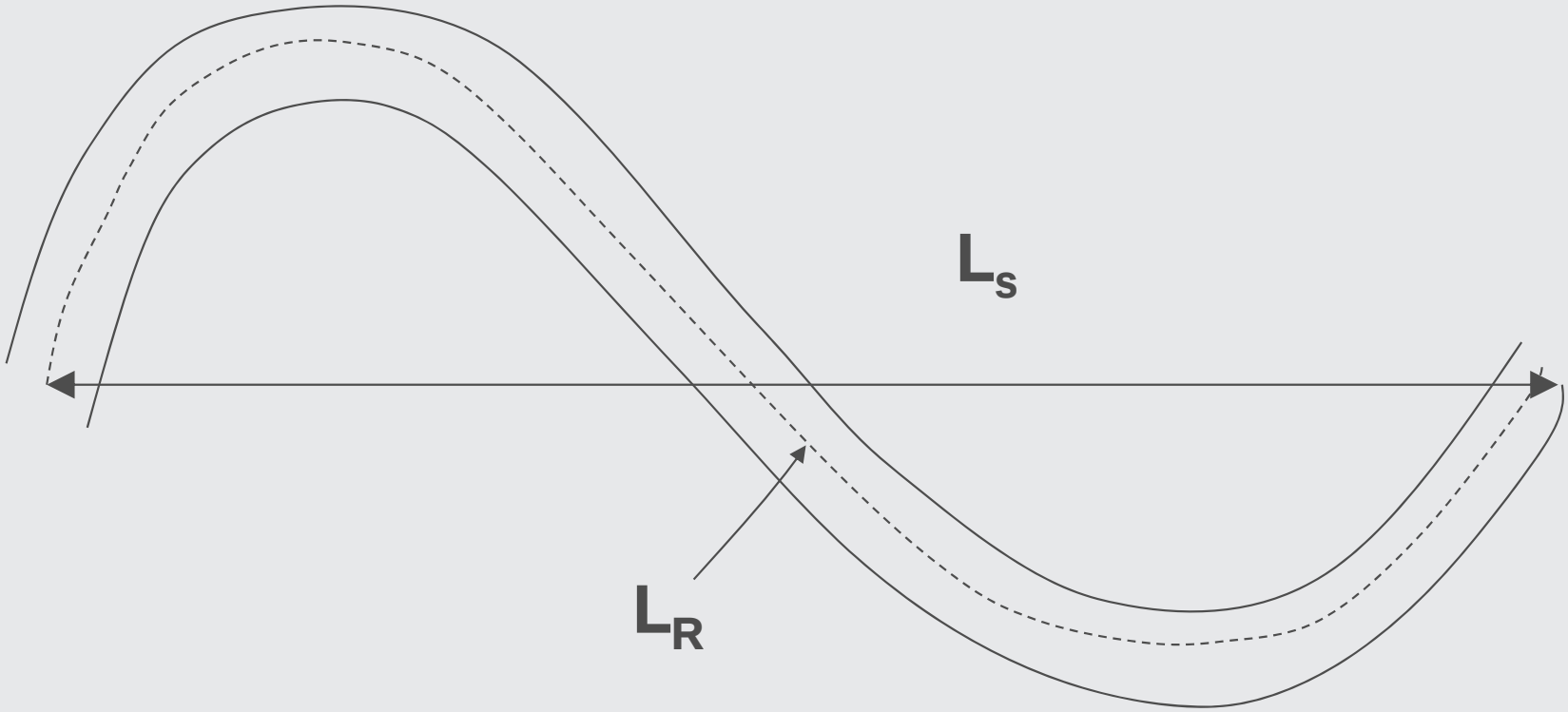
What is the resistance coefficient?

- A number which describes the resistance of the channel to flow
- Depends upon the resistance equation being used
- We concentrate on Manning's equation due to its international use
- It has limitations e.g. varies with depth

What affects resistance?

> Bed surface material
> Channel irregularity
> Channel alignment and sinuosity
> Depth and discharge velocity
> Vegetation and sediments
> Gradient (as surrogates for other parameters)

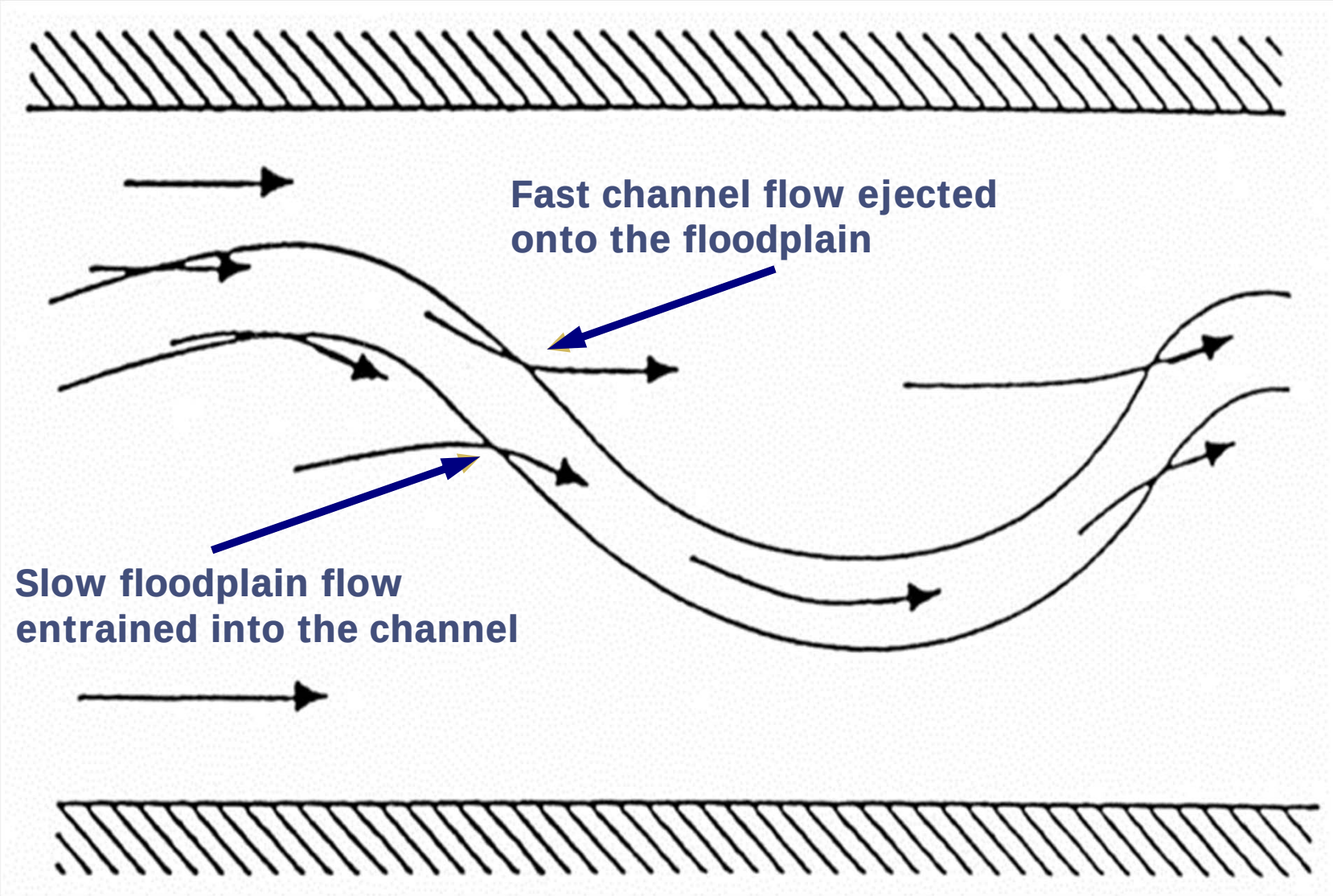
Sinuosity



Sinuosity $S = L_R/L_S$

Sinuous river

Interaction between channel and floodplain



Evidence of flow interaction

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Classification of flows

Flow states

Sub-critical

> Slow and deep - low kinetic energy

Super-critical

> Fast and shallow - high kinetic energy

Critical

> Special, unique relation between velocity and "mean" depth, y

$$V_c = (gy)^{1/2}$$

Froude number classification

Froude number definition

$$Fr = \frac{V}{(g\,y)^{0.5}}$$

where V is velocity (m/s)

y is depth (m)

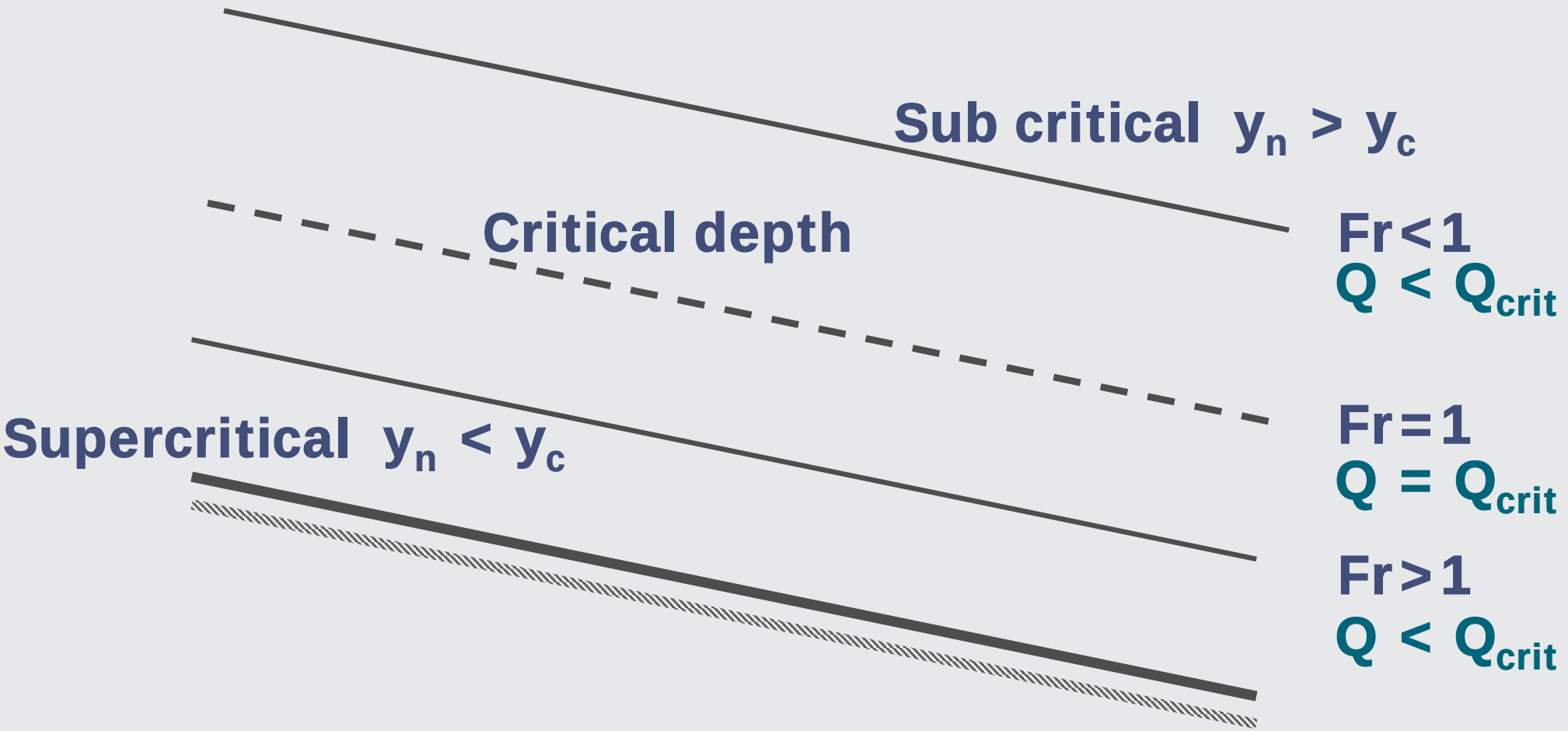
g is acceleration due to gravity (m/s^2)

Fr < 1 subcritical flow

Fr = 1 critical flow (maximum discharge for a given slope)

Fr > 1 supercritical flow

Normal and critical depths



Transition - Hydraulic jump

Transition to supercritical flow

Photograph from BBC website

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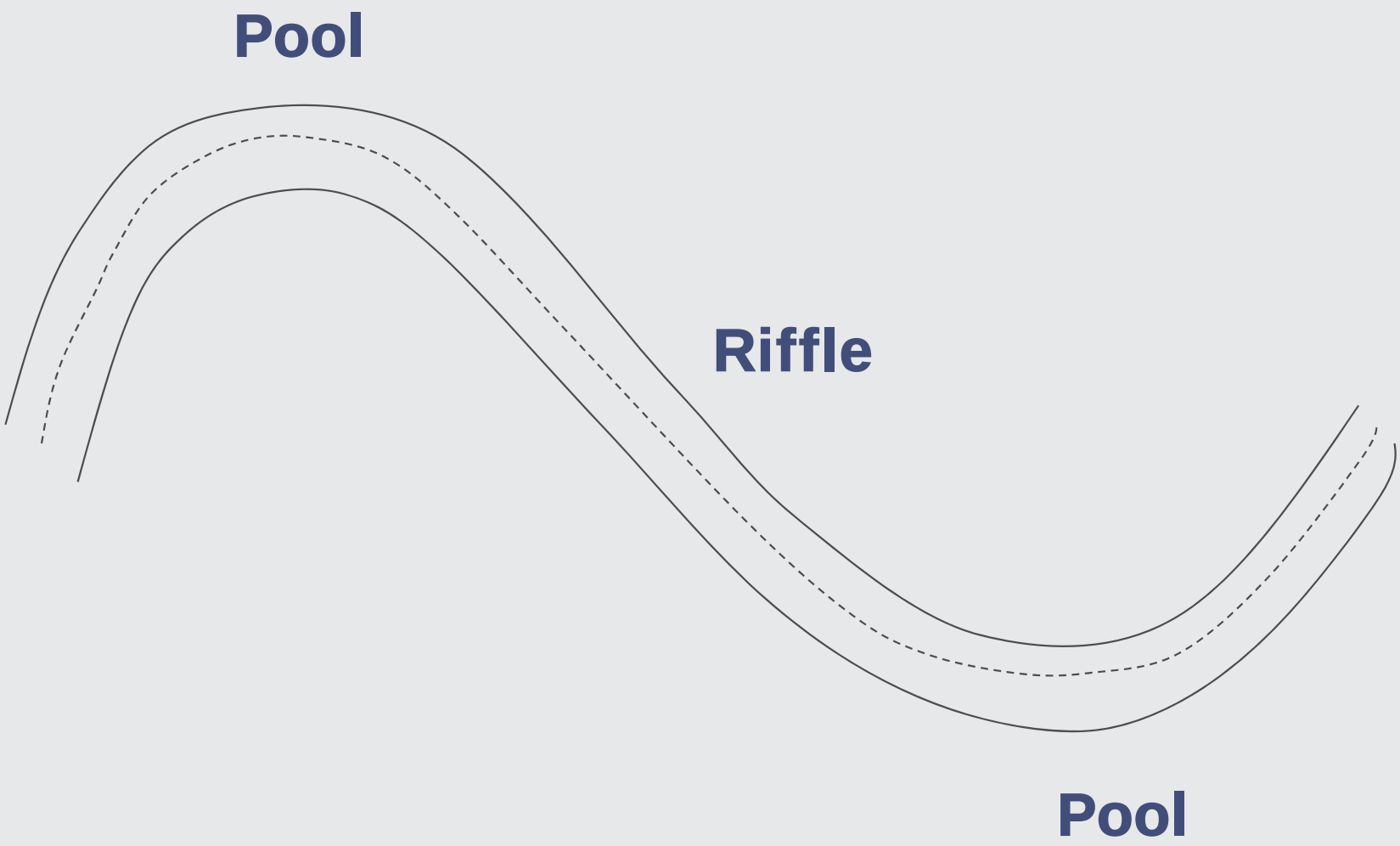
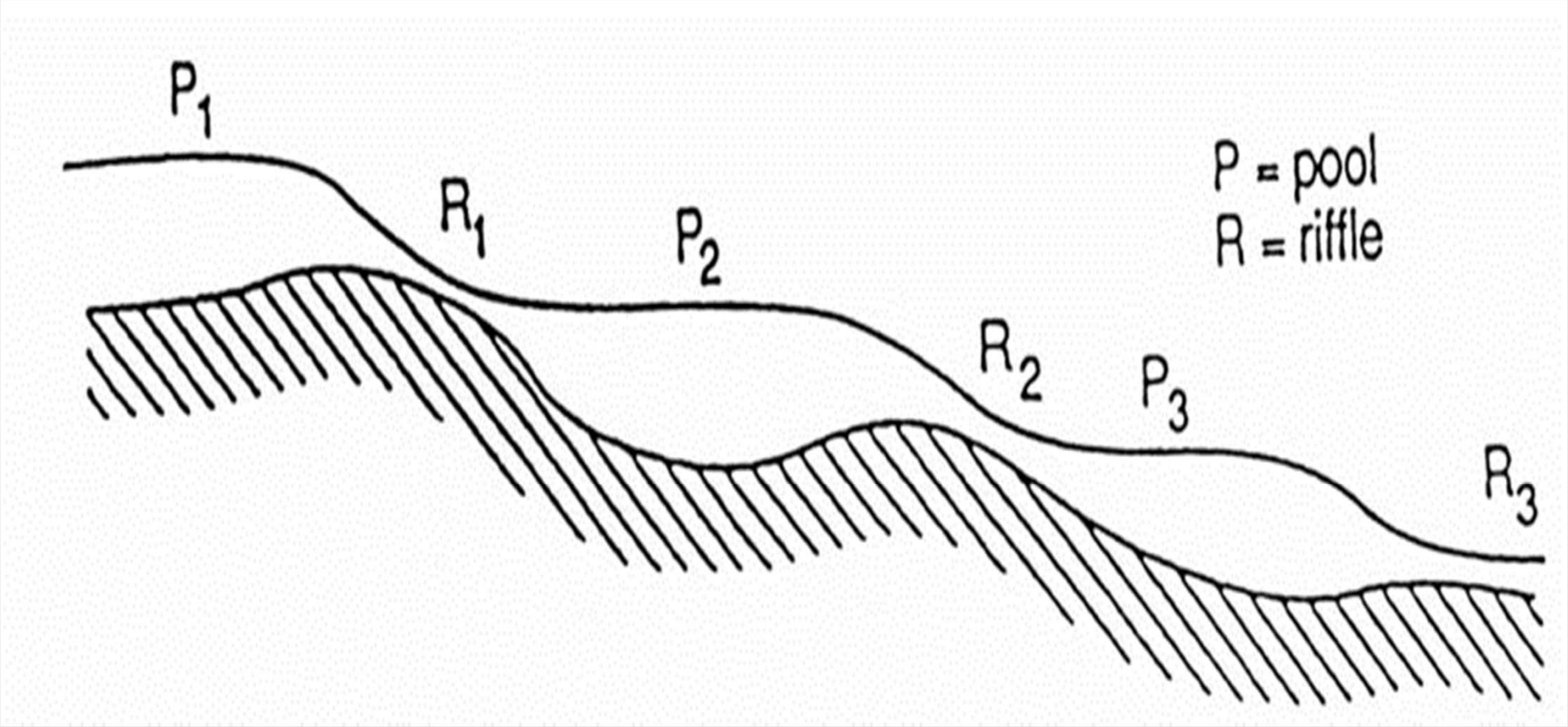
Interpreting flow profiles

Pool and riffle locations



Low flow profile



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Riffle and pool

What have we learnt?

Simple principles of different flow states

Definition and calculation of :

> Uniform flow

> Conveyance

> Flow resistance

Typical water surface profiles for various conditions

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Any questions?

HR Wallingford
Howbery Park, Wallingford, Oxfordshire OX10 8BA, United Kingdom
tel +44 (0)1491 835381 fax +44 (0)1491 832233 email info@hrwallingford.com