457.562 Special Issue on River Mechanics (Sediment Transport) .10 Bed forms

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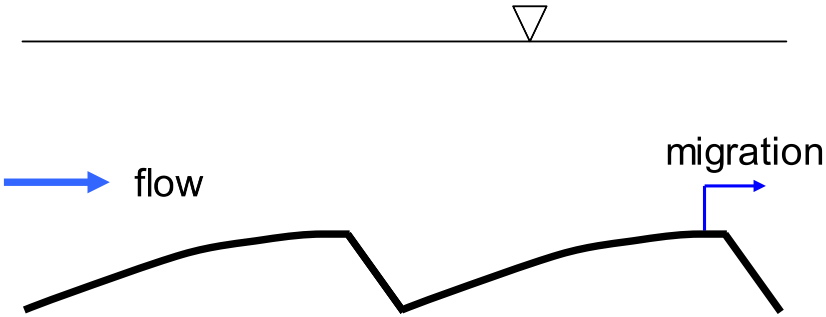
TOUR OF BEDFORMS IN RIVERS: RIPPLES

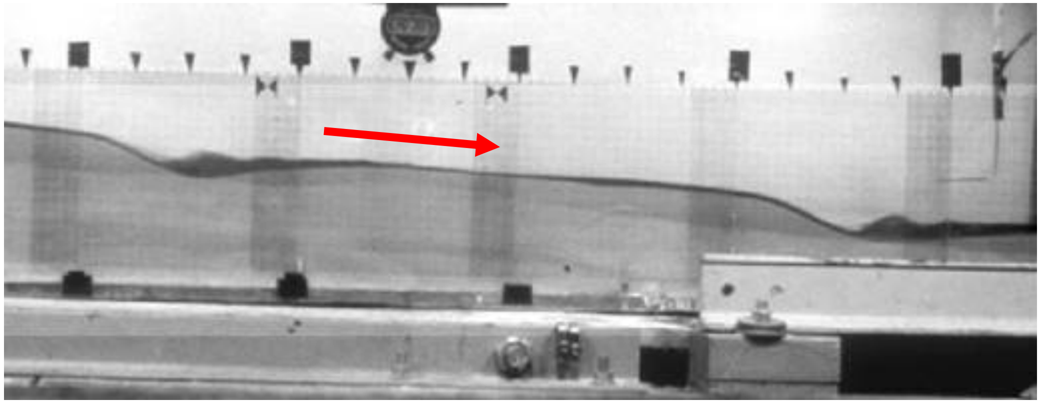


View of the Rum River, Minnesota USA

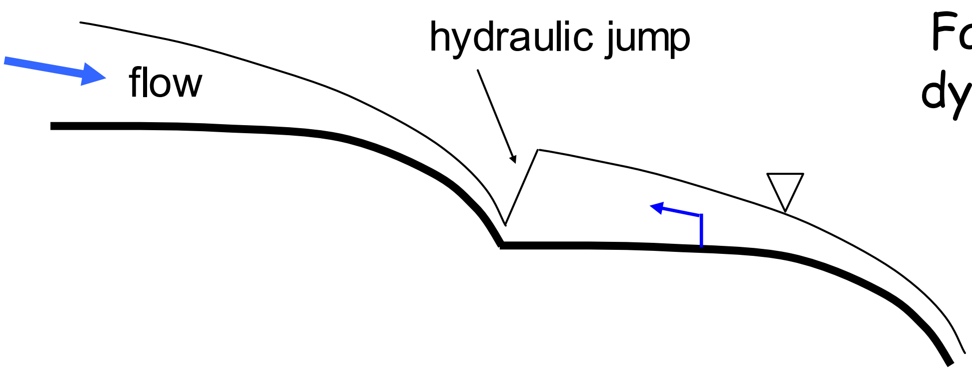
Ripples in the Rum River, Minnesota USA at very low flow

TOUR OF BEDFORMS IN RIVERS: CYCLIC STEPS (CHUTE AND POOL TRAINS)

Trains of **cyclic steps** occur in very steep flows with supercritical Froude numbers. They are long-wave relatives of antidunes. The steps are delineated by hydraulic jumps (immediately downstream of which the flow is locally subcritical). The steps migrate upstream. These features are also called chute-and-pool topography.

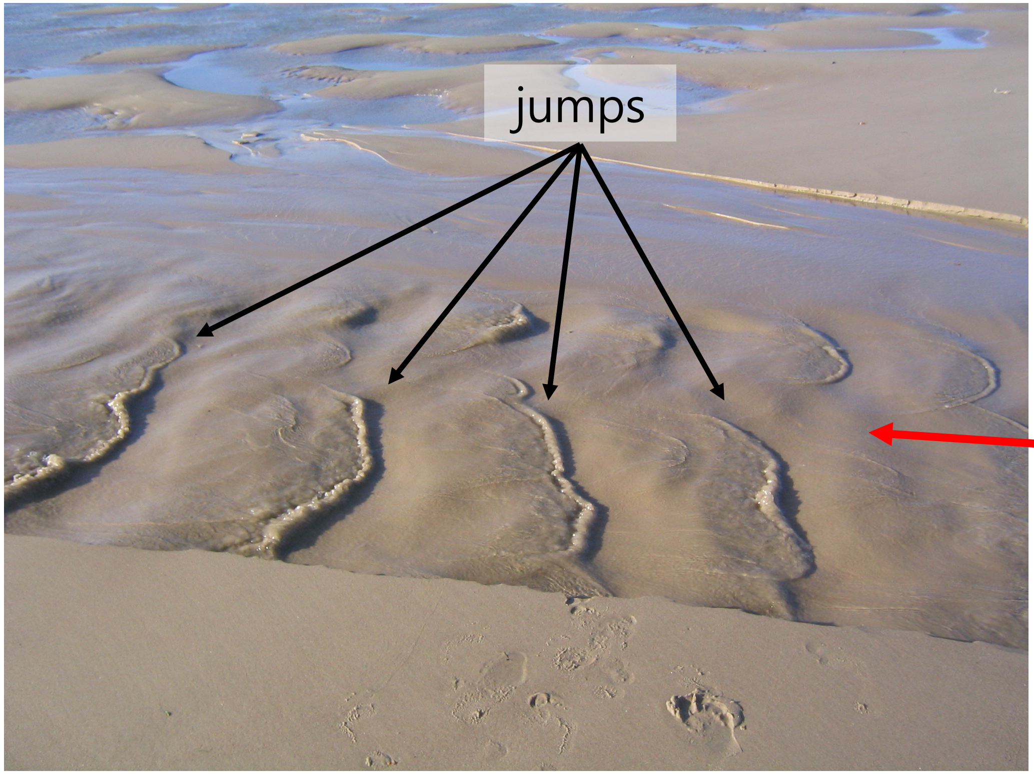


Train of cyclic steps in a small laboratory channel at St. Anthony Falls Laboratory. The water has been dyed to aid visualization; two hydraulic jumps can be seen in the figure.



TOUR OF BEDFORMS IN RIVERS: CYCLIC STEPS (contd.)

Cyclic steps form in the field when slopes are steep, the flow is supercritical and there is a plethora of sediment.



Trains of cyclic steps in a coastal outflow channel on a beach in Calais, France. Image courtesy H. Capart.

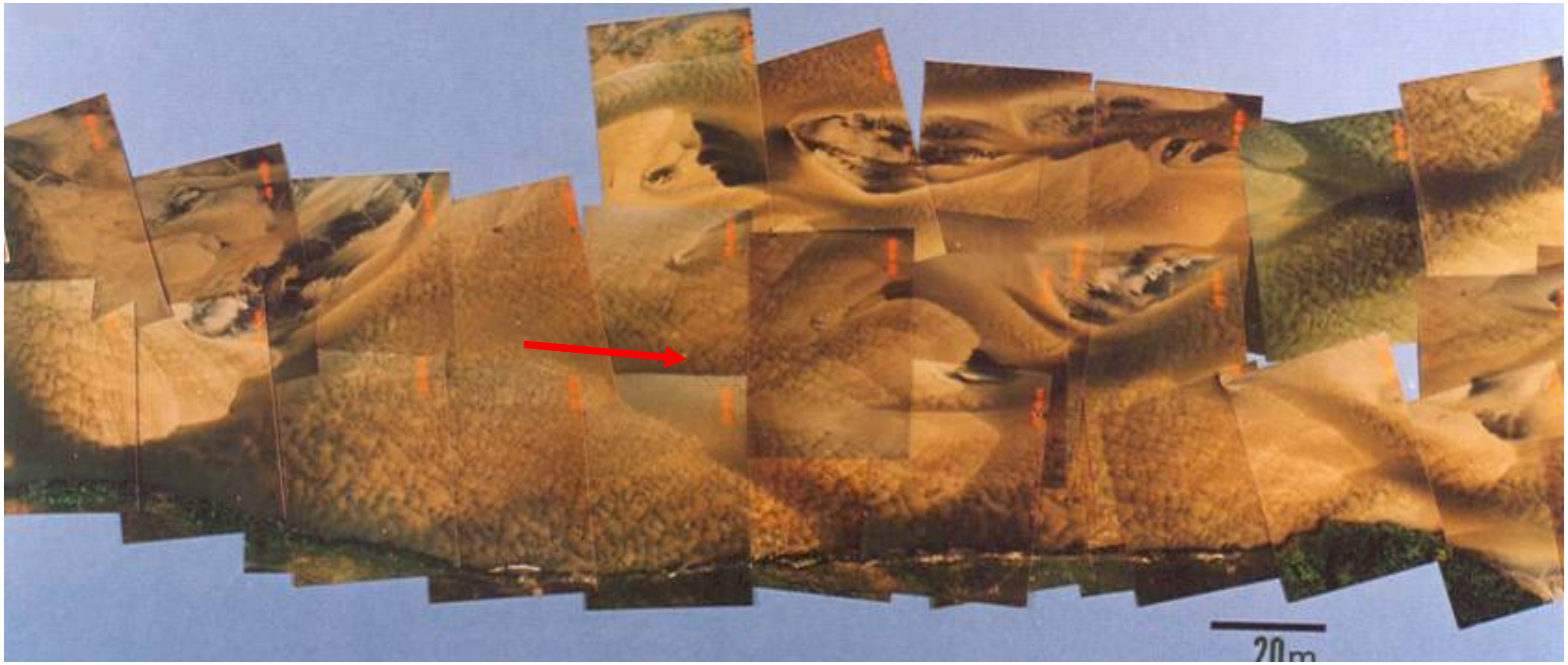
TOUR OF BEDFORMS IN RIVERS: ALTERNATE BARS

Alternate bars occur in rivers with sufficiently large (> ~ 12), but not too large width-depth ratio B/H. Alternate bars migrate downstream, and often have relatively sharp fronts. They are often precursors to meandering. Alternate bars may coexist with dunes and/or antidunes.

Alternate bars in the Naka River, an artificially straightened river in Japan. Image courtesy S. Ikeda.

TOUR OF BEDFORMS IN RIVERS: MULTIPLE-ROW LINGUOID BARS

Multiple-row bars (linguoid bars) occur when the width-depth ratio B/H is even larger than that for alternate bars. These bars migrate downstream. They may co-exist with dunes or antidunes.



Plan view of superimposed linguoid bars and dunes in the North Loup River, Nebraska USA. Image courtesy D. Mohrig. Flow is from left to right.

BEDFORMS IN THE LABORATORY AND FIELD: DUNES

Dunes in a flume in Tsukuba University, Japan: flow turned off. Image courtesy H. Ikeda.

Dunes on an exposed point bar in the meandering Fly River, Papua New Guinea

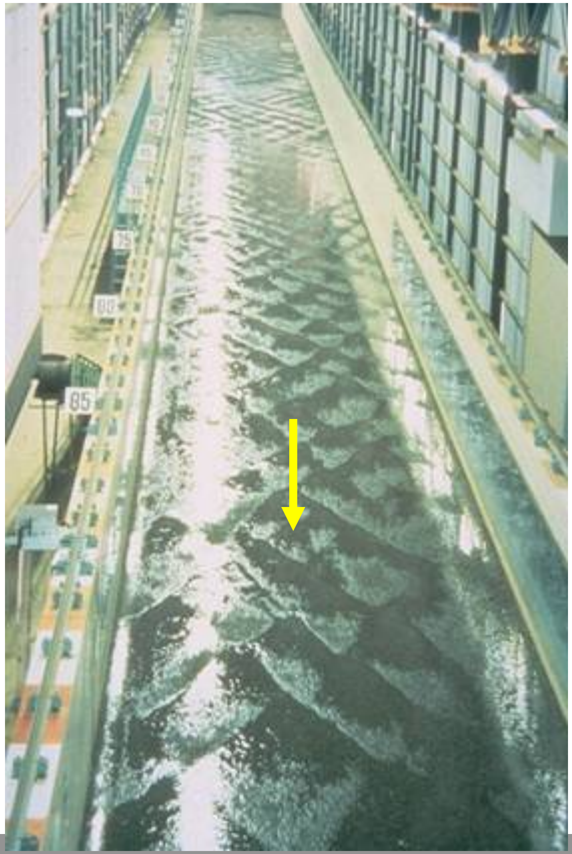
BEDFORMS IN THE LABORATORY AND FIELD: ALTERNATE BARS

Alternate bars in a flume in Tsukuba University, Japan: flow turned low. Image courtesy H. Ikeda.

Alternate bars in the Rhine River between Switzerland and Lichtenstein. Image courtesy M. Jaeggi.

BEDFORMS IN THE LABORATORY AND FIELD: MULTIPLE-ROW (LINGUOID) BARS

Linguoid bars in a flume in Tsukuba University, Japan: flow turned off. Image courtesy H. Ikeda.



Linguoid bars in the Fuefuki River, Japan. Image courtesy S. Ikeda.

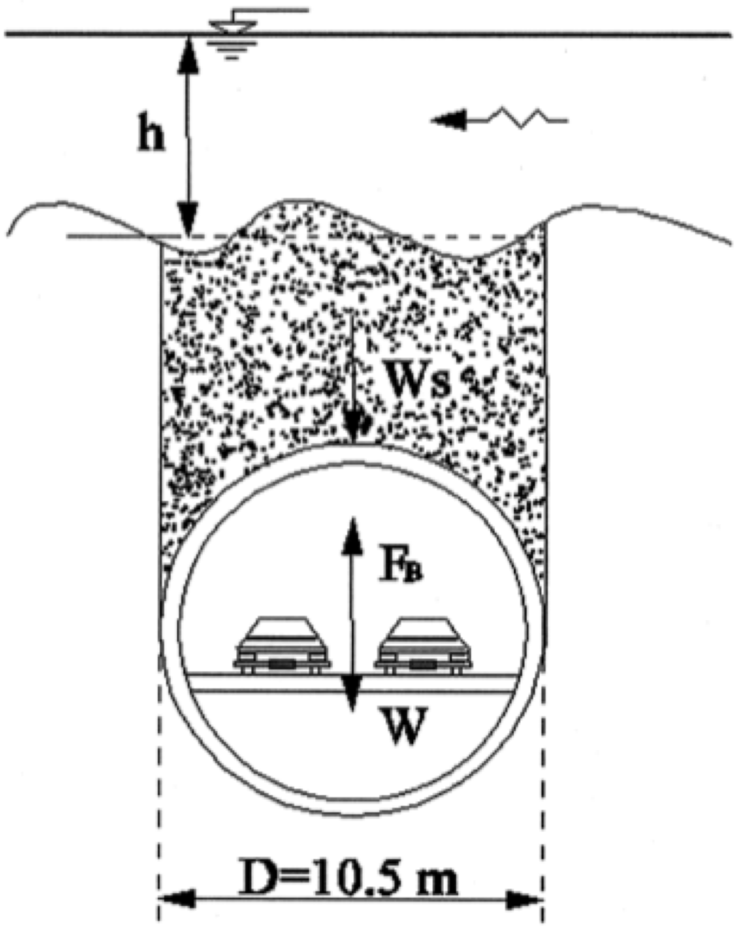
WHEN THE FLOW IS INSUFFICIENT TO COVER THE BED, THE RIVER MAY DISPLAY A BRAIDED PLANFORM

Braiding in a flume in Tsukuba University, Japan: flow turned low. Image courtesy H. Ikeda.

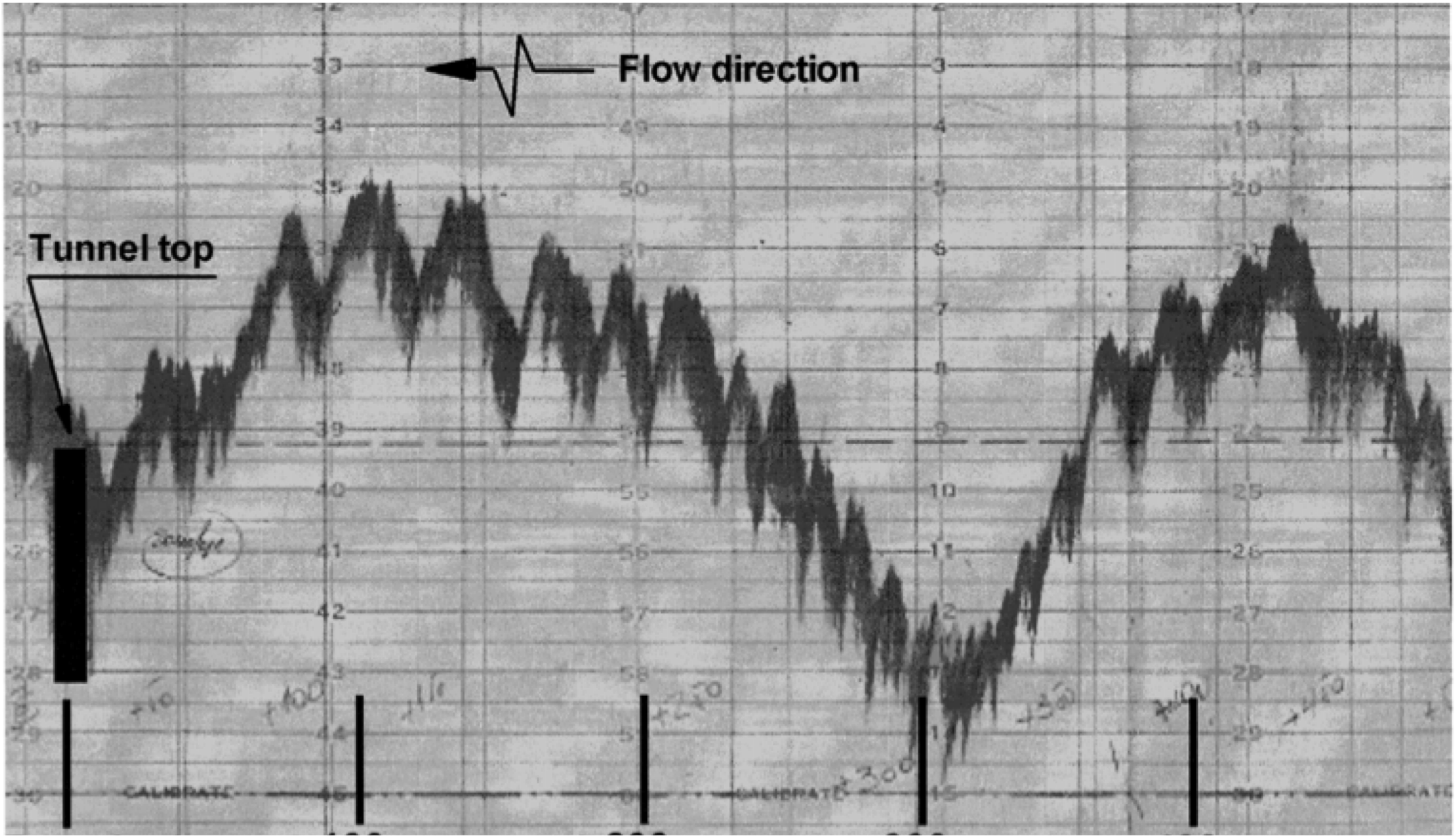
Braiding in the Ohau River, New Zealand. Image courtesy P. Mosley.

1. Bed forms

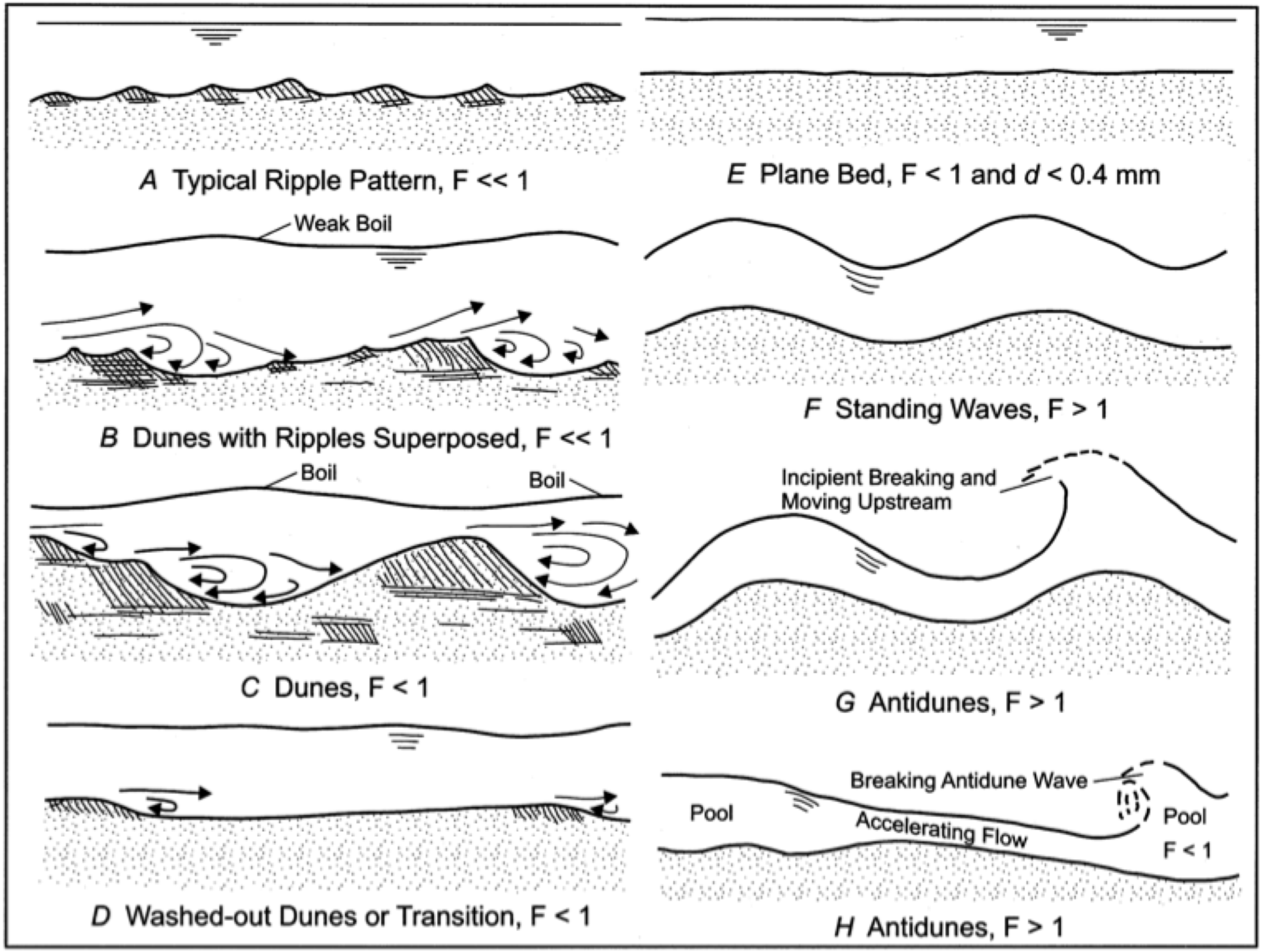
- Bed form change the river characteristics
  - Change friction
  - Decreasing depth
  - Increasing (or decreasing) weight on the underground structure
  - Migration of river and scouring (by trough of the wave)



Bed forms



2. Dunes, Antidunes, Ripples and Alternate Bars



2. Dunes, antiduens, ripples, and alternate bars

- The ripples, dunes, and antidunes are the classic bed for ms of erodible-bed, open-channel flow.
- They are the product of flow and sediment transport.
- They influence flow and sediment transport.
- Sorry, but the previous description of bed load equations are not valid in the presence of bed forms.
- Bed form wave's description

λ : Wave length

Δ : Wave height

H : Depth

Dunes

2. Dunes, antiduens, ripples, and alternate bars

- Dunes:
  - Well developed dunes tend to have wave height Δ scaling up to about one-sixth of the depth; i.e.

$$\frac{\Delta}{H} \leq \frac{1}{6}$$

  - Wave number range for dunes

$$0.25 < k < 4.0 \qquad k = \frac{2\pi H}{\lambda}$$

  - Dunes migrate downstream. Shapes are triangular and po sse a slip face.
  - A dune progresses forward as bed load accretes on the sli p face.

2. Dunes, antiduens, ripples, and alternate bars

- Dunes:
  - Dunes are characteristic of subcritical flow in the Froude s ense.
  - In a shallow-water (long-wave) model, the Froude criterion dividing subcritical (Fr<1) and supercritical (Fr>1) flow is

$$Fr = \frac{U}{\sqrt{gH}}$$

  - However, dunes do not qualify as long waves, in that their wavelength is of the order of the flow depth.
  - Kennedy gave criterion for critical flow over a bedform

$$Fr^2 = \frac{1}{k}\tanh k$$

2. Dunes, antiduens, ripples, and alternate bars

- Dunes:
  - Note that as k goes to zero, tanh k goes k, and condition is recovered in the long-wave limit.
  - For dunes occur, then the condition

$$Fr^2 < \frac{1}{k}\tanh k$$

  - Must be satisfied.
  - Bothe dunes and antidunes cause the water surface to un dulate as well as the bed.
  - In the case of dunes, the undulation of the water surface is usually of much smaller amplitude than that of the bed; the two are nearly 180° out of phase.

2. Dunes, antiduens, ripples, and alternate bars

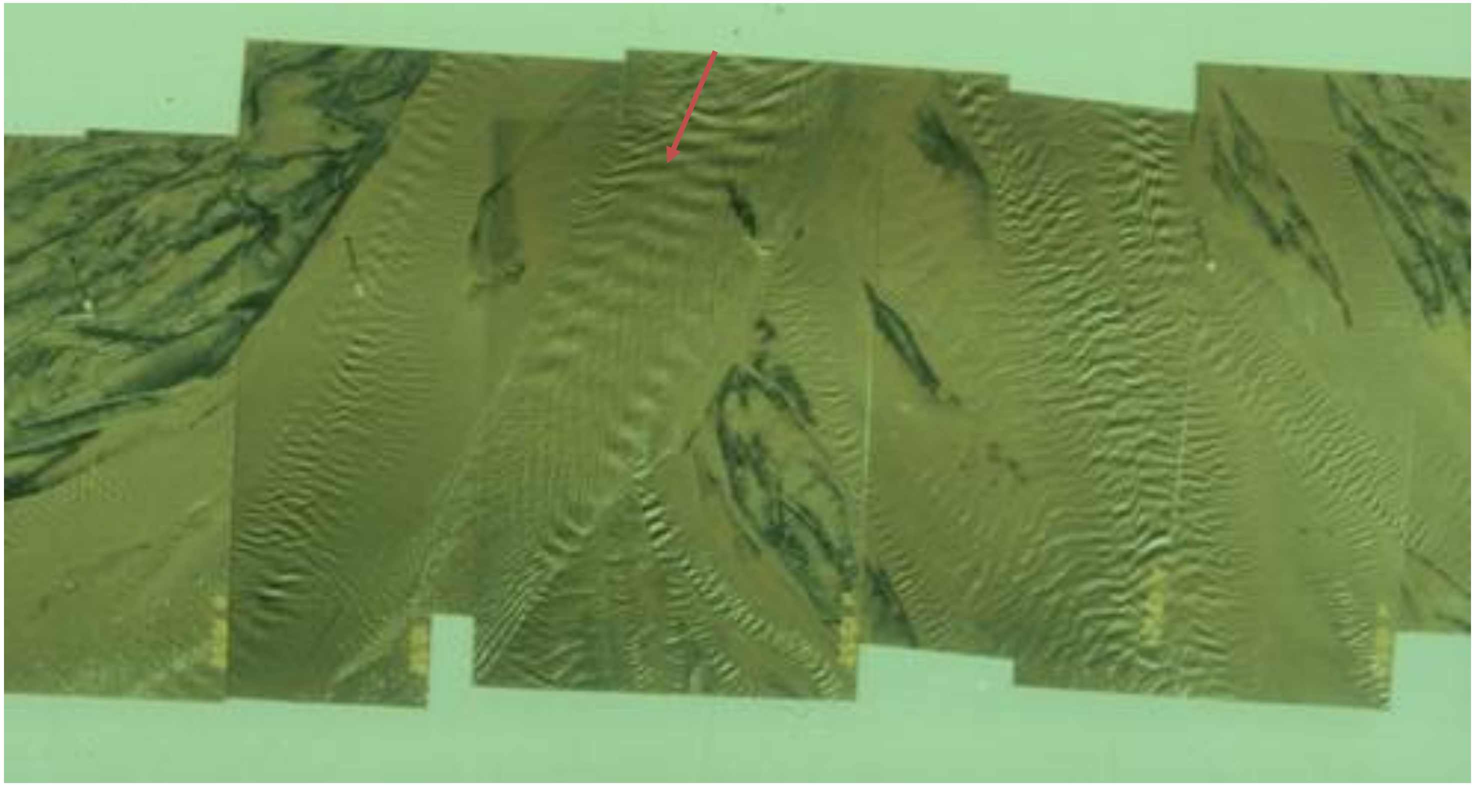
- Dunes:
  - Let c denotes the wave speed of the dune. The bed load transport rate by dunes can be estimated as the volume of material transported forward per unit bed area per unit time by a migrating dune.
  - If the dune is approximated as triangular in shape, the following approximation holds

$$q \cong \frac{1}{2}\Delta c\left(1-\lambda_p\right) \qquad \Delta: \text{amplitude, } \lambda_p: \text{porosity of sediment}$$

  - This is the bed form transport rate (not bed load).
  - Kondap and Garde

$$\frac{c}{U} = 0.02 \times Fr^3$$

Antidunes



Trains of surface waves indicating the presence of antidunes in braided channels of the tailings basin of the Hibbing Taconite Mine, Minnesota, USA. Flow is from top to bottom.

2. Dunes, antiduens, ripples, and alternate bars

- Antidunes:
  - Antidunes are distinguished from dunes by the fact that the water surface undulations are nearly in phase those of the bed

$$Fr^2 > \frac{1}{k}\tanh k$$

  - Antidunes may migrate either upstream or down stream.
  - Upstream-migrating anitdunes are usually rather symmetri cal.
  - Down stream migrating antidunes are rather rare. These h ave a well-defined slip face look rather like dunes.

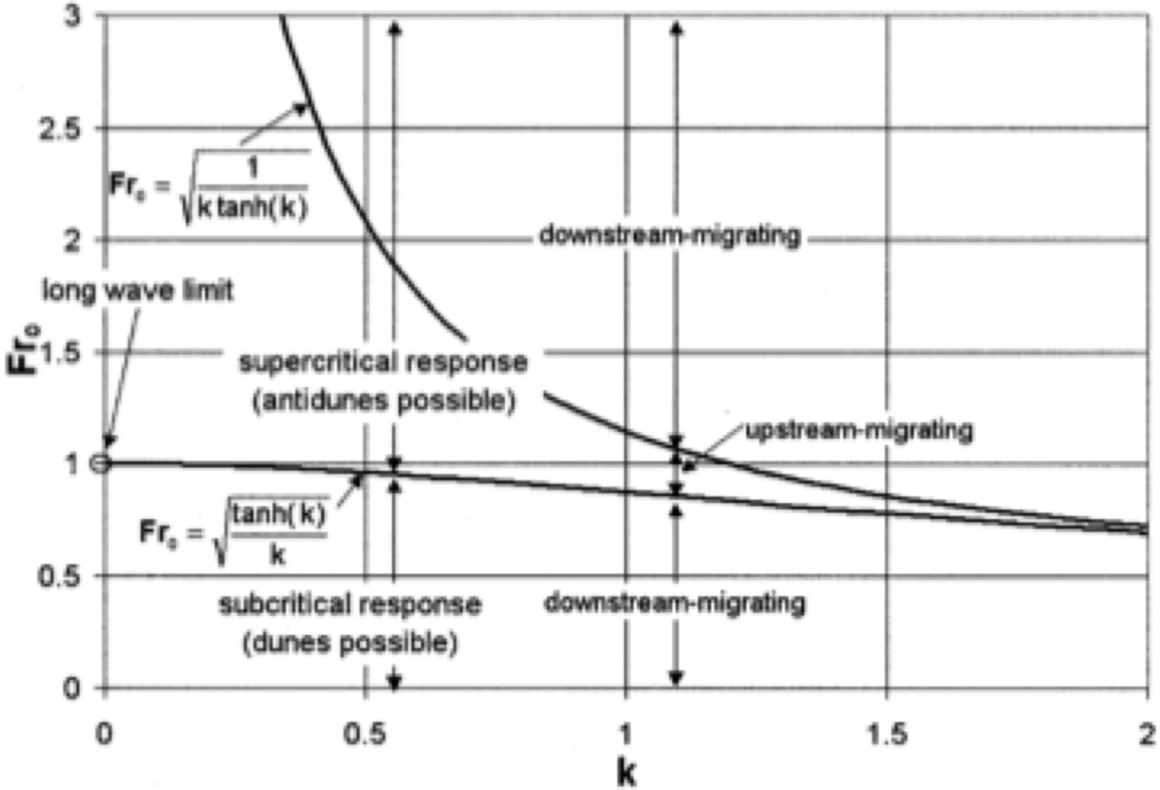
2. Dunes, antiduens, ripples, and alternate bars

- Antidunes:
  - The potential flow criterion diving upstream-migrating antid unes from downstream-migrating antidunes is

$$Fr^2 = \frac{1}{k \tanh k}$$

  - Values lower than the above are associated with upstream migrating antidunes

2. Dunes, antiduens, ripples, and alternate bars



2. Dunes, antiduens, ripples, and alternate bars

- Ripples
  - Ripples are dune-like features that occur most of the time i n the present of a viscous sublayer.
  - Ripple look very much like dunes in that they migrate down stream and have a pronounced slip face.
  - They are much more three-dimensional in structure than d unes, however, and have little effect on the water surface.
  - Ripple will form when viscous sublayer exist, so

$$R_p = \frac{u_* D}{\nu} \le 11.6 \quad (\text{since } \delta_v = 11.6\frac{\nu}{u_*})$$

2. Dunes, antiduens, ripples, and alternate bars

- Alternate bars
  - Alternate bars are bed forms most commonly found in strai ght alluvial channels.
  - Their geometry is three-dimensional.
  - Navigation conditions and streambank stability can be affe cted by alternate bars.
  - Channel meandering from pool to pool. And this can affect to the channel bank and leading to the initiation of stream meandering.
  - Pools are good for habitat and play important role in strea m ecology