

**RIVER BANK INSTABILITY, CHANNEL FORMATION AND
RATES OF INCISION IN MICRO-CANYONS
OF THE EXPOSED DEAD SEA**

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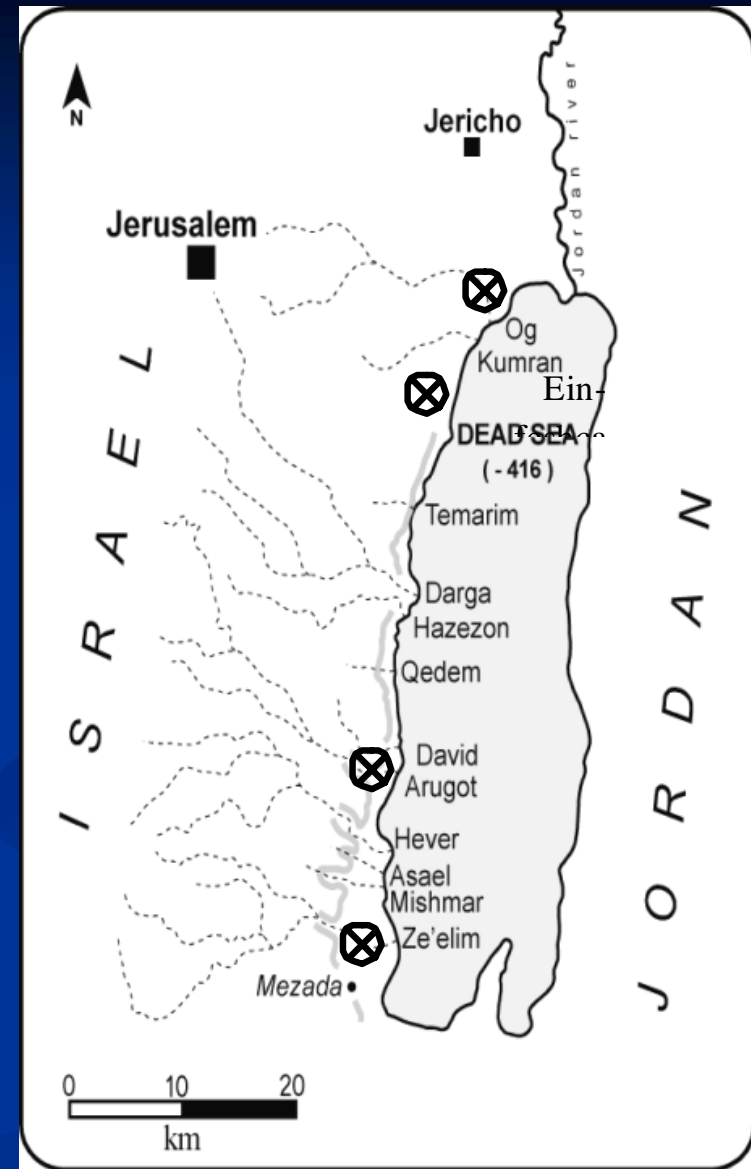


Outline

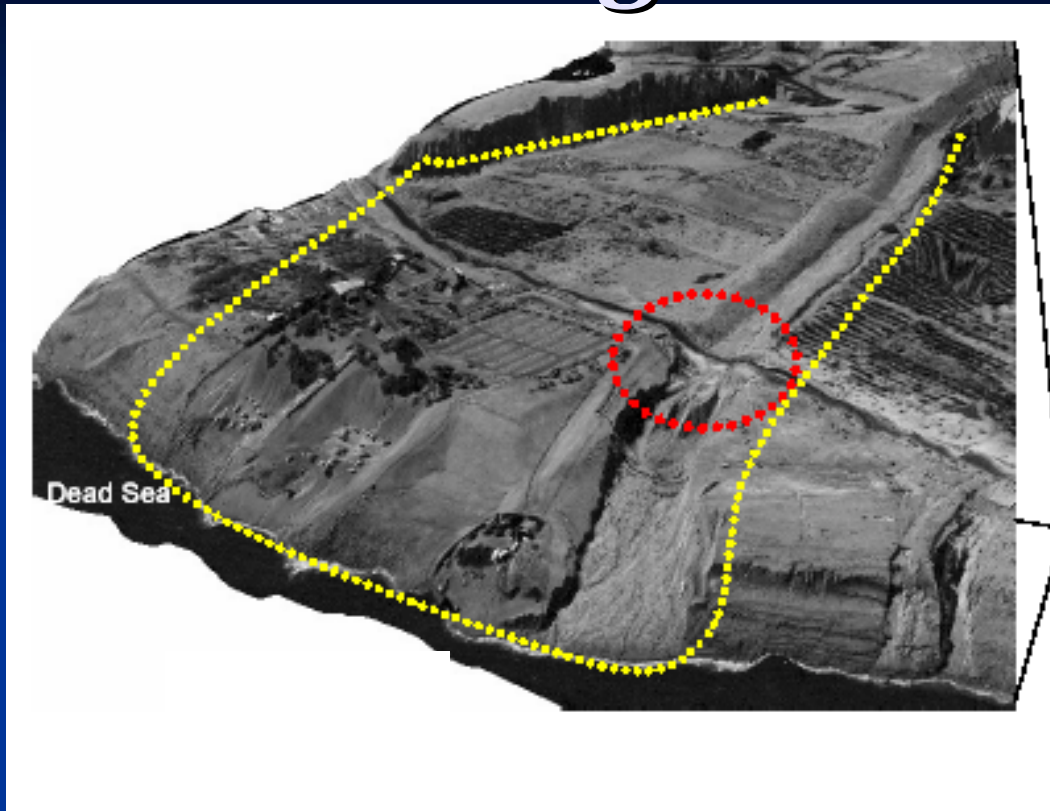
1
rate of entrenchment-widening
Wadi Arugot

2
bank instability & channel
formation in the
spring-fed Ein Fescha &

3
flash flood Wadi Zeelim



the Arugot Fan near Ein Gedi



basin area 232 km²

entrenchment initiated 1963/64

deltaic fan surface slope 1.2°

11.8° on delta front, channel longitudinal slope: 1.1-3.7°

max entrenchment 16 m

measurement of entrenchment and widening



based on EDM, GPS & digital elevation models using the Erdas Imagine orthobase on stereo aerial photos

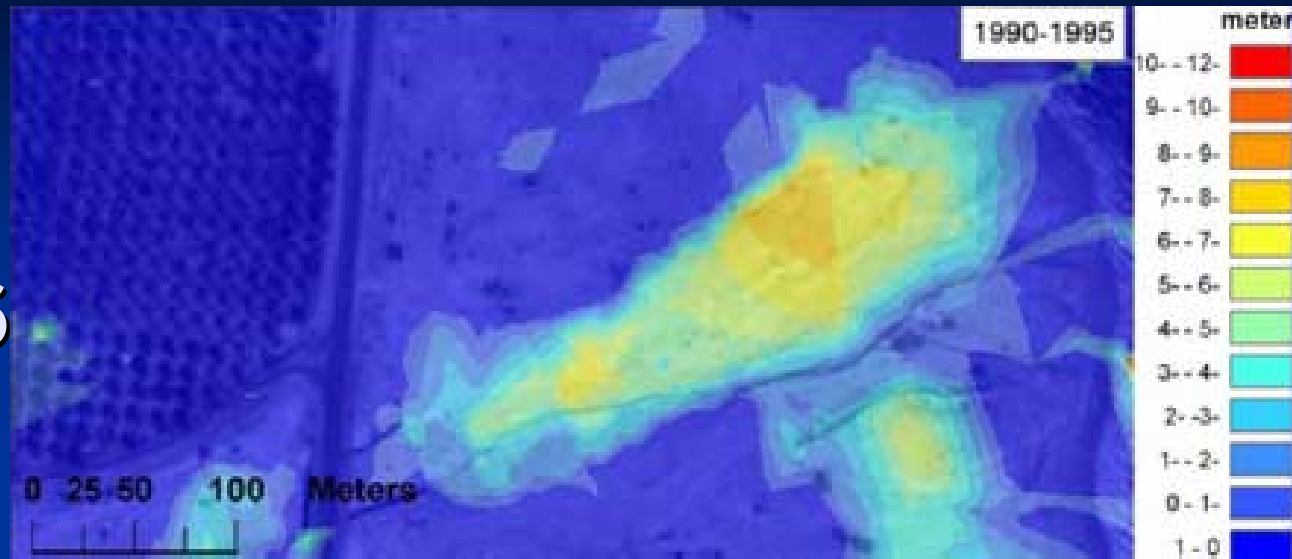
photo year	pixel size m	control points	pixel RMSE xy	vertical error [*] m
2002	0.16	16	1.05	0.46
1999	0.16	10	1.20	0.65
1995	0.25	10	1.10	0.78
1990	0.25	6	1.10	0.77

Pixel RMSE is given in pixel units

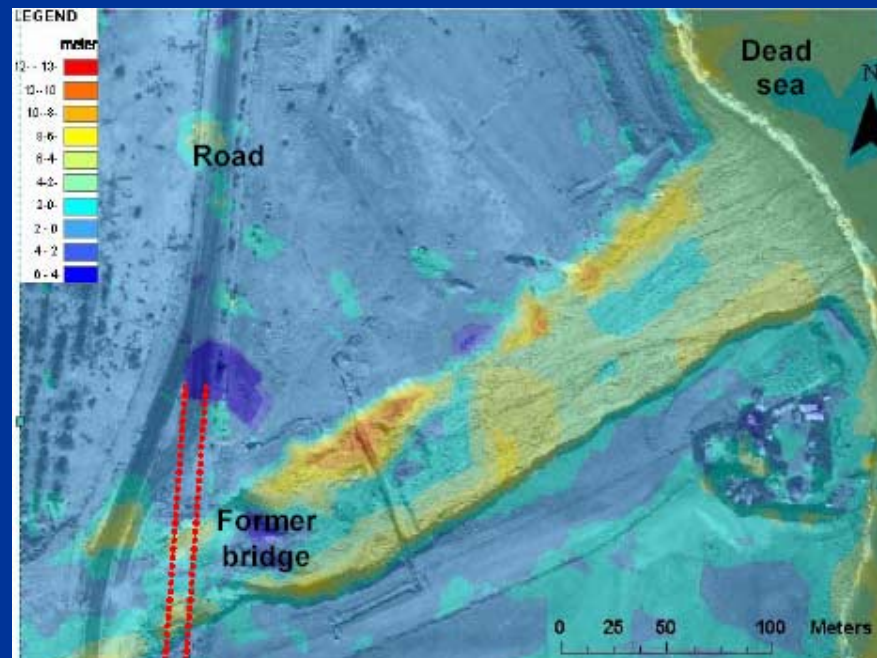
Compared to total station; separately also known for GPS

change detection maps

1990-1995



1999-2002



period	period length *	peak flow	flow volume	flow duration	vertical incision	widening	sea drop*
	yr	m ³ /s	10 ⁶ m ³	hr	m/yr	m/yr	m
1990-95	7.7	160	12.2	700	0.59	2.6	3.9
1995-99	2.4	137	4.6	458			
1999-02	3.1	418	3.5	179			
1995-02	5.5	418	8.1	637	0.65	2.3	5.6

* between flow events

thus:

magnitudes of entrenchment and widening are related not only to flood peaks and volumes, but also to their number and timing

Summary of Wadi Arugot measurements:

**rates of incision are excessively high,
almost as those of the receding Dead Sea**

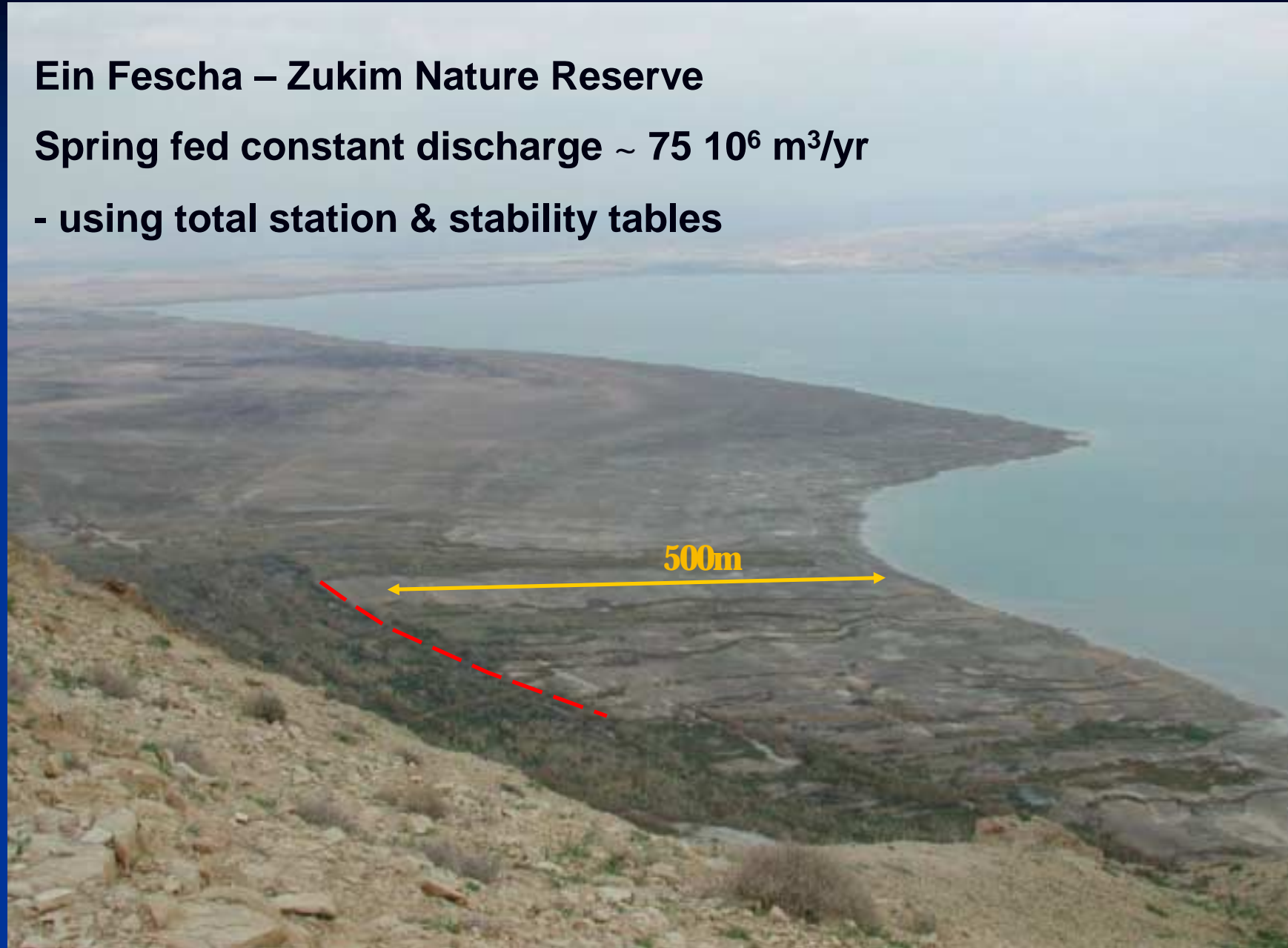
rates of widening are also very high

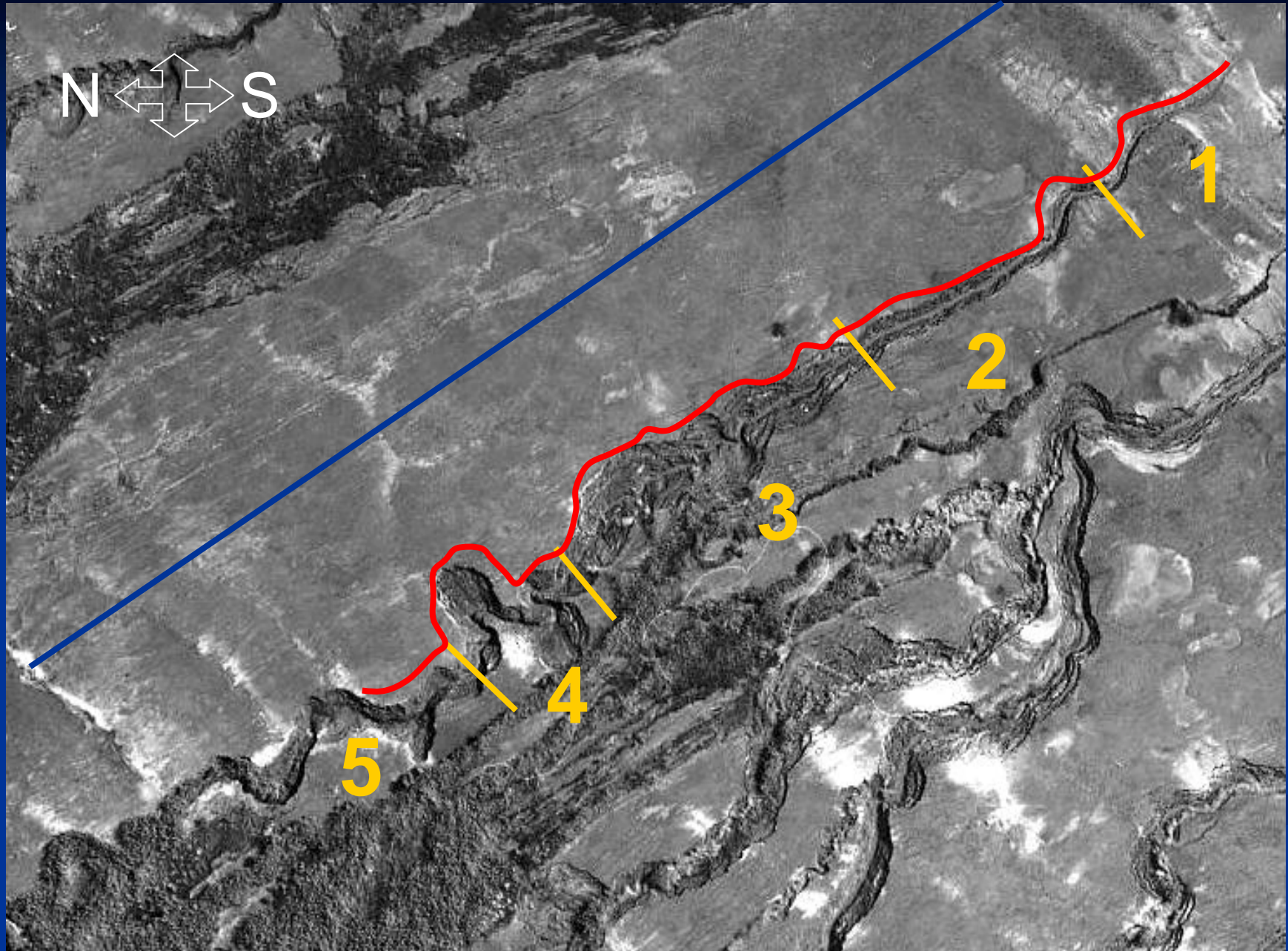
**these are fundamentally fast rates at this
particular narrow location with respect to
stability of a future bridge. A safe bridge
is apparently prohibitively unfeasible.**

Ein Fescha – Zukim Nature Reserve

Spring fed constant discharge $\sim 75 \cdot 10^6 \text{ m}^3/\text{yr}$

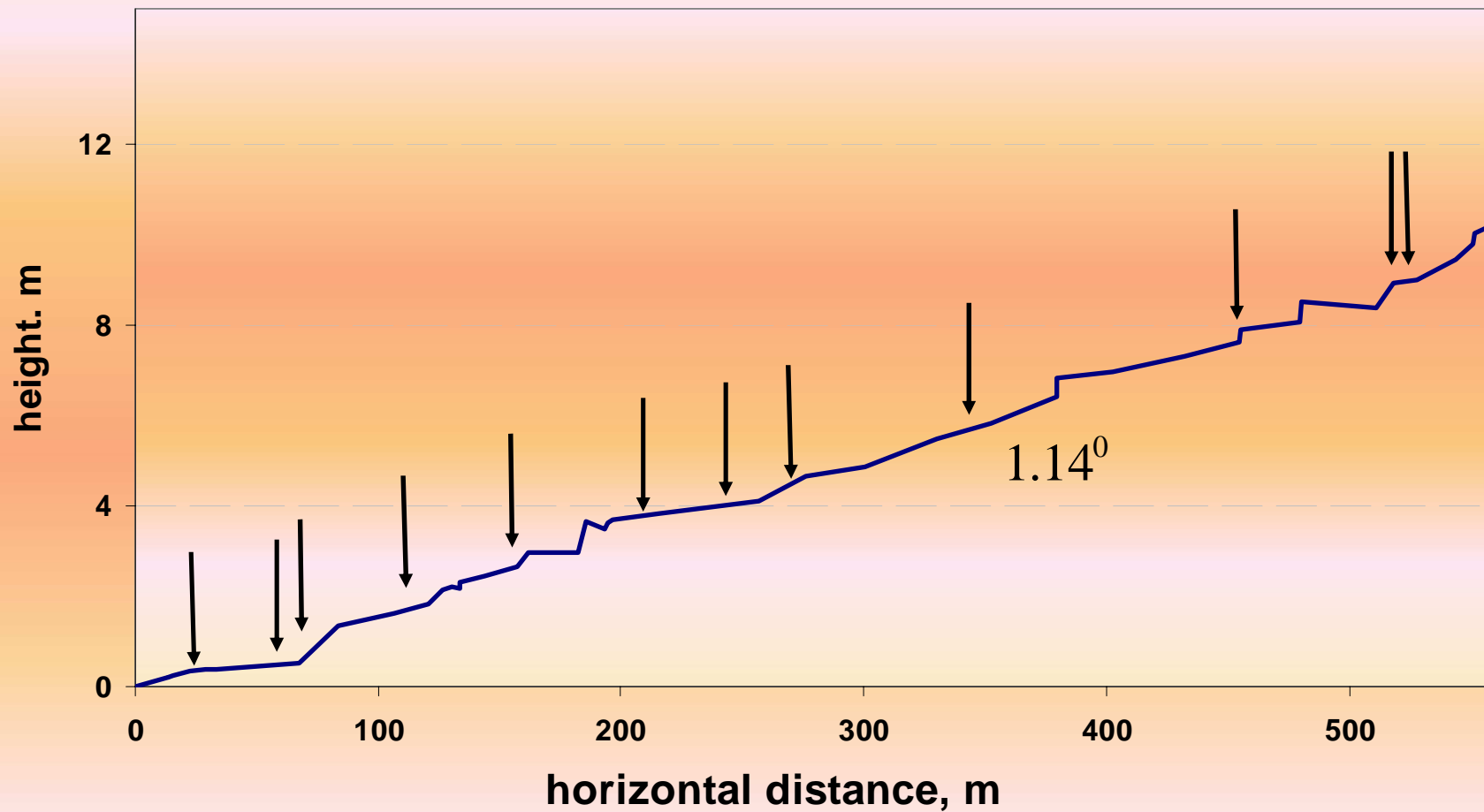
- using total station & stability tables



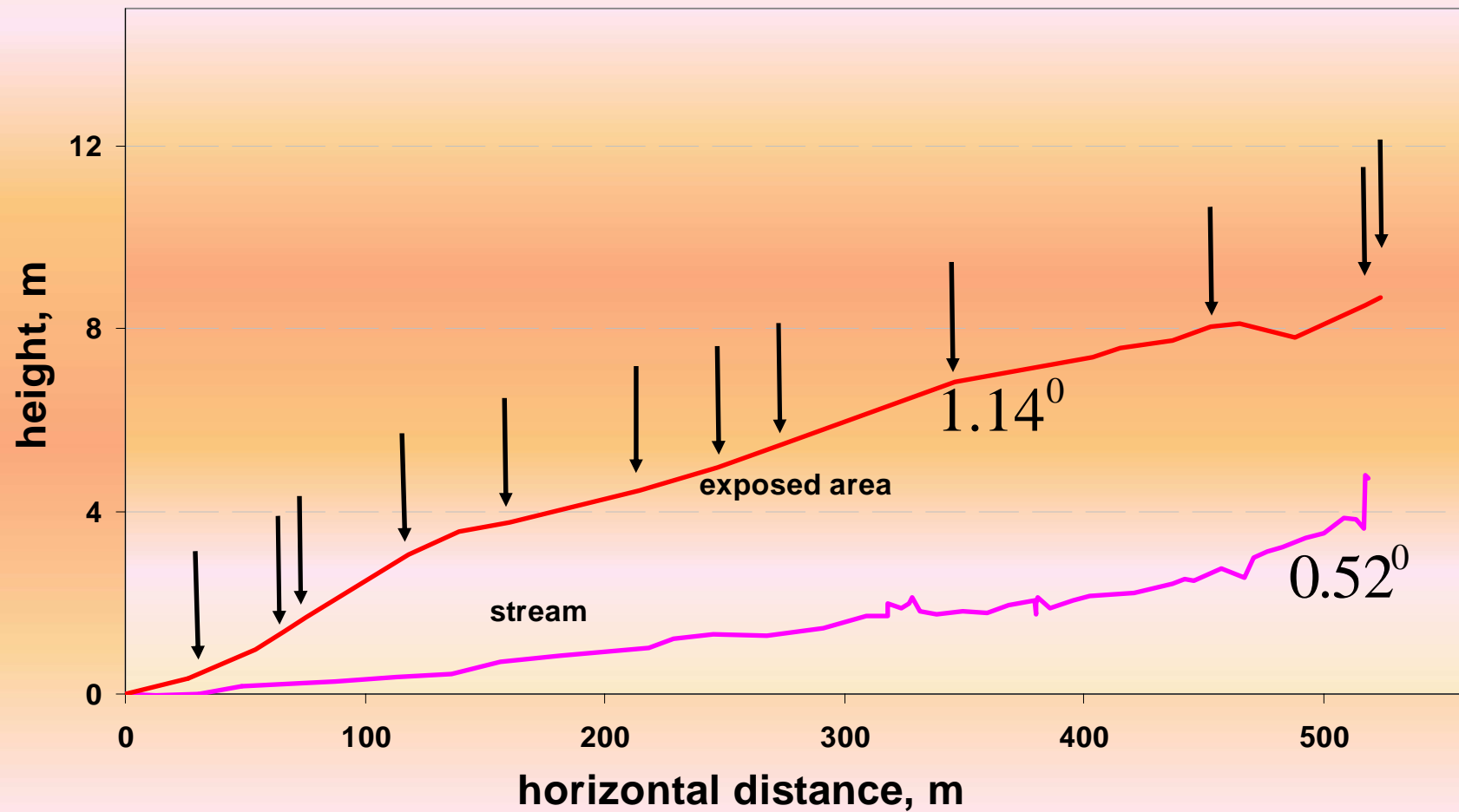


the exposed area

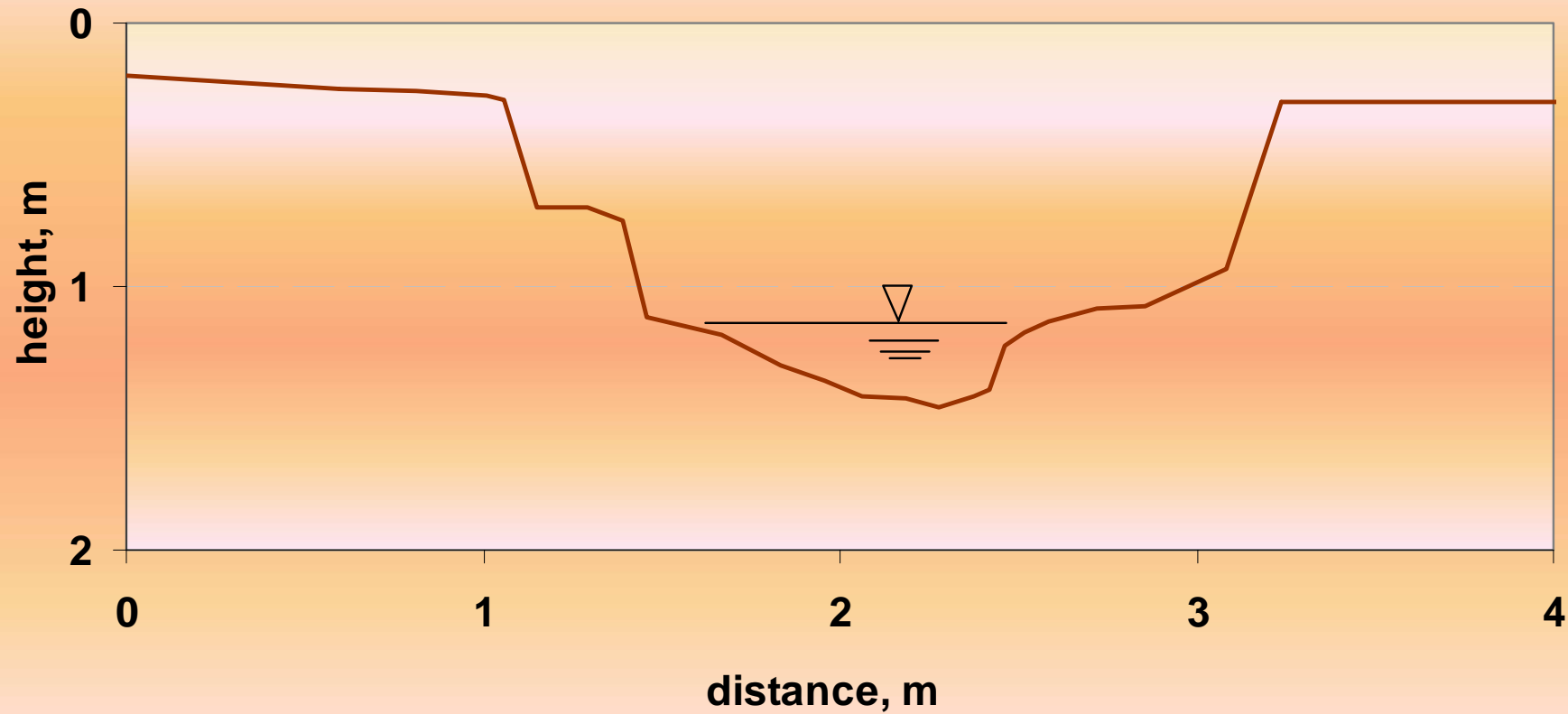
longitudinal profile



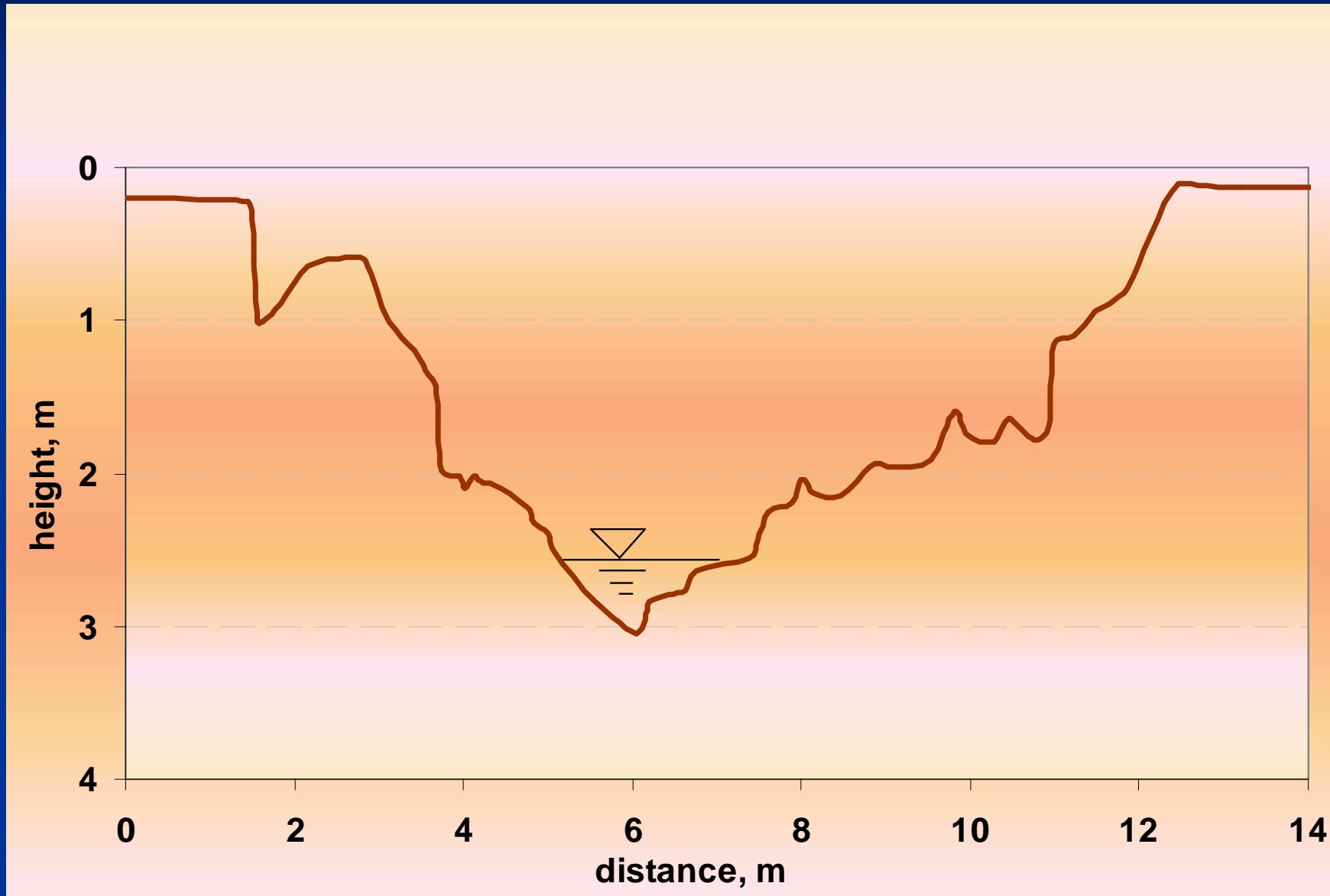
longitudinal profiles of exposed area & stream



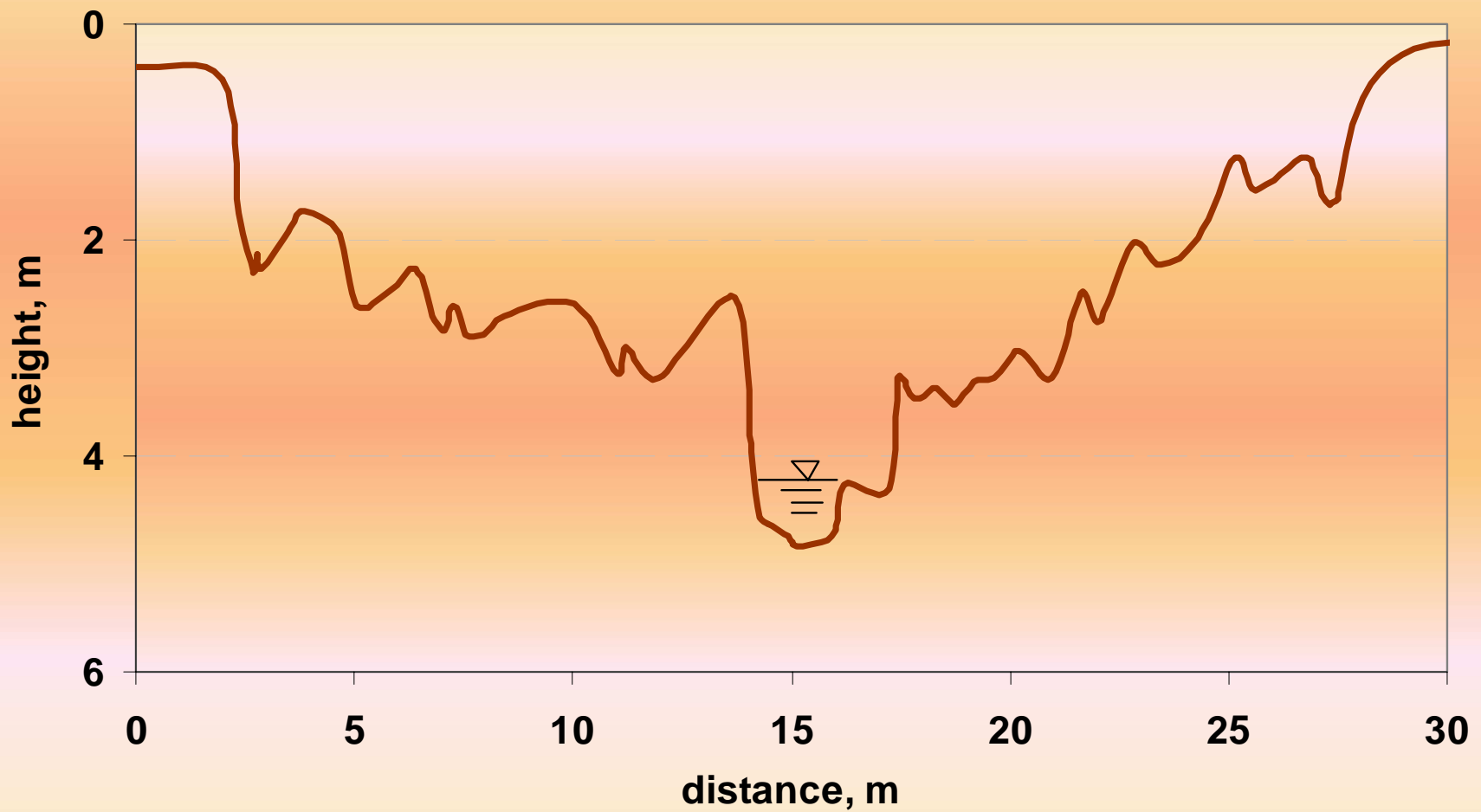
area 1: incision near the shore



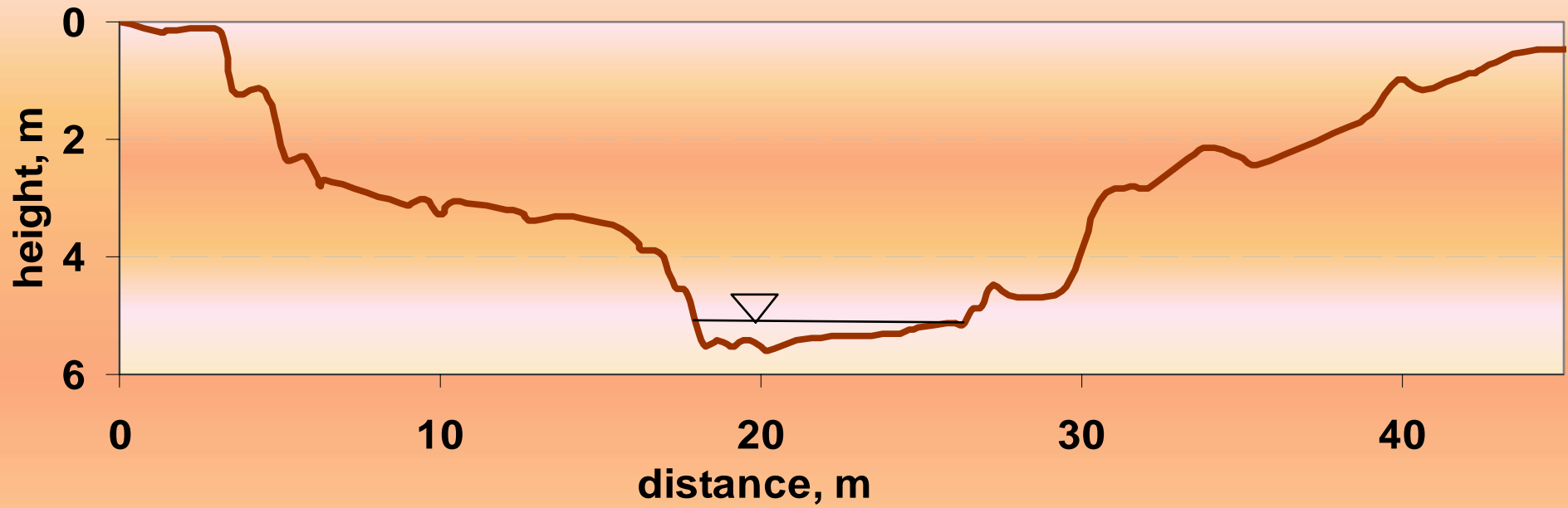
area 2: inception of bank failures



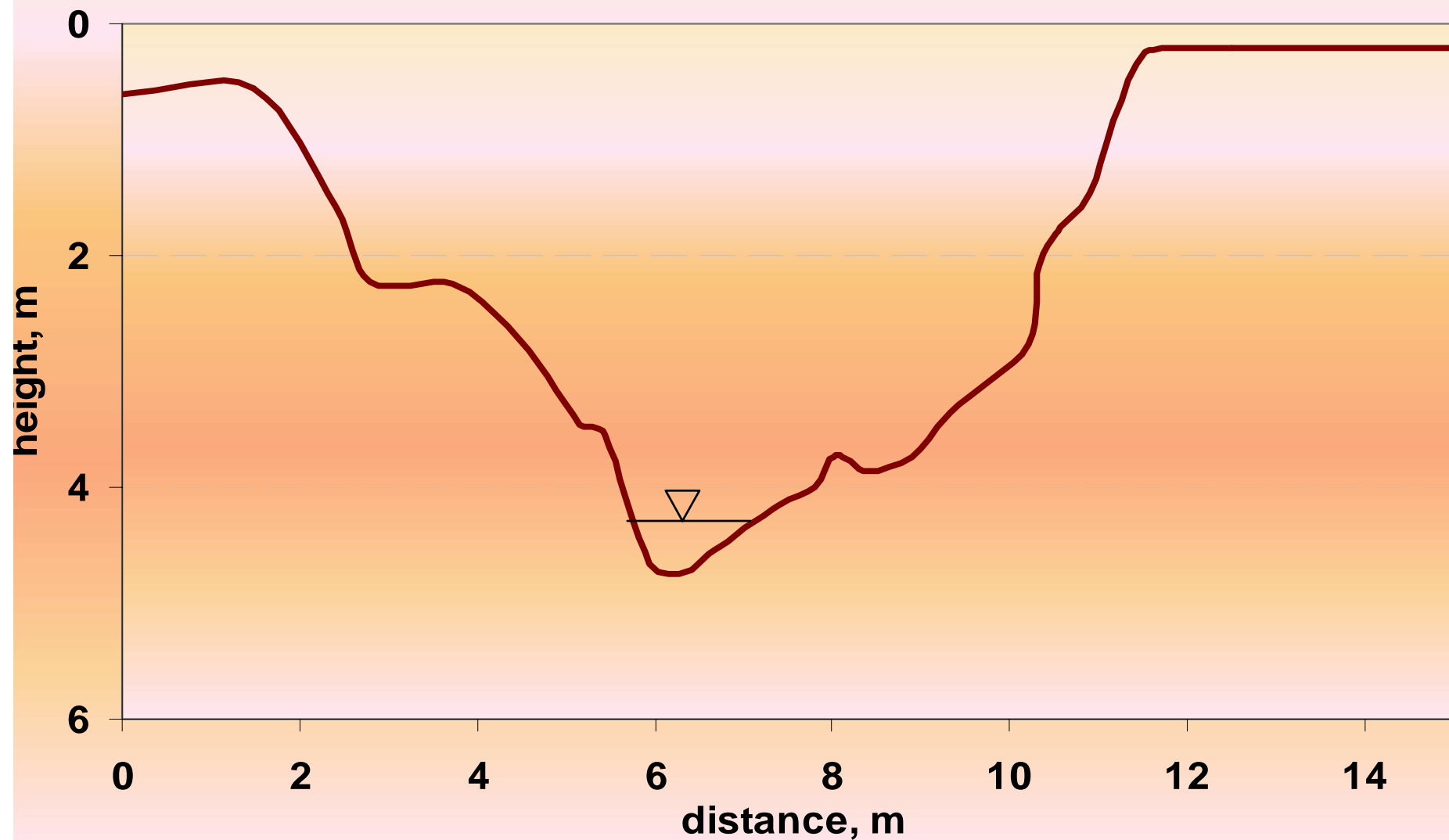
area 3: massive bank failures



area 4: meanders



area 5: vegetation & cementation



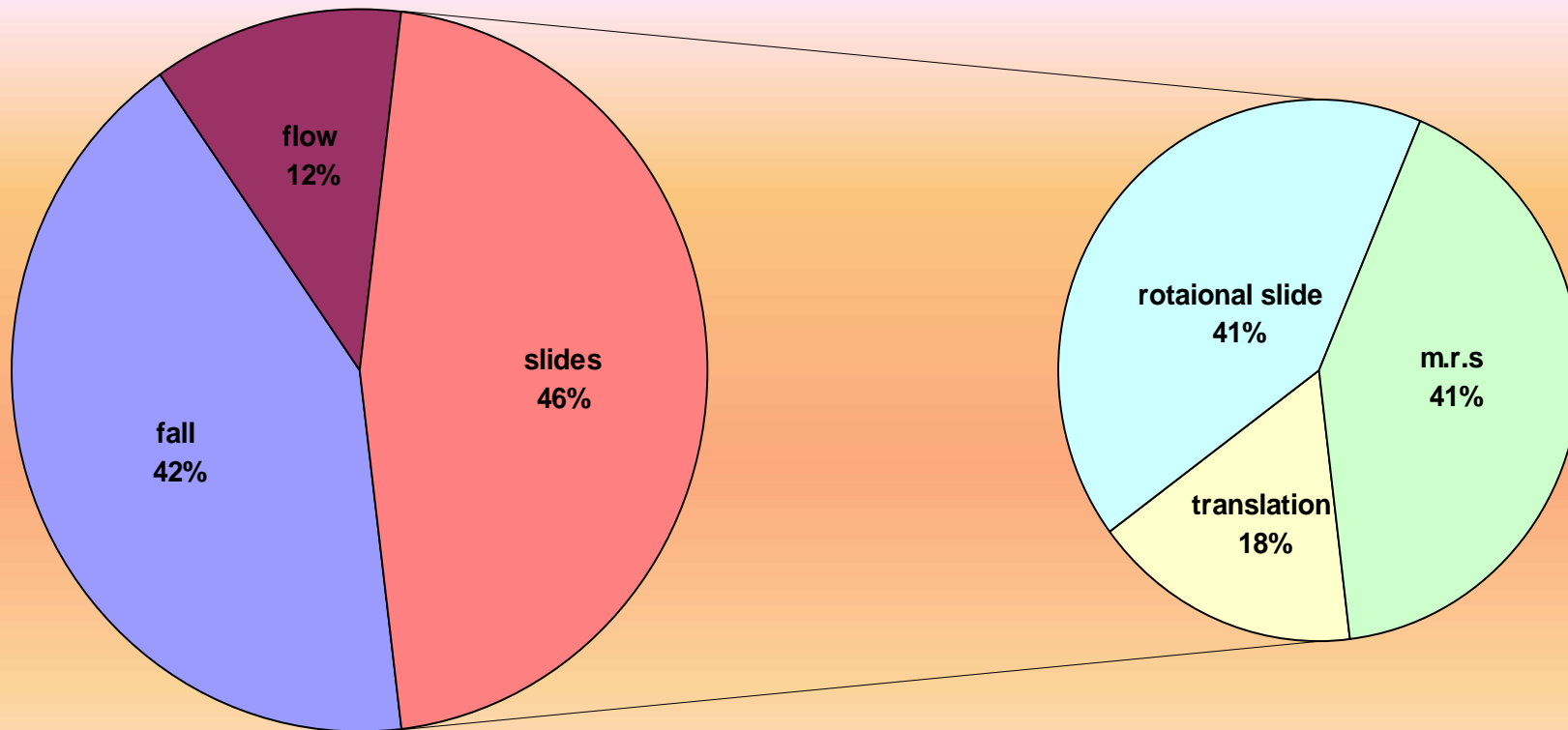
types of failures



types of failures



frequency of failures based on 12 measured x-sections



fall

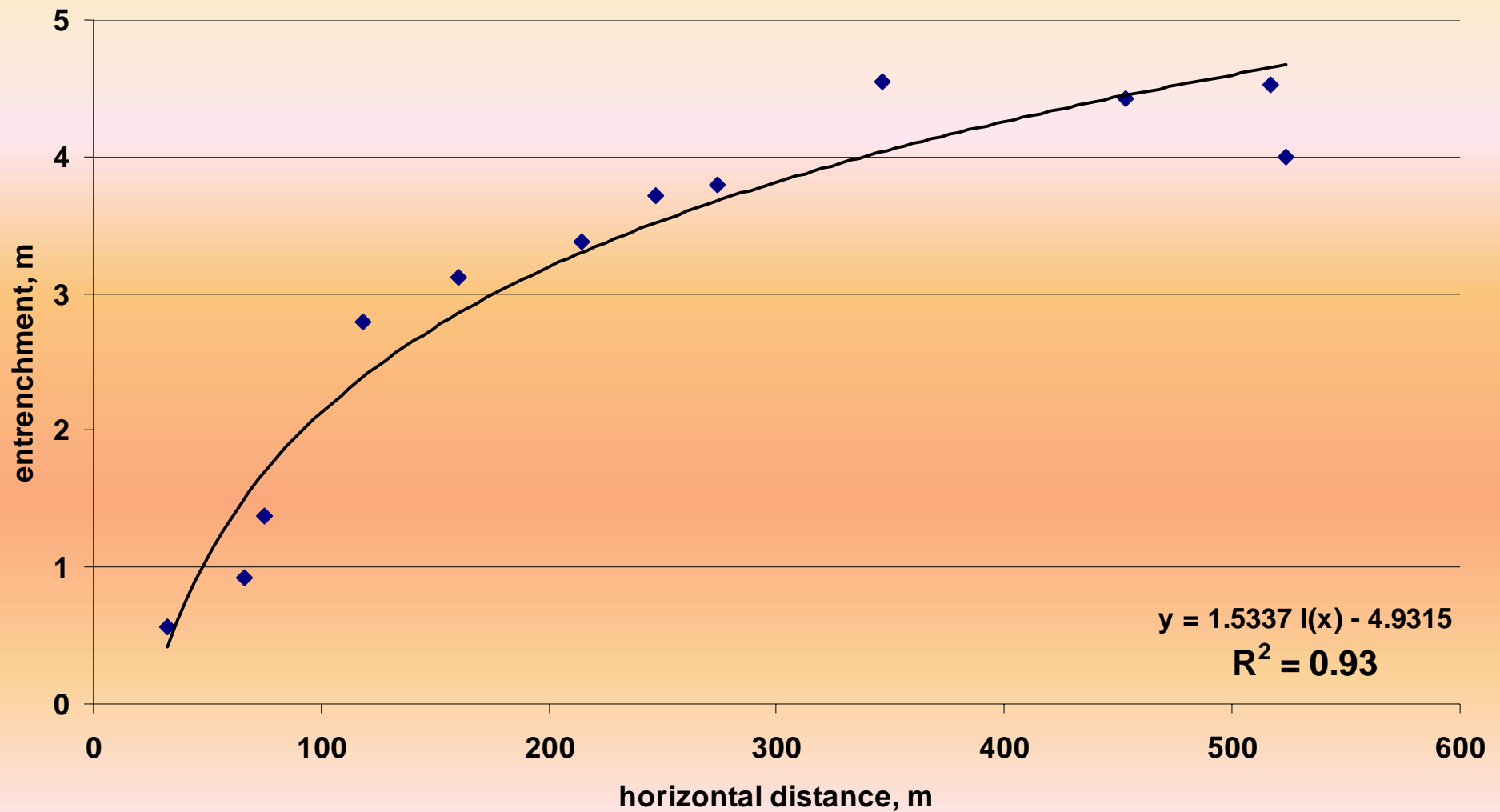
flow

translation

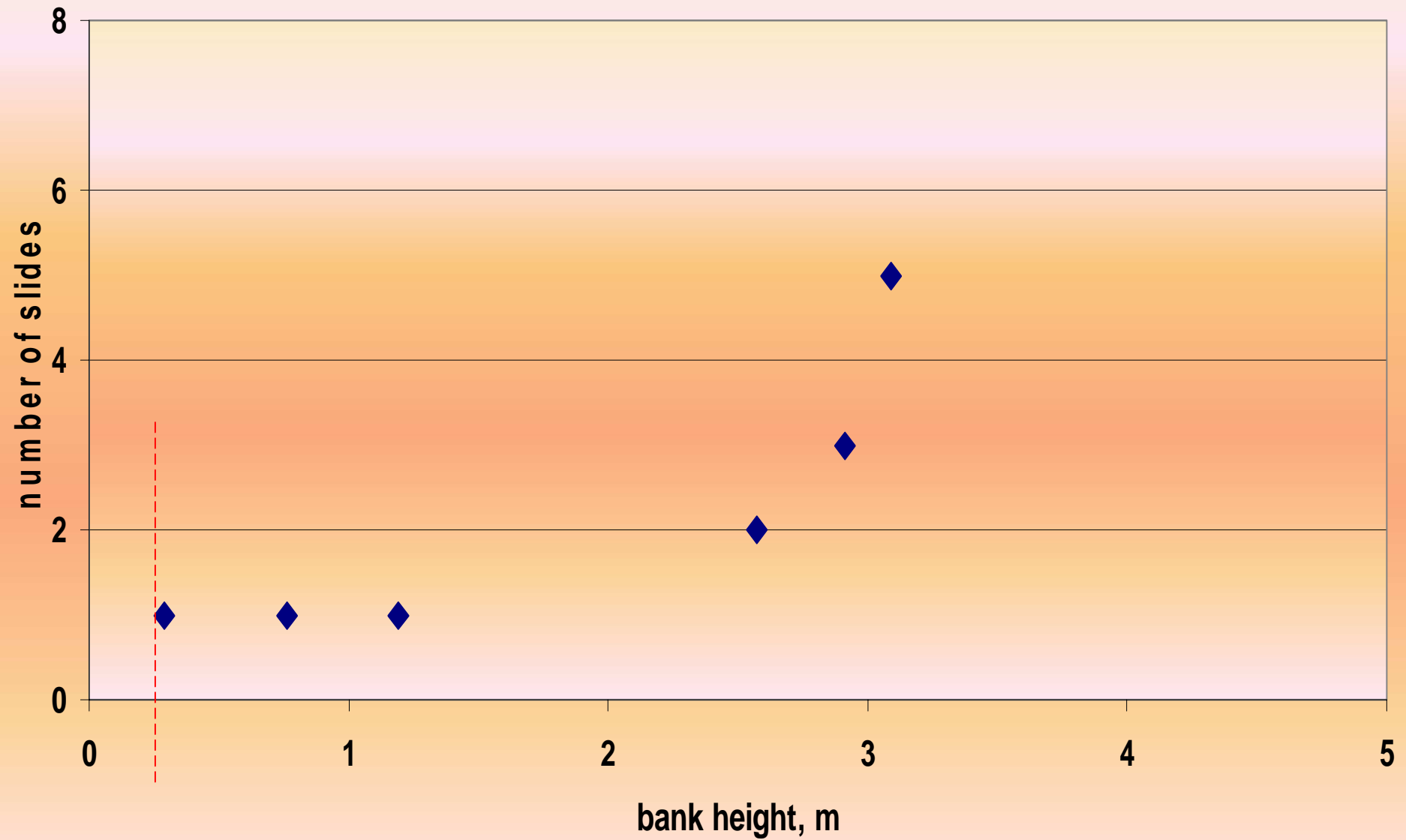
rotational slide

m.r.s

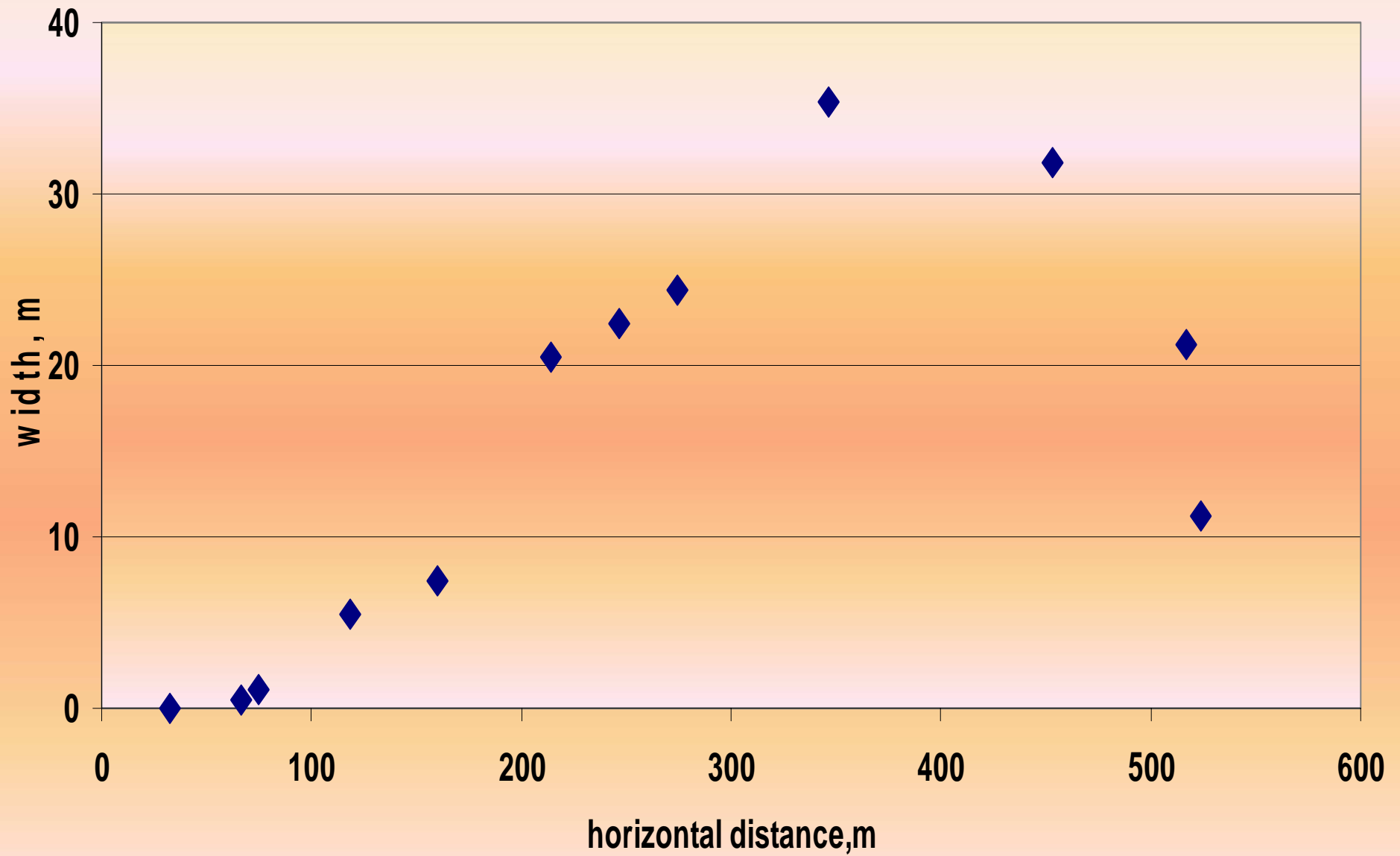
magnitude of entrenchment with distance from shore



number of slides vs bank height



width of deflation zone vs distance from shore



Ein Fescha - conclusions

- Failure development is unrelated to direct shear stress of the flowing stream. It is influenced by the lack of flushing of most of the failed material in wider sections.
- The number of failures depends on bank height and the width of the deflation zone.
- Depth of entrenchment increases with distance from the receding base level; but decreases in proximity to the reserve due to stability, in part regained by vegetation and cementation at this point in time.
- The question is not whether the nature reserve will be entrenched, but when.

Zeelim Fan - flash flood regime

Zeelim fan - flash flood regime

- based on a series of cartoons



first mechanism of lateral widening: undercutting

1st stage:

exposure of the sea bed and divergent flow in channels

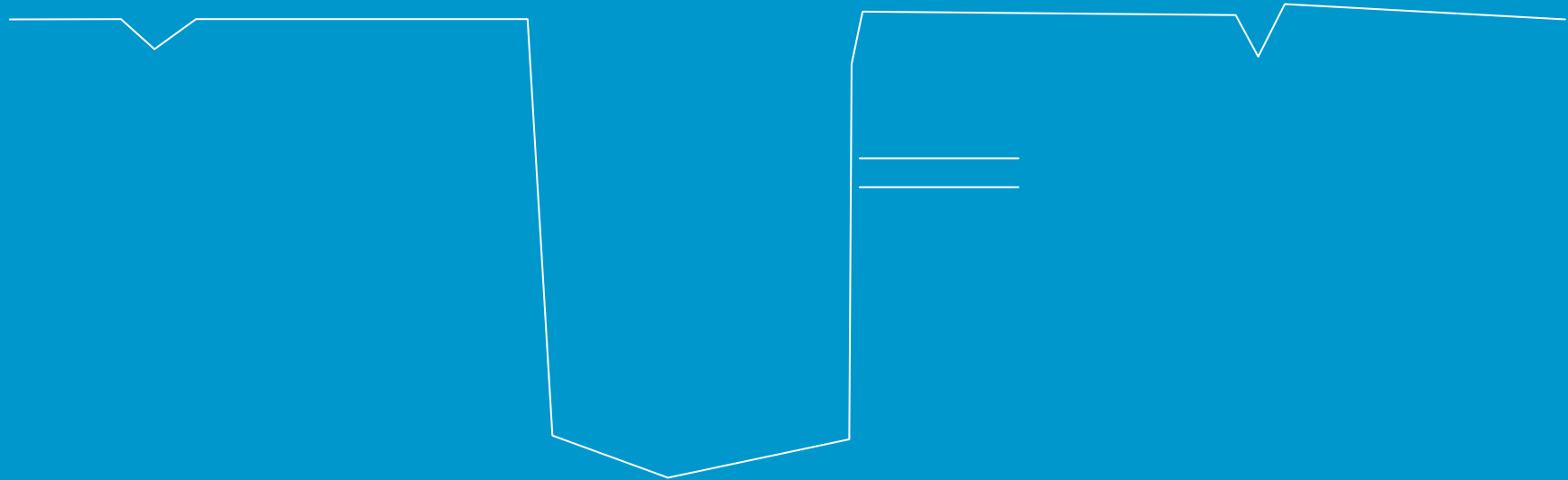


2nd stage:

entrenchment with widening by preference

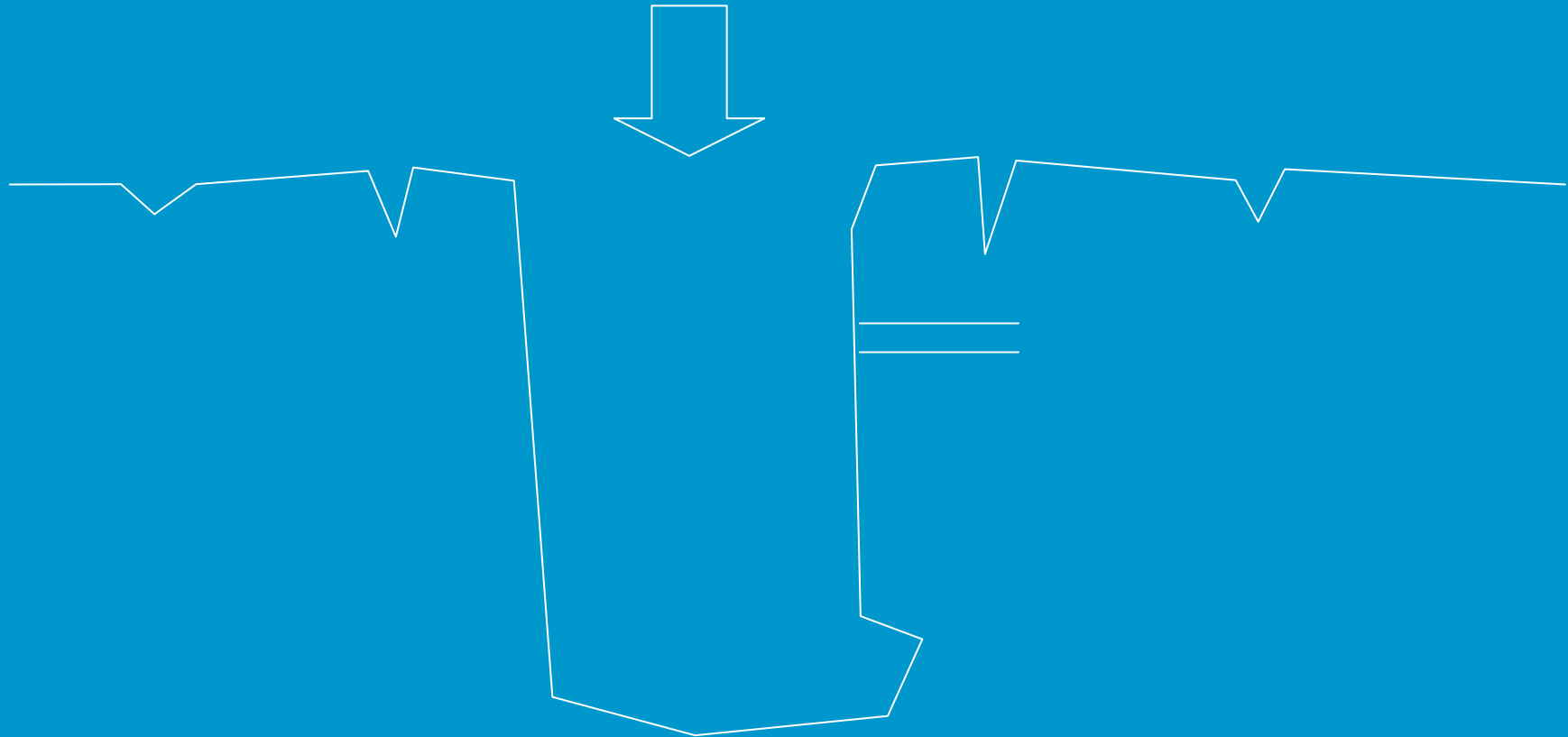


3rd stage:
continued entrenchment



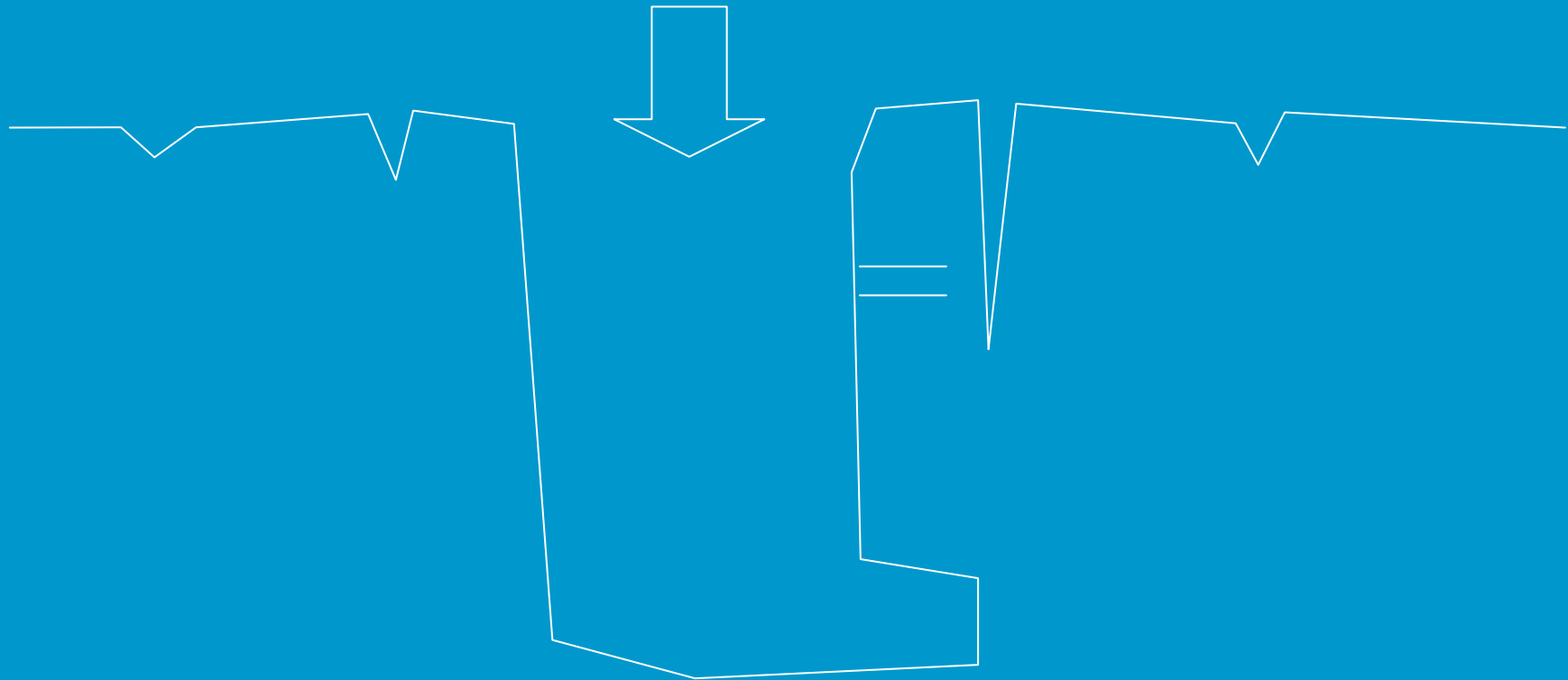
4th stage:

initial mechanism of lateral widening, tension cracks occur,
continued vertical entrenchment and initial undercutting

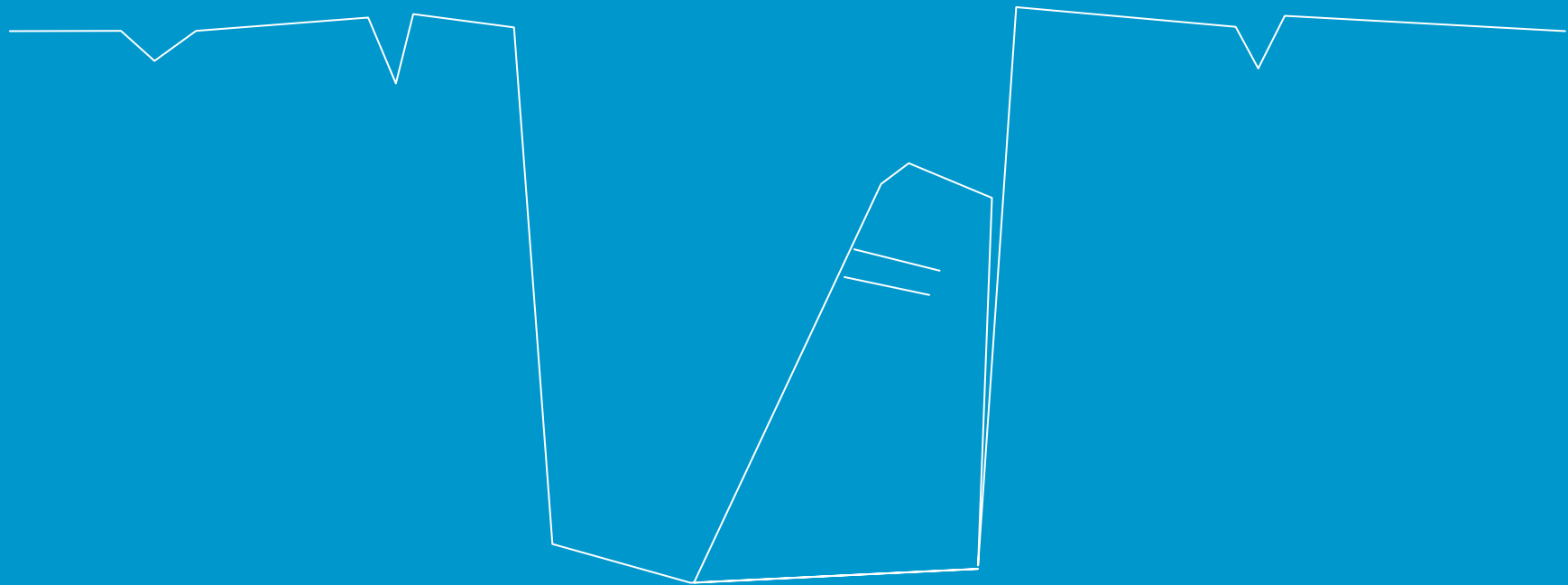
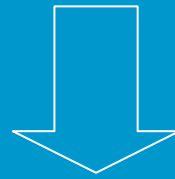


5th stage:

advanced undercutting, widening of tensile cracks
and formation of overhanging cliffs



6th stage:
block failure and inclination

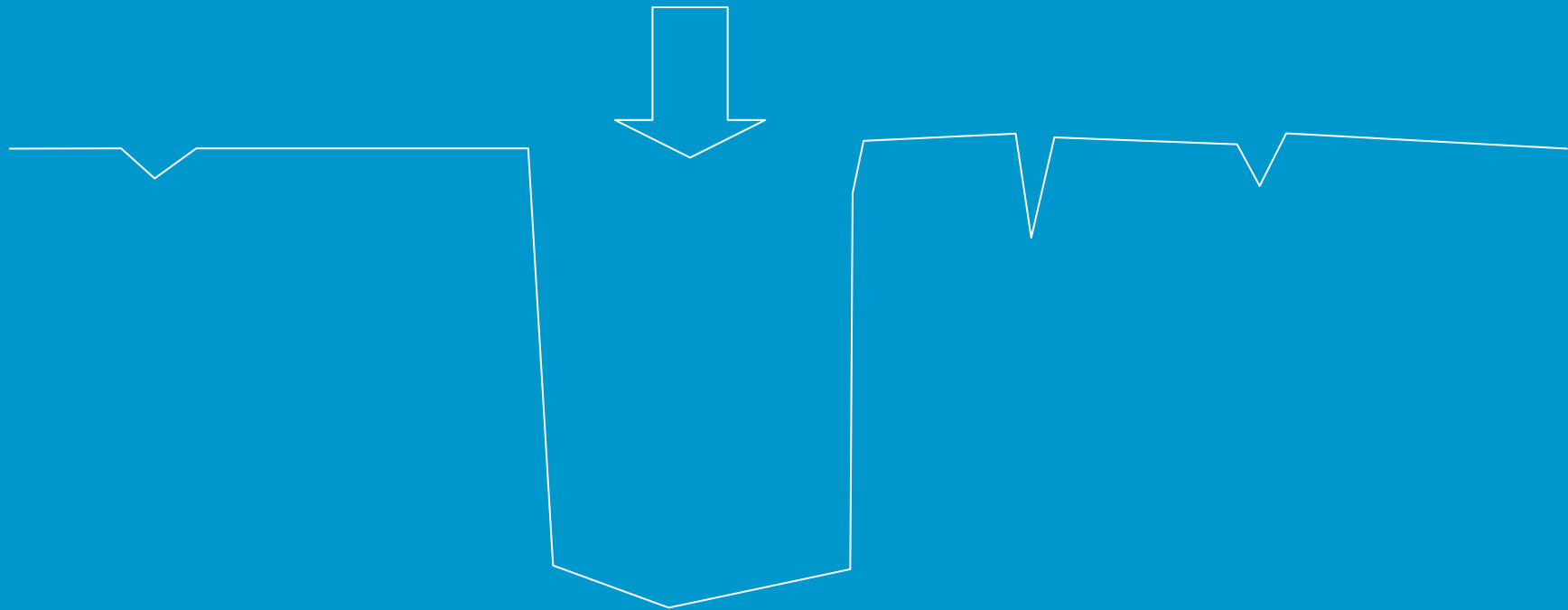




second mechanism of lateral widening: **sliding**

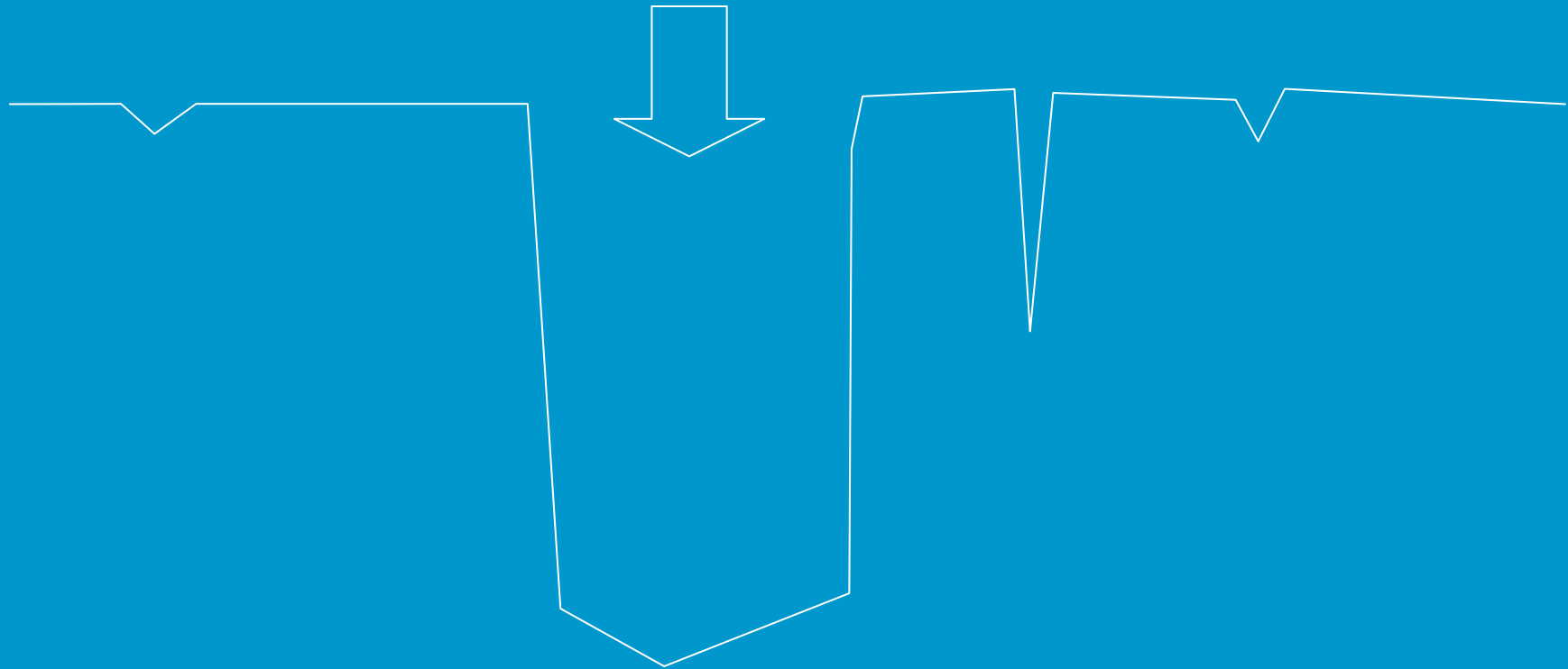
1st stage:

entrenchment and appearance of tensile cracks

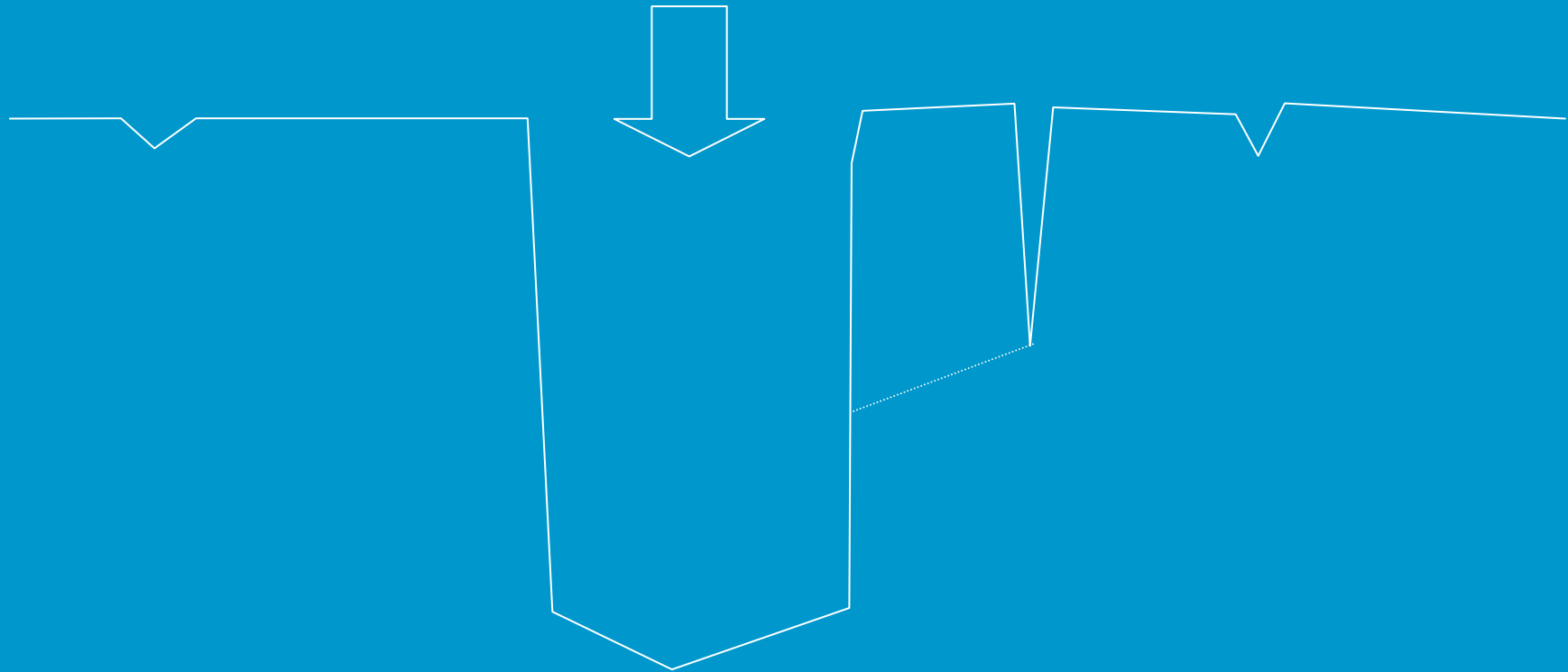


2nd stage:

deep entrenchment and widening of tensile cracks



3rd stage:
development of planar failure planes and sliding



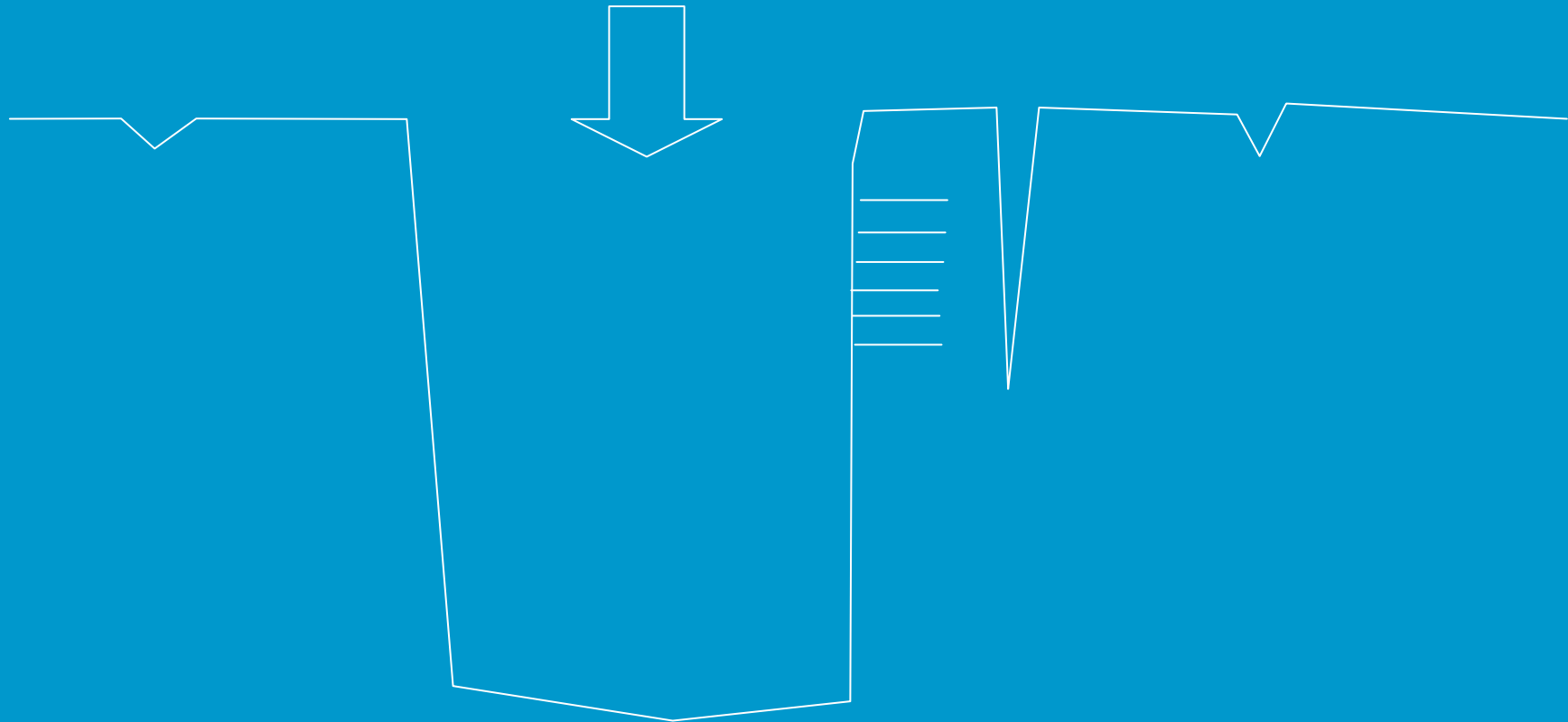




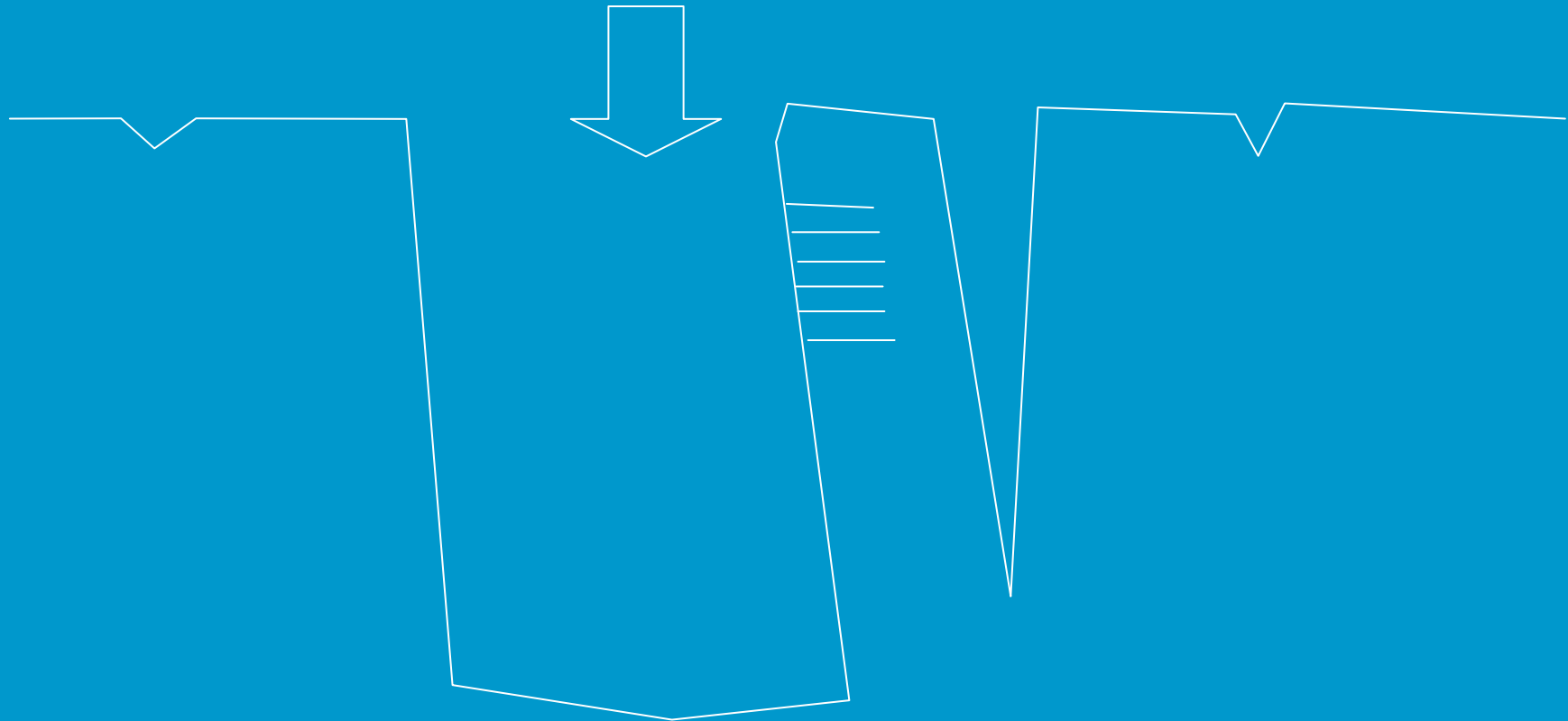
third mechanism of lateral widening: **toppling**

1st stage:

development of tensile cracks in high banks



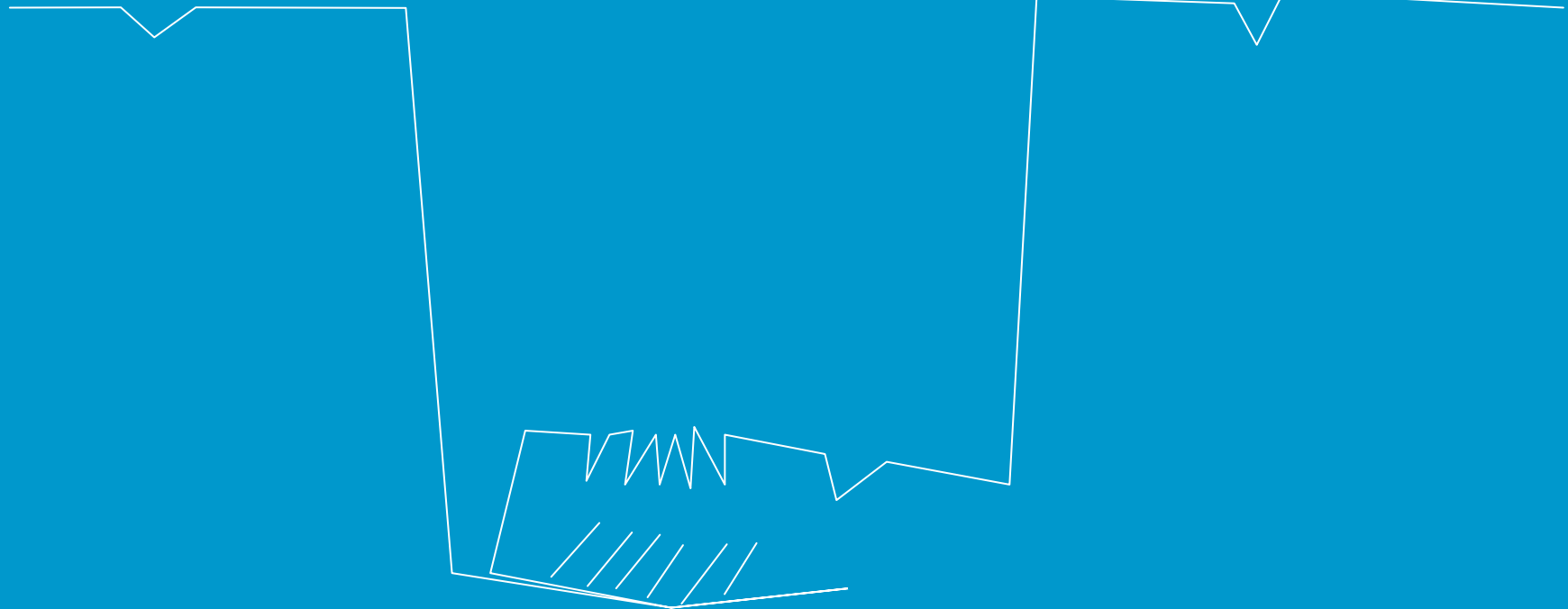
2nd stage:
collapse of bank



toppling



toppling





flushing of failed bank material

6.1.2004



10.5.2005



11.2.2004



flushing of failed bank material



31.3.2005



6.1.2004



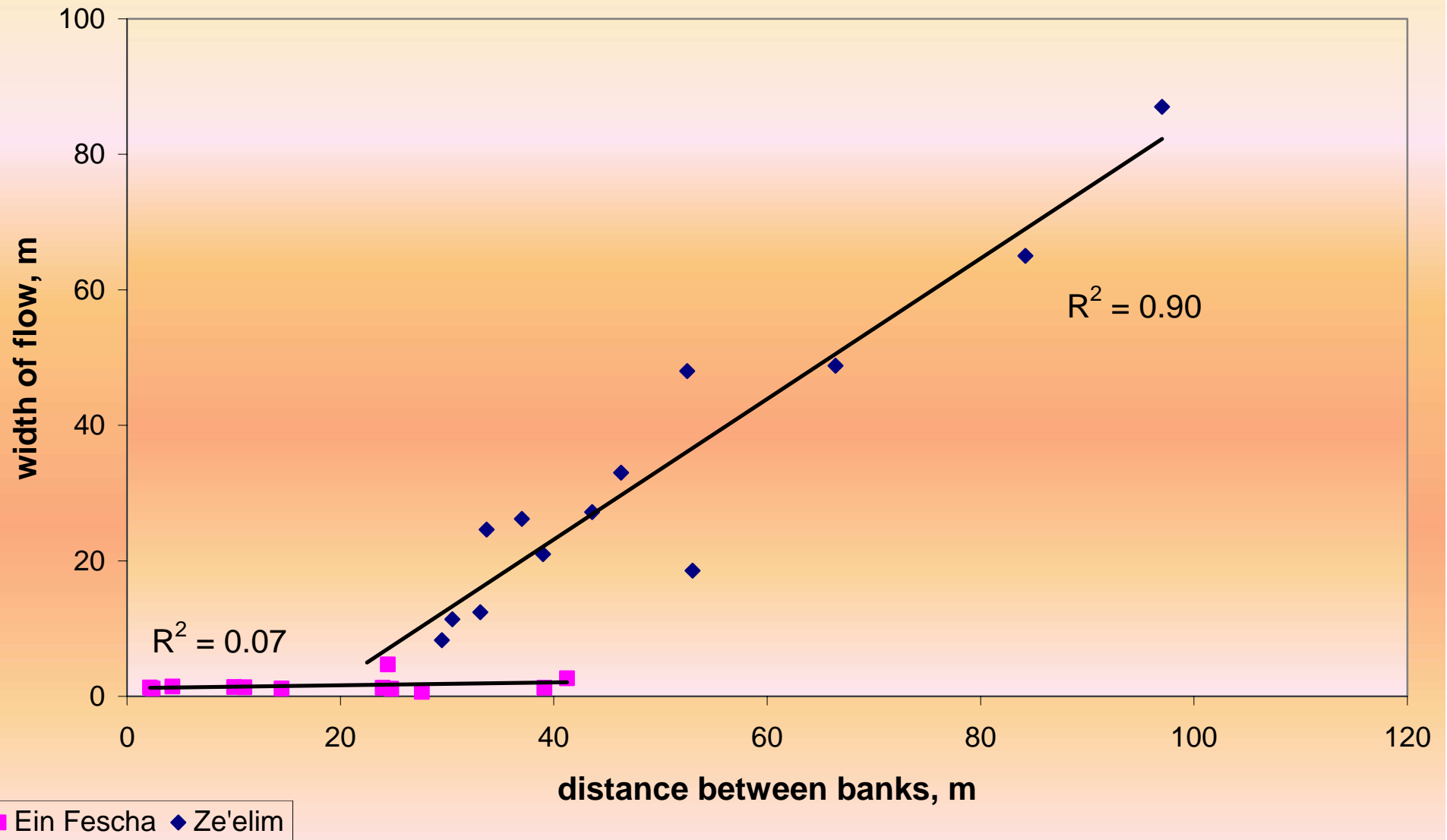
Ze-elim entrenchment takes place on an identical lacustrine deposit to that in Ein Fescha, though the Ze-elim bed is covered by a thin veneer of coarse alluvium that limits faster incision rates



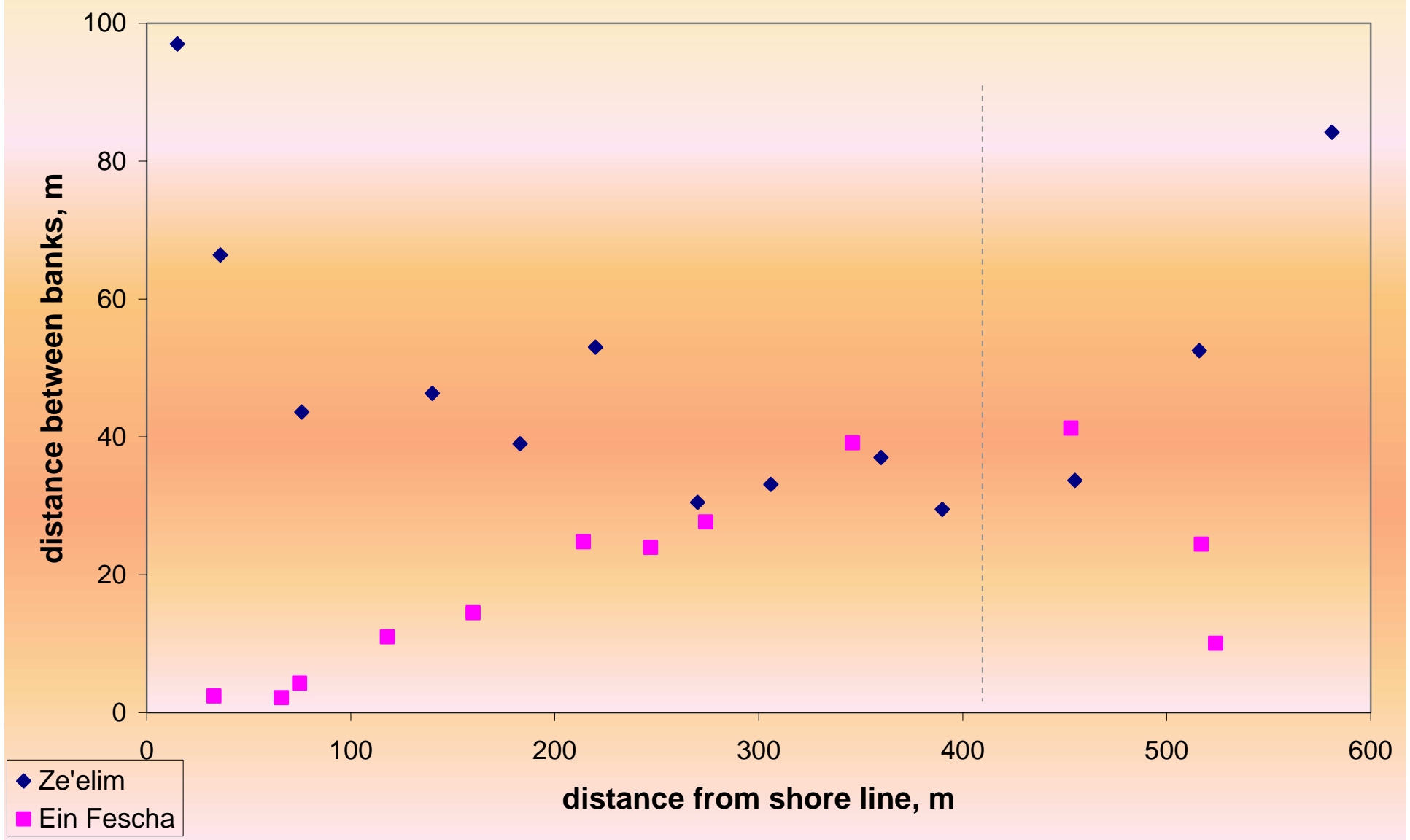
Ze-elim - conclusions

- Failure development is related to shear stress of the flowing stream: undercutting and transport of failed material. Rotational slides are infrequent – unlike at Ein Fescha.
- Bank height at Ze-elim is more than 2-fold compared to Ein Fescha, due to large discharges and undercutting availed by flushing of failed material.
- Depth of entrenchment increases with distance from the receding base level; but decreases in proximity to the upper fan area due to large input of coarse sediment.

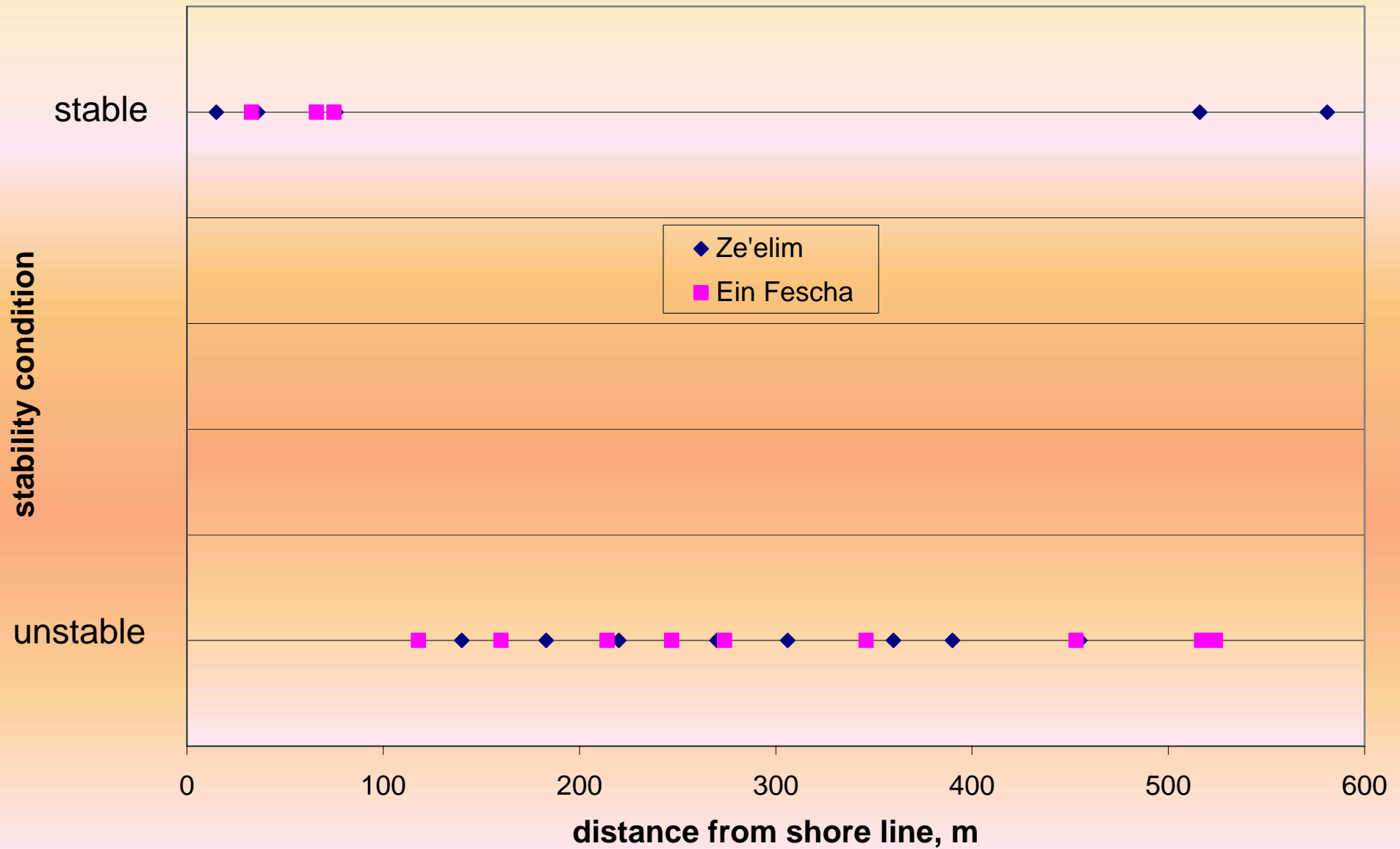
width of flow vs distance between banks



distance between banks vs distance from shore



bank stability* vs distance from shore



* Based on the Thorne-Simon-Rinaldi stability criteria

Wadi Og

**flash flood regime supplemented by
treated sewage base flow**



thank you

