Study of bedform geometry in large rivers

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SUMMARY

The geometry of bedforms in large rivers is investigated during average and flood conditions. The method proposed by van Rijn (1984) for predicting dune height and dune wavelength is tested against field data from large rivers around the world, and particularly with field data measured during the recent floods on the Meuse river and the Rhine river branches. The method proposed by van Rijn generally underpredicts the dune height of most large rivers. In large rivers, the parameters describing dune height and dune steepness do not decrease as the transport-stage parameter T increases in the range $10 < T < 25$. Analysis of the Meuse river and the Rhine river branches indicates that the method of van Rijn is suitable for most average flow conditions but underpredicts dune height at high discharge. During floods, dune height and length generally increase with discharge, while dune steepness remains relatively constant.

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Notation

Symbol	description	Unit
C'	grain Chezy coefficient	$m^{½}/s$
D_{50}	mean bed particle diameter	m
D_{84}	84% passing bed particle diameter	m
D_{90}	90% passing bed particle diameter	m
D_*	dimensionless particle diameter	-
Fr	Froude number	-
g	gravitational acceleration	m/s^2
h	flow depth	m
Q	flow discharge	m^3/s
R_b	hydraulic radius at the bed	m
Re_*	grain Reynolds number	-
s	specific density of particles	-
T	transport-stage parameter	-
$\overline{u}$	depth-averaged velocity	m/s
u_*	shear velocity	m/s
u'_*	grain shear velocity	m/s
u_{*c}	critical shear velocity	m/s
Δ	dune height	m
λ	dune length	m
ν	kinematic viscosity	m^2/s
ω	particle fall velocity	m/s
τ'	grain shear stress	N/m^2
τ_c	critical shear stress	N/m^2

STUDY OF BEDFORM GEOMETRY IN LARGE RIVERS

1. Introduction

In most river engineering problems, the prediction of water level during floods depends primarily on hydraulic roughness caused by the dimension of bedforms such as dunes and ripples. In turn, the length and height of dunes is viewed as a complex function of hydraulic and sediment parameters pertaining to sediment motion in alluvial rivers. Among existing bedform dimension predictors, van Rijn's method has become widely used for the determination of dune height and dune length, or dune steepness, in alluvial channels.

Van Rijn's method to determine bedform dimension is based on an analysis of flume and field observations with particle diameters ranging from 190-3600 μm. Only experiments in the lower and transitional flow regime with dune-type bedforms were considered. Given the applied shear stress on bed particles τ' and the critical shear stress τ_c corresponding to the beginning of motion of bed particles, the relative excess shear stress defines the transport-stage parameter T as $T = \frac{\tau' - \tau_c}{\tau_c}$. Van Rijn assumed plane-bed conditions at low and high values of the transport stage parameter, respectively when T = 0 and T > 25.

Some doubt has recently arisen, however, regarding the applicability of van Rijn's method at high values of the Shields parameter, or high T values, as expected during floods. This doubt originates from field measurements of bedform dimensions on the Rhine river branches in the Netherlands, on the Mississippi river in the USA, and on the Jamuna river (lower Brahmaputra river) in Bangladesh.

1.1 Objectives

The present investigation aims at testing the applicability of van Rijn's method (at high values of the Shields parameter, or transport-stage parameter T) in order to improve the prediction of bedform height and length during floods. The analysis is focused on extended laboratory and field conditions on large rivers, with a particular emphasis on the Rhine river branches and the Meuse river.

1.2 Approach

The approach used for this investigation of bedform dimensions from laboratory flumes and large rivers consisted of the following:

1) data analysis focused on large values of the transport-stage parameter T; and
2) specific observations on the Meuse river and the Rhine river branches during recent floods.

Data bases for the analysis of bedform dimensions include laboratory measurements from large and small flumes at Colorado State University and Delft Hydraulics. The field data base includes observations from the Mississippi, Missouri, Meuse, Rhine, Jamuna, Parana and Red Deer rivers. More specifically, this investigation stems from the analysis of van Rijn (1984), and particularly focuses on dune height Δ and dune length λ at large values of the transport-stage parameter T, in the region of possible transition to upper regime. Van Rijn concluded that transition begins at $T > 15$ with plane bed conditions at $T > 25$.

Three interesting hypotheses are particularly considered:

1) can lower regime bedforms be observed at values of $T > 25$ at low values of the Froude number?;
2) can suspension, as described by $\frac{u_*}{\omega}$ be quite low when T is large?; and
3) can boundary conditions change from hydraulically smooth to hydraulically rough as the result of changes in Re_* during major floods?

This report has been subdivided into two major sections: 1) analysis of bedform dimensions (Section 2); and 2) bedforms of the Meuse river and the Rhine river branches (Section 3).

2. Analysis of bedform dimensions

This section provides a general overview and analysis of the changes in lower regime bedform geometry from laboratory and field observations. Van Rijn's method is first presented in Subsection 2.1, with a discussion of parameter accuracy in Subsection 2.2. Previous investigations of Termes (1986) and Raslan (1991) are summarized in Subsection 2.3 and 2.4. An analysis of bedform dimensions in large rivers is then presented in Subsection 2.5, while Subsection 2.6 presents a discussion of the three hypotheses stated in the introduction.

2.1 The method of van Rijn (1984)

A method for the classification of bed forms and the prediction of bedform dimensions has been presented by van Rijn (1984) after defining a dimensionless particle diameter D_* and a transport-stage parameter T as follows:

$$D_* = D_{50} \left(\frac{(s-1)g}{\nu^2} \right)^{1/3} \tag{2.1}$$

and

$$T = \frac{(u'_*)^2 - (u_{*c})^2}{(u_{*c})^2} \tag{2.2}$$

in which D_{50} is the mean bed particle diameter (50% passing by weight); s is the particle specific density; ν is the kinematic viscosity; the critical grain shear velocity u_{*c} is obtained from the Shields diagram; the grain shear velocity $u'_* = \bar{u} \frac{\sqrt{g}}{C'}$ varies with depth-averaged flow velocity $\bar{u}$, gravitational acceleration g and grain Chézy coefficient C' = 18 log $(12R_b/3D_{90})$ given the hydraulic radius related to the bed R_b obtained from the Vanoni-Brooks method, and the 90% passing bed particle diameter D_{90}.

Van Rijn proposed the bedform classification diagram shown on Figure 1, in which ripples are found for $D_* < 10$ and $T < 3$. Dunes occur when $T < 15$ while washed-out dunes correspond to $15 < T < 25$, and flat bed corresponds to $T > 25$.

Bedform dimensions in terms of height and steepness were analysed by van Rijn (1984) after selecting the data according to: 1) dune bedforms; 2) width-depth ratio larger than 3; 3) flow depth larger than 0.1 m; and 4) transport-stage parameter T smaller than 25. Regression analysis was performed considering 84 data points from flume experiments with particle diameters from 190-2300 μm and 22 field data points with particle diameters ranging from 490-3600 μm.

The best agreement obtained by regression analysis for the dune height Δ as a function of the average flow depth h, bed particle diameter D_{50}, and transport-stage parameter T is given by:

$$\frac{\Delta}{h} = 0.11 \left(\frac{D_{50}}{h}\right)^{0.3} (1-e^{-0.5T})(25-T) \tag{2.3}$$

The agreement of the bedform height predictor with laboratory and field data is shown on Figure 2.

The best agreement obtained for the dune steepness defined as the ratio of dune height Δ to dune length λ is similarly written as a function of flow depth h, bed particle diameter D_{50}, and transport-stage parameter T:

$$\frac{\Delta}{\lambda} = 0.015 \left(\frac{D_{50}}{h}\right)^{0.3} (1-e^{-0.5T})(25-T) \tag{2.4}$$

The agreement of the bedform steepness predictor with laboratory and field data is shown on Figure 3.

Accordingly, the expression for the bedform length λ can be derived from Eqs (2.3) and (2.4), thus:

$$\lambda = 7.3h \tag{2.5}$$

which is close to Yalin's theoretically derived value $\lambda = 2\pi h$.

2.2 Parameter Evaluation

Van Rijn's method figures among the most practically oriented techniques available for the analysis of the geometry of bedforms. The parameters for bedform height and steepness are simple functions of flow depth and mean grain size D_{50}. Errors in the evaluation of flow depth may arise from estimating the average bed elevation for dune beds of large amplitude. Likewise, the average dune height is perturbed by the presence of dunes of smaller amplitude, often leading to a separate analysis for large bedforms called dunes and smaller bedforms called megaripples. Similarly, megaripples of smaller amplitude and wavelength tend to reduce the effective wavelength of bedforms in natural channels.

The grain size is also subject to interpretation in that the sediment size distribution locally varies in natural channels. Reasonable accuracy can be obtained through the analysis of several bed material samples. One may also appropriately question using the median grain size D_{50} instead of a coarser fraction D_{84} or D_{90}; obviously, the accuracy increases for uniform sediment size distributions. In van Rijn's method, the exponent of sediment size is far less than unity (0.3), which dampens the effect of inaccuracies in particle diameter on bedform height and steepness.

Another point of discussion in van Rijn's method is the transport-stage parameter T which depends primarily on grain roughness and critical shear stress. As bedforms reach large amplitude, the grain shear stress calculated from the logarithmic relationship easily becomes of the same order of magnitude as the critical shear stress, thus at times providing a negative value of T for large bedforms. Large bedforms are possible at very low values of the parameter T. This can result in large variability in the calculation of dune height and dune steepness in natural channels when using Equations 2.3 and 2.4 at values of $T < 2$.

2.3 Analysis of Termes (1986)

More recent laboratory experiments by Termes (1986) led to the observation that sand bed roughness is decreasing with increasing discharge due to bedform stretching while the bedform height remains more or less constant. Klaassen suggested that the bedforms increase in length instead of decreasing in height at increasing discharge. The most relevant conclusions of the Delft Hydraulics sand flume tests as compiled by Termes (1986) are:

1) the relative bedform height $\frac{\Delta}{h}$ from bedform height Δ and flow depth h is almost constant at $5 < T < 25$, see Figure 4;
2) the Chezy coefficient increases with increasing grain shear stress τ';
3) complete flat bed did not occur, even for $T = 25$ and $Fr = 0.8$, see Figure 4;
4) Van Rijn's method underestimates the bedform height by a factor 2 at $T > 8$;
5) the bedform steepness is underestimated by a factor 1.5 at $T > 8$;
6) both the bedform height and steepness appear not to approach zero when $T = 25$, see Figure 4; and
7) at high values of T, the bedform height is not drastically decreasing but the bedform steepness does decrease.

Conclusions from both laboratory and field data on the Zaire river, the Missouri river and the Rhine river branches are:

1) the relative bedform height does not change significantly with increasing discharge, see Figure 5 for the Missouri river;
2) the bedform length increases with increasing discharge; and
3) consequently, the bedform steepness decreases with increasing discharge.

2.4 **Analysis of Raslan (1991)**

A recent investigation at Colorado State University with laboratory data from a 15 cm wide flume by Raslan (1991), and with field data from the Red Deer river and the Mississippi river indicates, as shown in Figure 6, that:

1) the dune height at low values of the parameter T ($T < 5$) are higher than predicted by van Rijn's method, and seem independent of the parameter T;
2) the Mississippi river data shows that the dune height does not vanish at $T = 25$ but rather remains relatively high at values of T as high as 50;
3) the measured bedform steepness parameters for laboratory data at $T < 5$ are several times larger than predicted by van Rijn's method; and
4) the recorded bedform steepness parameters from field data on the Red Deer and Mississippi rivers are about five times larger than predicted by van Rijn's method, and extend to values up to $T = 50$.

2.5 **Bedforms of large rivers**

The foregoing analysis of bedform dimensions focuses on dune height and steepness measured in large rivers around the world. The data sets from four large rivers are considered, except the Mississippi river discussed in the previous Subsection, and the Dutch rivers to be detailed in the next section. The following data sets are included in the foregoing analysis: 1) Missouri river data from Shen et al. (1978); 2) Zaire river data from Peters (1978), as previously analysed and reported by Termes (1986); 3) data set for the Jamuna river provided by G. Klaassen; and 4) data set for the Parana river provided by L. van Rijn. All four data sets are listed in Appendix A.

Plots of bedform height and steepness for the four large rivers are presented on Figure 7. It is observed that van Rijn's method underpredicts the bedform height. The bedform steepness is somewhat better predicted by van Rijn's method although significant scatter is found in the data. The analysis, particularly with relevance to bedform height, confirms previous observations of Termes and Raslan in that bedform height is underpredicted from van Rijn's method. Also, van Rijn's dune height parameter remains rather constant at different values of T and does not decline at values of T approaching 25.

2.6 Analysis of three parameters

This Section discusses the effects of three parameters, namely Fr, u_*/ω, and Re_* at high values of the transport-stage parameter T.

Consider the influence of the first parameter, the Froude number Fr. Van Rijn assumed that the transition between lower and upper regimes ranges from $15 < T < 25$ with plane bed conditions at $T > 25$. It is hypothesized that large bedforms can be observed in large rivers at values of $T > 25$, because the Froude number is still quite low. This is evidenced when plotting the Froude number for large rivers versus the sediment transport-stage parameter T. As opposed to laboratory data, it is shown on Figure 8 that relatively low values of the Froude number are effectively observed in large rivers at high values of T. For laboratory data, T equals 25 as the Froude number approaches unity. In large rivers, the flow remains subcritical as T approaches 25.

The influence of the parameter u_*/ω is then considered. It has been discussed and argued that the bed material enters suspension at $T > 25$, hence preventing the formation of bedforms. The previous hypothesis stating that suspension can be small although $T > 25$ is however unsupported. One may first question whether suspension is described by $\frac{u_*}{\omega}$ or $\frac{u_*'}{\omega}$. It is not at all clear as to whether the suspension is related to total shear or grain shear, but it is obvious that the total shear stress u_* is always greater or equal to grain shear u_*'. In any case, since the parameter T is function of grain shear, large values of T are expected to give large sediment transport rates in suspension. With reference to Figure 9a, and considering the most favorable case, $u_* = u_*'$, one may expect large sediment transport rates in suspension for all sand fractions as T increases. At a given T, it should be added that the suspension rate, as described by the parameter u_*/ω, increases for finer particles. If the formation of bedforms was hindered by large suspended loads, this effect would become obvious for fine particles on Figure 1. Since there is no physical evidence that the transition zone is shifted for finer sand fractions, there is no reason to believe that bedform height is reduced because of increased suspended load.

The third parameter Re_* describes the type of boundary condition. Figure 9b illustrates that for most sand fractions, the boundary type is in the transitional range between hydraulically smooth and hydraulically rough.

Furthermore, considering the slope, grain size and temperature to remain relatively constant during floods, an increase in flow depth is represented by vertical motion on this diagram. It is shown that, other parameters remaining constant, an extremely large increase in flow depth is therefore required to change from hydraulically smooth to rough boundary conditions. Conversely, changes in grain size and water temperature correspond to horizontal changes on this diagram. It is thus concluded that changes from hydraulically smooth to rough conditions are not likely to occur during floods from changes in flow depth and slope, unless significant changes in water temperature or grain size are observed.

It can be concluded from the analysis of these three parameters that:

1) low values of the Froude number are observed for large T values in large rivers, supporting the hypothesis that large bedforms can be found in large rivers at values of $T > 25$;
2) it is argued that the height of bedforms is not decreasing as a result of increasing u_*/ω;
3) at a given water temperature, slope, and grain size, extremely large increases in flow depth are required to change from hydraulically smooth to hydraulically rough boundary conditions.

3. Bedforms of the Meuse River and the Rhine River Branches

The analysis of bedforms in the Rhine river branches and the Meuse river specifically focuses on the applicability of van Rijn's method to calculate dune height and dune steepness. The analysis of field data from five reaches shown on Figure 10 first reviews values of the parameters cited in the literature. Case studies of changes in bedform geometry during recent floods on the Meuse and Rhine rivers are then detailed in Subsections 3.1, 3.2 and 3.3.

Brilhuis (1988) carried out an analysis of bedform configurations of the Rhine river branches in the Netherlands based on existing bedform predictors. The bedform predictors considered included the Liu-Albertson diagram, the Simons-Richardson diagram, the Chabert-Chauvin diagram and the Athaullah-Simons diagram. Most diagrams, shown in Appendix B, indicate a wide range of bedform configurations, with predominance of dunes suggesting transition to upper flow regime during floods. The analysis was based on statistical distributions of the hydraulic parameters, such as discharge and flow depth, without specific comparisons with field measurements of dune height and wavelength.

The recent investigations of Termes (1986), Adriaanse (1986), Brilhuis (1988), Kamphuis (1990), and Wijbenga (1991) included field measurements of dune height and length of the Meuse and Rhine river branches. The data sets are listed in Appendix C. The corresponding graphics for dune height and length parameters are shown in Figure 11 a and b respectively. Note that although Wijbenga (1991) separately reported the height of dunes and megaripples, the sum of both heights has been used for the Waal data set as it better reflects the dune height measured on bathymetric profiles. It is observed on Figure 11 that most of the data at low values of the parameter T is in relatively good agreement with van Rijn's dune height and steepness predictors. Whereas most of the data points were measured during relatively average flow conditions, the Bergsche Maas data was measured during the flood of February 1984 at discharge exceeding 2500 m^3/s. The dune heights during this flood are substantially higher than predicted by van Rijn's method. It is also noticeable that although values of T did not exceed 20, there is absolutely no decreasing trend in van Rijn's parameters at values of T exceeding 5. Similar remarks apply to the dune steepness parameter on Figure 11b. It is interesting that all values of dune steepness are confined within the range prescribed by van Rijn for the Waal and IJssel, while all measurements for the Meuse and Bergsche Maas plot above van Rijn's upper curve. Likewise, it is noticeable on Figure 11b that the dune steepness parameter does not decrease as T increases.

3.1 Bedforms of the Meuse river during the 1988 flood

The 1988 flood of the Meuse river is particularly interesting. The peak flow discharge reached 1743 m^3/s on March 19, followed by a second peak at 1310 m_3/s on March 30, as shown on Figure 12. Daily bathymetric records were available during the falling limb of the hydrograph on a daily basis from March 19 until March 24. Typical strip chart recordings are shown on Figure 13 at cross-sections 190 and 200. As the discharge gradually decreases from 1743 m^3/s on March 19 to 1163 m^3/s on March 24, both the dune height Δ and wavelength λ significantly decrease. Graphs of the variability of the dune height Δ and steepness $\frac{\Delta}{\lambda}$ with discharge are presented on Figure 14a and b. The corresponding dune height and steepness parameters, defined by van Rijn, are then presented on Figure 14c and d, indicating changes in van Rijn dune height and dune steepness parameters during flood recession. It is found that all parameters increase with discharge, the dune steepness $\frac{\Delta}{\lambda}$, however, slightly increases with discharge. The time scale for the formation of typical bedforms ($\Delta = 0.8$ m, $\lambda = 10$ m) at peak flow discharge is on the order of 3-5 hours. Loop-rating effects due to bedform growth are therefore not significant on daily records.

Figure 15 shows the downstream variability in bed sediment size distribution, as described by D_{10}, D_{50}, and D_{90}, from samples taken at a 1 kilometer interval between km 176 and km 201. The corresponding dune height Δ recorded on a daily basis between km 176 and km 190 are shown on the same Figure. Little spatial variation in either grain size distribution or bedform dimension is observed during this flood. The dune height which is quite uniform in the downstream direction decreases rather uniformly in time during the considered period of falling discharge.

3.2 Bedforms of the Bergsche Maas during the 1984 flood

The 1984 flood of the Meuse river is somewhat larger in magnitude than the 1988 flood. The peak discharge reached 2231 m^3/s on February 12 at Lith, as shown on Figure 16. Bathymetric records of the lower Meuse (Bergsche Maas) between km 220 and km 250 have been analyzed by Adriaanse (1986). Sequences of bathymetric profiles at kms 223, 224, 230, 234, 236, 246 and 247 are compiled in Appendix D for January 8,13,14,15 and 20. Data analysis shows that the amplitude and wavelength of bedforms change rapidly during floods. Soundings prior to the flood, Q = 1434 cms on February 8, are quite similar to those after the flood, Q = 654 cms on February 20. At higher discharge, the largest bedforms showed rounded crests and some dunes measured up to 3 m in amplitude. Figure 17 from Adriaanse (1986) suggests that the changes in dune size in the downstream direction may at first glance be somewhat correlated with the sediment size distribution. A careful interpretation also requires including transversal changes in sediment size distribution in this gently curved channel.

Changes in dune height, wavelength and steepness are plotted as function of discharge on Figure 18. It is observed that both the average dune height and wavelength generally increase as a function of discharge. The dune steepness defined as the ratio of dune height to wavelength remains, however, quite constant during the flood. A loop rating effect can be observed for dune height and wavelength, thus indicating that at a given discharge, both the dune height and wavelength are larger under falling discharge than increasing discharge. The loop-rating effect pertains to the time scale required for the formation of bedforms which is on the order of 1-3 days as calculated from bedload equations. The corresponding dune height and steepness parameters, defined by van Rijn, are also presented on Figure 19a and b. It is found that the dune height parameter increases with discharge while the dune steepness parameter was larger prior to the flood on February 8.

3.3 Bedforms of the Rhine river branches during the 1988 flood

During the 1988 flood, the discharge of the Rhine river at Lobith reached 10274 m^3/s on March 30 after a first peak of 8324 m^3/s on March 20 as shown on Figure 20. Bathymetric records of the Rhine and the Waal were previously analyzed by Wijbenga (1991) for comparisons between permanent and non permanent flow conditions. Sequences of bathymetric profiles of the Rhine between km 863 and 866 are compiled on Figure 21 for the period between March 18 and April 11, 1988. Dunes are shown to form rather rapidly as a result of increasing discharge. At high flow, the dune crests are rounded and irregular profiles form during the falling limb of the hydrograph. Characteristic dune heights between km 863-867 of the Rhine river and km 867-884 of the Waal are plotted on Figure 22a, showing longitudinal changes in bedform geometry. Similar graphs for the IJssel river between km 879 and km 903 are presented on Figure 22b. It is found that the most interesting reach for the analysis of dune growth is located on the Rhine river between km 864 and km 866, given the symmetrical cross-sectional profile of this relatively straight river reach.

The bathymetric profiles of the Rhine river between km 865 and km 866 were scrutinized to determine the average dune height Δ from the total bed elevation drop on the lee side of the dunes divided by the number of dunes η over the 1 km reach. The average dune length λ is calculated from the reach length over the number of dunes. This average dune height roughly equals one-half to two-thirds of the maximum dune height Δ_m over the 1 km reach. It is also noticed that the average dune height is also roughly equal to the sum of the dune height and the ripple height as reported by Wijbenga (1991). Figure 23 shows the variability of the average dune height Δ, average dune length λ, and average dune steepness $\frac{\Delta}{\lambda}$ as a function of time (Figs 23a and b) and discharge (Figs 23c, d and e). The dune length steadily increases with time while the dune height changes in proportion with the discharge. The dune height and the dune steepness increase with discharge. This case is inconsistent because the average wavelength cannot indefinitely increase with time. Loop-rating effects are not significant on daily records because the time scale for the formation of dunes is of the order of 6-12 hours.

The corresponding dune height and steepness parameters are also presented on Figure 24. It is found that the dune height parameter generally increases with the transport-stage parameter T while the dune steepness parameter slightly increases with T. During floods, it can be concluded that both parameters increase with discharge and the parameter T. These results oppose those of van Rijn in which both parameters decrease with T as T > 5. At high discharge, van Rijn's method underpredicts both the dune height and the dune steepness.

3.4 Improved Prediction of Bedform Geometry

This analysis of field and laboratory bedform data suggests the following improvements in the prediction of dune height and length from van Rijn's method:

1) the dune height parameter $1 < \frac{\Delta}{h}\left(\frac{h}{D_{50}}\right)^{0.3} < 4$ for values of T>5;

2) the dune steepness parameter $0.2 < \frac{\Delta}{\lambda}\left(\frac{h}{D_{50}}\right)^{0.3} < 2$ for values of T>5;

3) higher values of both parameters in 1) and 2) are generally encountered during floods; and

4) better accuracy can be obtained from site specific measurements and analysis of bedform geometry.

4. Summary and Conclusions

This study tested the applicability of van Rijn's method in order to improve the prediction of dune height and dune length during floods. Several field data sets from large rivers were scrutinized, particularly the Rhine river branches and the Meuse river.

Considering an alluvial stream of flow depth h, median grain size D_{50}, dune height Δ, and dune length λ, van Rijn defined a dune height parameter $\frac{\Delta}{h}\left(\frac{h}{D_{50}}\right)^{0.3}$ and a dune steepness parameter $\frac{\Delta}{\lambda}\left(\frac{h}{D_{50}}\right)^{0.3}$ as a function of the transport-stage parameter T.

The following can be concluded regarding the applicability of the dune height parameter:

1) the dune height parameter represents quite well the average flow conditions of the Rhine river branches and the average flow conditions of the Meuse river (Fig. 11a, 24a);
2) van Rijn's method significantly underestimates the height of dunes of other large rivers (Fig. 5a, 6a, 7a);
3) both the dune height and the dune height parameter increase with discharge, as observed on the Rhine river (Fig. 23c, 24a) and the Meuse river (Fig. 14a, 14c, 18, 19a) during major floods;
4) as opposed to van Rijn's diagram, the dune height parameter does not decrease with discharge at values of $T > 10$, this parameter remains relatively constant at values of T up to 40 (Fig. 6a, 7a);

With regard to the dune steepness parameter, van Rijn's method generally underestimates the dune steepness of the Meuse (Fig. 11b), the Rhine river during floods (Fig. 24b) and other large rivers (Fig. 6b, 7b). The agreement with the Waal and IJssel is significantly better. The dune length generally increases with discharge (Fig. 18, 14b) while the dune steepness slightly increases with discharge (Fig. 14b, 18, 23e).
Suggested improvements for predicting bedform height and length during floods are spelled out in Subsection 3.4. In terms of applicability to the Meuse river and the Rhine river branches, it can be generally concluded that the dune height and dune length determined from van Rijn method are representative of average flow conditions, but underestimate the dune height during floods. Specific conditions for the Meuse river are given for

average flow conditions (Fig. 11) and flood conditions (Fig.14, 18, 19). Field data for the Waal and IJssel can be found for average flow (Fig. 11) and during extreme floods (Fig. 22). Extreme flood conditions of the Rhine river are presented on Figures 23 and 24.

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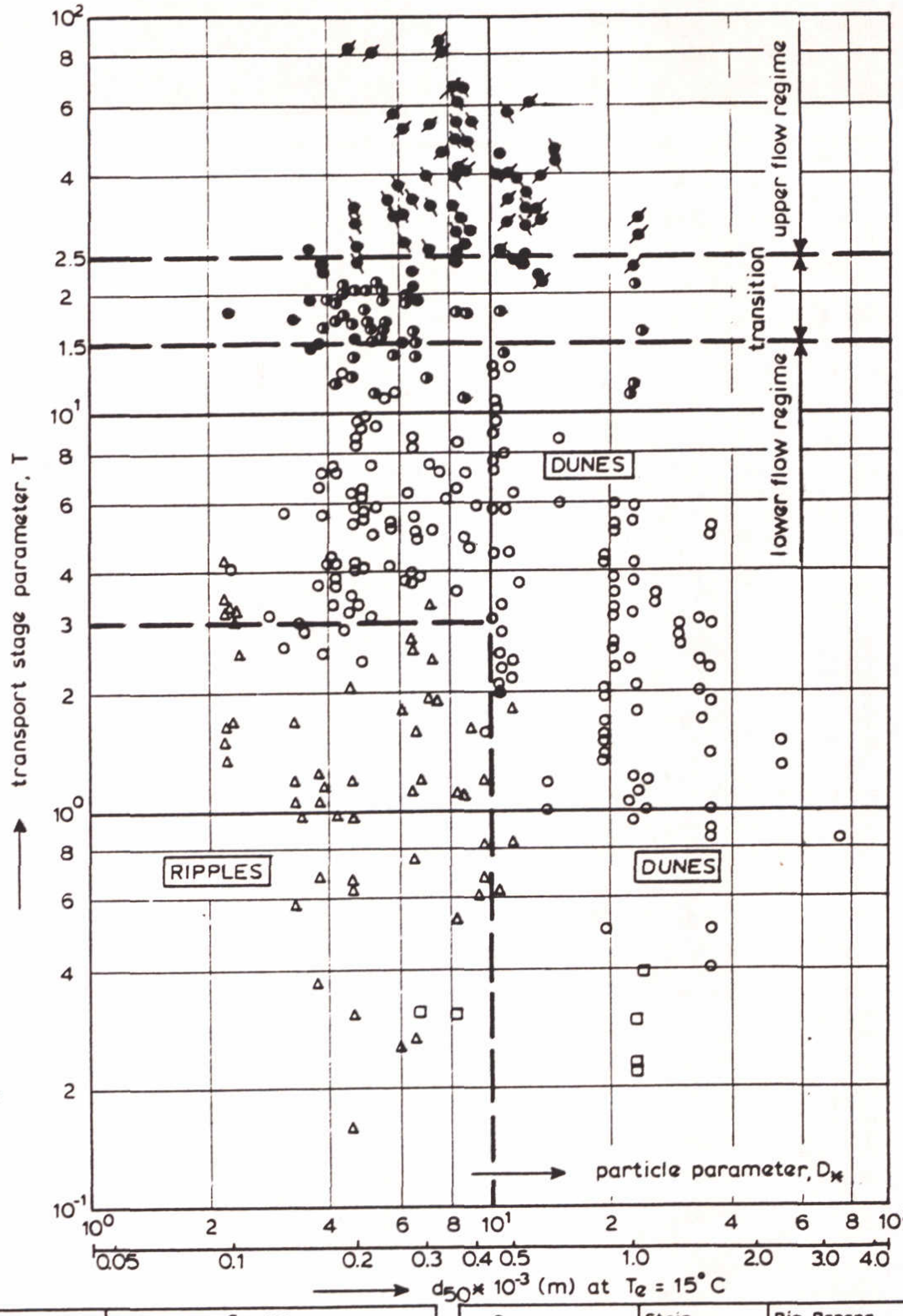
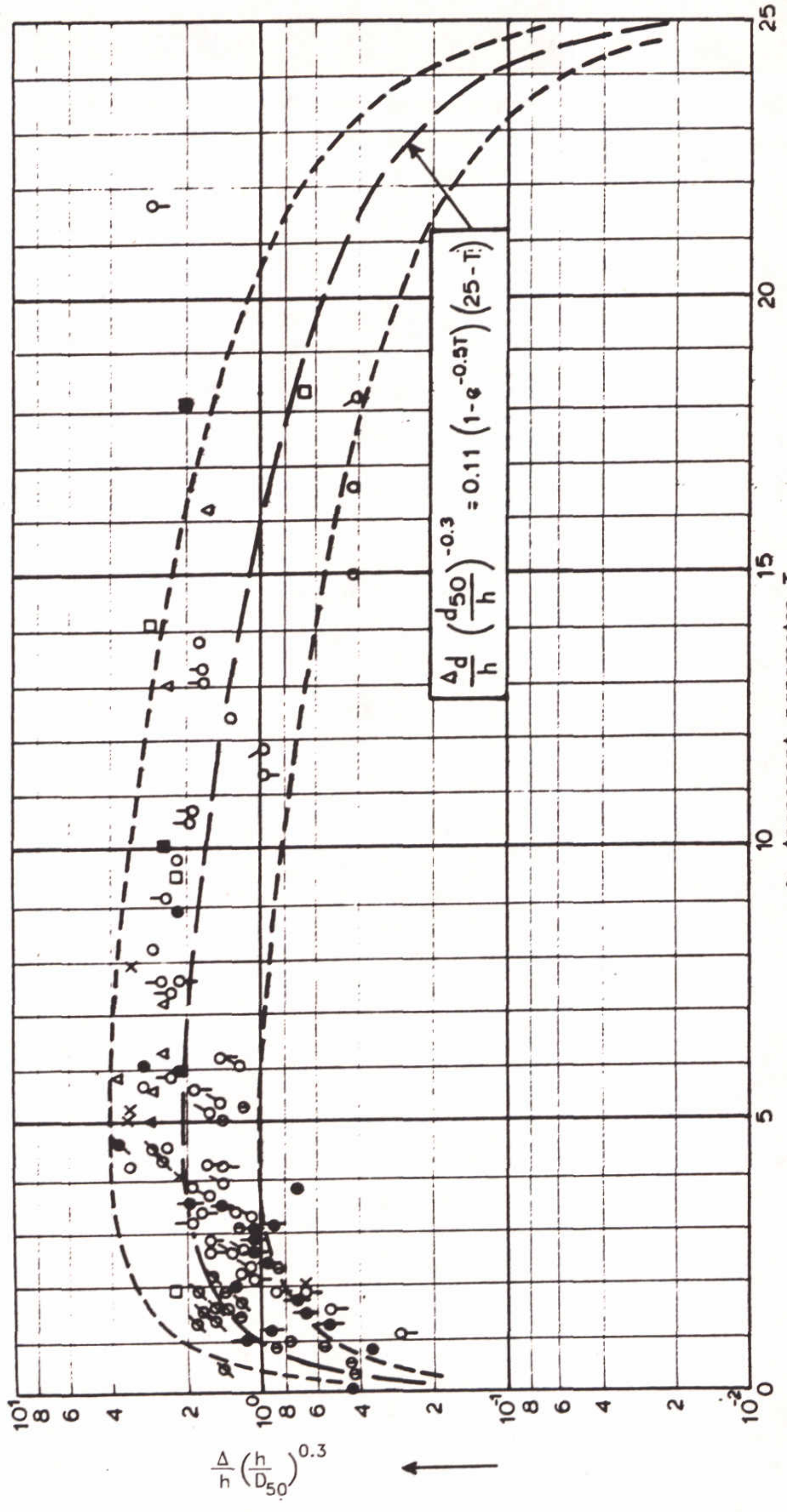


Bed-forms	Source: Flume Data	Source: Field Data
□ Plane bed (no motion)	Guy et al	
△ Ripples	Guy et al Ackers Laursen	
o Dunes	Guy et al Delft Hydr. Lab.	Dutch Rivers Pakistan Canals

o Dunes	Stein Williams Znamenskaya	Rio Parana Hii River (Japan)
● Transition	Guy et al	Missouri River (U.S.A.)
● Plane bed	Guy et al	
Anti-dunes (standing waves)	Guy et al	Rio Grande (U.S.A.)
Anti-dunes (breaking waves)	Guy et al	

BEDFORM CLASSIFICATION DIAGRAM
PROPOSED BY VAN RIJN (1984)

DELFT HYDRAULICS | R 1386 | FIG. 1

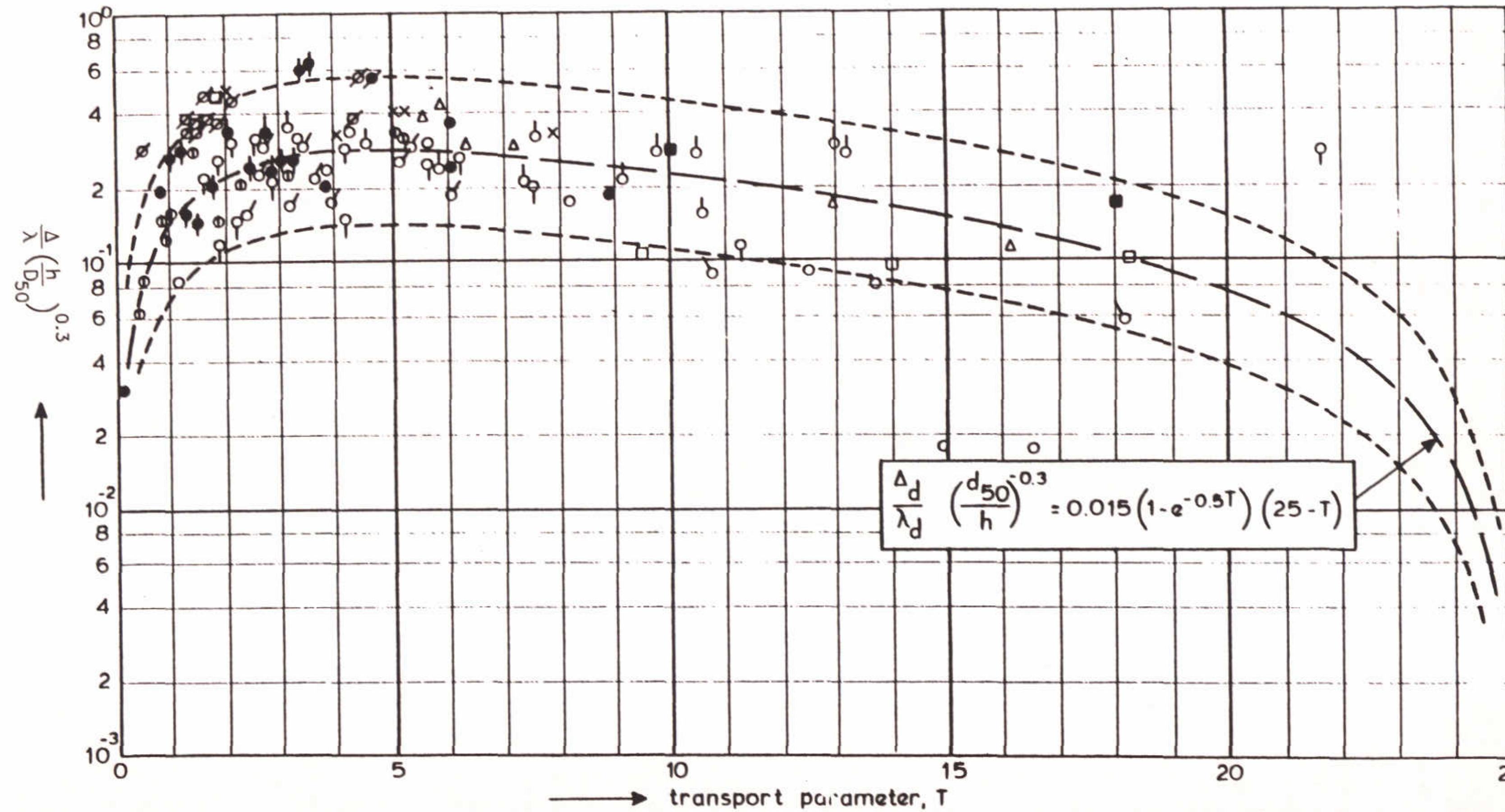


	source	flow velocity ū (m/s)	flow depth h (m)	particle size d_{50} (µm)	temperature (°C)
flume data	o Guy et al	0.34-1.17	0.16-0.22	190	8-34
	x Guy et al	0.41-0.85	0.14-0.34	270	8-34
	▲ Guy et al	0.47-1.15	0.16-0.32	280	8-34
	b Guy et al	0.77-0.98	0.16	330	8-34
	□ Guy et al	0.48-1.00	0.10-0.25	450	8-34
	ϙ Guy et al	0.53-1.15	0.12-0.34	930	8-34
	● Williams	0.54-1.06	0.15-0.22	1350	25-28
	Delft Hydr. Lab.	0.45-0.87	0.26-0.49	790	12-18
	Stein	0.52-0.95	0.24-0.31	400	20-26
	Znamenskaya	0.53-0.80	0.11-0.21	800	–

	source	ū (m/s)	h (m)	d_{50} (µm)	temp. (°C)
field data	● Dutch Rivers	0.85-1.55	4.4-9.5	490-3600	5-20
	Rio Parana	1.0	12.7	400	–
	Japanese Channels	0.53-0.89	0.25-0.88	1100-2300	–
	■ Mississippi River	1.35-1.45	6-16	350-550	–

BEDFORM HEIGHT PREDICTOR
PROPOSED BY VAN RIJN (1984)

DELFT HYDRAULICS | R 1386 | FIG. 2



	source	flow velocity $\bar{u}$ (m/s)	flow depth h (m)	particle size d_{50} (μm)	temperature (°C)
flume data	o Guy et al	0.34-1.17	0.16-0.22	190	8-34
	x Guy et al	0.41-0.65	0.14-0.34	270	8-34
	Δ Guy et al	0.47-1.15	0.16-0.32	280	8-34
	ƀ Guy et al	0.77-0.98	0.16	330	8-34
	◻ Guy et al	0.48-1.00	0.10-0.25	450	8-34
	ϙ Guy et al	0.53-1.15	0.12-0.34	930	8-34
	● Williams	0.54-1.06	0.15-0.22	1350	25-28
	ø Delft Hydr. Lab.	0.45-0.87	0.26-0.49	790	12-18
	ȯ Stein	0.52-0.95	0.24-0.31	400	20-26
	ơ Znamenskaya	0.53-0.80	0.11-0.21	800	–

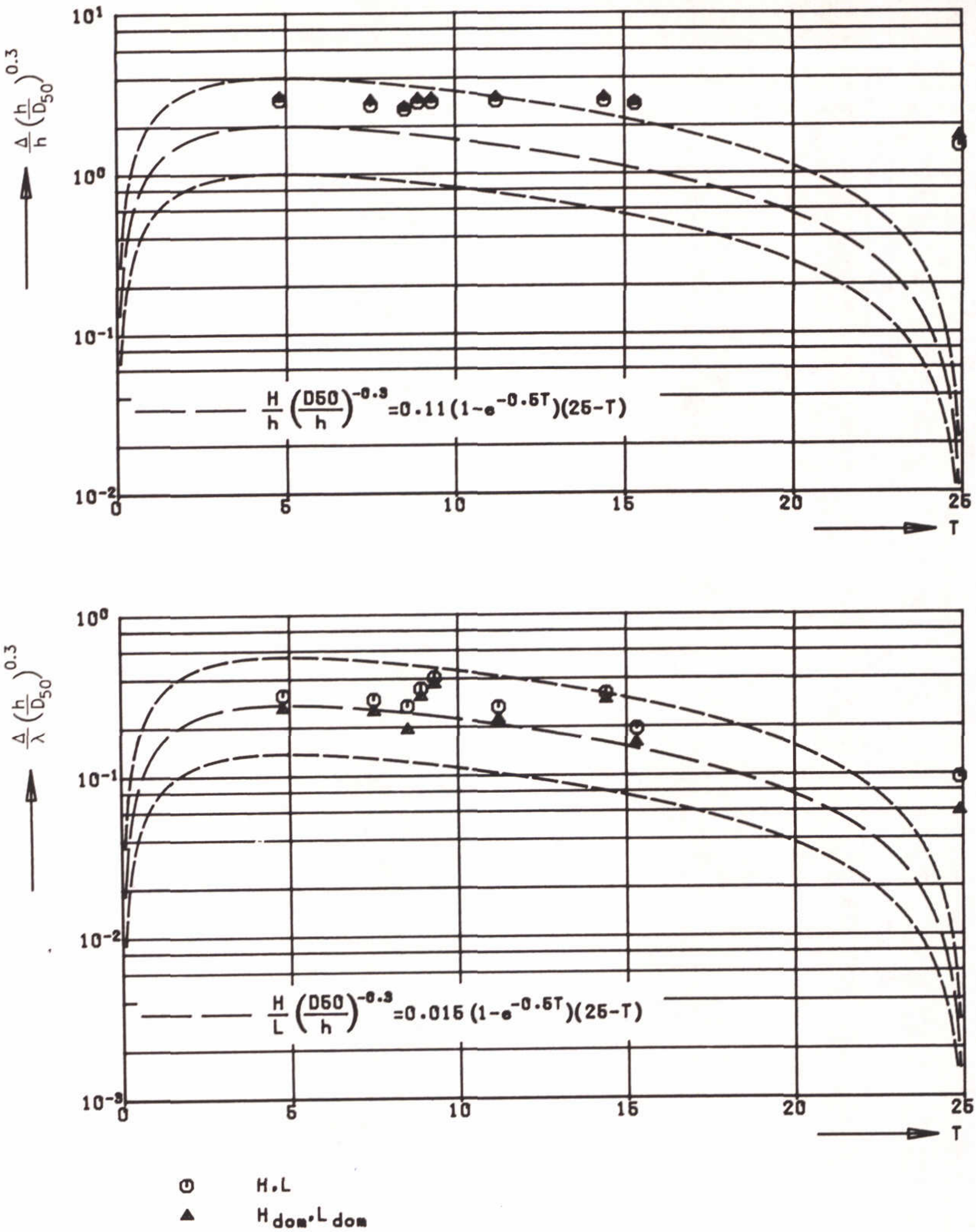
	source	$\bar{u}$ (m/s)	h (m)	d_{50} (μm)	temp (°C)
field data	● Dutch Rivers	0.85-1.55	4.4-9.5	490-3600	5-20
	ø Rio Parana	1.0	12.7	400	–
	ɸ Japanese Channels	0.53-0.89	0.25-0.88	1100-2300	–
	■ Mississippi River	1.35-1.45	6-16	350- 550	–

BEDFORM STEEPNESS PREDICTOR
PROPOSED BY VAN RIJN (1984)

DELFT HYDRAULICS

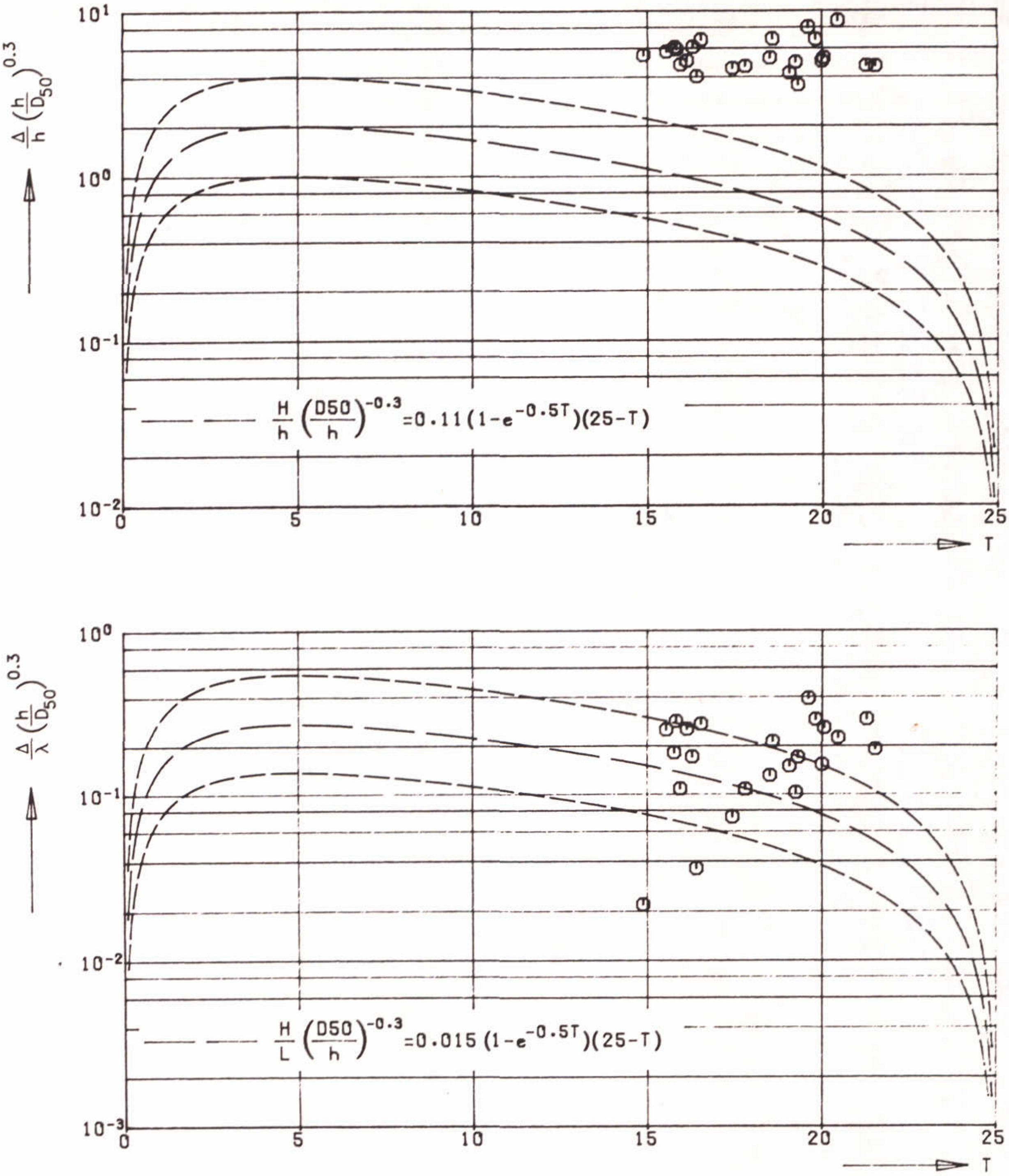
R 1386

FIG. 3



BEDFORM HEIGHT AND STEEPNESS FOR LABORATORY DATA, FROM TERMES (1986)

DELFT HYDRAULICS	R 1386	FIG. 4

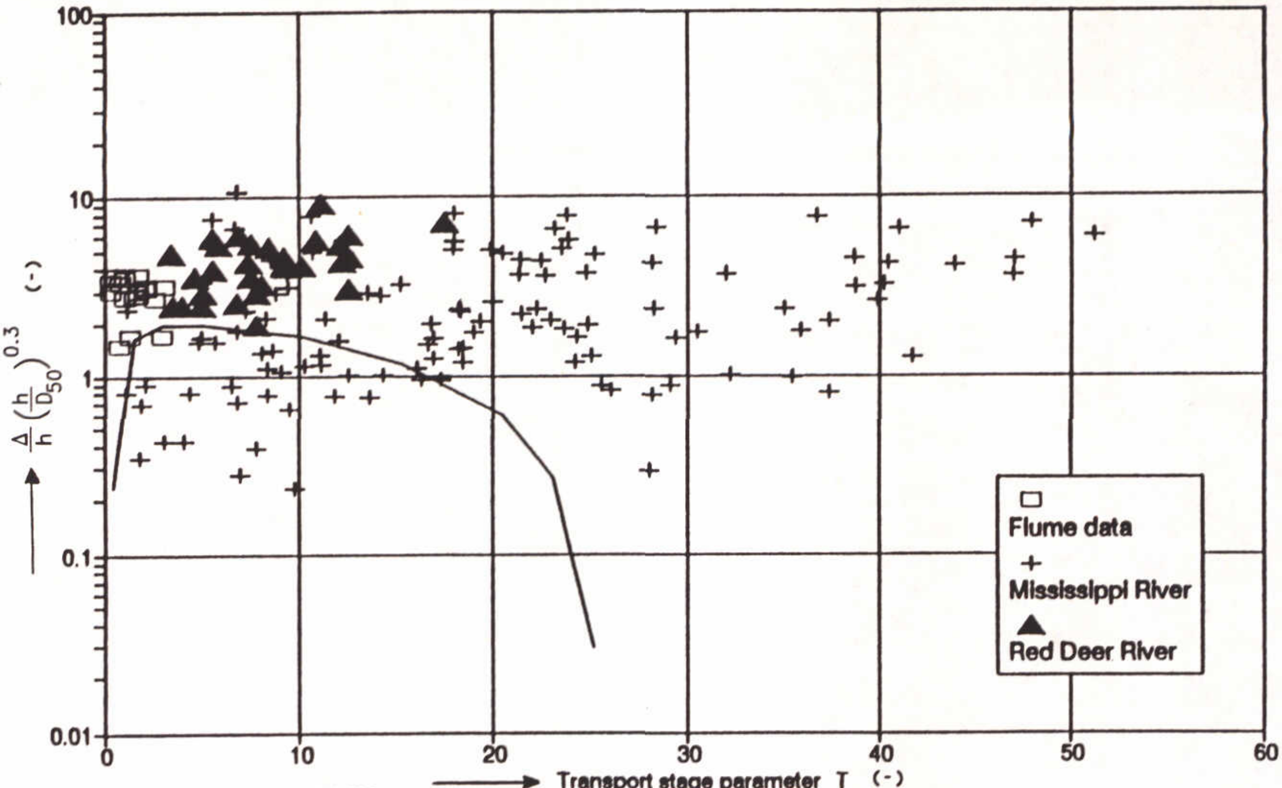


BEDFORM HEIGHT AND STEEPNESS FOR THE MISSOURI RIVER, FROM TERMES (1986)

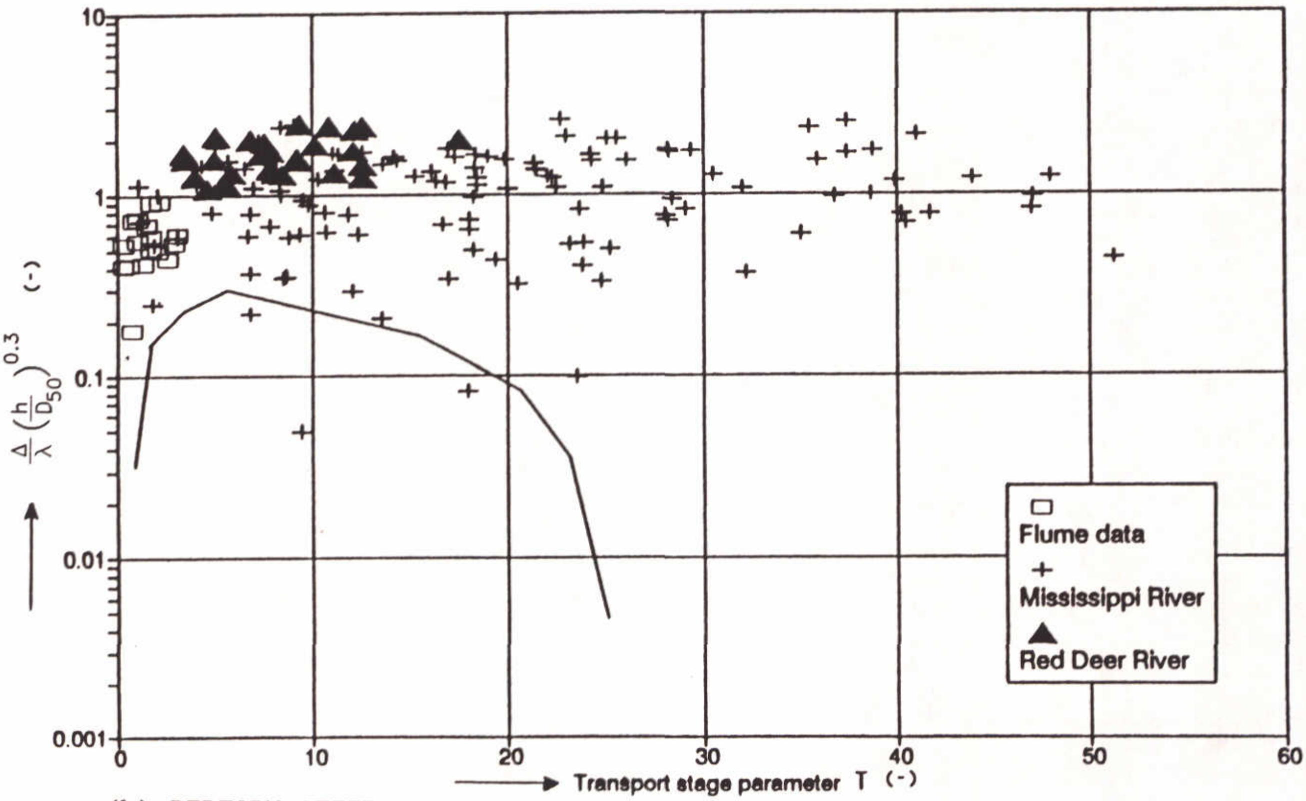
DELFT HYDRAULICS

R 1386

FIG. 5



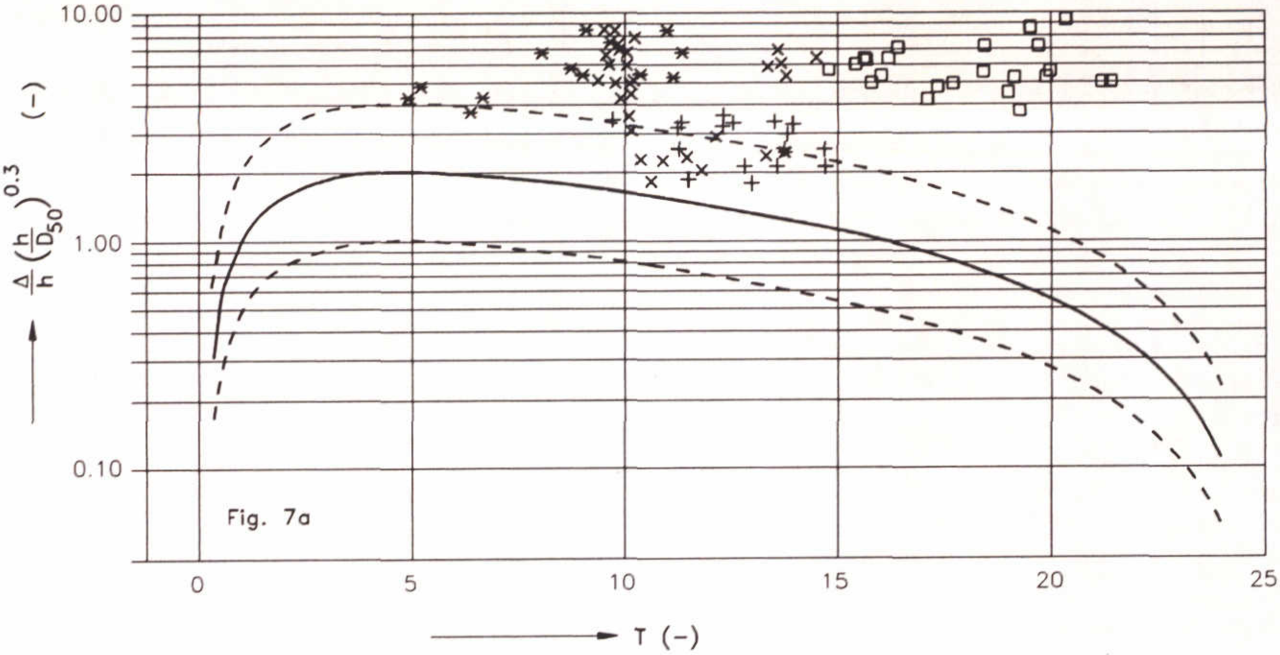
(a) BEDFORM HEIGHT



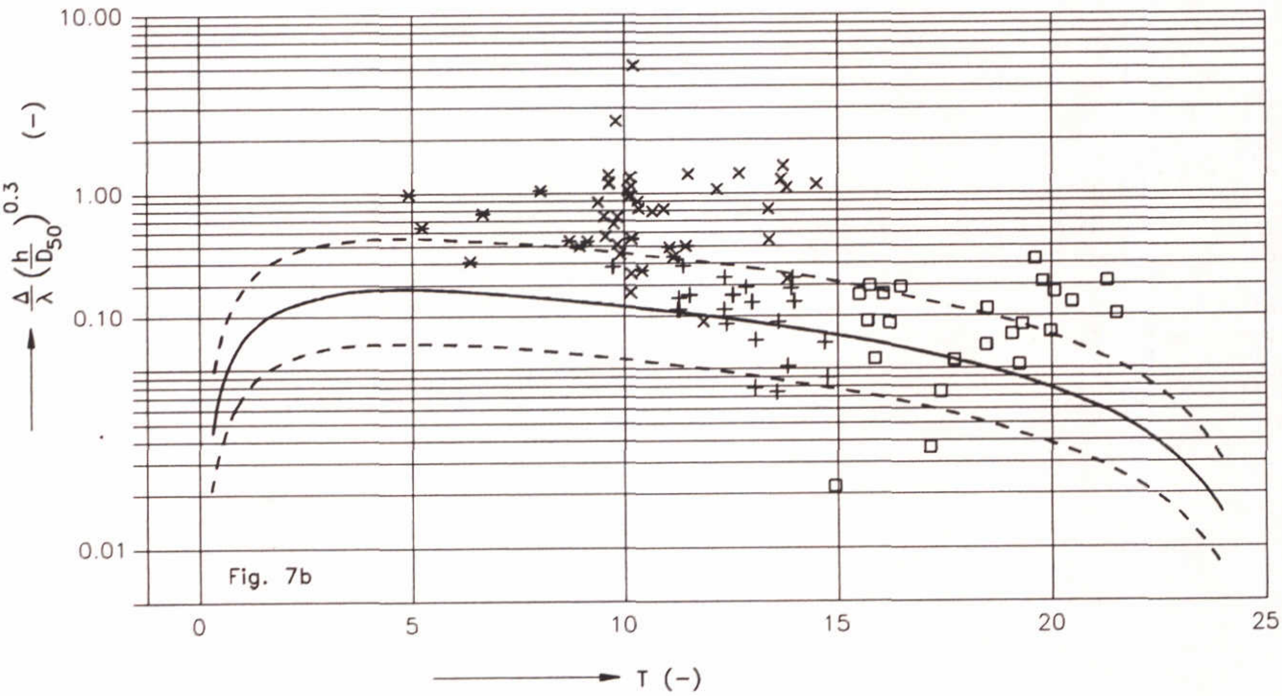
(b) BEDFORM STEEPNESS

BEDFORM HEIGHT (a) AND STEEPNESS (b) FROM RASLAN (1991)

DELFT HYDRAULICS | R 1386 | FIG. 6



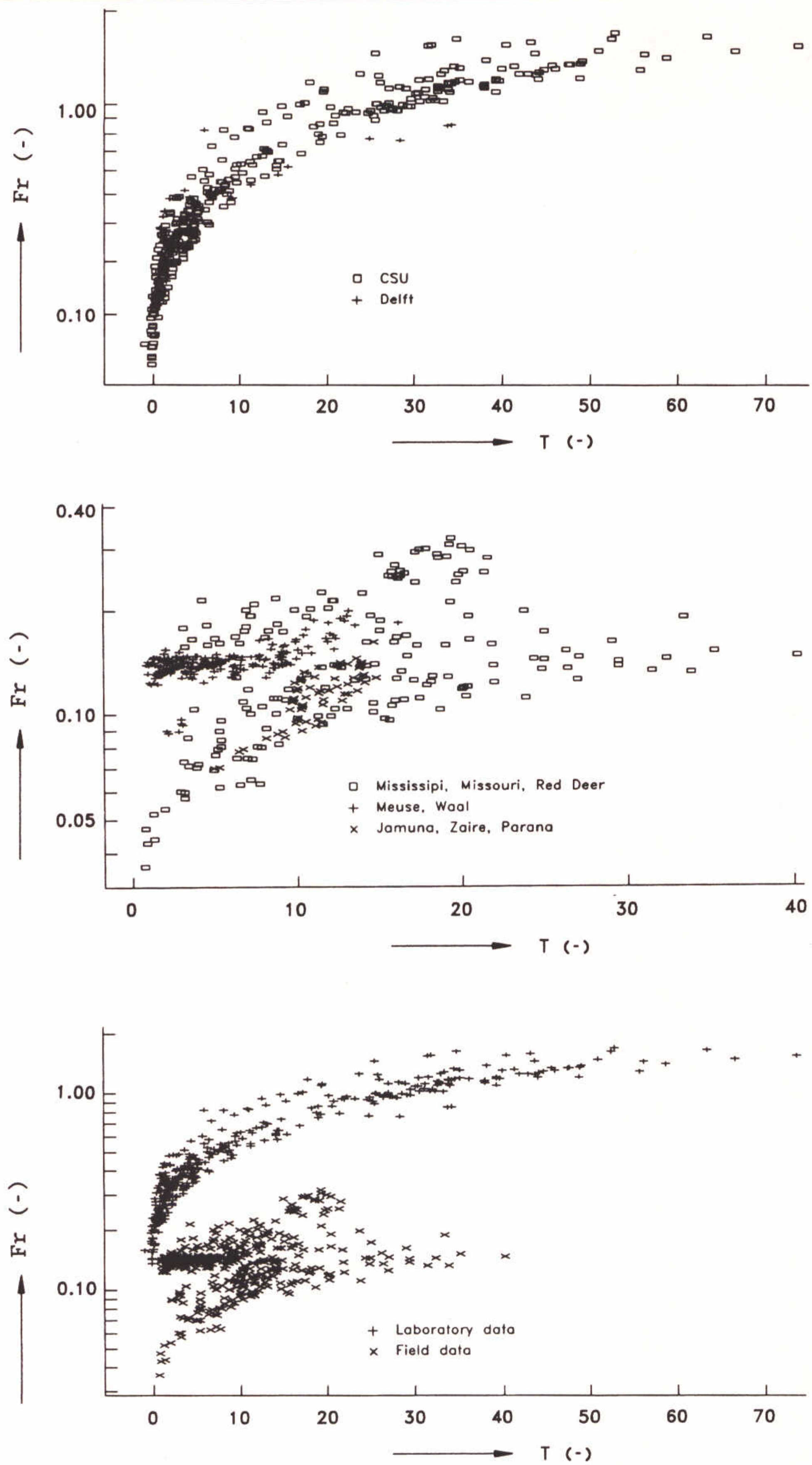
(a) BEDFORM HEIGHT



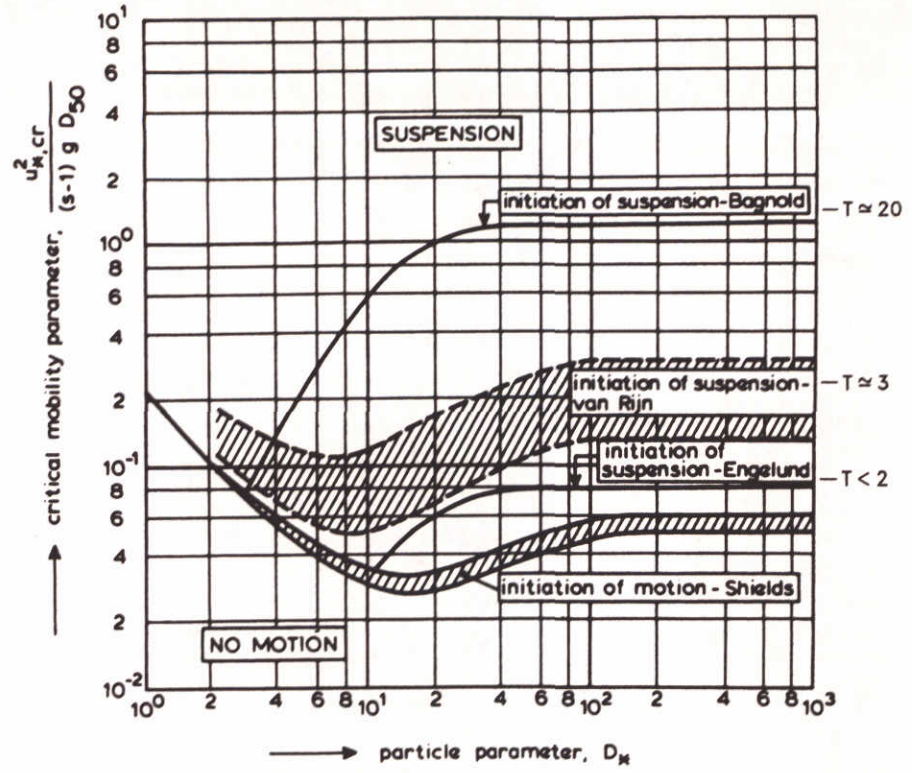
(b) BEDFORM STEEPNESS

□ Missouri
\+ Zaire
× Jamuna
⁎ Parana

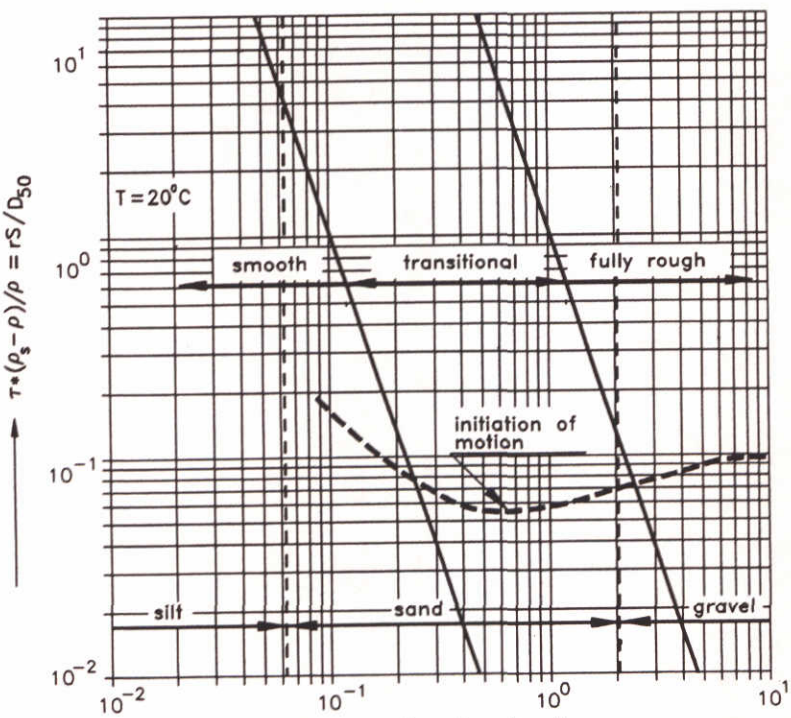
BEDFORM HEIGHT (a) AND STEEPNESS (b) FOR FOUR LARGE RIVERS		
DELFT HYDRAULICS	R 1386	FIG. 7



FROUDE NUMBER VERSUS TRANSPORT PARAMETER FOR LABORATORY (a), FIELD (b) AND COMBINED DATA (c)		
DELFT HYDRAULICS	R 1386	FIG. 8

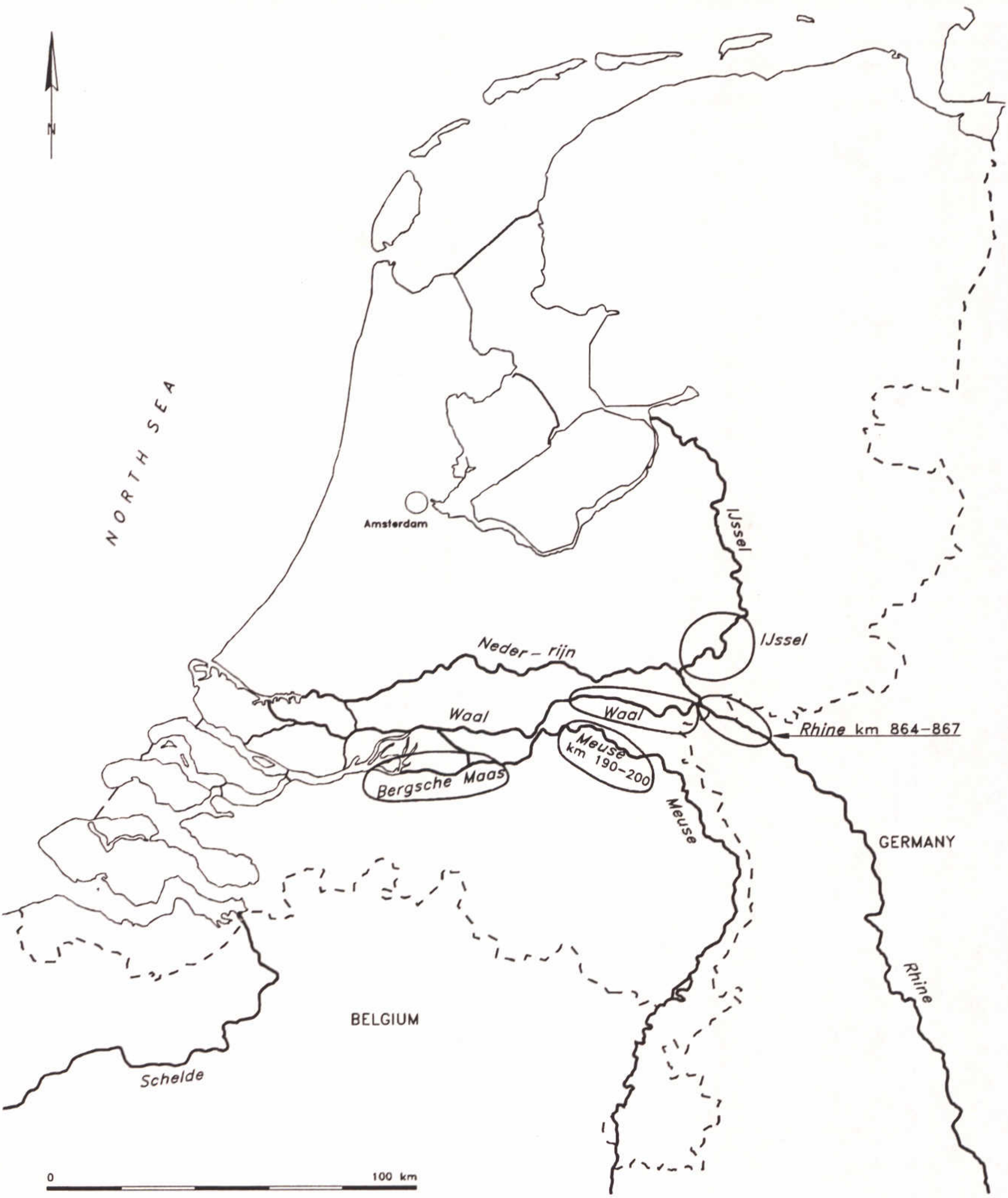


(a) INITIATION OF MOTION AND SUSPENSION (FROM VAN RIJN, 1984)

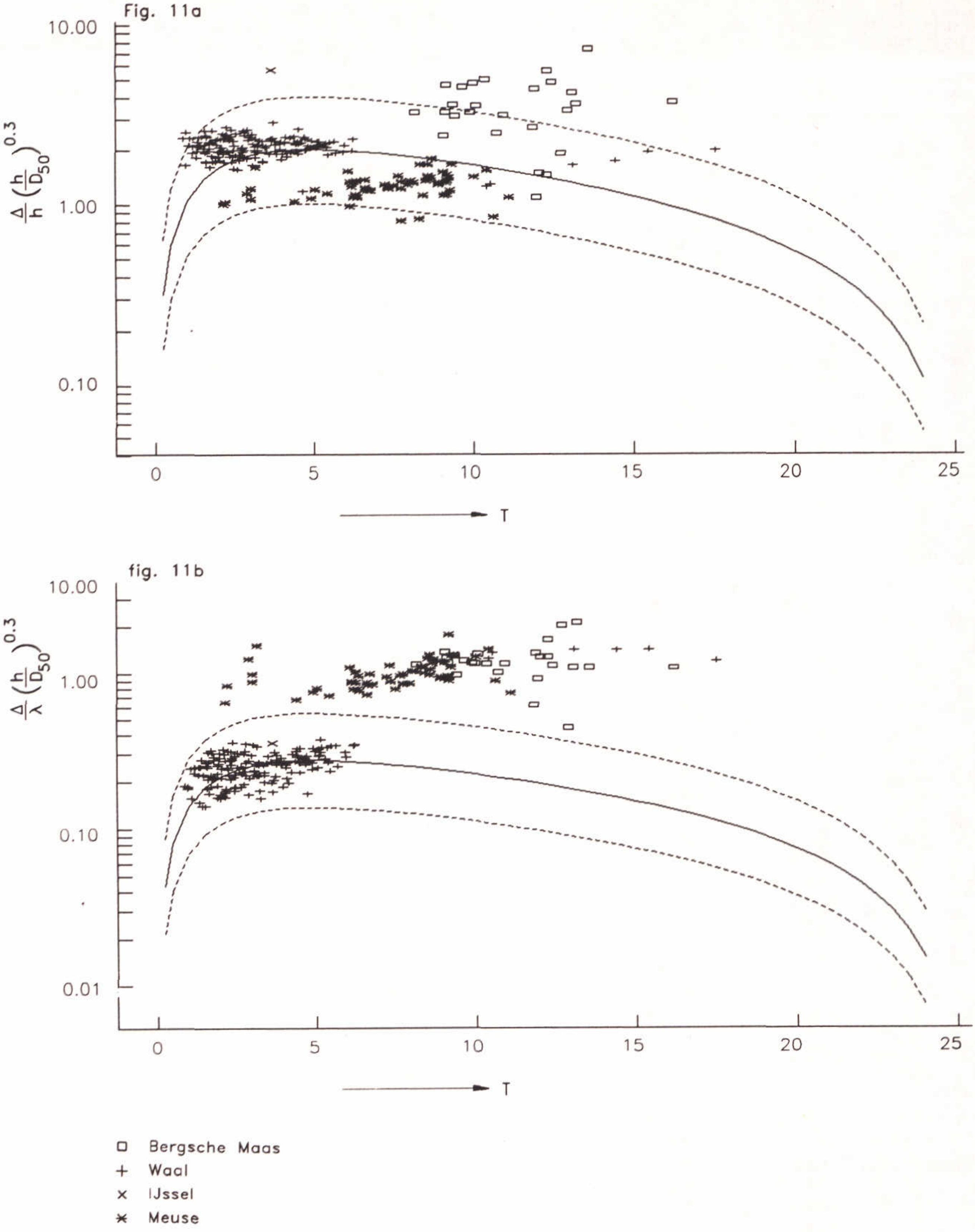


(b) TRANSITION FROM HYDRAULICALLY SMOOTH TO ROUGH BOUNARY

INITIATION OF MOTION AND SUSPENSION (FROM VAN RIJN, 1984)		
DELFT HYDRAULICS	R 1386	FIG. 9



MAP OF THE MEUSE AND RIVER RHINE BRANCHES IN THE NETHERLANDS UNDER STUDY		
DELFT HYDRAULICS	R 1386	FIG.10

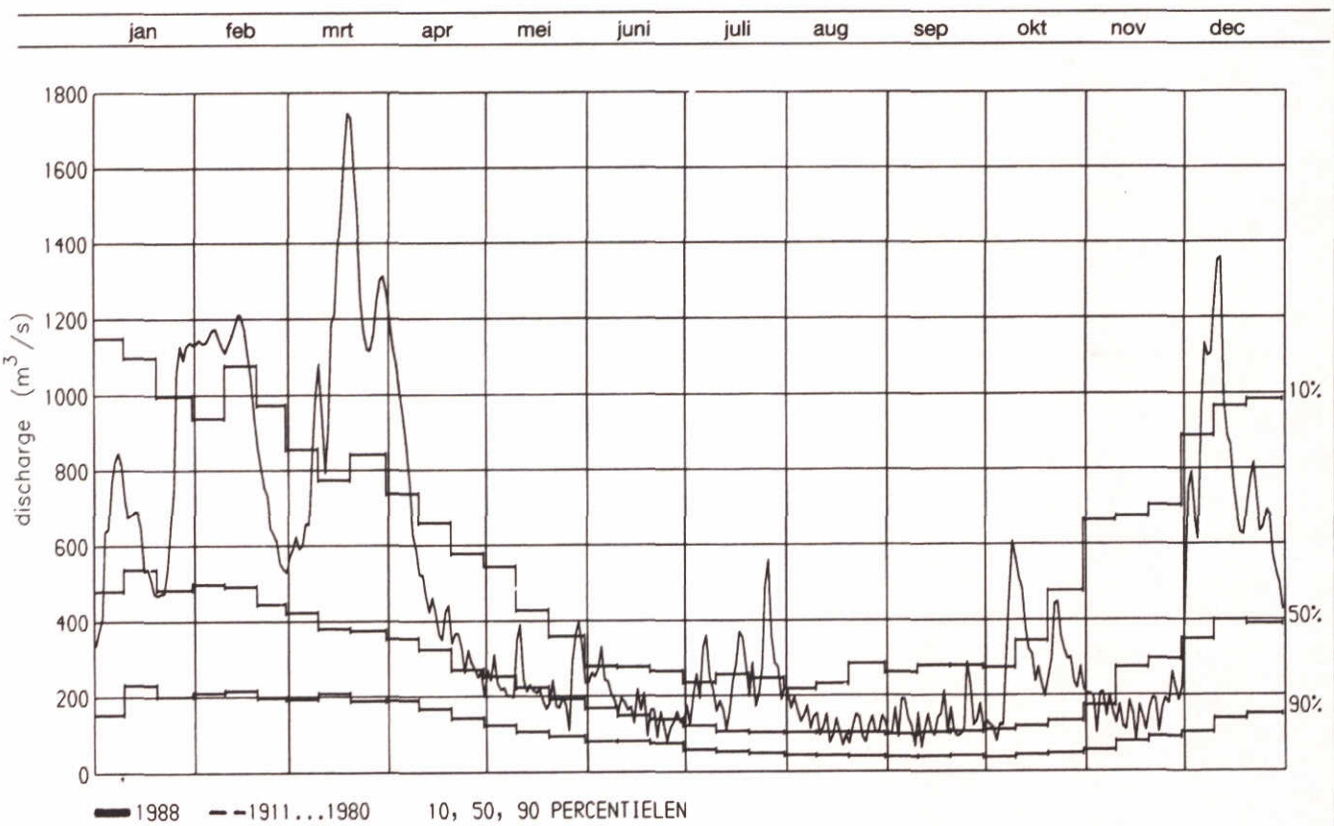


BEDFORM HEIGHT (a) AND STEEPNESS (b) FOR THE MEUSE AND RHINE RIVER BRANCHES

DELFT HYDRAULICS

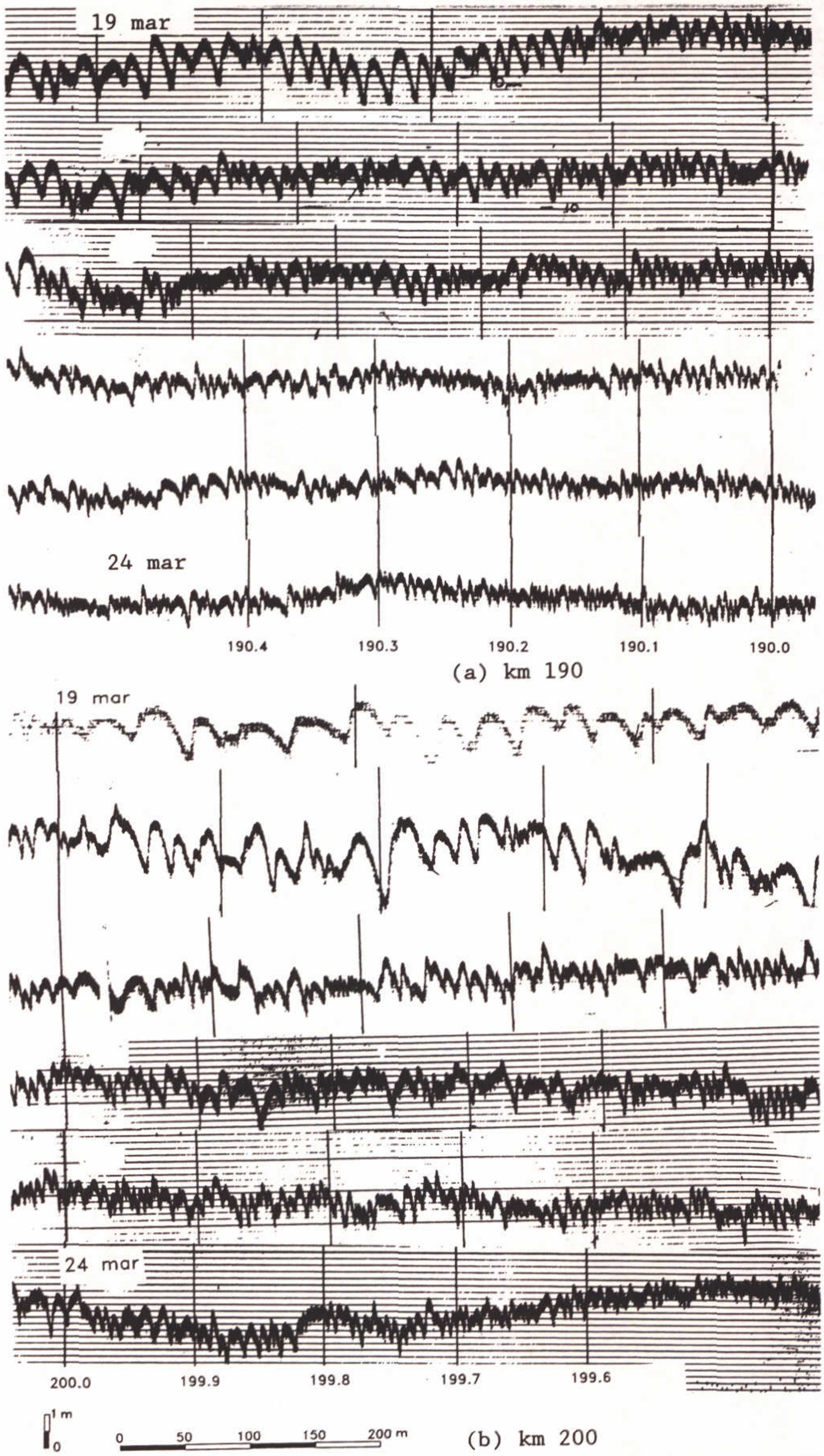
R 1386

FIG. 11



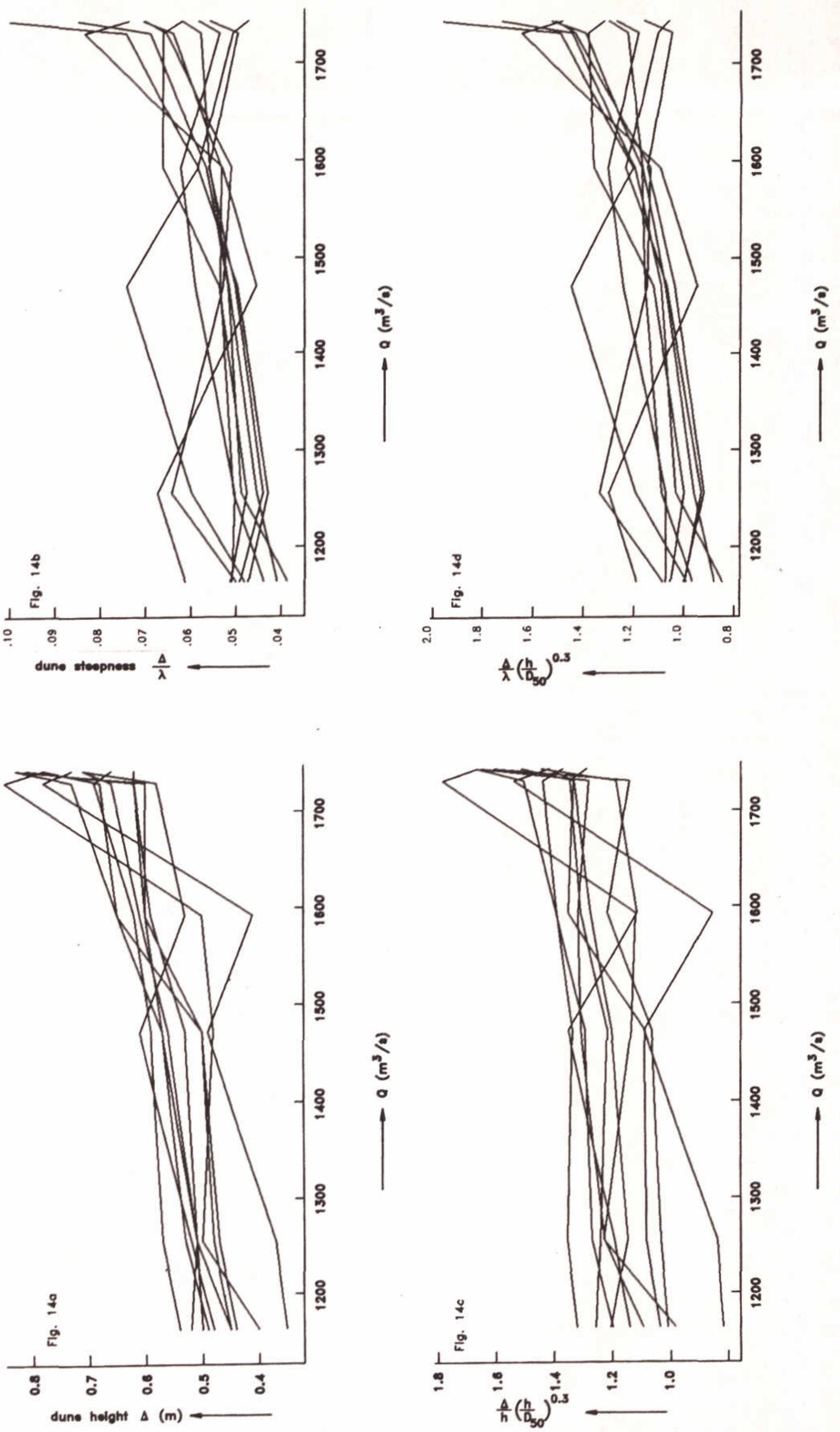
FLOW DISCHARGE OF THE MEUSE AT LITH, 1988

DELFT HYDRAULICS | R 1386 | FIG. 12



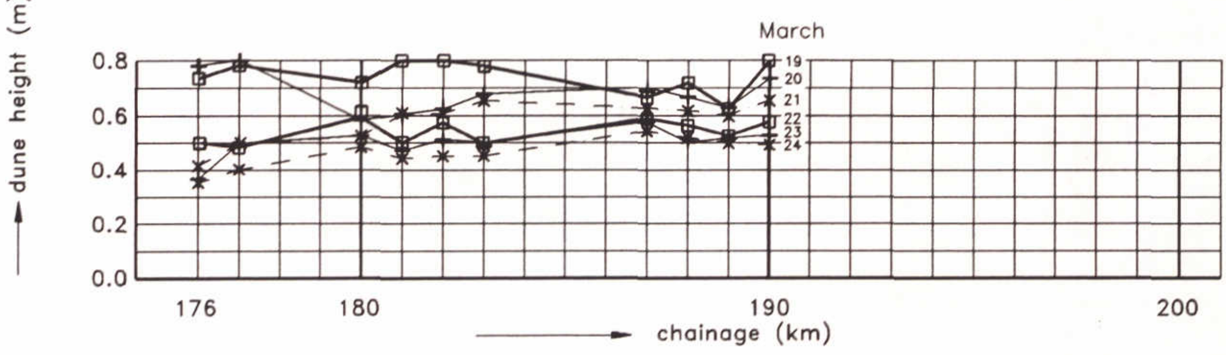
BED PROFILES OF THE MEUSE RIVER
AT km 190 (a) AND km 200 (b)

DELFT HYDRAULICS	R 1386	FIG. 13

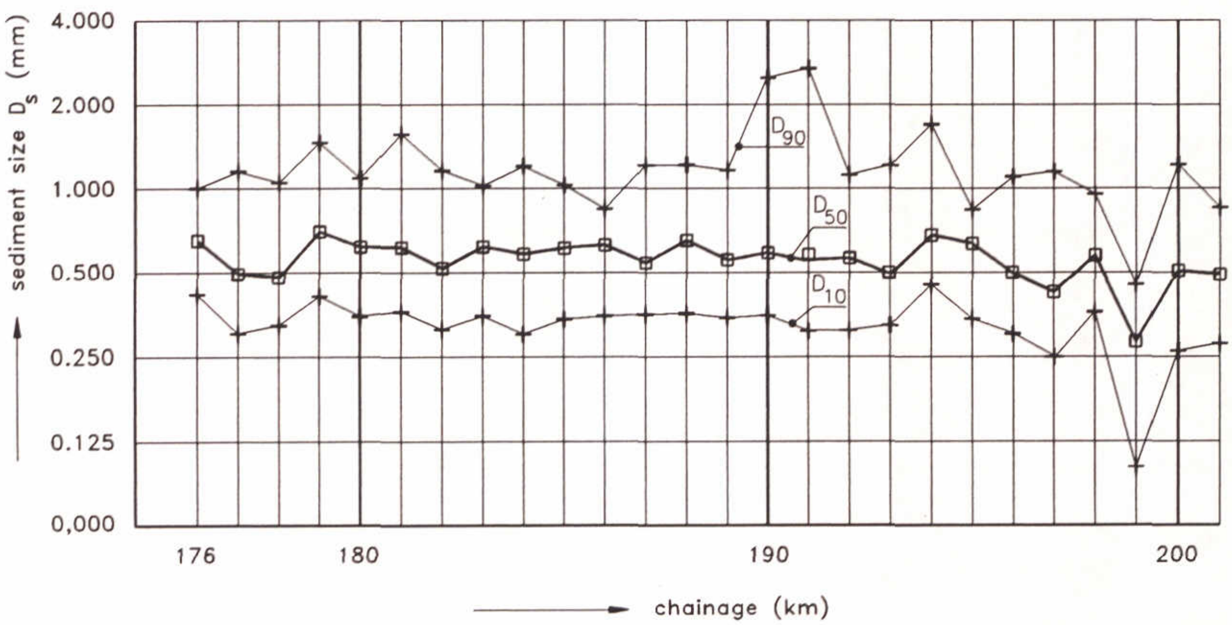


BEDFORM HEIGHT AND STEEPNESS
FOR THE MEUSE RIVER, 1988

DELFT HYDRAULICS	R 1386	FIG. 14

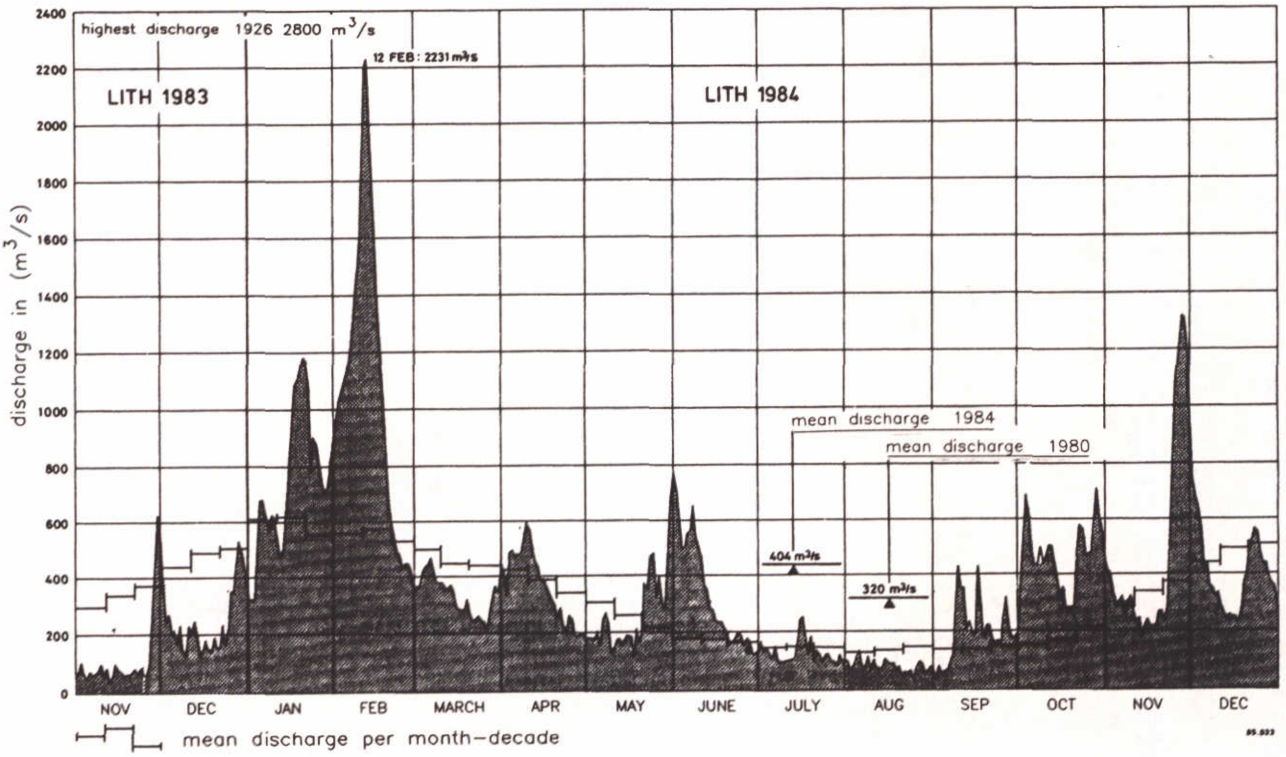


(a) Dune heigt versus chainage

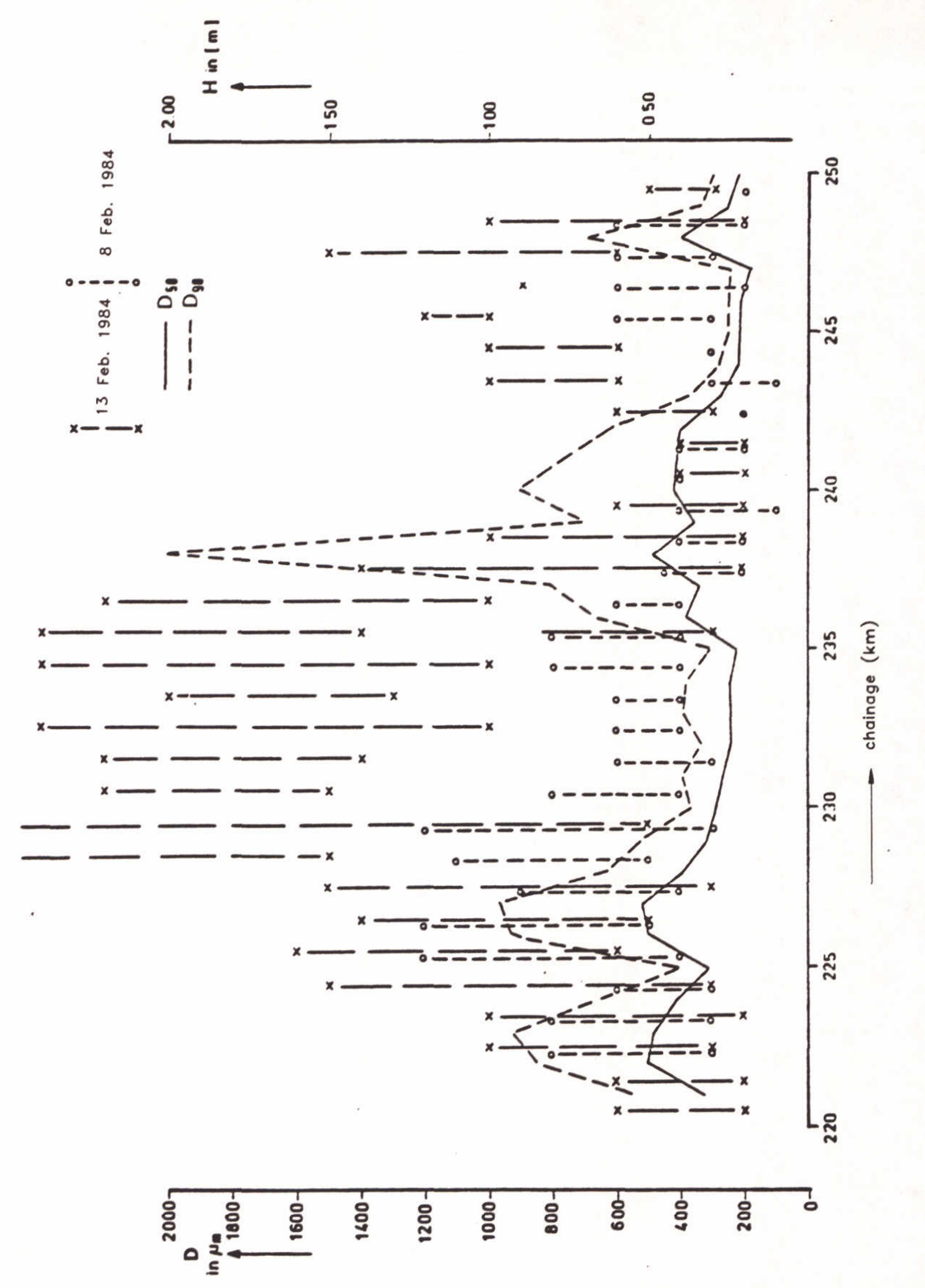


(b) Sediment size versus chainage

SEDIMENT SIZE AND DUNE HEIGHT PROFILES FOR THE MEUSE RIVER, 1988		
DELFT HYDRAULICS	R 1386	FIG. 15

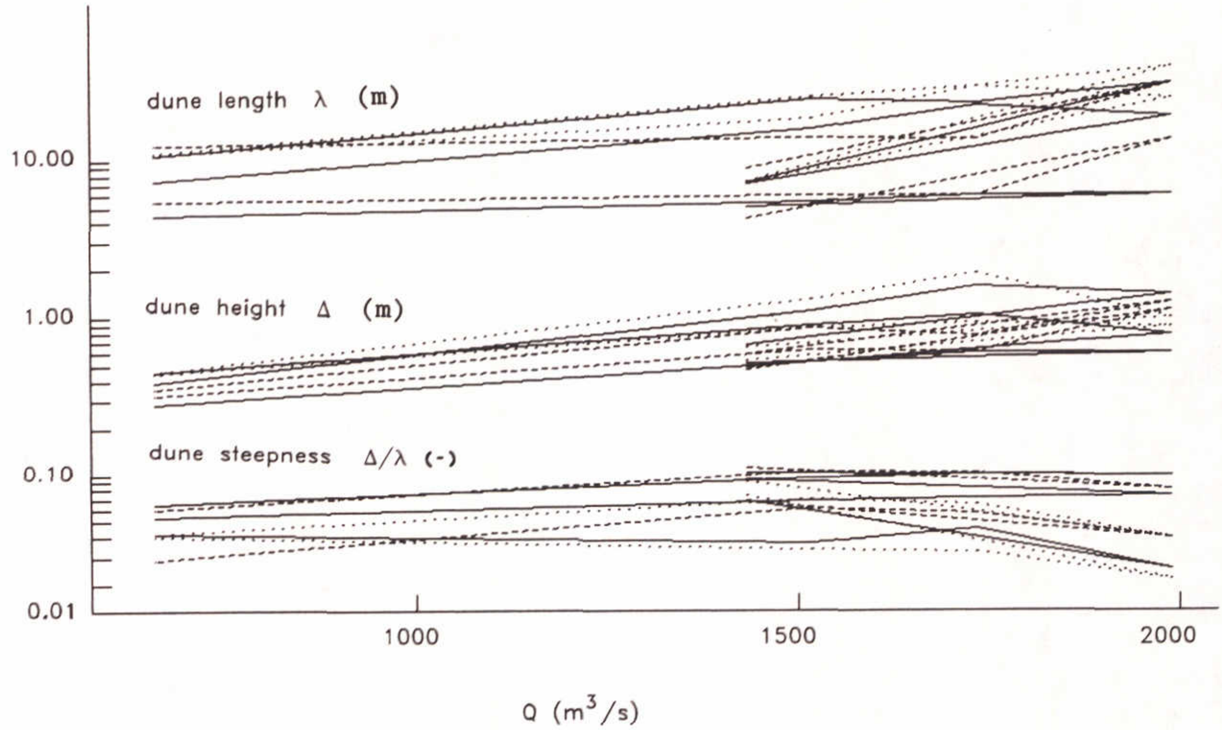


FLOW DISCHARGE OF THE MEUSE RIVER AT LITH, 1984		
DELFT HYDRAULICS	R 1386	FIG. 16



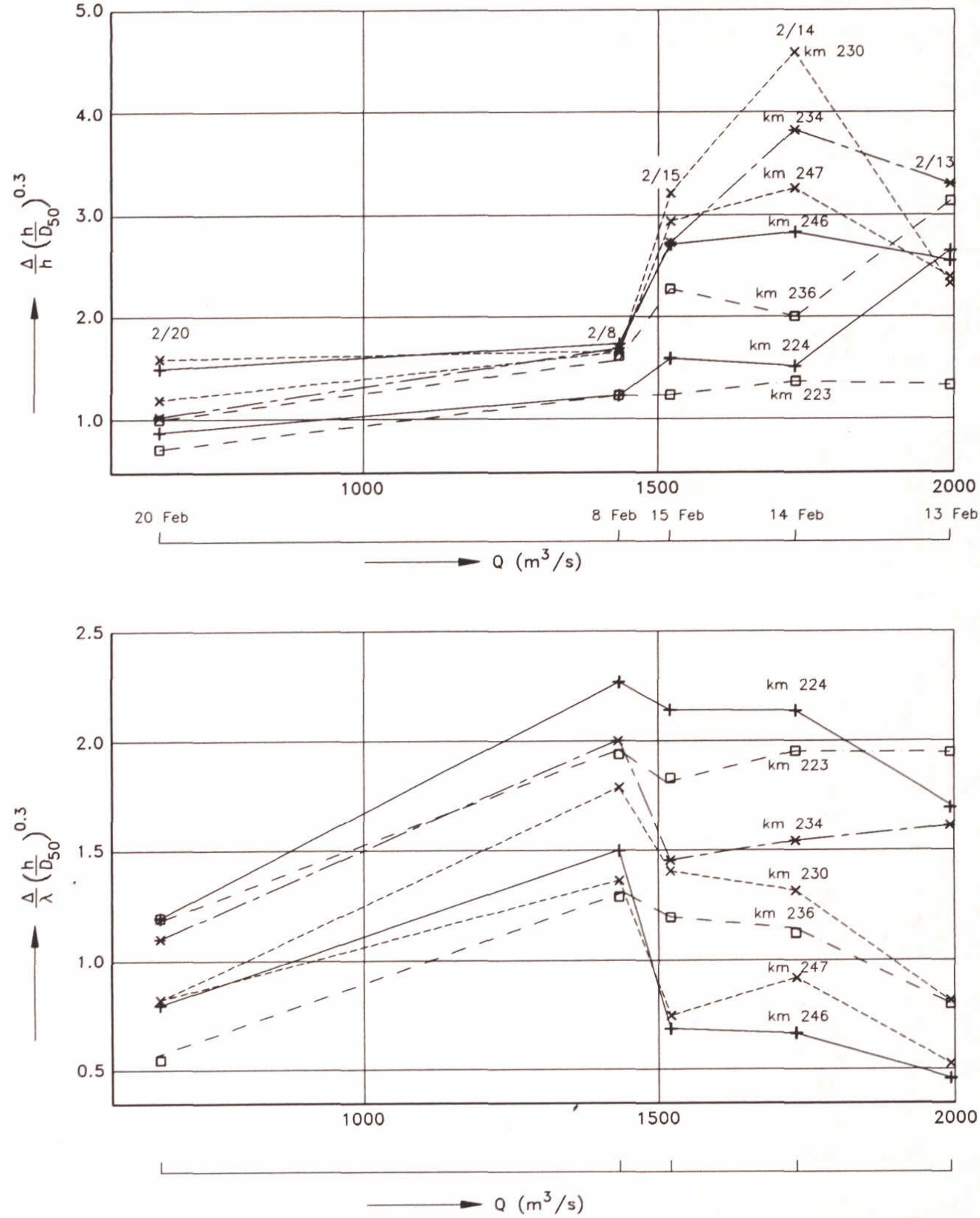
SEDIMENT SIZE AND DUNE HEIGHT PROFILES FOR BERGSCHE MAAS, 1984 (FROM ADRIAANSE, 1986)

DELFT HYDRAULICS	R 1386	FIG. 17

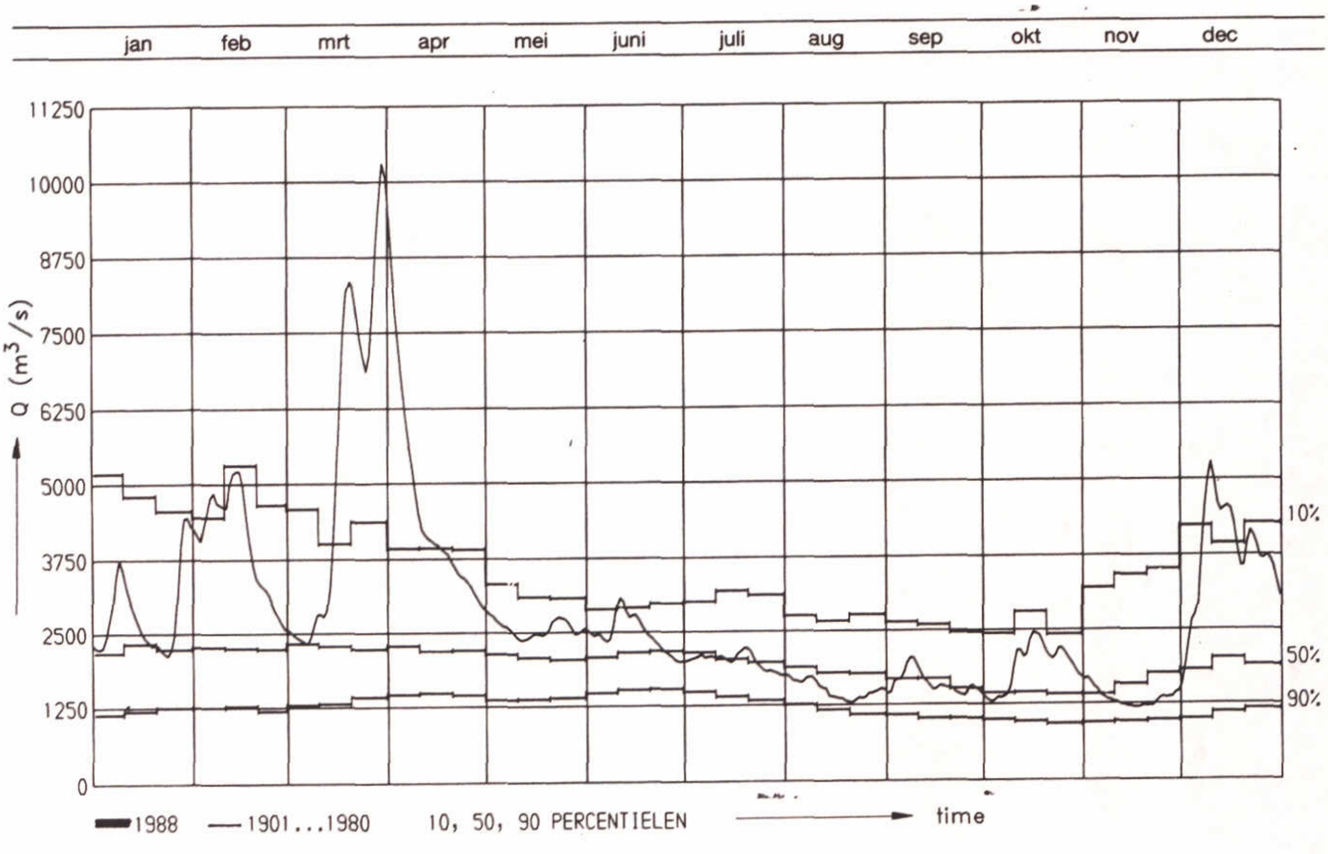


BEDFORM HEIGHT (a) LENGTH (b) AND STEEPNESS (c) FOR THE BERGSCHE MAAS, 1984

DELFT HYDRAULICS	R 1386	FIG. 18

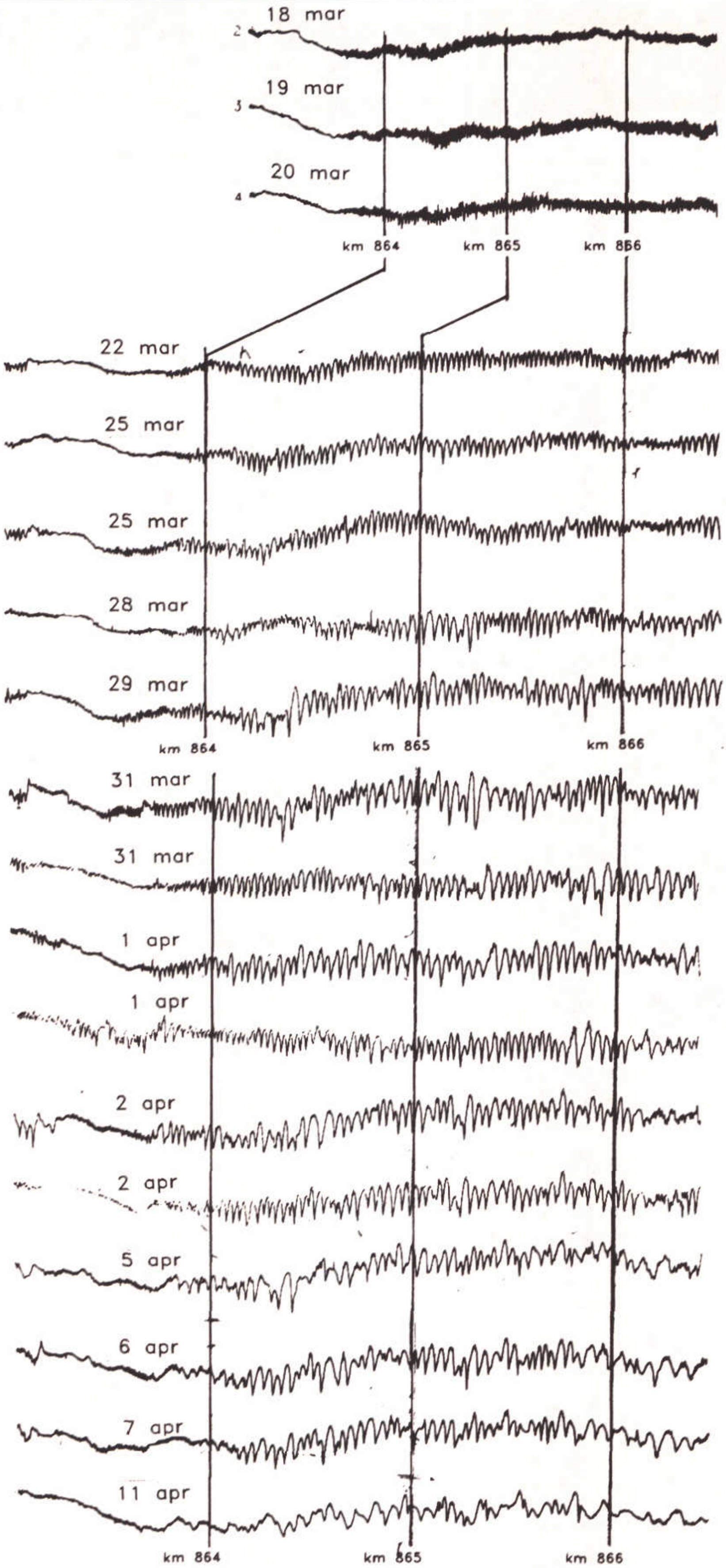


BEDFORM HEIGHT (a) AND STEEPNESS (b) PARAMETERS FOR THE BERGSCHE MAAS, 1989		
DELFT HYDRAULICS	R 1386	FIG. 19



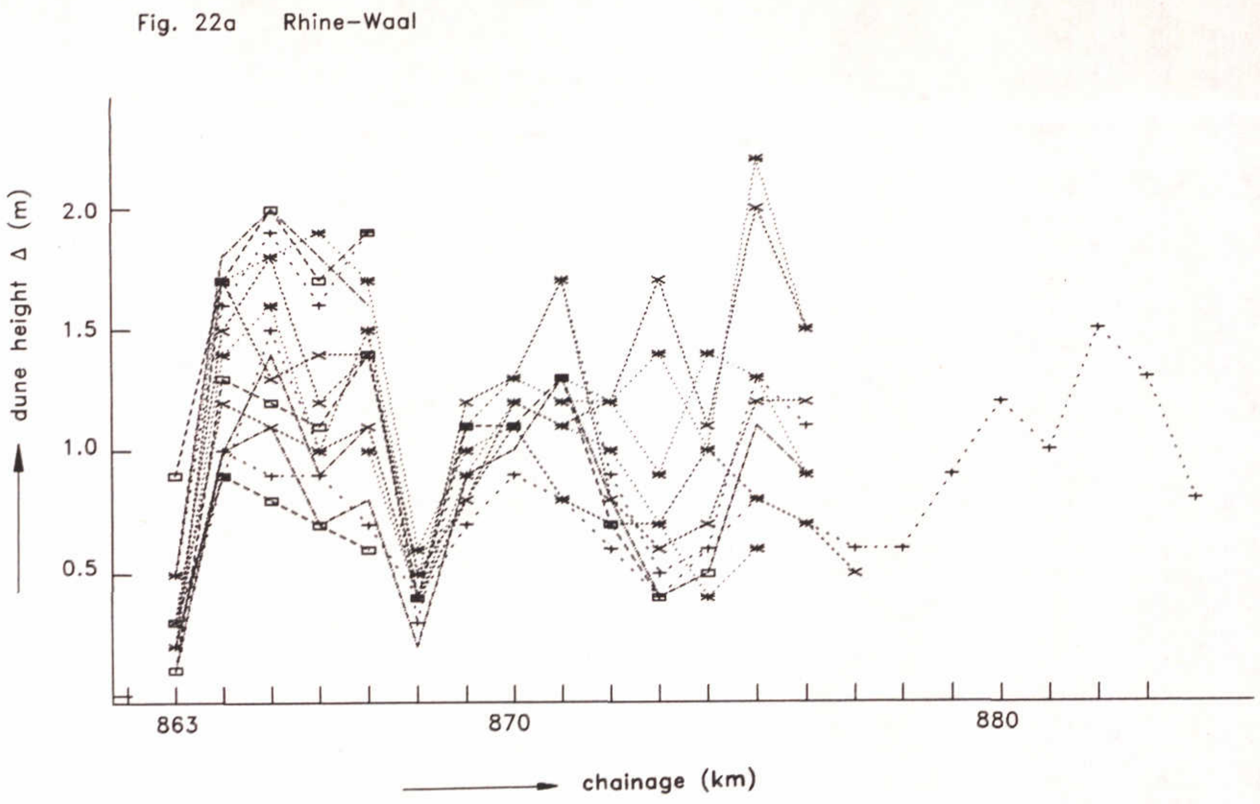
FLOW DISCHARGE OF THE RHINE AT LOBITH, 1988

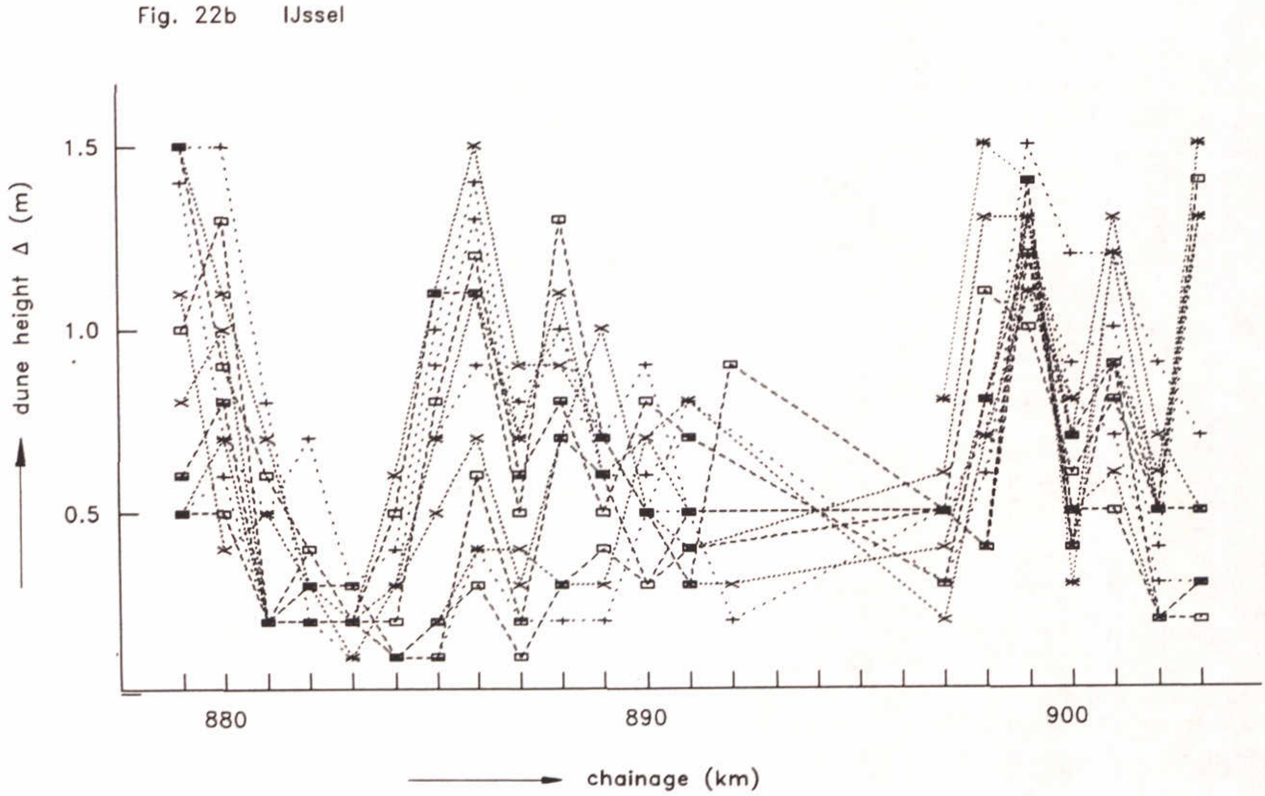
DELFT HYDRAULICS | R 1386 | FIG. 20



BED PROFILES OF THE RHINE-WAAL, 1988

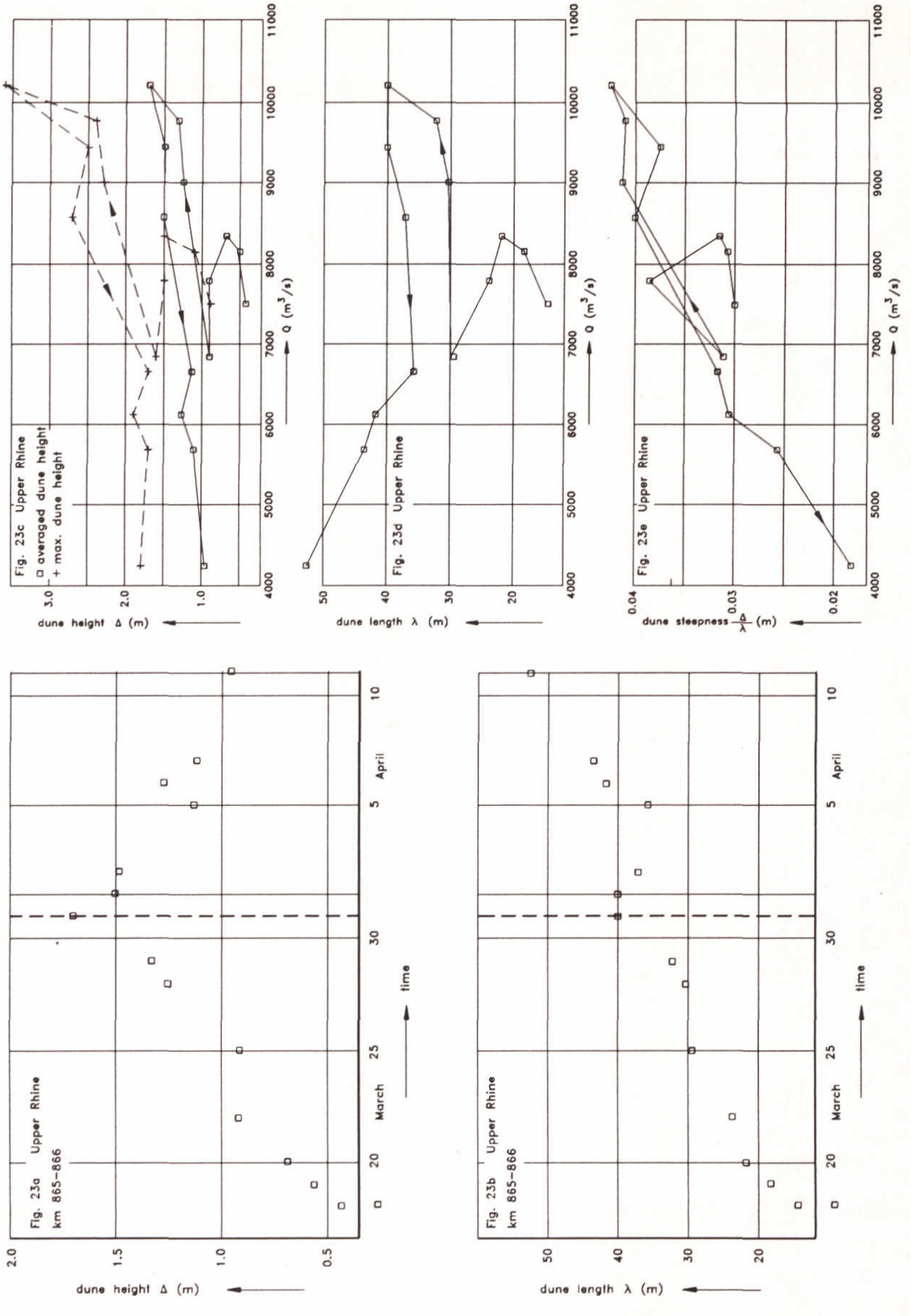
DELFT HYDRAULICS	R 1386	FIG. 21



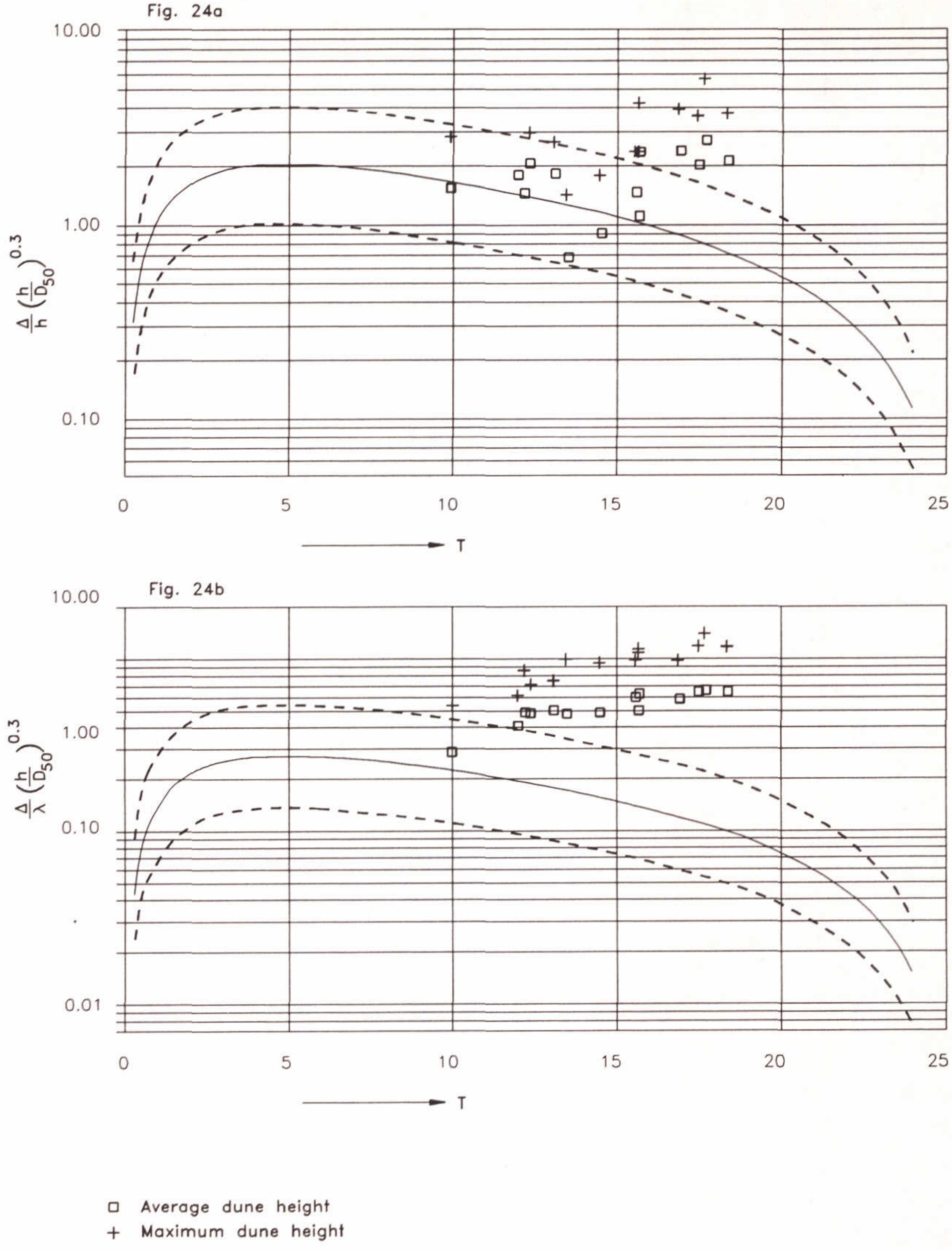


BEDFORM HEIGHT PROFILES FOR THE RHINE-WAAL (a) AND THE IJSSEL (b)

DELFT HYDRAULICS	R 1386	FIG. 22



BEDFORM HEIGHT (a,c), LENGTH (b,d) AND STEEPNESS (e) FOR THE UPPER RHINE, 1988		
DELFT HYDRAULICS	R 1386	FIG. 23



BEDFORM HEIGHT (a) AND STEEPNESS (b) PARAMETERS FOR THE UPPER RHINE, 1988

DELFT HYDRAULICS

R 1386

FIG. 24

APPENDIX A

Bedform data sets for four large rivers

Missouri river, from Shen et al. (1978), and Termes (1986)
Zaire river, from Peters (1978) , and Termes (1986)
Jamuna river, from G. Klaassen
Parana river, from L. van Rijn

Bedform data for Missouri River

datum	Q m^3/s	i $x10^{-4}$ -	h m	u m/s	Fr -	C $m^{\frac{1}{2}}/s$	k m	C' $m^{\frac{1}{2}}/s$	D_{50} $x10^{-6}$ m	D_{90} $x10^{-6}$ m	temp. °C	ν $x10^{-6}$ m^2/s	W_s $x10^{-3}$ m/s
08-09-'66	2980	1,55	3,08	1,37	0,25	62,9	0,012	83,4	199	286	22	0,957	25,0
13-09-'66	3050	1,61	3,15	1,37	0,25	61,1	0,015	82,4	208	333	23	0,976	26,5
19-09-'66	2930	1,44	3,00	1,40	0,26	67,1	0,007	82,9	193	299	18	1,078	22,0
26-09-'66	2970	1,46	3,04	1,40	0,26	66,2	0,008	83,1	207	294	18	1,078	24,5
03-10-'66	2950	1,52	2,92	1,44	0,27	68,1	0,006	82,9	209	288	14	1,161	23,6
10-10-'66	3060	1,47	2,83	1,52	0,29	74,6	0,002	82,5	209	295	16	1,124	24,1
17-10-'66	3270	1,54	2,85	1,63	0,31	78,5	0,002	82,3	223	304	9	1,329	23,7
24-10-'66	3070	1,48	2,78	1,56	0,30	76,9	0,002	82,4	222	295	10	1,310	23,8
07-11-'66	3080	1,47	2,81	1,56	0,30	76,8	0,002	82,5	209	292	7	1,440	20,3
21-08-'67	3170	1,45	3,09	1,40	0,25	66,0	0,008	83,1	204	298	22	1,003	25,2
25-09-'67	3190	1,53	2,91	1,58	0,30	74,6	0,003	83,0	199	285	17	1,078	23,0
24-10-'67	3030	1,57	3,00	1,53	0,28	70,3	0,005	81,5	210	357	13	1,208	23,1
22-11-'67	3080	1,60	2,77	1,67	0,32	79,7	0,001	82,1	224	306	5	1,524	21,7
10-09-'68	2920	1,25	3,09	1,38	0,25	70,5	0,005	83,4	200	289	19	1,041	23,8
07-10-'68	3110	1,52	2,94	1,63	0,30	76,8	0,002	83,0	222	289	13	1,180	25,6
02-12-'68	2940	1,52	2,94	1,55	0,29	73,1	0,003	82,9	208	293	2	1,654	18,3
23-09-'69	5000	1,44	4,28	1,66	0,26	66,9	0,010	84,4	227	349	19	1,024	29,3
14-10-'69	4550	1,41	3,86	1,73	0,28	73,8	0,004	84,9	209	296	11	1,289	21,9
04-11-'69	4030	1,47	3,59	1,68	0,28	73,3	0,004	84,4	220	294	7	1,421	22,2
01-12-'69	3160	1,42	3,07	1,61	0,29	77,1	0,002	83,0	218	299	3	1,631	19,9
09-10-'75	6020	1,47	4,94	1,67	0,24	61,9	0,022	84,5	266	401	16	1,115	35,3
29-10-'75	5950	1,49	4,82	1,73	0,25	64,4	0,015	84,4	260	395	10	1,310	30,4
18-11-'75	6030	1,48	4,76	1,76	0,26	66,6	0,011	84,3	260	395	8	1,412	28,9

datum	θ_{cr} -	H m	L m	H/h -	H/L -	θ -	θ' -	θ'_{top} -	θ'_R -	T -	u'_*/w_s -	k v.Rijn m	C v.Rijn $m^{\frac{1}{2}}/s$	k Eng. m	C Eng. $m^{\frac{1}{2}}/s$	h Eng. m
08-09-'66	0,049	1,01	64	0,33	0,016	1,45	0,80	1,15	0,82	15,8	2,04	0,363	36,1	0,200	45,7	5,79
13-09-'66	0,048	0,88	62	0,28	0,014	1,48	0,78	1,05	0,81	15,8	1,90	0,290	38,1	0,140	47,6	5,15
19-09-'66	0,052	1,01	107	0,34	0,009	1,36	0,85	1,22	0,90	16,2	2,34	0,234	39,4	0,080	51,8	5,07
26-09-'66	0,050	1,04	102	0,34	0,010	1,30	0,80	1,16	0,83	15,6	2.07	0,258	38,7	0,098	50,6	5,25
03-10-'66	0,051	0,79	128	0,27	0,006	1,29	0,84	1,12	0,87	16,1	2,22	0,125	44,1	0,027	58,4	4,00
10-10-'66	0,051	0,85	113	0,30	0,008	1,21	0,91	1,26	0,98	18,3	2,32	0,161	41,8	0,037	57,3	4,78
17-10-'66	0,052	0,82	137	0,29	0,007	1,19	0,98	1,34	1,07	19,5	2,48	0,126	43,8	0,023	61,0	4,64
24-10-'66	0,052	0,76	120	0,27	0,006	1,12	0,91	1,22	0,98	17,8	2,38	0,123	43,8	0,023	60,6	4,47
07-11-'66	0,056	0,73	174	0,26	0,004	1,20	0,95	1,26	1,04	17,5	2,84	0,081	47,2	0,011	65,2	3,89
21-08-'67	0,049	1,16	76	0,38	0,015	1,33	0,81	1,23	0,84	16,2	2,07	0,406	35,3	0,220	45,8	6,44
25-09-'67	0,051	1,43	113	0,49	0,013	1,36	1,02	1,80	1,10	20,6	2,49	0,427	34,4	0,200	47,5	7,24
24-10-'67	0,052	1,16	96	0,39	0,012	1,36	0,93	1,43	1,02	18,6	2,44	0,334	36,6	0,142	49,0	6,21
22-11-'67	0,055	0,58	58	0,21	0,010	1,20	1,02	1,28	1,12	19,4	2,77	0,142	42,6	0,029	59,5	4,92
10-09-'68	0,050	0,98	70	0,32	0,014	1,17	0,78	1,11	0,83	15,6	2,10	0,319	37,2	0,133	49,5	6,22
07-10-'68	0,050	0,85	96	0,29	0,009	1,22	0,98	1,34	1,05	20,1	2,28	0,187	41,0	0,045	56,9	5,41
02-12-'68	0,064	0,91	735	0,31	0,001	1,30	0,95	1,33	1,02	14,9	3,15	0,031	54,9	0,003	73,5	2,93
23-09-'69	0,046	1,04	68	0,24	0,015	1,65	0,98	1,28	1,03	21,4	2,07	0,365	38,7	0,143	50,4	7,53
14-10-'69	0,054	0,94	94	0,25	0,010	1,58	1,13	1,46	1,20	21,3	2,81	0,230	41,5	0,054	56,9	6,56
04-11-'69	0,054	0,82	101	0,23	0,008	1,45	1,04	1,32	1,09	19,2	2,76	0,167	43,4	0,034	59,2	5,48
01-12-'69	0,060	0,70	341	0,23	0,002	1,21	0,97	1,23	1,04	16,4	2,92	0,039	53,5	0,004	73,0	3,43
09-10-'75	0,043	2,07	101	0,42	0,021	1,65	0,87	1,40	0,89	19,7	1,75	0,914	32,6	0,710	41,0	11,27
29-10-'75	0,047	1,71	112	0,35	0,015	1,67	0,95	1,40	0,98	19,8	2,10	0,598	35,7	0,318	46,0	9,50
18-11-'75	0,049	1,31	96	0,28	0,014	1,64	0,97	1,31	1,02	19,7	2,21	0,418	38,4	0,166	50,1	8,35

Bedform data from Zaire River (indices g = large bedforms a = all small bedforms, s = bedforms with steep lee side)

datum	raai	Q m^3/s	i $\times 10^{-5}$ -	h m	u m/s	Fr -	C $m^{1/2}/s$	k m	C' $m^{1/2}/s$	D_{50} $\times 10^{-6}$ m	D_{90} $\times 10^{-6}$ m	temp. °C	ν $\times 10^{-6}$ m^2/s	w_s $\times 10^{-3}$ m/s	θ_{cr} -	H_g m	L_g m	H_g/h -
26-09-'68	1	18580	4,83	13,2	1,30	0,11	51,5	0,22	89,8	345	545	27	0,853	54,6	0,033	-	-	-
	2			17,6	1,30	0,10	44,6	0,70	92,0									
	3			12,0	1,20	0,11	49,8	0,25	89,0									
16-10-'68	1	19950	5,04	14,5	1,37	0,11	50,7	0,27	90,5	345	545	28	0,835	55,1	0,032	1,5	150	0,103
	2			14,0	1,37	0,12	51,6	0,23	90,2							1,9	125	0,136
	3			10,5	1,25	0,12	54,3	0,12	88,0							1,6	95	0,152
13-11-'68	1	23680	5,60	14,5	1,46	0,12	51,2	0,25	90,5	345	545	29	0,816	55,7	0,032	1,6	170	0,110
	2			13,5	1,50	0,13	54,6	0,15	89,9							1,8	140	0,133
	3			10,0	1,38	0,14	58,3	0,07	87,6							1,3	90	0,130
24-12-'68	1	28490	6,34	15,5	1,52	0,12	48,5	0,38	91,0	345	545	29	0,816	55,7	0,032	1,5	160	0,097
	2			15,0	1,55	0,13	50,3	0,29	90,8							1,5	280	0,100
	3			10,0	1,44	0,15	57,2	0,08	87,6							1,5	450	0,150
21-01-'69	1	27700	6,22	17,0	1,51	0,12	46,4	0,54	91,7	345	545	29	0,816	55,7	0,032	1,4	200	0,082
	2			15,0	1,55	0,13	50,7	0,27	90,8							1,3	370	0,087
	3			10,5	1,42	0,14	55,6	0,10	88,0							1,3	370	0,124
14-02-'69	1	24040	5,66	17,0	1,48	0,11	47,7	0,46	91,7	345	545	29	0,816	55,7	0,032	1,2	220	0,071
	2			14,5	1,50	0,13	52,4	0,21	90,5							1,5	370	0,103
	3			10,0	1,38	0,14	58,0	0,07	87,6							1,6	200	0,160
18-03-'69	1	21100	5,22	16,5	1,40	0,11	47,7	0,44	91,5	345	545	28	0,835	55,1	0,032	1,2	120	0,073
	2			14,5	1,43	0,12	52,0	0,22	90,5							1,9	225	0,131
	3			9,5	1,32	0,14	59,3	0,06	87,2							1,4	140	0,147
08-04-'69	1	24830	5,78	17,0	1,48	0,11	47,2	0,49	91,7	345	545	27	0,853	54,6	0,033	1,4	130	0,082
	2			14,0	1,51	0,13	53,1	0,19	90,2							1,7	150	0,121
	3			10,0	1,40	0,14	58,2	0,07	87,6							1,5	130	0,150
16-06-'75	III-21	13940	4,21	11,3	0,52	0,05	23,8	6,46	90,4	300	430	25	0,890	45,7	0,036	-	-	-
	III-22			12,8	0,59	0,05	25,4	5,96	91,4									
	IV -39			8,3	0,75	0,08	40,1	0,59	88,0									
10-12-'75	IV -22	27220	6,32	6,8	1,28	0,16	61,7	0,03	86,4	300	430	29	0,816	47,5	0,035	-	-	-
	III-31			13,4	1,69	0,15	58,1	0,10	91,7									

datum	raai	H_g/L_g -	H_a m	L_a m	H_a/h -	H_a/L_a -	H_s m	L_s m	H_s/h -	H_s/L_s -	θ -	θ' -	θ'_{top} -	θ'_R -	T -	s_t $\times 10^{-5}$ m^2/s	s_b $\times 10^{-5}$ m^2/s	u'_*/w_s -
26-09-'68	1	-	-	-	-	-	-	-	-	-	1,12	0,39	-	0,37	10,3	5,903	1,910	0,85
	2										1,49	0,39		0,35	9,7	21,01	12,85	0,85
	3										1,02	0,34		0,32	8,8	13,37	5,208	0,80
16-10-'68	1	0,010	0,30	8,0	0,021	0,038	0,25	70	0,017	0,004	1,28	0,43	0,48	0,40	11,4	-	-	0,90
	2	0,015	0,25	8,5	0,018	0,029	0,20	30	0,014	0,007	1,24	0,43	0,50	0,40	11,5			0,90
	3	0,017	0,25	7,5	0,024	0,033	0,30	30	0,029	0,010	0,93	0,36	0,42	0,36	10,0			0,82
13-11-'68	1	0,009	0,30	9,0	0,021	0,033	0,20	40	0,014	0,005	1,43	0,48	0,54	0,46	13,2	-	-	0,94
	2	0,013	0,35	7,0	0,026	0,050	0,20	40	0,015	0,005	1,33	0,50	0,57	0,49	14,2			0,96
	3	0,014	0,30	8,5	0,030	0,035	0,20	40	0,020	0,005	0,98	0,44	0,50	0,44	12,6			0,90
24-12-'68	1	0,009	0,40	12,0	0,026	0,033	0,20	40	0,013	0,005	1,73	0,53	0,59	0,49	14,3	-	-	0,98
	2	0,005	0,50	15,0	0,033	0,033	0,20	25	0,013	0,008	1,67	0,54	0,60	0,51	15,0			0,99
	3	0,003	0,30	10,0	0,030	0,030	0,25	20	0,025	0,013	1,11	0,48	0,56	0,48	13,8			0,93
21-01-'69	1	0,007	0,30	10,0	0,018	0,030	0,20	30	0,012	0,007	1,86	0,52	0,57	0,48	13,8	-	-	0,97
	2	0,004	0,35	10,0	0,023	0,035	0,20	20	0,013	0,010	1,64	0,54	0,59	0,51	15,0			0,99
	3	0,004	0,35	10,0	0,033	0,035	0,20	20	0,019	0,010	1,15	0,47	0,53	0,46	13,3			0,92
14-02-'69	1	0,006	0,25	10,0	0,015	0,025	-	-	-	-	1,69	0,49	0,53	0,46	13,2	-	-	0,94
	2	0,004	0,25	10,0	0,017	0,025	0,25	30	0,017	0,008	1,44	0,50	0,56	0,48	14,0			0,95
	3	0,008	0,20	8,0	0,020	0,025	0,20	30	0,020	0,007	0,99	0,44	0,52	0,44	12,6			0,89
18-03-'69	1	0,010	0,15	8,0	0,009	0,019	0,15	30	0,009	0,005	1,51	0,44	0,47	0,41	11,7	-	-	0,90
	2	0,008	0,15	9,0	0,010	0,017	0,15	30	0,010	0,005	1,33	0,46	0,53	0,44	12,5			0,92
	3	0,010	0,15	8,0	0,016	0,019	0,15	20	0,016	0,008	0,87	0,40	0,47	0,40	11,4			0,86
08-04-'69	1	0,011	0,25	6,5	0,015	0,039	0,20	30	0,012	0,007	1,73	0,50	0,54	0,46	13,0	-	-	0,97
	2	0,011	0,30	7,5	0,021	0,040	0,20	25	0,014	0,008	1,42	0,51	0,58	0,49	14,0			0,98
	3	0,012	0,30	7,5	0,030	0,040	0,20	20	0,020	0,010	1,02	0,45	0,53	0,45	12,7			0,92
16-06-'75	III-21	-	1,00	65,0	0,089	0,015	0,40	110	0,035	0,004	0,96	0,09	0,10	0,07	1,0	13,19	8,333	0,46
	III-22	-	1,00	65,0	0,078	0,015	0,40	110	0,031	0,004	1,09	0,11	0,12	0,08	1,3	13,89	8,333	0,51
	IV -39	-	1,00	65,0	0,121	0,015	0,40	110	0,048	0,004	0,71	0,17	0,19	0,15	3,0	0,694	0,694	0,63
10-12-'75	IV -22	-	0,60	40,0	0,088	0,015	0,40	60	0,059	0,007	0,87	0,45	0,49	0,44	11,6	56,94	17,36	1,00
	III-31	-	0,60	40,0	0,045	0,015	0,40	60	0,030	0,007	1,71	0,71	0,74	0,69	18,7	81,25	18,75	1,24

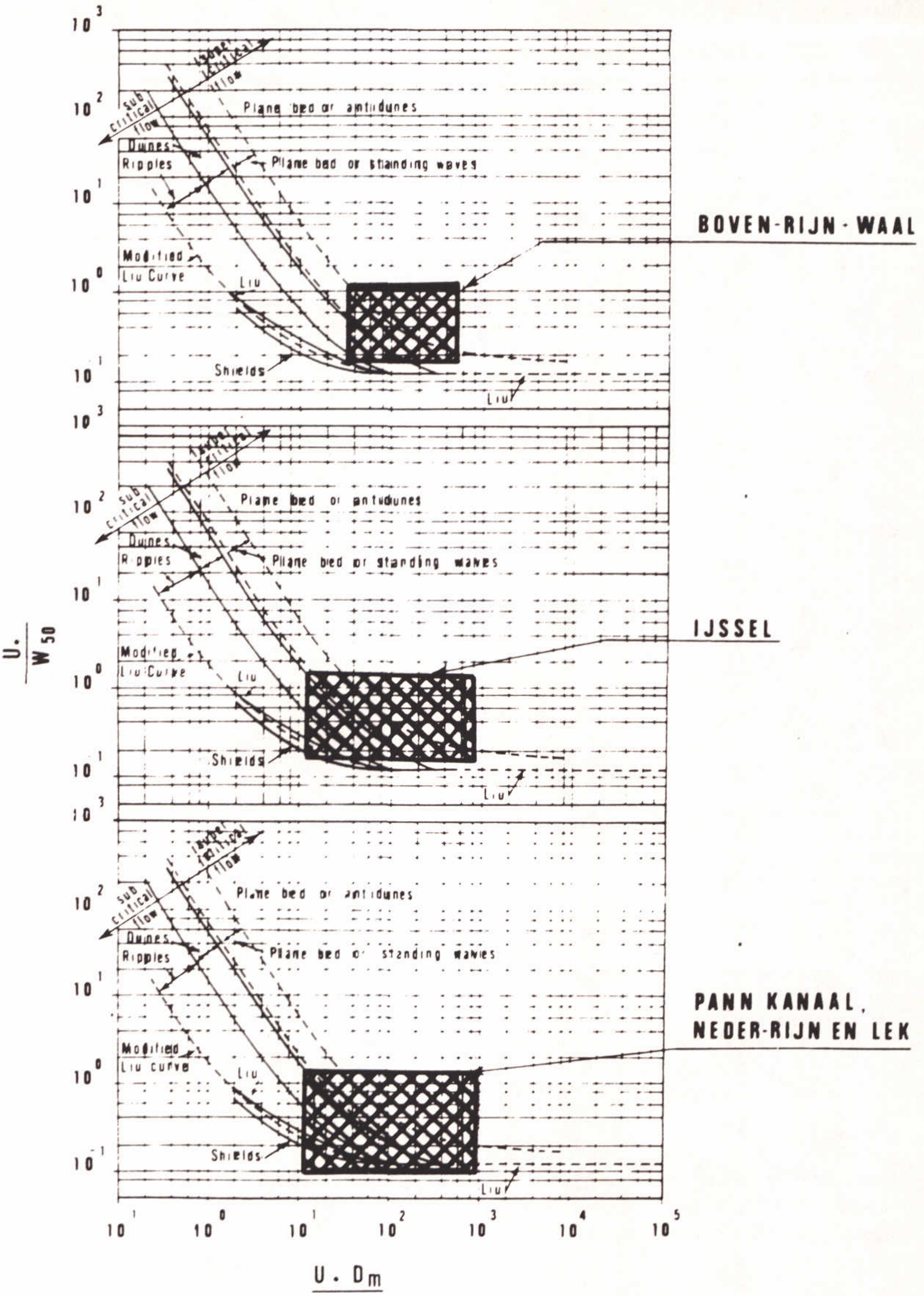
datum	raai	Φ_t -	Φ_b -	k_g v.Rijn m	C_g v.Rijn $m^{1/2}/s$	k_a v.Rijn m	C_a v.Rijn $m^{1/2}/s$	k_s v.Rijn m	C_s v.Rijn $m^{1/2}/s$	k_g Eng. m	C_g Eng. $m^{1/2}/s$	k_a Eng. m	C_a Eng. $m^{1/2}/s$	k_s Eng. m	C_s Eng. $m^{1/2}/s$	h_g Eng. m	h_a Eng. m	h_s Eng. m
26-09-'68	1	2,290	0,741	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	8,149	4,984															
	3	5,186	2,020															
16-10-'68	1	-	-	0,367	48,2	0,202	52,8	0,025	69,1	0,080	58,0	0,044	61,7	0,002	81,8	11,1	9,8	5,6
	2			0,662	43,3	0,145	55,2	0,035	66,2	0,240	51,3	0,023	65,8	0,003	79,6	14,2	8,6	5,9
	3			0,606	41,7	0,157	52,3	0,075	58,1	0,246	50,1	0,032	62,5	0,008	71,7	12,4	7,9	6,0
13-11-'68	1	-	-	0,371	48,1	0,188	53,4	0,027	68,4	0,079	58,2	0,036	63,1	0,002	81,4	11,3	9,6	5,7
	2			0,546	44,5	0,276	49,8	0,027	67,9	0,155	54,4	0,082	58,3	0,002	81,9	13,6	11,8	6,0
	3			0,435	43,9	0,195	50,2	0,027	65,5	0,125	54,7	0,044	61,2	0,002	80,3	11,4	9,1	5,3
24-12-'68	1	-	-	0,346	49,1	0,250	51,7	0,027	68,9	0,073	58,4	0,061	59,6	0,002	81,0	10,7	10,3	5,6
	2			0,208	52,9	0,313	49,7	0,042	65,5	0,028	64,5	0,085	57,7	0,003	78,6	9,1	11,4	6,1
	3			0,134	53,2	0,176	51,0	0,075	57,6	0,015	67,4	0,035	62,3	0,008	72,0	7,2	8,4	6,3
21-01-'69	1	-	-	0,249	52,4	0,176	55,2	0,035	67,7	0,040	62,1	0,032	63,6	0,003	79,4	9,5	9,1	5,8
	2			0,122	57,0	0,226	52,2	0,050	64,0	0,012	70,3	0,049	61,2	0,004	77,3	7,8	10,3	6,5
	3			0,122	54,3	0,226	49,4	0,050	61,2	0,014	68,2	0,058	59,1	0,004	75,4	7,0	9,3	5,7
14-02-'69	1	-	-	0,170	55,4	0,129	57,6	-	-	0,020	66,9	0,017	67,8	-	-	8,7	8,4	-
	2			0,161	54,6	0,129	56,3	0,053	63,2	0,018	67,9	0,017	68,1	0,004	77,3	8,6	8,6	6,6
	3			0,321	46,3	0,104	55,1	0,035	63,5	0,068	58,4	0,014	68,3	0,003	78,6	9,9	7,2	5,5
18-03-'69	1	-	-	0,294	50,9	0,063	62,9	0,021	71,5	0,054	60,4	0,006	74,6	0,002	82,6	10,3	6,8	5,5
	2			0,399	47,5	0,058	62,6	0,021	70,5	0,086	57,8	0,005	75,9	0,002	83,0	11,7	6,8	5,7
	3			0,342	45,4	0,063	58,6	0,030	64,5	0,079	57,4	0,006	73,2	0,002	79,5	10,1	6,2	5,3
08-04-'69	1	-	-	0,365	49,4	0,172	55,4	0,035	67,7	0,079	58,1	0,033	63,5	0,003	79,8	11,2	9,4	6,0
	2			0,463	46,1	0,210	52,2	0,042	64,9	0,116	56,1	0,046	61,8	0,003	79,1	12,6	10,3	6,3
	3			0,415	44,3	0,210	49,6	0,050	60,8	0,110	55,4	0,053	60,0	0,004	75,9	11,0	9,4	5,9
16-06-'75	III-21	6,309	3,986	-	-	0,353	46,5	0,040	63,6	-	-	0,301	39,8	0,009	60,6	-	4,1	1,8
	III-22	6,644	3,986	-	-	0,353	47,5	0,040	64,6	-	-	0,257	42,1	0,008	63,3	-	4,7	2,1
	IV -39	0,332	0,332	-	-	0,353	44,1	0,040	61,2	-	-	0,185	46,8	0,005	68,5	-	6,1	2,8
10-12-'75	IV -22	27,24	8,304	-	-	0,208	47,8	0,069	56,4	-	-	0,042	60,1	0,007	71,6	-	7,6	5,4
	III-31	38,87	8,969	-	-	0,208	52,0	0,069	60,6	-	-	0,027	66,0	0,005	77,3	-	10,4	7,6

Bedform data for the Jamuna River								
Q m^3/s	S cm/km	h m	$\bar{u}$ m/s	D_{50} μm	Δ m	λ m	C' $m^{1/2}/s$	T
8000.0	7.0	10.5	1.3	200.0	.9	30.0	92.4	11.1
8000.0	7.0	12.0	1.3	200.0	.8	29.0	93.3	10.8
8000.0	7.0	13.8	1.3	200.0	1.1	40.0	94.3	10.5
8000.0	7.0	15.6	1.3	200.0	1.6	45.0	95.1	10.3
8000.0	7.0	15.1	1.3	200.0	2.6	15.0	94.9	10.4
8000.0	7.0	18.0	1.3	200.0	2.5	177.0	96.1	10.1
8000.0	7.0	19.5	1.3	200.0	5.1	251.0	96.6	9.9
8000.0	7.0	18.6	1.3	200.0	3.0	188.0	96.3	10.0
8000.0	7.0	15.5	1.3	200.0	2.3	205.0	95.1	10.3
8000.0	7.0	16.2	1.3	200.0	1.9	211.0	95.4	10.2
7000.0	7.0	14.2	1.4	200.0	1.0	158.0	94.4	12.0
7000.0	7.0	12.0	1.4	200.0	1.3	34.0	93.2	12.3
7000.0	7.0	17.0	1.4	200.0	1.3	32.0	95.6	11.6
10000.0	7.0	11.0	1.5	200.0	1.0	86.0	92.7	13.9
10000.0	7.0	10.7	1.5	200.0	2.1	55.0	92.5	14.0
10000.0	7.0	11.3	1.5	200.0	2.5	50.0	92.9	13.8
10000.0	7.0	13.1	1.5	200.0	2.7	98.0	94.0	13.5
10000.0	7.0	8.2	1.5	200.0	2.1	48.0	90.5	14.7
10000.0	7.0	11.5	1.5	200.0	2.9	68.0	93.0	13.8
10000.0	7.0	17.8	1.5	200.0	2.3	57.0	96.1	12.8
10000.0	7.0	13.2	1.5	200.0	1.1	60.0	94.0	13.5
5000.0	7.0	13.4	1.3	200.0	4.0	156.0	93.9	9.7
5000.0	7.0	14.9	1.3	200.0	2.6	87.0	94.5	9.5
5000.0	7.0	12.8	1.3	200.0	3.3	85.0	93.6	9.8
5000.0	7.0	10.2	1.3	200.0	2.3	61.0	92.0	10.2
5000.0	7.0	13.5	1.3	200.0	3.1	158.0	93.9	9.7
5000.0	7.0	13.1	1.3	200.0	2.8	63.0	93.7	9.8
5000.0	7.0	11.6	1.3	200.0	3.1	34.0	92.9	10.0
5000.0	7.0	10.0	1.3	200.0	2.6	73.0	91.9	10.3
5000.0	7.0	9.1	1.3	200.0	2.8	82.0	91.2	10.4
5000.0	7.0	9.8	1.3	200.0	1.9	42.0	91.7	10.3
5000.0	7.0	12.9	1.3	200.0	3.4	86.0	93.6	9.8
5000.0	7.0	11.3	1.3	200.0	2.9	111.0	92.7	10.0

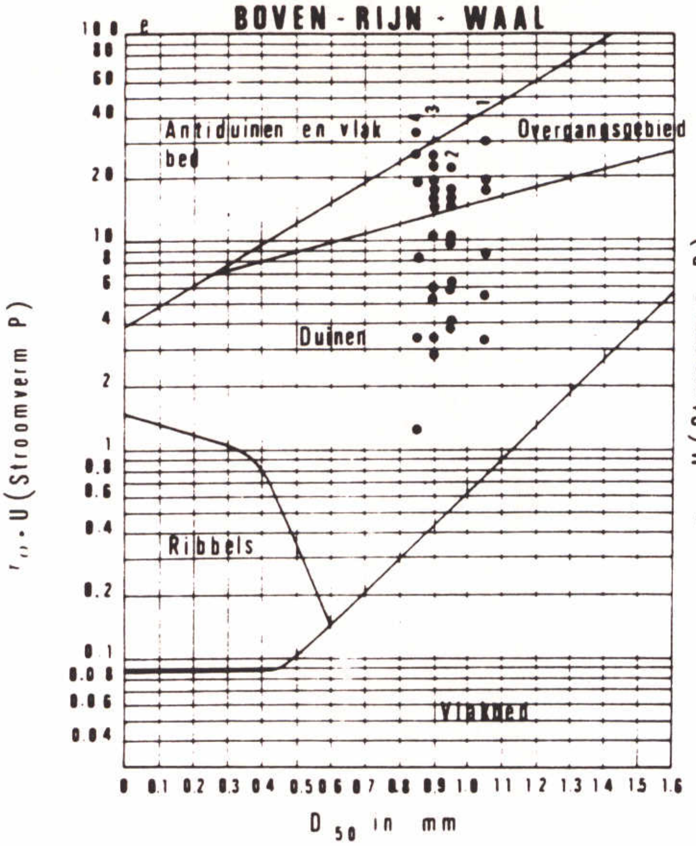
Bedform data for the Parana River								
Q m^3/s	S cm/km	h m	$\bar{u}$ m/s	D_{50} μm	Δ m	λ m	C' $m^{½}/s$	T
25000.0	5.0	25.5	1.5	370.0	6.0	350.0	93.6	11.5
25000.0	5.0	26.0	1.5	370.0	7.5	450.0	93.7	11.1
25000.0	5.0	24.0	1.5	370.0	4.5	300.0	93.2	11.3
25000.0	5.0	23.0	1.4	370.0	7.5	350.0	92.9	10.5
25000.0	5.0	26.0	1.4	370.0	7.5	400.0	93.7	10.3
25000.0	5.0	25.5	1.4	370.0	4.8	400.0	93.6	9.3
25000.0	5.0	23.0	1.3	370.0	4.5	250.0	92.9	8.8
25000.0	5.0	23.0	1.3	370.0	5.5	250.0	92.9	9.1
25000.0	5.0	22.5	1.3	370.0	3.0	150.0	92.8	8.1
25000.0	5.0	22.0	1.2	370.0	3.5	200.0	92.7	6.5
25000.0	5.0	22.0	1.2	370.0	3.5	125.0	92.6	6.8
25000.0	5.0	22.0	1.0	370.0	3.5	100.0	92.7	5.0
25000.0	5.0	23.0	1.1	370.0	4.0	175.0	93.0	5.3

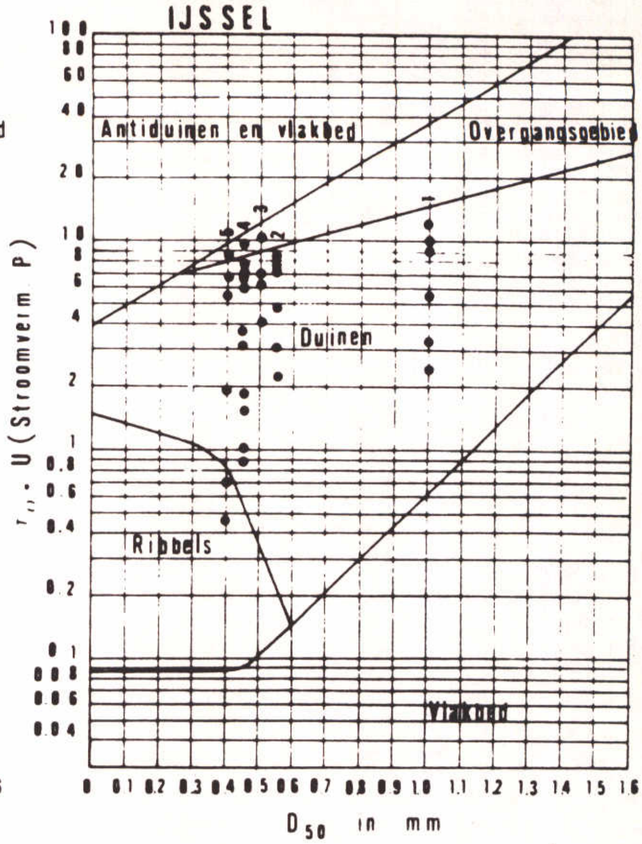
APPENDIX B

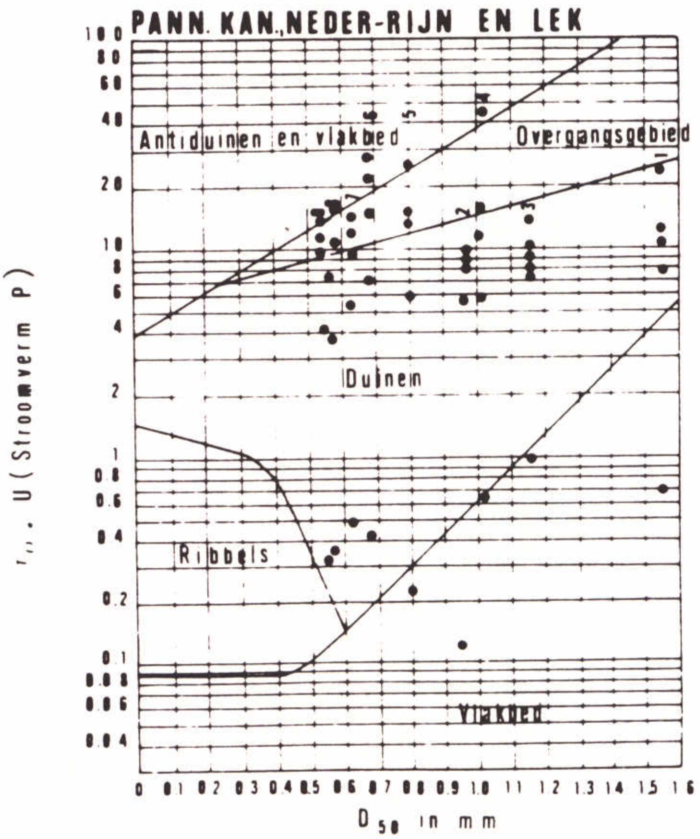
Bedform predictors for the Rhine river branches from Brilhuis (1988)



Liu-Albertson bedform diagram





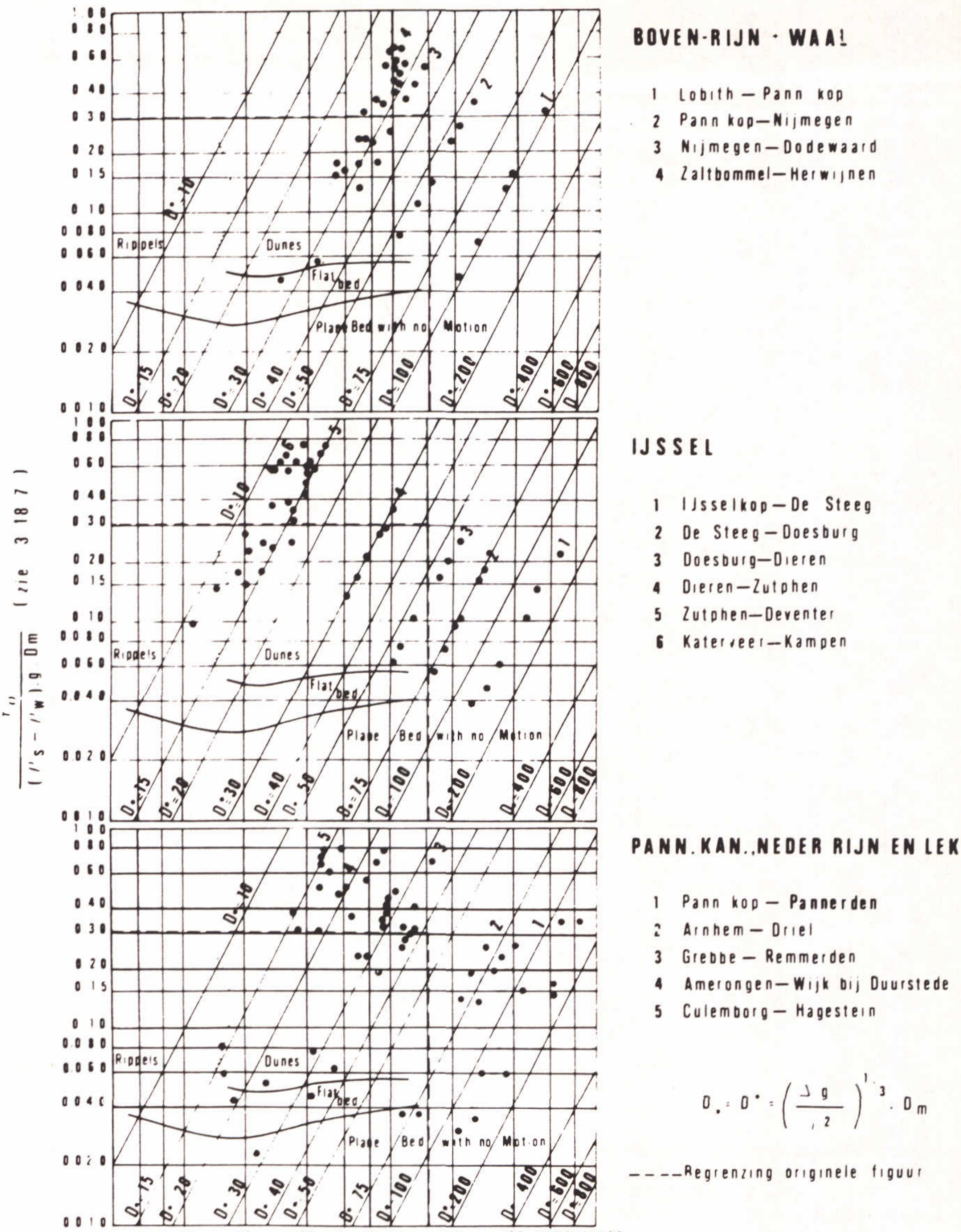


Boven-Rijn + Waal
1 Nijmegen - Dodewaard
2 Dodewaard - Tiel
3 Tiel - Zaltbommel
4 Zaltbommel - Herwijnen

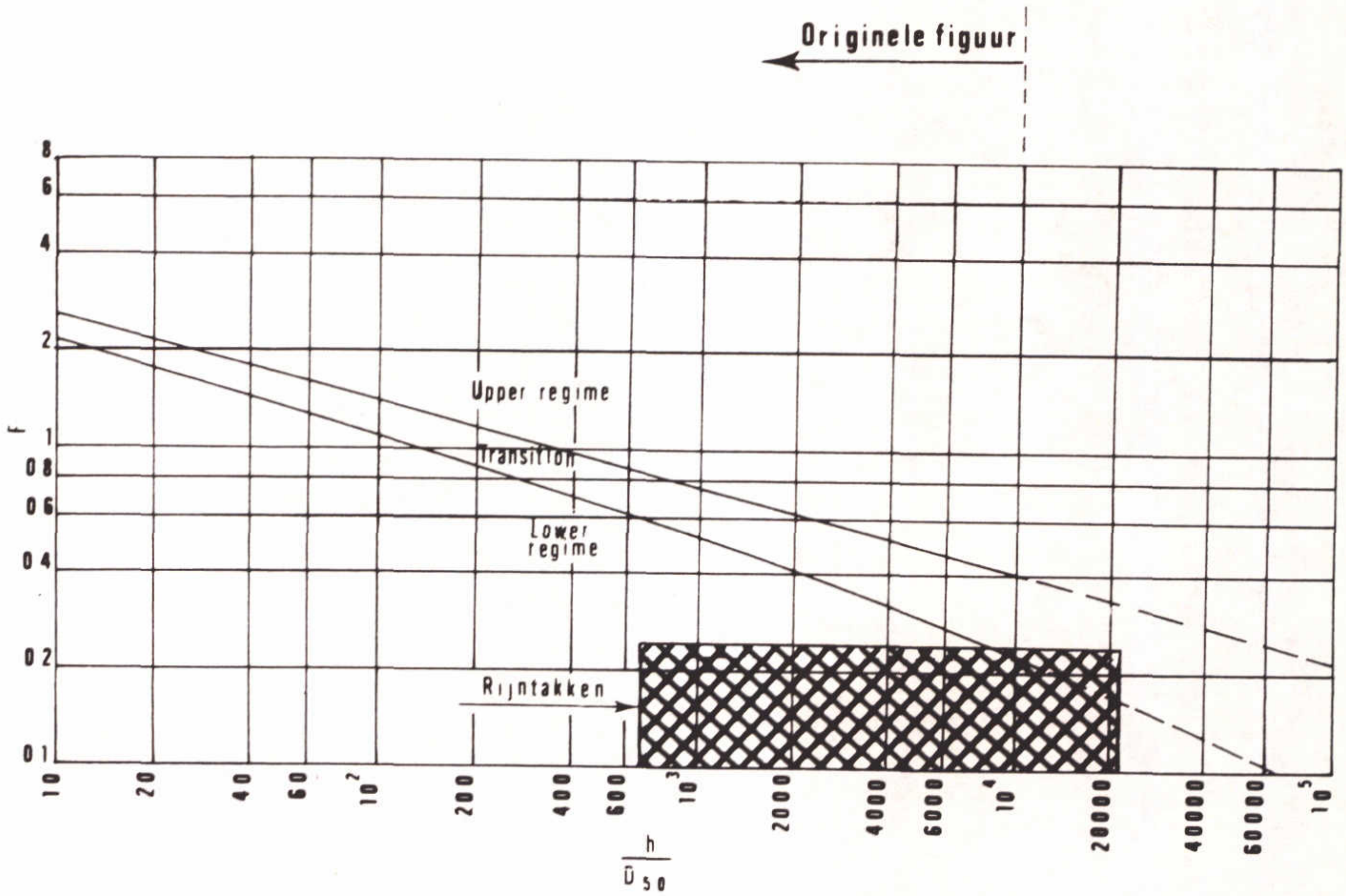
IJssel
1 Dieren Zutphen
2 Zutphen Deventer
3 Deventer - Olst
4 Olst - Katerveer
5 Katerveer Kampen

Pann Kan Neder-Rijn en Lek
1 Arnhem Driel
2 Driel - Lexkensveer
3 Lexkensveer Grebbe
4 Grebbe Remmerden
5 Remmerden Eck en Wiel
6 Eck en Wiel - Amerongen
7 Amerongen - Wijk bij Duurstede
8 Wijk bij Duurstede - Culemborg
9 Culemborg - Herwijnen

Simons-Richardson bedform diagram



Chabert-Chauvin bedform diagram



Lower regime : **Gebied waar ribbels-en duinvorming optreedt**

Transition : **Overgangsgebied**

Upper regime : **Gebied waar afbraak van beddingvormen optreedt**

Athaullah-Simons bedform diagram

APPENDIX C

Bedform data sets for the Meuse river and the Rhine river branches

Waal and Rhine, from Wijbenga (1991)

IJssel, from Kamphuis (1990)

Bergsche Maas, from Adriaanse (1986)

Meuse and Bergsche Maas, from bathymetric profiles

Rhine, Waal and IJssel, from bathymetric profiles

Bedform dimensions Rhine River during equilibrium (km 890 - km 894, axis)

Date	Time	Q	h	Ripples Δ	Ripples λ	Dunes Δ	Dunes λ	u*' Δ	T	d50/h	(km. 890 - km. 894; D90 = 0,0038 m)
		(m^3/s)	(m)	(m)	(m)	(m)	(m)	(m/s)	(-)	($*10^{-3}$)	
870413	9:17	1851	6,46	0,280	7,05	0,595	69,9	0,0501	2,77	0,183	
870427	7:58	1697	6,12	0,290	8,11	0,600	51,4	0,0487	2,57	0,193	
870428	8:12	1654	5,94	0,275	7,89	0,630	59,9	0,0491	2,63	0,199	
870506	8:36	1523	5,73	0,265	8,48	0,565	59,7	0,0471	2,34	0,206	
870507	8:09	1626	5,92	0,270	8,22	0,600	60,1	0,0484	2,53	0,199	
870513	9:20	1851	6,51	0,295	7,98	0,605	53,9	0,0496	2,70	0,181	
870520	10:57	1969	6,62	0,290	8,56	0,610	54,9	0,0518	3,03	0,178	
870522	10:04	1922	6,53	0,280	7,83	0,530	45,8	0,0513	2,96	0,181	
870525	10:35	1989	6,63	0,345	12,07	0,720	64,2	0,0522	3,10	0,178	
870526	12:18	1989	6,52	0,315	9,75	0,533	48,5	0,0532	3,26	0,181	
870602	8:32	1688	6,09	0,265	6,29	0,600	49,5	0,0487	2,57	0,194	
870603	8:11	1741	6,20	0,295	8,16	0,660	52,8	0,0493	2,66	0,190	
870612	7:49	2296	7,36	0,335	8,90	0,780	57,7	0,0537	3,34	0,160	
870616	7:56	2413	7,47	0,365	9,56	0,715	50,2	0,0555	3,63	0,158	
870713	8:28	2487	7,51	0,335	9,22	0,705	53,2	0,0569	3,87	0,157	
870714	8:12	2413	7,36	0,360	9,90	0,730	52,5	0,0564	3,79	0,160	
870722	8:09	2079	6,90	0,335	10,12	0,700	54,3	0,0523	3,11	0,171	
870723	7:59	2148	7,11	0,330	9,38	0,690	51,6	0,0522	3,10	0,166	
870727	8:07	2100	7,02	0,335	10,08	0,680	52,5	0,0518	3,03	0,168	
870728	8:03	2089	7,00	0,335	9,99	0,710	54,0	0,0516	3,01	0,169	
870825	8:59	1523	5,70	0,295	10,85	0,660	64,6	0,0474	2,38	0,207	
870828	8:52	1572	5,88	0,300	12,13	0,615	63,8	0,0472	2,36	0,201	
870901	8:40	1617	6,05	0,260	8,22	0,540	48,0	0,0471	2,33	0,195	
870910	8:15	1593	5,94	0,270	8,87	0,455	41,5	0,0473	2,36	0,199	
870911	10:07	1675	6,12	0,265	7,90	0,470	41,0	0,0481	2,48	0,193	
870914	8:31	1487	5,70	0,265	8,70	0,610	53,1	0,0462	2,21	0,207	
870924	8:10	1263	5,14	0,260	9,35	0,550	60,0	0,0440	1,92	0,230	
870924	8:10	1263	5,04	0,270	9,44	0,550	58,6	0,0450	2,05	0,234	
870925	8:18	1304	5,26	0,290	12,69	0,690	74,2	0,0443	1,96	0,224	
870925	8:18	1304	5,19	0,260	10,06	0,540	61,9	0,0450	2,04	0,227	
870928	8:56	1315	5,30	0,280	11,75	0,560	64,6	0,0443	1,95	0,223	
870928	8:56	1315	5,20	0,260	8,86	0,460	50,8	0,0453	2,08	0,227	
870929	9:05	1252	5,18	0,260	8,70	0,460	46,9	0,0433	1,82	0,228	
870929	9:05	1252	5,11	0,250	9,27	0,510	59,5	0,0440	1,91	0,231	

Date	Time	Q	h	Ripples	Ripples	Dunes	Dunes	u*'	T	d50/h (km. 890-km. 894, 60m left from axis)
				Δ	λ	Δ	λ	Δ		
		(m^3/s)	(m)	(m)	(m)	(m)	(m)	(m/s)	(-)	(*10^{-3})
870520	8:17	1969	6,68	0,275	8,52	0,275	27,5	0,0513	4,53	0,136
870525	8:56	1989	6,70	0,290	9,25	0,635	79,4	0,0516	4,61	0,136
870603	12:25	1741	6,24	0,285	8,39	0,535	58,2	0,0489	4,03	0,146
870713	12:37	2487	7,51	0,335	9,38	0,745	55,8	0,0569	5,80	0,121
870722	12:20	2079	6,99	0,330	10,38	0,630	47,8	0,0515	4,57	0,130
870727	12:39	2100	7,06	0,330	10,31	0,790	60,4	0,0515	4,57	0,129
870825	12:51	1523	5,80	0,280	10,93	0,665	75,4	0,0464	3,53	0,157
870831	12:11	1646	5,99	0,343	13,20	0,613	53,8	0,0484	3,92	0,152
870911	12:19	1675	6,13	0,240	7,13	0,535	58,1	0,0480	3,85	0,148
870924	11:21	1263	5,11	0,260	10,30	0,570	63,0	0,0444	3,14	0,178
870928	11:50	1315	5,28	0,265	9,76	0,630	76,4	0,0446	3,18	0,173

Date	Time	Q	h	Ripples	Ripples	Dunes	Dunes	u*'	T	d50/h (km. 890-km. 894, 60m right from axis)
				Δ	λ	Δ	λ	Δ		
		(m^3/s)	(m)	(m)	(m)	(m)	(m)	(m/s)	(-)	(*10^{-3})
870428	12:03	1654	5,87	0,400	15,61	0,730	60,3	0,0497	1,83	0,249
870428	12:03	1654	6,23	0,450	16,44	0,870	60,8	0,0466	1,48	0,234
870507	12:37	1626	5,90	0,350	12,68	0,730	61,8	0,0486	1,70	0,247
870507	12:37	1626	6,25	0,380	13,89	0,830	66,6	0,0456	1,38	0,234
870513	12:41	1851	6,74	0,370	14,96	0,730	62,2	0,0477	1,60	0,217
870513	12:41	1851	6,24	0,360	15,98	0,840	81,1	0,0520	2,09	0,234
870513	12:41	1851	6,22	0,440	14,43	0,800	61,1	0,0522	2,11	0,235
870522	8:30	1922	6,38	0,360	13,75	0,670	57,5	0,0527	2,17	0,229
870522	8:30	1922	6,85	0,450	14,40	0,960	64,6	0,0487	1,71	0,213
870602	12:41	1688	5,87	0,320	11,45	0,690	57,3	0,0508	1,95	0,249
870602	12:41	1688	6,30	0,380	11,77	0,850	56,6	0,0469	1,52	0,232
870612	12:22	2296	7,30	0,420	12,39	0,860	56,3	0,0542	2,35	0,200
870612	12:22	2296	7,68	0,400	10,89	0,820	49,0	0,0512	2,00	0,190
870616	11:52	2413	7,37	0,420	11,72	0,770	50,6	0,0563	2,63	0,198
870616	11:52	2413	7,77	0,450	13,28	0,900	56,5	0,0531	2,23	0,188
870714	12:21	2413	7,23	0,600	23,10	0,880	69,3	0,0575	2,79	0,202
870714	12:21	2413	7,56	0,530	16,73	0,920	61,5	0,0548	2,43	0,193
870723	12:32	2148	6,96	0,410	12,87	0,910	58,4	0,0534	2,26	0,210
870723	12:32	2148	7,36	0,420	12,99	0,910	60,3	0,0502	1,88	0,198
870728	12:39	2089	6,82	0,420	14,54	0,840	61,7	0,0532	2,23	0,214
870728	12:39	2089	7,24	0,460	16,27	0,840	65,8	0,0497	1,83	0,202
870901	12:06	1617	6,35	0,260	10,34	0,760	84,8	0,0446	1,27	0,230
870901	12:06	1617	5,76	0,250	7,34	0,620	65,4	0,0497	1,82	0,253
870910	12:10	1593	5,85	0,280	9,93	0,500	44,7	0,0481	1,64	0,250
870910	12:10	1593	6,29	0,310	9,70	0,620	46,2	0,0444	1,25	0,232
870914	12:01	1487	5,58	0,290	11,90	0,640	64,9	0,0473	1,56	0,262
870914	12:01	1487	6,06	0,330	10,96	0,630	47,1	0,0432	1,13	0,241
870925	11:10	1304	5,08	0,330	17,42	0,570	74,2	0,0461	1,43	0,287
870925	11:10	1304	5,51	0,370	18,68	0,720	81,6	0,0421	1,02	0,265
870929	12:35	1252	4,96	0,300	14,57	0,620	75,3	0,0454	1,36	0,294

km. 902 - km. 906; D90 = 0,0038 m.

Date	Time	Q	h	Ripples	Ripples	Dunes	Dunes	u*'	T	d50/h
				Δ	λ	Δ	λ	Δ		
		(m^3/s)	(m)	(m)	(m)	(m)	(m)	(m/s)	(-)	($*10^{-3}$)
870413	9:17	1851	6,38	0,330	7,62	0,610	50,4	0,0505	4,69	0,136
870427	7:58	1697	6,05	0,320	8,04	0,635	50,9	0,0491	4,38	0,144
870428	8:12	1654	5,97	0,320	7,81	0,695	53,1	0,0486	4,27	0,146
870506	8:36	1523	5,61	0,290	7,60	0,660	56,8	0,0480	4,14	0,155
870507	8:09	1626	5,82	0,315	8,44	0,795	66,6	0,0491	4,38	0,149
870513	9:20	1851	6,48	0,330	8,87	0,660	51,6	0,0496	4,49	0,134
870520	9:56	1969	6,58	0,330	8,86	0,630	47,1	0,0520	5,02	0,132
870522	10:04	1922	6,56	0,325	8,51	0,605	51,4	0,0509	4,77	0,133
870525	10:35	1989	6,56	0,330	9,36	0,620	48,9	0,0526	5,17	0,133
870526	10:28	1989	6,65	0,350	9,96	0,675	50,9	0,0519	5,00	0,131
870602	8:32	1688	6,05	0,310	6,97	0,610	44,4	0,0489	4,32	0,144
870603	8:11	1741	6,10	0,310	7,51	0,710	56,5	0,0500	4,57	0,143
870612	7:49	2296	7,29	0,385	9,70	0,715	48,5	0,0540	5,50	0,119
870616	7:56	2413	7,34	0,395	10,57	0,740	48,7	0,0564	6,08	0,119
870713	8:28	2487	7,55	0,355	8,93	0,645	44,0	0,0563	6,07	0,115
870714	8:12	2413	7,48	0,350	9,25	0,610	47,0	0,0552	5,78	0,116
870722	8:09	2079	6,90	0,385	10,71	0,675	50,5	0,0520	5,03	0,126
870723	7:59	2148	6,99	0,365	9,91	0,675	46,1	0,0529	5,25	0,124
870727	8:07	2100	7,05	0,340	9,63	0,655	47,1	0,0513	4,86	0,123
870728	8:03	2089	6,95	0,360	10,08	0,690	47,9	0,0518	4,99	0,125
870804	9:48	2241	7,21	0,380	10,49	0,690	47,1	0,0534	5,35	0,121
870825	8:59	1523	5,75	0,315	10,09	0,615	49,9	0,0467	3,86	0,151
870828	8:52	1572	5,86	0,310	9,20	0,615	50,0	0,0472	3,96	0,148
870901	8:40	1617	5,90	0,305	8,35	0,515	37,7	0,0481	4,16	0,147
870910	8:15	1593	5,73	0,305	9,01	0,600	45,6	0,0490	4,35	0,152
870911	8:33	1675	6,00	0,290	8,30	0,550	40,9	0,0489	4,34	0,145
870914	8:31	1487	5,64	0,300	9,27	0,590	47,7	0,0466	3,84	0,154
870924	8:10	1263	4,99	0,270	7,18	0,605	57,1	0,0454	3,59	0,175
870925	8:18	1304	5,11	0,295	9,04	0,575	53,5	0,0456	3,63	0,170
870928	8:56	1315	5,20	0,275	7,58	0,620	61,4	0,0451	3,53	0,167
870929	9:05	1252	5,10	0,270	7,88	0,535	53,6	0,0439	3,29	0,171

km. 902 - km. 906; D90 = 0,0038 m.

Date	Time	Q	h	Ripples Δ	Ripples λ	Dunes Δ	Dunes λ	u*' Δ	T	d50/h
		(m^3/s)	(m)	(m)	(m)	(m)	(m)	(m/s)	(-)	($*10^{-3}$)
870713	12:37	2487	7,51	0,320	7,73	0,650	59,0	0,0566	3,30	0,172
870722	12:20	2079	6,96	0,320	7,98	0,600	47,9	0,0515	2,56	0,185
870727	12:39	2100	7,13	0,330	7,50	0,685	54,2	0,0506	2,44	0,181
870825	12:51	1523	5,92	0,295	7,82	0,525	46,6	0,0452	1,74	0,218
870831	12:11	1646	5,90	0,363	11,18	0,750	51,4	0,0490	2,22	0,219
870911	12:19	1675	6,23	0,290	6,84	0,570	44,8	0,0469	1,95	0,207
870924	11:21	1263	5,17	0,275	7,22	0,475	41,2	0,0436	1,55	0,250
870928	11:50	1315	5,37	0,280	7,73	0,470	44,1	0,0435	1,54	0,240

Date	Time	Q	h	Ripples	Ripples	Dunes	Dunes	u*'	T	d50/h	km 902 - km. 906; D90 = 0,00365 m.
				Δ	λ	Δ	λ	Δ			
		(m^3/s)	(m)	(m)	(m)	(m)	(m)	(m/s)	(-)	($*10^{-3}$)	
870428	12:03	1654	5,77	0,380	11,93	0,765	52,4	0,0505	1,29	0,305	
870507	12:37	1626	5,73	0,370	12,17	0,695	53,8	0,0501	1,25	0,307	
870513	12:41	1851	6,35	0,443	14,42	0,850	60,4	0,0508	1,31	0,277	
870522	8:30	1922	6,36	0,430	14,29	0,740	54,0	0,0527	1,49	0,277	
870602	12:41	1688	5,83	0,365	9,95	0,740	45,3	0,0510	1,33	0,302	
870612	12:22	2296	7,19	0,375	10,29	0,735	46,4	0,0549	1,71	0,245	
870616	11:52	2413	7,29	0,430	11,61	0,755	46,7	0,0568	1,89	0,241	
870714	12:21	2413	7,15	0,585	17,69	0,890	59,0	0,0580	2,03	0,246	
870723	12:32	2148	6,87	0,425	11,50	0,840	47,1	0,0540	1,62	0,256	
870728	12:39	2089	6,78	0,450	12,06	0,905	52,0	0,0533	1,55	0,260	
870804	11:59	2241	7,09	0,460	12,86	0,865	52,3	0,0544	1,66	0,248	
870901	12:45	1617	6,11	0,283	7,18	0,597	55,0	0,0463	0,92	0,288	
870910	12:10	1593	5,77	0,335	10,28	0,740	52,8	0,0487	1,13	0,305	
870914	12:01	1487	5,57	0,340	10,20	0,720	49,4	0,0472	1,00	0,316	
870925	11:10	1304	5,02	0,390	15,27	0,785	68,4	0,0465	0,94	0,351	
870929	12:35	1252	4,95	0,370	13,37	0,705	60,9	0,0454	0,85	0,356	

Date	Time	Q	h	Ripples	Ripples	Dunes	Dunes	u*'	T	d50/h	km. 916 - km. 920; D90 = 0,0034 m.
				Δ	λ	Δ	λ	Δ			
		(m^3/s)	(m)	(m)	(m)	(m)	(m)	(m/s)	(-)	(*10^{-3})	
870429	10:22	1605	5,77	0,308	7,41	0,610	45,1	0,0486	3,52	0,170	
870518	11:51	1937	6,40	0,300	7,75	0,580	46,3	0,0522	4,22	0,153	
870527	12:36	1948	6,49	0,345	9,16	0,685	45,7	0,0518	4,13	0,151	
870615	11:48	2301	7,10	0,378	9,33	0,690	41,0	0,0553	4,86	0,138	
870715	10:76	2274	7,02	0,358	8,87	0,700	45,5	0,0554	4,86	0,140	
870721	10:80	2042	6,76	0,345	8,33	0,705	45,3	0,0518	4,14	0,145	
870729	9:45	2073	6,80	0,365	9,48	0,680	45,1	0,0523	4,22	0,144	
870805	9:49	2257	7,10	0,358	8,86	0,765	48,8	0,0543	4,63	0,138	
870827	11:68	1585	5,71	0,310	8,50	0,653	50,1	0,0485	3,50	0,172	
870902	11:21	1572	5,81	0,300	8,04	0,540	38,9	0,0472	3,27	0,169	
870909	10:49	1511	5,63	0,290	8,51	0,603	45,6	0,0470	3,22	0,174	
870923	11:49	1213	4,90	0,283	9,07	0,593	52,7	0,0441	2,71	0,200	
870930	11:29	1293	5,08	0,285	8,53	0,545	47,6	0,0452	2,90	0,193	

km . 916 - km. 920; D90 = 0,0034 m.

Date	Time	Q	h	Ripples	Ripples	Dunes	Dunes	u*'	T	d50/h
				Δ	λ	Δ	λ	Δ		
		(m^3/s)	(m)	(m)	(m)	(m)	(m)	(m/s)	(-)	($*10^{-3}$)
870429	7:56	1605	5,95	0,270	6,37	0,570	55,9	0,0470	3,84	0,148
870615	10:06	2301	7,28	0,295	6,81	0,640	55,5	0,0538	5,36	0,121
870715	8:54	2274	7,32	0,290	7,40	0,630	58,8	0,0528	5,13	0,120
870721	8:17	2042	6,93	0,300	7,08	0,685	59,7	0,0505	4,59	0,127
870729	8:14	2073	6,93	0,285	7,57	0,695	58,3	0,0512	4,75	0,127
870805	8:19	2257	7,31	0,290	7,49	0,720	56,7	0,0526	5,07	0,120
870827	9:37	1585	6,04	0,270	6,76	0,540	43,1	0,0456	3,57	0,146
870831	12:11	1646	6,31	0,380	11,77	0,890	58,6	0,0451	3,47	0,139
870902	8:50	1572	5,84	0,335	11,25	0,665	52,5	0,0470	3,85	0,151
870909	11:44	1511	5,92	0,270	6,87	0,530	41,6	0,0445	3,35	0,149
870923	10:07	1213	5,13	0,280	8,64	0,550	47,0	0,0419	2,86	0,172
870930	9:07	1293	5,26	0,285	7,32	0,590	46,5	0,0434	3,14	0,167

km. 916 - km. 920; D90 = 0,0034 m.

Date	Time	Q	h	Ripples Δ	Ripples λ	Dunes Δ	Dunes λ	u*' Δ	T	d50/h
		(m^3/s)	(m)	(m)	(m)	(m)	(m)	(m/s)	(-)	($*10^{-3}$)
870429	11:26	1605	5,80	0,390	13,43	0,770	59,3	0,0484	2,04	0,150
870513	12:41	1851	6,59	0,480	14,56	0,910	56,6	0,0483	2,04	0,132
870518	11:20	1937	6,45	0,370	12,88	0,670	53,8	0,0518	2,50	0,135
870527	12:06	1948	6,41	0,430	15,17	0,805	58,9	0,0525	2,58	0,136
870615	11:49	2301	7,15	0,470	13,03	0,795	49,5	0,0549	2,93	0,122
870715	10:30	2274	7,22	0,420	13,00	0,885	58,0	0,0536	2,75	0,120
870721	12:16	2042	6,69	0,475	12,44	0,845	48,3	0,0524	2,58	0,130
870723	14:42	2148	7,36	0,490	13,32	0,970	54,3	0,0496	2,20	0,118
870729	10:01	2073	6,79	0,460	13,34	0,900	56,0	0,0524	2,57	0,128
870805	10:15	2257	7,12	0,490	13,73	0,855	51,1	0,0541	2,81	0,122
870827	11:14	1585	5,79	0,390	11,76	0,690	48,9	0,0478	1,98	0,150
870901	13:22	1617	5,74	0,300	7,25	0,560	38,5	0,0492	2,16	0,152
870902	10:30	1572	6,28	0,270	6,76	0,690	49,0	0,0433	1,45	0,139
870909	9:03	1511	5,72	0,335	9,77	0,660	47,1	0,0462	1,78	0,152
870923	11:50	1213	5,00	0,355	15,10	0,685	67,5	0,0431	1,41	0,174
870930	10:41	1293	5,18	0,325	12,11	0,640	61,3	0,0441	1,54	0,168

Bedform data Waal unsteady conditions 1988 (Wijbenga, 1992)

Date	Q	Reach begining	end	Dunes		"Ripples"	
	(m^3/s)	(km)		Δ	λ	Δ	λ
880318	5188	864	866	0	0	.51	12.84
880319	5522	864	866	0	0	.6	15.32
880322	5345	864	866	0	0	.83	19.88
880325	4869	864	866	0	0	.81	21.78
880328	5943	864	866	.81	73.32	.79	18.74
880329	6341	864	866	.73	46.11	.83	18.4
880331	6553	864	866	.94	39.9	.78	14.9
880401	6172	864	866	.94	71.14	1	23.27
880402	5728	864	866	.78	52.99	.86	20.96
880405	4774	864	866	.78	52.72	.64	18.66
880406	4504	864	866	.82	59.13	.74	21.26
880407	4284	864	866	.76	59.9	.76	23.5
880411	3560	864	866	.52	62.6	.44	22.36
880318	5188	866	868			.51	13.74
880319	5522	866	868	.42	43.05	.42	12.2
880321	5555	866	868	.55	44.49	.52	16.86
880322	5345	866	868			.74	19.21
880322	5345	866	868	.4	48.51	.31	13.33
880325	4869	866	868	.57	73.49	.68	20.28
880328	5943	866	868			.97	24.52
880328	5943	866	868	.47	26.5	.34	9.75
880329	6341	866	868	.78	63.63	.75	19.15
880329	6341	866	868	.58	27.17	.42	9.68
880331	6553	866	868	.73	43.73	.72	16.12
880401	6172	866	868	.69	45.9	.6	14.61
880402	5728	866	868	.7	54.79	.85	23.04
880405	4774	866	868	.79	66.89	.6	19.25
880406	4504	866	868	.65	50.42	.56	18.65
880406	4504	866	868	.63	57.37	.42	13.62
880407	4284	866	868	.71	58.43	.58	20.43
880407	4284	866	868	.54	65.42	.43	23.24
880411	3560	866	868	.55	78.56	.31	17.94
880319	4126	870	872	0	0	.5	11.76
880321	4159	870	872	.54	49.94	.55	13.03
880322	4030	870	872	.94	181.68	.71	17.55
880328	4380	870	872	.69	53.31	.75	17.57
880329	4597	870	872	.74	41.31	.58	13.55
880406	3484	870	872	.71	53.09	.59	17.52
880407	3340	870	872	.73	53.73	.61	18.96
880319	4126	872	874	.57	93.05	.42	10.53
880321	4159	872	874	.64	83.4	.42	9.98
880322	4030	872	874	.58	71.66	.5	12.8
880328	4380	872	874	.55	43.77	.49	12.02
880329	4597	872	874	.62	41.33	.57	13.64
880406	3484	872	874	.61	50.32	.69	20.26
880407	3340	872	874	.59	43.68	.5	14.84

Bedform data IJssel (from Kamphuis 1990)							
Q m^3/s	D_{50} μm	h m	u m/s	Δ m	λ m	T	C' $m^{½}/s$
141.0	500.0	5.0	.828	1.8	80.0	3.6	75.6

Bedform Data Bergsche Maas (February 13, 1989) from Adriaanse (1986)								
Q m^3/s	S cm/km	h m	v m/s	ds μm	Δ m	λ m	T	C' $m^{1/2}/s$
2160.00	12.50	8.60	1.35	480.00	1.50	22.50	9.09	81.62
2160.00	12.50	8.00	1.35	410.00	1.00	14.00	9.05	84.23
2160.00	12.50	10.50	1.30	300.00	1.50	30.00	8.15	89.61
2160.00	12.50	10.00	1.40	500.00	1.60	32.00	9.41	82.54
2160.00	12.50	7.60	1.40	520.00	1.40	21.00	9.88	80.45
2160.00	12.50	8.40	1.40	380.00	1.50	22.50	10.05	84.40
2160.00	12.50	8.70	1.70	300.00	1.50	30.00	16.18	85.83
2160.00	12.50	7.50	1.55	250.00	2.50	50.00	13.55	87.97
2160.00	12.50	8.30	1.50	260.00	1.80	36.00	12.38	88.03
2160.00	12.50	9.50	1.35	230.00	1.80	36.00	9.62	90.76
2160.00	12.50	8.80	1.35	240.00	1.80	36.00	9.97	88.68
2160.00	12.50	9.00	1.30	240.00	1.80	36.00	9.13	88.85
2160.00	12.50	9.60	1.50	220.00	2.20	33.00	12.25	90.99
2160.00	12.50	8.70	1.50	370.00	1.90	28.50	11.86	84.22
2160.00	12.50	8.20	1.35	330.00	2.00	36.00	10.32	82.50
2160.00	12.50	8.20	1.35	480.00	1.40	22.40	10.88	75.24
2160.00	12.50	8.10	1.40	350.00	1.00	20.00	10.68	83.34
2160.00	12.50	8.00	1.50	420.00	.60	9.00	12.25	81.16
2160.00	12.50	7.80	1.50	410.00	.60	9.00	12.00	82.07
2160.00	12.50	6.80	1.50	400.00	.40	8.00	11.91	83.07
2160.00	12.50	6.40	1.50	270.00	.60	6.00	12.68	86.69
2160.00	12.50	5.80	1.50	220.00	1.00	10.00	13.16	88.46
2160.00	12.50	6.20	1.50	210.00	1.20	24.00	13.04	89.53
2160.00	12.50	6.60	1.50	210.00	1.00	50.00	12.90	89.97
2160.00	12.50	8.30	1.50	180.00	.90	36.00	11.79	91.82
2160.00	12.50	8.10	1.35	400.00	1.50	22.50	9.34	83.36

Bedform data Meuse River from March 1988 profiles								
Q m^3/s	S cm/km	h m	v m/s	D_{50} µm	Δ m	λ m	T	C' $m^{½}/s$
1743.00	14.14	9.00	1.55	650.00	.73	9.90	9.98	80.73
1743.00	14.14	8.80	1.32	500.00	.78	11.15	9.31	79.88
1743.00	14.14	8.60	1.45	620.00	.71	7.03	9.16	80.15
1743.00	14.14	9.30	.89	610.00	.83	9.79	3.12	78.18
1743.00	14.14	9.25	1.30	520.00	.81	11.49	8.55	80.20
1743.00	14.14	9.20	1.22	620.00	.78	12.62	6.06	81.08
1743.00	14.14	8.85	1.31	540.00	.66	11.33	8.58	79.58
1743.00	14.14	8.60	1.35	650.00	.71	12.71	7.64	79.38
1743.00	14.14	8.77	1.28	550.00	.62	13.13	7.93	79.88
1743.00	14.14	9.03	1.25	580.00	.83	13.42	8.33	74.01
1731.00	13.79	8.80	1.57	650.00	.78	9.36	10.38	80.58
1731.00	13.79	9.00	1.28	500.00	.85	13.00	8.68	80.03
1731.00	13.79	8.51	1.45	620.00	.58	7.80	9.25	80.08
1731.00	13.79	9.52	.87	610.00	.60	8.70	2.86	78.35
1731.00	13.79	9.05	1.32	520.00	.62	9.70	8.89	80.04
1731.00	13.79	9.04	1.24	620.00	.68	11.75	6.24	80.95
1731.00	13.79	8.80	1.31	540.00	.69	12.87	8.57	79.55
1731.00	13.79	8.50	1.36	650.00	.66	13.31	7.75	79.30
1731.00	13.79	8.22	1.36	550.00	.62	12.24	9.16	79.42
1731.00	13.79	8.68	1.29	580.00	.73	11.04	9.05	73.74
1593.00	13.21	8.10	1.57	650.00	.41	7.73	10.57	80.01
1593.00	13.21	8.20	1.30	500.00	.50	9.81	9.06	79.38
1593.00	13.21	8.20	1.39	620.00	.53	9.10	8.42	79.82
1593.00	13.21	8.70	.87	610.00	.60	10.60	2.98	77.70
1593.00	13.21	8.30	1.32	520.00	.60	11.28	9.13	79.44
1593.00	13.21	8.33	1.23	620.00	.65	11.64	6.34	80.38
1593.00	13.21	7.92	1.34	540.00	.62	9.98	9.22	78.80
1593.00	13.21	8.10	1.31	650.00	.61	10.90	7.23	78.96
1593.00	13.21	8.00	1.28	550.00	.59	10.10	8.13	79.23
1593.00	13.21	8.20	1.25	580.00	.65	9.84	8.65	73.34
1472.00	12.50	7.40	1.59	650.00	49	10.76	11.06	79.38
1472.00	12.50	7.60	1.29	500.00	.48	9.09	9.16	78.84
1472.00	12.50	7.60	1.38	620.00	.61	8.22	8.50	79.28
1472.00	12.50	8.10	.87	610.00	.50	9.66	2.98	77.18
1472.00	12.50	7.80	1.30	520.00	.57	10.66	8.91	79.00
1472.00	12.50	7.80	1.22	620.00	.50	9.70	6.24	79.91
1472.00	12.50	7.80	1.26	540.00	.59	10.00	8.02	78.70
1472.00	12.50	7.80	1.26	650.00	.56	11.16	6.64	78.70
1472.00	12.50	7.60	1.25	550.00	.53	10.65	7.72	78.87
1472.00	12.50	7.55	1.26	580.00	.57	10.60	8.89	72.75
1256.00	12.50	7.20	1.40	650.00	.37	5.50	8.29	79.19
1256.00	12.50	7.20	1.16	500.00	.50	7.78	7.31	78.46
1256.00	12.50	7.24	1.24	620.00	.52	8.69	6.68	78.94
1256.00	12.50	7.76	.77	610.00	.47	9.60	2.18	76.87
1256.00	12.50	7.30	1.19	520.00	.51	10.07	7.34	78.53
1256.00	12.50	7.40	1.10	620.00	.48	10.54	4.91	79.54
1256.00	12.50	7.30	1.15	540.00	.57	11.31	6.59	78.23
1256.00	12.50	7.30	1.15	650.00	.51	11.58	5.42	78.23
1256.00	12.50	7.00	1.16	550.00	.51	11.84	6.60	78.28
1256.00	12.50	7.00	1.16	580.00	.53	11.12	7.51	72.21
1163.00	12.50	6.90	1.35	650.00	.35	5.71	7.74	78.89
1163.00	12.50	7.20	1.08	500.00	.40	8.00	6.12	78.46
1163.00	12.50	6.90	1.20	620.00	.48	9.95	6.32	78.60
1163.00	12.50	7.30	.76	610.00	.44	11.36	2.12	76.43
1163.00	12.50	7.20	1.11	520.00	.45	10.25	6.36	78.44
1163.00	12.50	7.20	1.04	620.00	.45	10.97	4.38	79.34
1163.00	12.50	7.00	1.11	540.00	.54	10.59	6.13	77.93
1163.00	12.50	7.00	1.11	650.00	.52	10.54	5.04	77.93
1163.00	12.50	6.70	1.12	550.00	.50	10.54	6.17	77.97
1163.00	12.50	6.80	1.10	580.00	.49	9.55	6.77	72.00

Bedform data Meuse from March 1988 profiles						
River km	Date day	Q m^3/s	D_{50} μm	D_{90} μm	Δ m	λ m
176	19	1743	650	1030	0.73	9.9
177	19	1743	500	1150	0.78	11.15
180	19	1743	620	1080	0.71	7.03
181	19	1743	610	1550	0.83	9.79
182	19	1743	520	1150	0.81	11.49
183	19	1743	620	1030	0.78	12.62
187	19	1743	540	1200	0.66	11.33
188	19	1743	650	1200	0.71	12.71
189	19	1743	550	1150	0.62	13.13
190	19	1743	580	2500	0.83	13.42
176	20	1731	650	1030	0.78	9.36
177	20	1731	500	1150	0.85	13
180	20	1731	620	1080	0.58	7.8
181	20	1731	610	1550	0.6	8.7
182	20	1731	520	1150	0.62	9.7
183	20	1731	620	1030	0.68	11.75
187	20	1731	540	1200	0.69	12.87
188	20	1731	650	1200	0.66	13.31
189	20	1731	550	1150	0.62	12.24
190	20	1731	580	2500	0.73	11.04
176	21	1593	650	1030	0.41	7.73
177	21	1593	500	1150	0.5	9.81
180	21	1593	620	1080	0.53	9.1
181	21	1593	610	1550	0.6	10.6
182	21	1593	520	1150	0.6	11.28
183	21	1593	620	1030	0.65	11.64
187	21	1593	540	1200	0.62	9.98
188	21	1593	650	1200	0.61	10.9
189	21	1593	550	1150	0.59	10.1
190	21	1593	580	2500	0.65	9.84
176	22	1472	650	1030	0.49	10.76
177	22	1472	500	1150	0.48	9.09
180	22	1472	620	1080	0.61	8.22
181	22	1472	610	1550	0.5	9.66
182	22	1472	520	1150	0.57	10.66
183	22	1472	620	1030	0.5	9.7
187	22	1472	540	1200	0.59	10
188	22	1472	650	1200	0.56	11.16
189	22	1472	550	1150	0.53	10.65
190	22	1472	580	2500	0.57	10.6
176	23	1256	650	1030	0.37	5.5
177	23	1256	500	1150	0.5	7.78
180	23	1256	620	1080	0.52	8.69
181	23	1256	610	1550	0.47	9.6
182	23	1256	520	1150	0.51	10.07
183	23	1256	620	1030	0.48	10.54
187	23	1256	540	1200	0.57	11.31
188	23	1256	650	1200	0.51	11.58
189	23	1256	550	1150	0.51	11.84
190	23	1256	580	2500	0.53	11.12
176	24	1163	650	1030	0.35	5.71
177	24	1163	500	1150	0.4	8
180	24	1163	620	1080	0.48	9.95
181	24	1163	610	1550	0.44	11.36
182	24	1163	520	1150	0.45	10.25
183	24	1163	620	1030	0.45	10.97
187	24	1163	540	1200	0.54	10.59
188	24	1163	650	1200	0.52	10.54
189	24	1163	550	1150	0.5	10.54
190	24	1163	580	2500	0.49	9.55

Bedform Data Bergsche Maas from February 1989 profiles						
River km	Date mo/day	Q m^3/s	D_{50} μm	D_{90} μm	Δ m	λ m
223	208	1434	450	910	0.52	5.06
223	213	1990	450	910	0.61	6.06
223	214	1735	450	910	0.6	5.97
223	215	1519	450	910	0.53	5.48
223	220	654	450	910	0.29	4.44
224	208	1434	350	590	0.48	4.26
224	213	1990	350	590	1.11	13.79
224	214	1735	350	590	0.62	5.97
224	215	1519	350	590	0.63	5.97
224	220	654	350	590	0.32	5.41
230	208	1434	370	595	0.65	7.25
230	213	1990	370	595	0.99	25
230	214	1735	370	595	1.91	29.41
230	215	1519	370	595	1.3	18.52
230	220	654	370	595	0.45	10.87
234	208	1434	320	540	0.67	7.14
234	213	1990	320	540	1.4	19.05
234	214	1735	320	540	1.58	22.22
234	215	1519	320	540	1.09	16
234	220	654	320	540	0.39	7.41
236	208	1434	365	605	0.59	8.96
236	213	1990	365	605	1.26	31.58
236	214	1735	365	605	0.77	13.64
236	215	1519	365	605	0.86	13.95
236	220	654	365	605	0.36	12.5
246	208	1434	275	400	0.54	7.35
246	213	1990	275	400	0.87	40
246	214	1735	275	400	0.94	29.41
246	215	1519	275	400	0.86	25.64
246	220	654	275	400	0.45	11.11
247	208	1434	275	400	0.49	7.25
247	213	1990	275	400	0.78	31.25
247	214	1735	275	400	1.04	23.26
247	215	1519	275	400	0.9	24.39
247	220	654	275	400	0.45	10.75

Bedform Data Rhine-Waal from 1988 profiles														
Dune height in m														
	March									April				
Km	18	19	20	21	22	25	28	29	31	1	2	5	6	7
863.0	.3	.2	.3	.0	.1	.1	.2	.2	.5	.5	.9	.5	.3	.2
864.0	.9	1.0	1.2	.0	1.0	1.3	.9	1.7	1.7	1.8	1.7	1.6	1.5	1.4
865.0	.8	.9	1.1	.0	1.1	1.2	1.5	1.3	1.8	2.0	2.0	1.9	1.8	1.6
866.0	.7	.9	1.0	.0	.7	1.1	1.0	1.4	1.9	1.8	1.7	1.6	1.2	1.0
867.0	.6	.7	1.1	1.0	.8	1.4	1.5	1.4	1.7	1.6	1.9	1.9	1.4	1.5
868.0	.0	.4	.4	.4	.2	.4	.3	.4	.6	.0	.0	.0	.5	.5
869.0	.0	.7	.8	.9	.9	1.1	1.1	1.2	1.0	.0	.0	.0	.8	1.1
870.0	.0	.9	1.1	1.0	1.0	1.3	1.3	1.3	1.1	.0	.0	.0	1.2	1.3
871.0	.0	.8	.8	1.3	1.3	.7	1.7	1.7	1.3	.0	.0	.0	1.1	1.2
872.0	.0	.6	.7	.8	.8	.4	.9	.8	1.2	.0	.0	.0	1.2	1.2
873.0	.0	.4	.7	.4	.4	.5	.5	.6	.9	.0	.0	.0	1.7	1.4
874.0	.0	.6	1.0	.5	.5	.0	.6	.7	1.4	.0	.0	.0	1.1	1.0
875.0	.0	.8	.8	.0	1.1	.0	1.3	1.2	1.3	.0	.0	.0	2.0	2.2
876.0	.0	.7	.7	.0	.9	.0	1.1	1.2	.9	.0	.0	.0	1.5	1.5
877.0	.0	.6	.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
878.0	.0	.6	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
879.0	.0	.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
880.0	.0	1.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
881.0	.0	1.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
882.0	.0	1.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
883.0	.0	1.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
884.0	.0	.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Bedform Data Rhine from 1988 profiles						
Date mo/day	Q m^3/s	h m	d_s μm	Δ m	Δm m	λ m
318	7476	11.2	990	0.43	0.9	14.29
319	8143	11.4	990	0.56	1.1	18.18
320	8324	11.4	990	0.68	1.5	21.74
322	7789	10.8	990	0.92	1.5	23.81
325	6838	11.1	990	0.91	1.6	29.41
328	8985	11.3	990	1.25	2.3	30.3
329	9782	11.7	990	1.32	2.4	32.26
331	10206	12.4	990	1.7	3.6	40
401	9444	11.9	990	1.5	2.5	40
402	8556	11.5	990	1.48	2.7	37.04
405	6648	10.5	990	1.13	1.7	35.71
406	6108	10.2	990	1.27	1.9	41.67
407	5668	9.9	990	1.12	1.7	43.48
411	4219	9.1	990	0.96	1.8	52.63

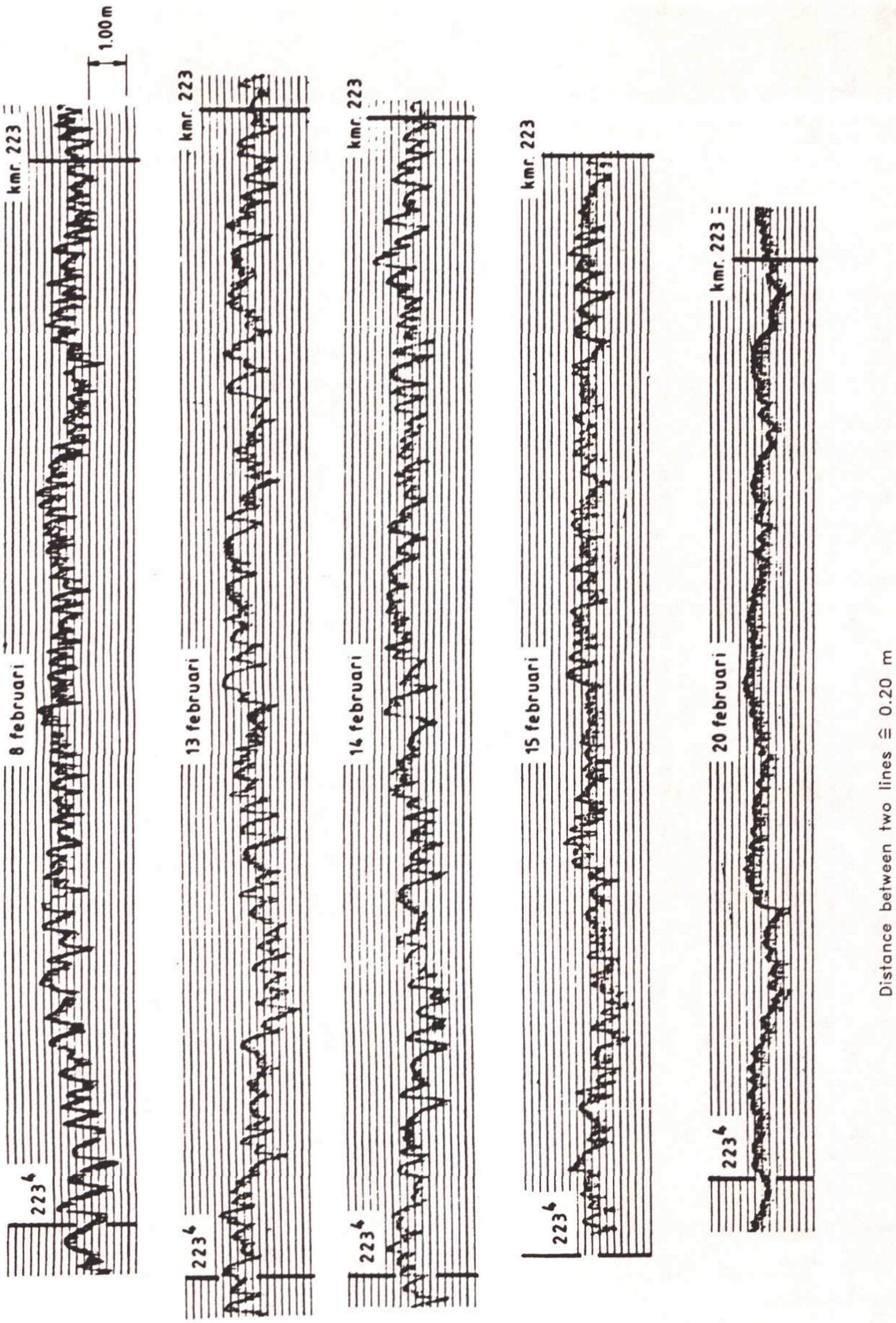
Bedform Data IJssel from 1988 profiles

Dune height in m

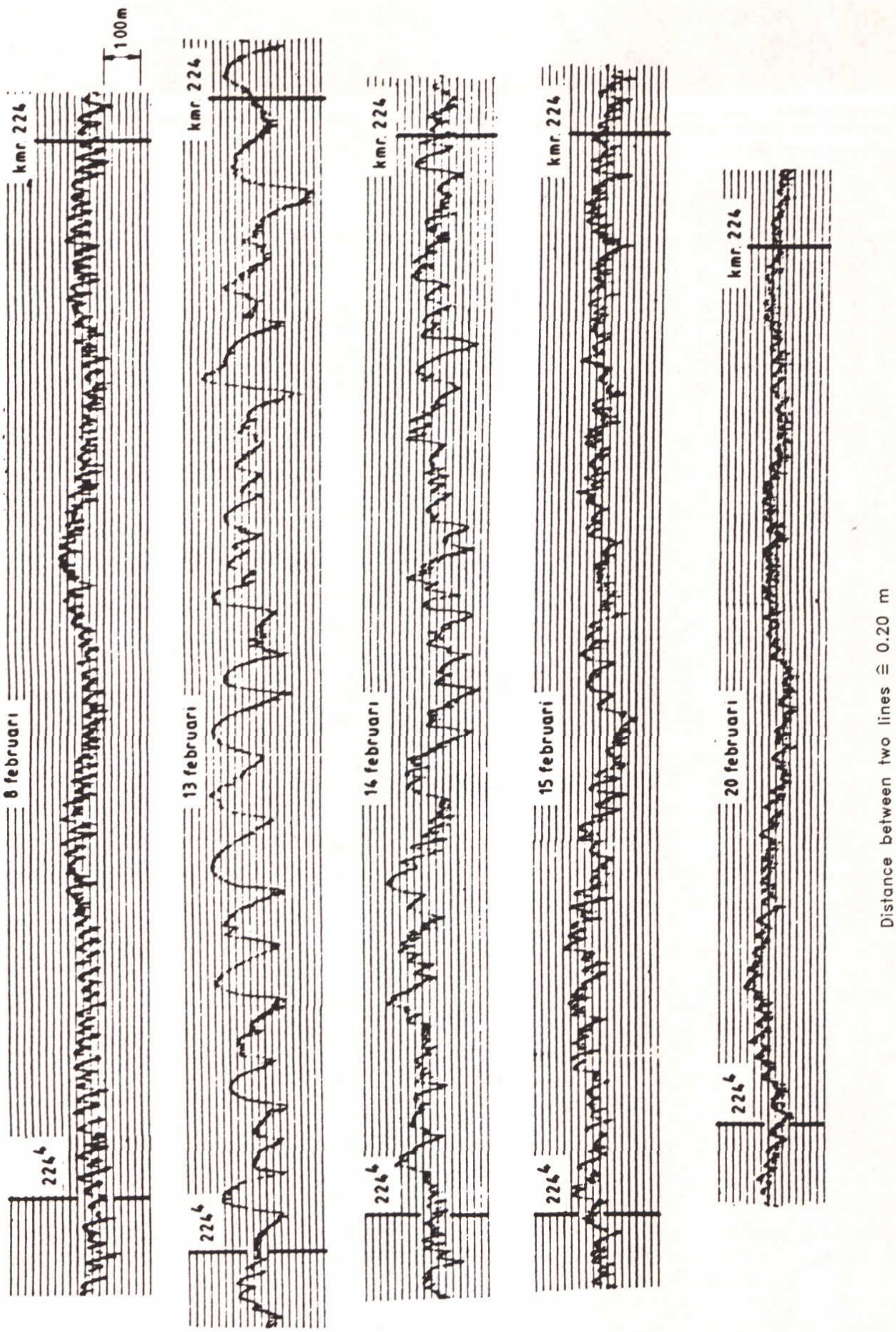
	March								April				
Km	18	19	20	21	22	28	29	31	1	2	5	6	11
880.0	.5	.6	.7	.8	.8	1.0	1.3	1.5	1.1	.9	.7	.4	.0
881.0	.2	.2	.2	.2	.2	.2	.2	.8	.7	.6	.5	.5	.0
882.0	.3	.2	.3	.4	.3	.2	.2	.2	.3	.4	.7	.3	.0
883.0	.3	.2	.2	.2	.1	.2	.2	.1	.1	.2	.3	.2	.0
884.0	.1	.1	.1	.1	.3	.6	.5	.3	.3	.2	.4	.3	.0
885.0	.2	.1	.2	.1	.9	1.1	1.1	.7	.7	.8	1.0	.5	.0
886.0	.3	.4	.4	.6	1.3	1.5	1.1	.9	1.1	1.2	1.4	.7	.0
887.0	.1	.2	.4	.2	.6	.9	.5	.8	.7	.6	.7	.3	.0
888.0	.3	.2	.3	.7	.8	.9	1.3	1.0	1.1	.8	1.0	.7	.0
889.0	.4	.2	.3	.6	.7	.7	.7	.7	.6	.5	.6	1.0	.0
890.0	.3	.5	.7	.3	.9	.5	.5	.5	.7	.8	.6	.5	.0
891.0	.4	.5	.5	.5	.5	.3	.3	.8	.8	.7	.7	.4	.0
892.0	.0	.0	.0	.0	.2	.3	.9	.0	.0	.0	.0	.0	.0
893.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
894.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
895.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
896.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
897.0	.5	.5	.5	.5	.5	.4	.5	.3	.2	.3	.3	.6	.8
898.0	.4	.6	.4	.4	.7	.8	1.1	.8	.7	.8	.6	1.3	1.5
899.0	1.2	1.3	1.3	1.4	1.5	1.3	1.0	1.2	1.1	1.2	1.1	1.3	1.4
900.0	.5	.8	.5	.4	1.2	.7	.6	.9	.8	.7	.7	.4	.3
901.0	.5	.7	.6	.9	1.2	1.3	.8	1.0	.9	.9	.8	1.2	1.2
902.0	.2	.3	.2	.2	.9	.7	.5	.5	.6	.5	.4	.5	.5
903.0	.2	.3	.3	.3	.7	.5	.5	1.5	1.3	1.4	1.3	1.3	1.5

APPENDIX D

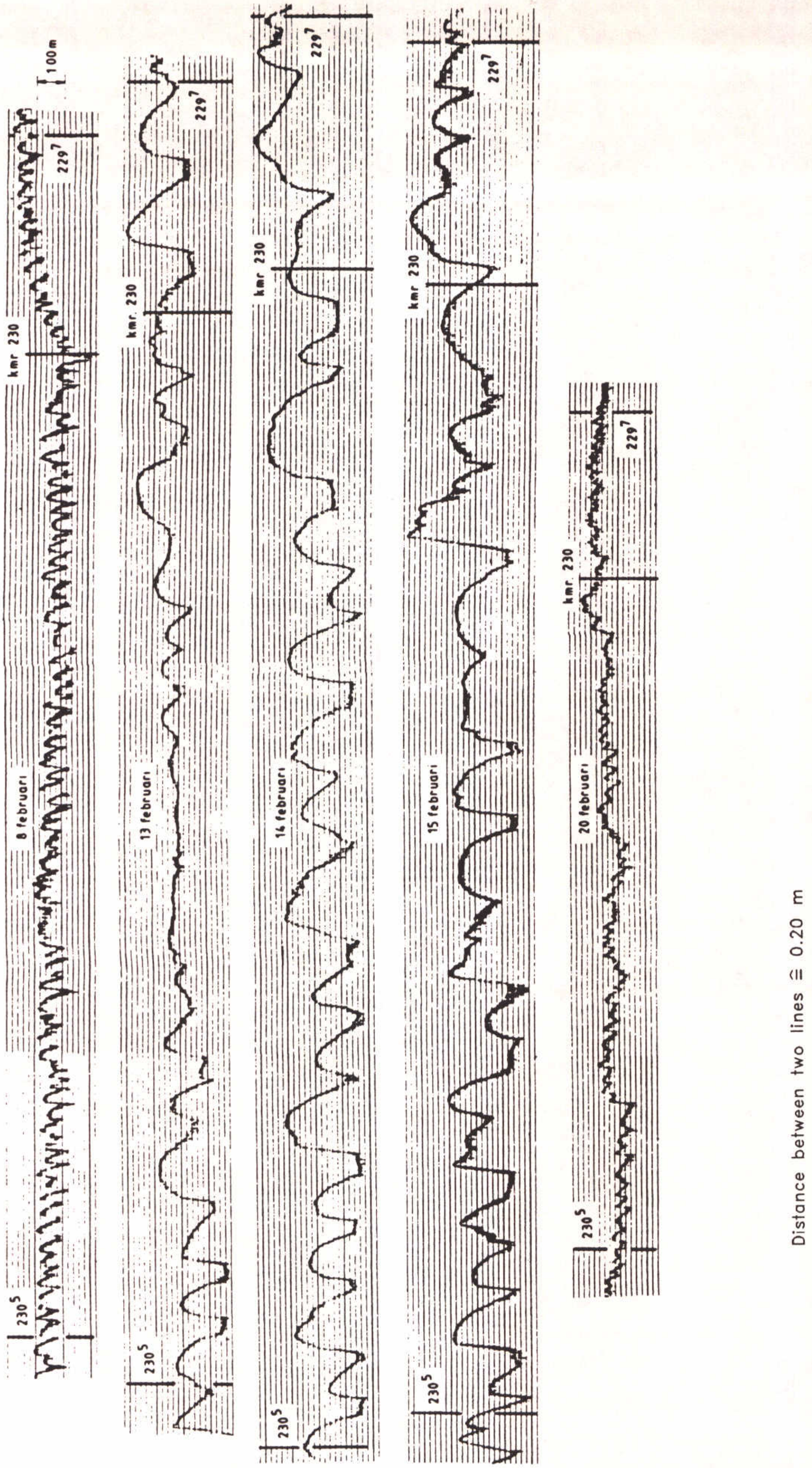
Bathymetric profiles of the Bergsche Maas, 1984 flood
at kms 223, 224, 230, 234, 236, 246, 247,
on February 8, 13, 14, 15, 20, 1984.
from Adriaanse (1986)



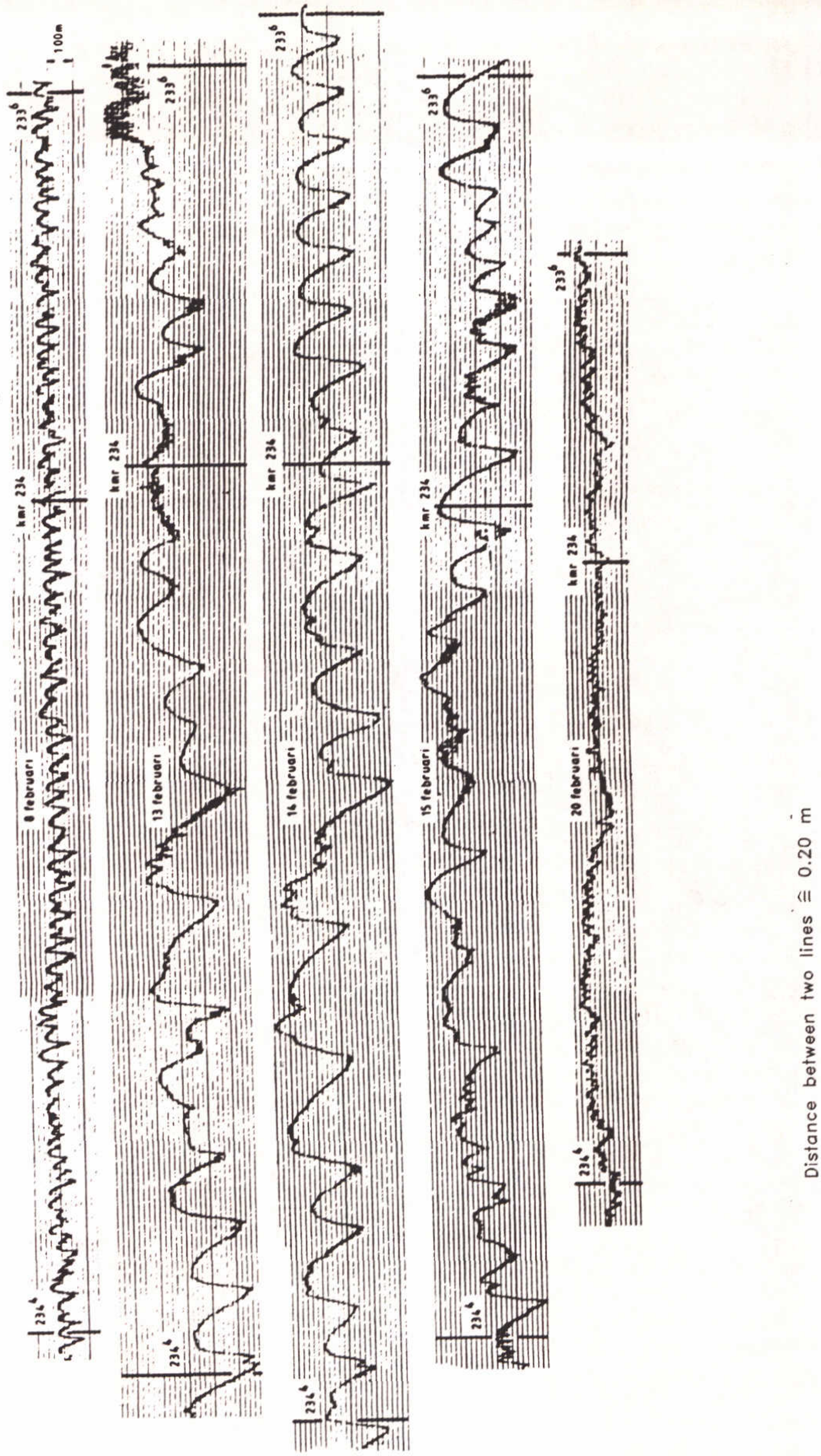
Length soundings Meuse, km. 223 - 223^4 during period of high discharge, 8-20 February 1984



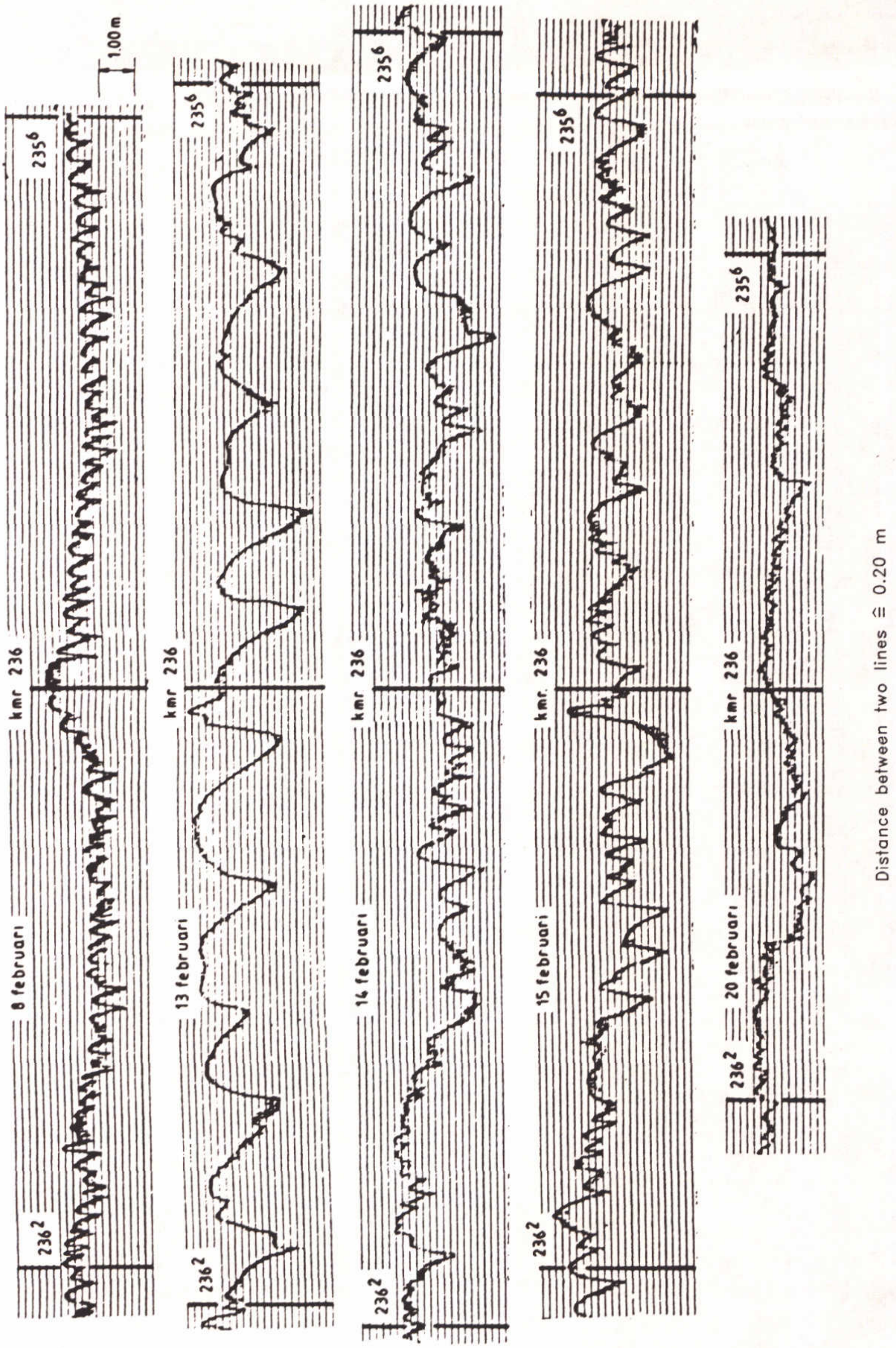
Length soundings Meuse, km. 224 - 224^4 during period of high discharge, 8-20 February 1984



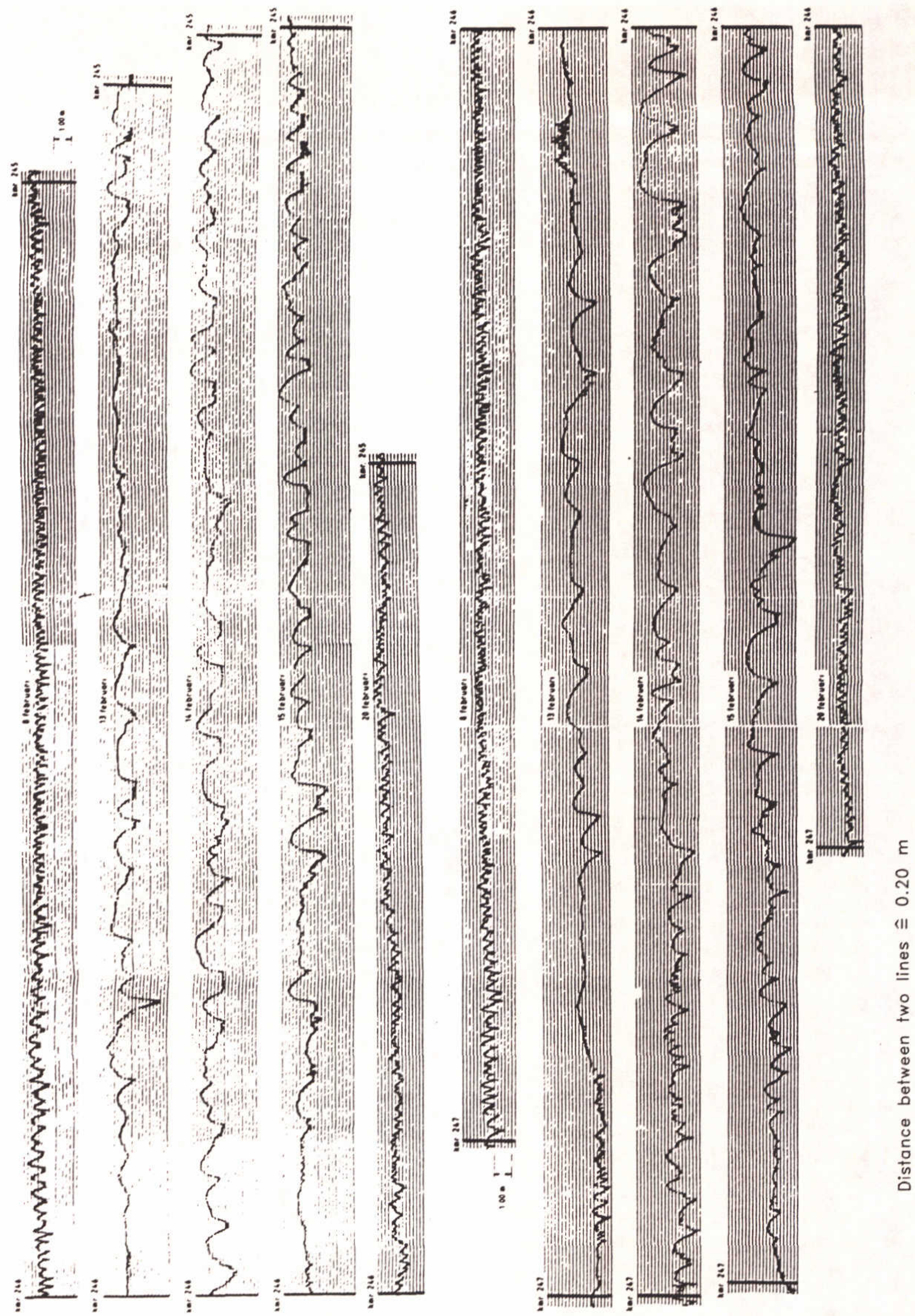
Length soundings Meuse, km. 229^7 - 230^5 during period of high discharge, 8-20 February 1984



Length soundings Meuse, km. 233^6 - 234^4 during period of high discharge, 8-20 February 1984



Length soundings Meuse, km. 235^6 - 236^2 during period of high discharge, 8-20 February 1984



Length soundings Meuse, km. 245 - 247 during period of high discharge, 8-20 February 1984

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