One-dimensional comparison of tidal basins as a unit ($E_\sigma$)

The vertical distribution of the corresponding relationships (A/F) are shown in Fig. 4.

As a first result it can be pointed out that

- the curves show a charakteristic distribution in the vertical and look rather similar,
- the (A/F) varies from about 2,500 at MLW up to 7,000 and more at MHW, and that
- there is an optimum near MHW, which has to be pointed out for future analysis.

In order to make the systems comparable the distribution functions were made uniform in both variables. Therefore the vertical component (z) was shifted to MLW (z') and related to the mean tidal range (H), with ($\zeta$ = z'/H). (4)

The abscissa (A/F = $\wp$) was related to the optimum value of ($\wp$), with

$\wp^* = [(A/F)/(A/F)_R]$ . (5)

This dimensionless relationship

$$\wp^* = f(\zeta) \qquad (6)$$

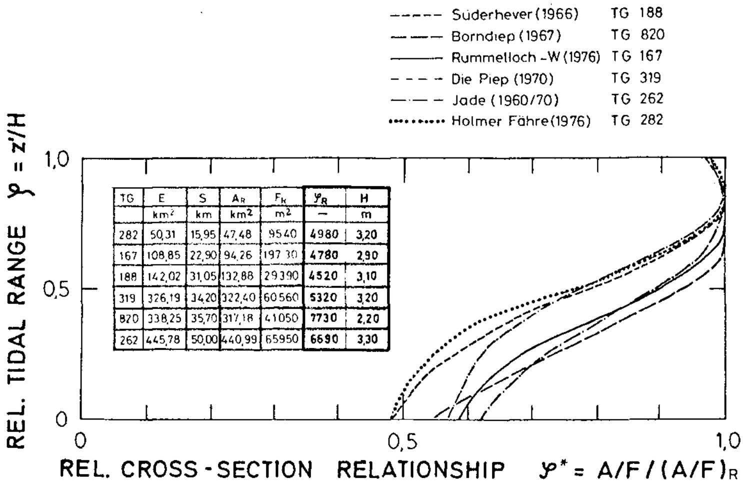
is used as a basic relationship for every further comparison (see Fig. 5).

The following 4 parameters are of main interest for the stability analysis:

- the vertical distribution curve ($\wp^*(\zeta)$)
- the range of the ($\wp_R$ )
- the range of the corresponding ($A_R$) ( meaning a "measuring area" for modelling purposes)
- the mean tidal range (H)

As a first result of this investigation about morphological similarity it was posible to work out some significant attributes:

- The vertical distribution-curve ($\wp^*(\zeta)$) shows a rather uniform characteristic,
- The ($\wp_R$ ) (at the optimum) was found to have an average value of about 5,200 for the inner German Bight with a mean tidal range of about 3 m (cf. table on Fig. 5 and upper graph of Fig. 10).
- One investigated tidal basin of an area with a smaller mean tidal range of about 2,2 m (Borndiep, The Netherlands) showed a greater $\wp_R$ -value.
- The $A_R$-value was found mearly to be almost equal with the area of the tidal basin (E) at MHW-level.




| TG | E | S | $A_R$ | $F_K$ | $\varphi_R$ | H |
|---|---|---|---|---|---|---|
| | km² | km | km² | m² | — | m |
| 282 | 50,31 | 15,95 | 47,48 | 9540 | 4980 | 3,20 |
| 167 | 108,85 | 22,90 | 94,26 | 19730 | 4780 | 2,90 |
| 188 | 142,02 | 31,05 | 132,88 | 29390 | 4520 | 3,10 |
| 319 | 326,19 | 34,20 | 322,40 | 60560 | 5320 | 3,20 |
| 820 | 338,25 | 35,70 | 317,18 | 41050 | 7730 | 2,20 |
| 262 | 445,78 | 50,00 | 440,99 | 65950 | 6690 | 3,30 |

Fig. 5

08 78 Re 05

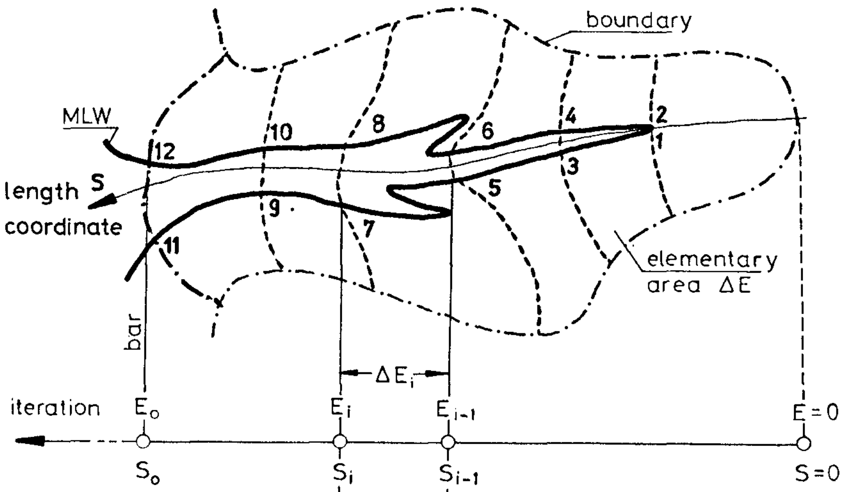



Fig. 6

## Two-dimensional comparison of tidal basins within the physiographical unit ($E_0$)

In order to ascertain the horizontal variation of the relationships within the tidal basins, the sections were iteratively varied along the gully axis (see Fig. 6); in other words:
the A(z) becomes an increasing variable due to the gully-length coordinate (s) (Ref. 7). Precisely the procedure of analysis was carried out at every section as explained before.

The vertical variation ($\gamma^*(\gamma)$) due to the gully length (s) of three investigates tidal basins of very different size and type is shown in the next three graphs (Figs. 7,8,9).

| Fig. | Tidal basin | Area at MHW ($E_0$) | Mean tidal range (H) |
|---|---|---|---|
| 7 | Süderhever, 1966 | 142 $km^2$ | 3,0 m |
| 8 | Born-diep (NL)1967 | 320 $km^2$ | 2,2 m |
| 9 | Jade-Estuary 1960/70 | 446 $km^2$ | 3,3 m |

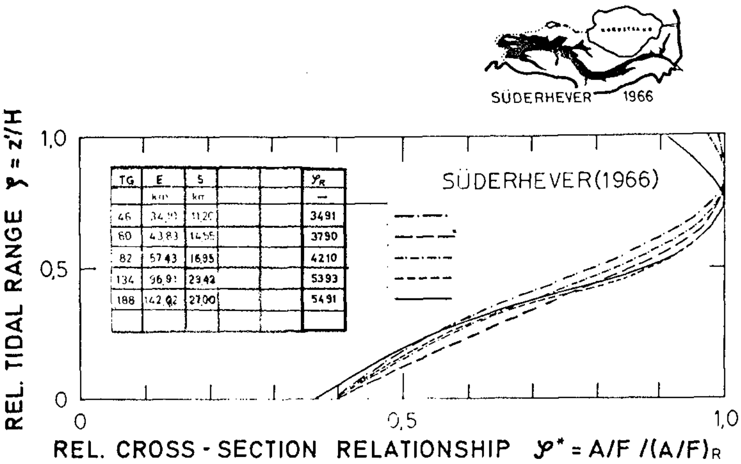
One most important result is that in every example the set of curves look rather similar and the curves always coincide very well.

The horizontal variation of the morphological characteristics only shows differences in the $\gamma_R$-value. The dimensionless reference parameter seems to depend mainly on the mean tidal range (Fig. 10). On the one hand it is dependent on the order of the tidal range in general and on the other hand it seems to increase due to the decreasing tidal range along the gully length coordinate from land to sea.

## The proof of instability

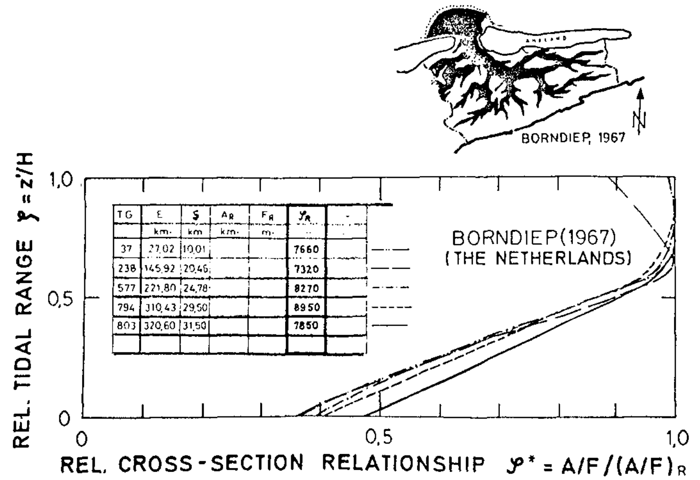
Referring to the last graphs on Fig. 10 we find some irregularities and deviations which may be of different origins, such as:

- methodical errors or mistakes
- influence of simplification (2 variables of space)
- individual attributes of the system that are not covered by the approach
- or even a certain degree of instability.




| TG | E | S | | | $\varphi_R$ |
|---|---|---|---|---|---|
| | km | km | | | — |
| 46 | 34,99 | 11,20 | | | 3491 |
| 60 | 43,83 | 14,55 | | | 3790 |
| 82 | 57,43 | 16,95 | | | 4210 |
| 134 | 96,91 | 23,42 | | | 5393 |
| 188 | 142,02 | 27,00 | | | 5491 |

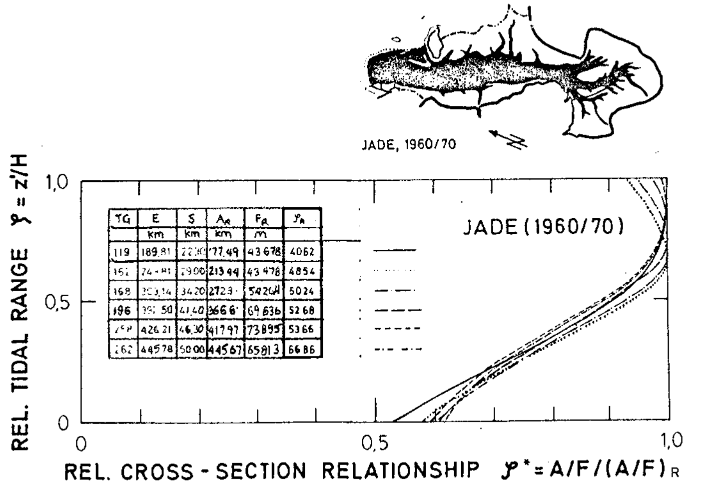
Fig. 7




| TG | E | S | $A_R$ | $F_R$ | $\varphi_R$ | - |
|---|---|---|---|---|---|---|
| | km | km | km | m | | |
| 37 | 27,02 | 10,01 | | | 7660 | |
| 238 | 145,92 | 20,46 | | | 7320 | |
| 577 | 221,80 | 24,78 | | | 8270 | |
| 794 | 310,43 | 29,50 | | | 8950 | |
| 803 | 320,60 | 31,50 | | | 7850 | |

Fig. 8

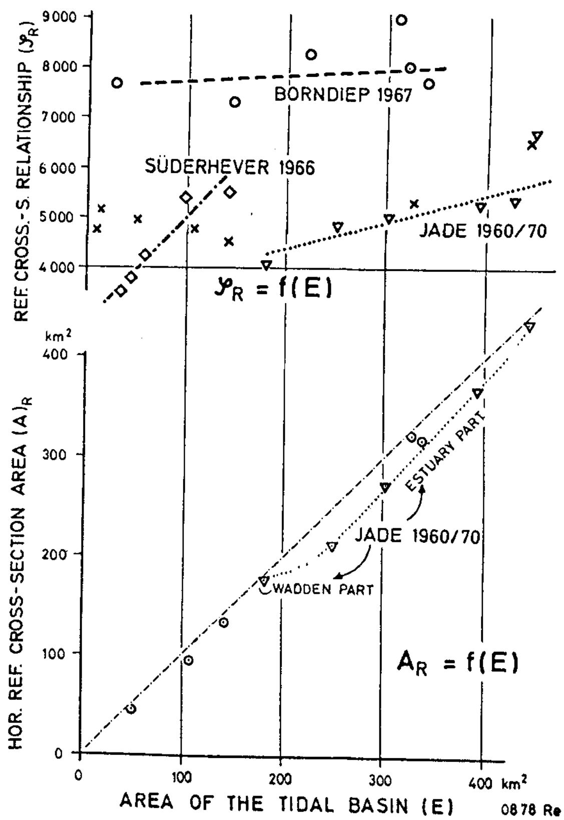
0878 Re 09




| TG | E | S | $A_R$ | $F_R$ | $\varphi_R$ |
|---|---|---|---|---|---|
| | km | km | km | m | |
| 119 | 189,81 | [illegible] | 77,49 | 43 678 | 4062 |
| 152 | [illegible] | 29 00 | 213 44 | 43 478 | 4854 |
| 168 | [illegible] | 34 20 | 2723 | 54 264 | 5024 |
| 196 | [illegible] | 41,40 | 366 6 | 69 636 | 52 68 |
| 258 | 426 21 | 46,30 | 417 97 | 73 895 | 5366 |
| 262 | 445 78 | 50 00 | 445 67 | 65 813 | 66 86 |

Fig. 9

0878 Re 08




0878 Re 10

Fig. 10

However, this is an open question at the present, and the deviations must be analized systematically by future investigations.

For these reasons we have to appreciate all the more the measurements of a tidal regime in the nature of which the non stability is well-known from its time-dependent change in the past towards an equilibrium state. The change of the characteristic form parameters are to be proved by the tidal river EIDER in the inner German Bight, which was dammed off at km 78 in 1936 (note the black part on Fig. 11.)
To get some idea about the change of the regime during the following 30 years the very heavy accumulation of about 50 Mio $m^3$ of silt has been observed outside the barrage over an area of about 25 $km^2$ and 30 km length.

In the lower part of the graph 3 time-stages of the investigated change of the regime are shown schematically (1935, 1936 and 1967). As an example the three time-stages are pointed out for the selected profiles nos. 78 and 115 at km 10 and km 20 in front of the barrage which are to be discussed subsequently in the next two graphs (Figs. 12 and 13).

The related (A/F)-distribution $\mathcal{Y}^*(\xi)$ is mearly the same just before and just after the damming off in 1935 and 1936 as can be shown on both profiles. But in contrast, the $\mathcal{Y}^*(\xi)$-curve of the situation 31 years later in 1967 after the heavy accumulation mentioned above is not quite similar.

The corresponding $\mathcal{Y}_R$-distribution due to the length-coordinate (s) is given in the next graph (Fig. 14). It is surprising to find that the $\mathcal{Y}_R$-values of the non-influenced tidal river EIDER as a constant almost exactly the same as the average value of about 5,200 that was analized from tidal basins, although the $\mathcal{Y}^*(\xi)$-curve was very different.

At the second time-stage just after the damming-off the reference values were found to be drastically diminished, as can be seen from the dotted line near the abscissa. Within the next 31 years the values had increased slowly towards the original level of 5,200 due to the accumulation of silt that had taken place.

At the moment we are not quite sure about the degree of non-stability (instability) because the type of the tidal basin has changed too much. But for other reasons a certain accumulation in consequence of the damming-off is still to be expected.

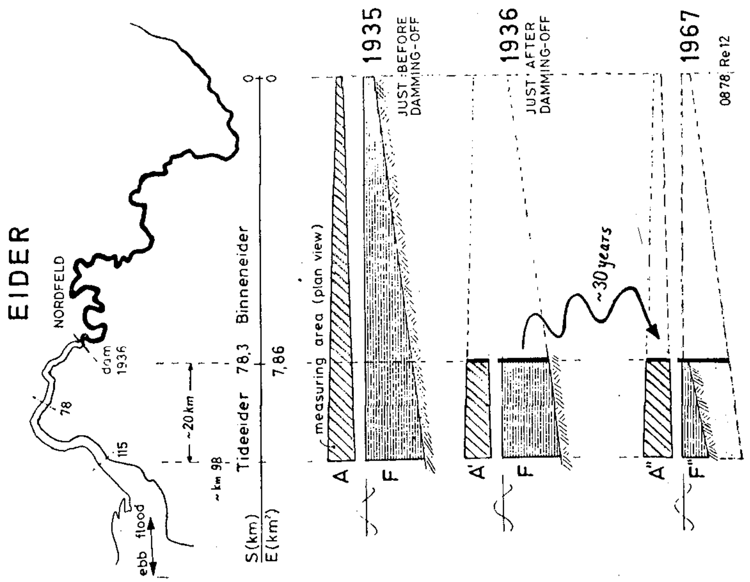



Fig. 11

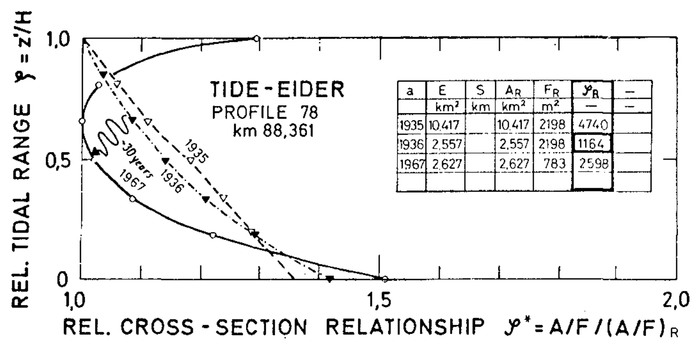



Fig. 12

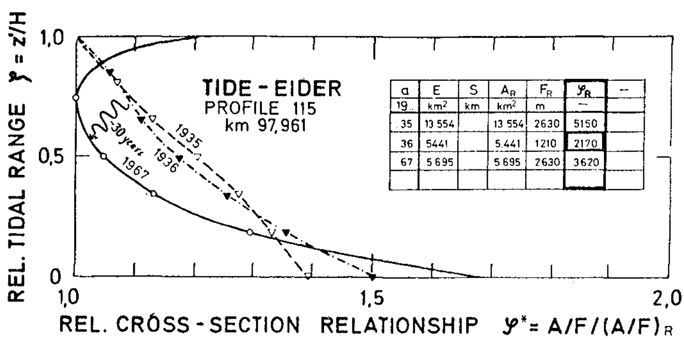



Fig. 13

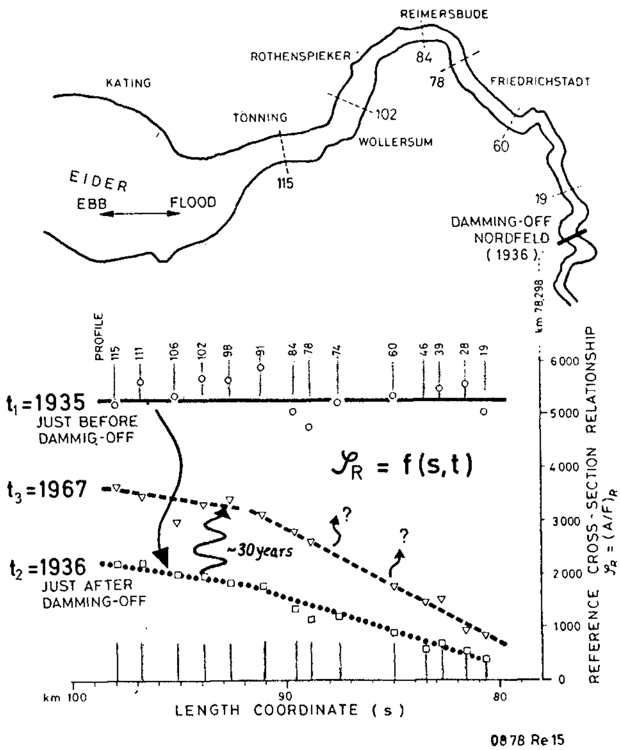

REIMERSBUDE
ROTHENSPIEKER
KATING
TÖNNING
WOLLERSUM
FRIEDRICHSTADT
EIDER
EBB
FLOOD
DAMMING-OFF
NORDFELD
(1936)
km 78,298
PROFILE
$t_1$=1935
JUST BEFORE
DAMMIG-OFF
$t_3$=1967
$t_2$=1936
JUST AFTER
DAMMING-OFF
~30years
$\mathcal{S}_R = f(s,t)$
REFERENCE CROSS-SECTION RELATIONSHIP
$\mathcal{S}_R = (A/F)_R$
LENGTH COORDINATE (s)
km 100
0878 Re 15

Fig. 14

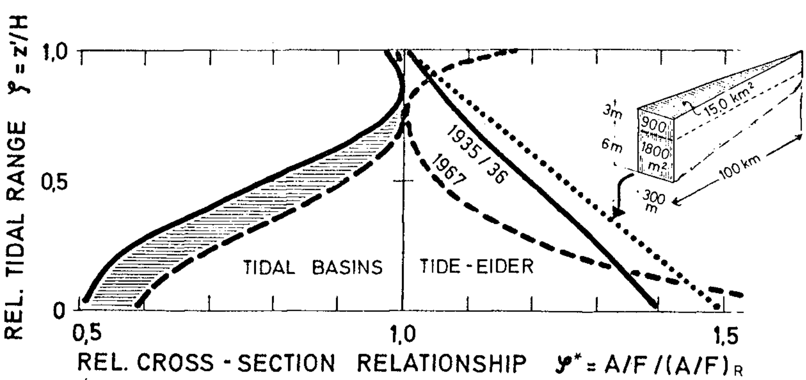

REL. TIDAL RANGE $\zeta = z'/H$
REL. CROSS-SECTION RELATIONSHIP $\mathcal{S}^* = A/F/(A/F)_R$
TIDAL BASINS
TIDE-EIDER
1935/36
1967
15,0 km²
900
1800
m²
3m
6m
300 m
100 km

Fig. 15

## Conclusions

Morphological change of tidal regimes is, to be precise, dependent on four variables:

- 3 variables of space and
- 1 variable of time

In addition complicated boundary conditions of the regime have to be covered. As a consequence a certain simplification due to the approach and a certain selection of parameters as well as a drastic data reduction is necessary and even possible.

In order to apply the method, morphological data (maps) in particular, as well as mean tidal conditions, must be known. The extensive quantity of data can only be handled with the help of computers, as has been pointed out in earlier publications.

Because of open boundary conditions in tidal flats, stability criteria must specified by further systematic investigations, and with reference to the boundary conditions. The universal application of these investigations to other tidal basin systems may result in similar equilibrium characteristics.

At the momant there are only a few results, and these have only exemplary significance. But these first results promise to be a good tool in stability analysis and forecasting modelling of tidal flats and tidal basins due to man-made influences on the regime.

## Acknowledgements

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