CHAPTER 118

SAND MOVEMENT INVESTIGATIONS BY MEANS OF RADIOACTIVE TRACERS IN A HYDRAULIC MODEL AND IN THE FIELD

by

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The Lower and the Outer Elbe constitute the sea-going navigation channel which has the heaviest shipping traffic in the Federal Republic of Germany. In order to obtain and maintain the fairway depth necessary for shipping, river construction works and dredging are applied to an equal extent (5). In order to investigate the practicability of these measures in detail, large hydraulic models of the River Elbe Estuary are available at the Coastal Department of the Federal Institute for Hydraulic Engineering (Außenstelle Küste der Bundesanstalt für Wasserbau) at Hamburg. The problems which result from the displacement of the sands and the fairways, as well as those of sediment transportation, are especially investigated in a model with a moveable bed consisting of granulated polystyrol (5). Details concerning the construction, instrumentation, and questions concerning the scale ratios of this model were given by VOLLMERS during the 13th International Conference on Coastal Engineering 1972 in Vancouver (7). Fig. 1 shows the River Elbe Estuary and the outer boundaries of the model, the length scale of which is 1 : 8oo and the depth scale 1 : 1oo. Fig. 2 shows a view of the model in the direction of the ebb current.

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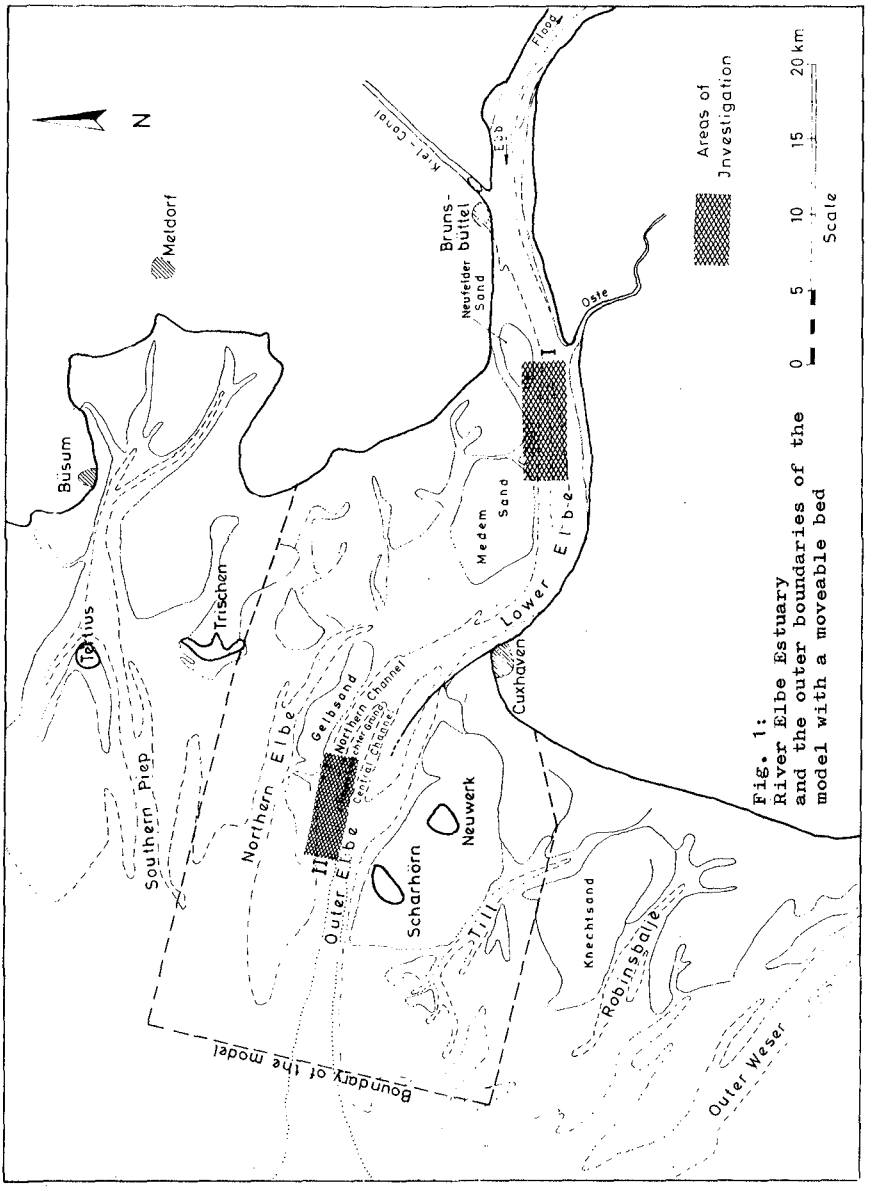

Fig. 1:
River Elbe Estuary
and the outer boundaries of the
model with a moveable bed

Fig. 2: The Elbe model with moveable bed

In 1973 an investigation was first undertaken to measure direct, with the aid of radioactive isotopes, the spreading of the moveable bed material. The aim was to find ideal situations in the River Elbe Estuary where dredged spoil taken from the fairway could be deposited without danger of the material being retransported - owing to the current - to positions where it could again hinder shipping. The hydraulic fill-fields must be accessible to deep-drawing hopper dredgers. In order to investigate the retransportation of the dredger spoil deposited, a small amount of the models bed material was labelled with the isotope Bromine 82 (Br 82 , half-life value 36 hours). From time to time, 25 g with an activity of lo Mikrocuries (µCi) were placed at different positions in the model, one after the other; and the distribution of the material after a period of 15o tides in each was investigated and then compared with current conditions prevailing at the time. An evaluation for the various dredge spoil hydraulic fill-fields was obtained from that data. Fig. 3 shows the

Fig. 3: Measurement equipment for the investigation of the spreading of radioactive material in the model

the measurement by scintillation counter of the spreading of the radioactive material in the model. The counting equipment hangs on a boom which can be moved transverse to the direction of movement of the mobile measurement bridge which spans the whole of the model. Thereby, every point of the model's surface can be reached by the counting equipment. On the left of the picture, one can see the printer with which the measurement values are registered. VOLLMERS provided details of the model investigations during the 15th IAHR Congress in Istanbul (8).

As yet, the comparison between the isotope measurements in the hydraulic model and corresponding measurements in the field were still not available. For such a comparison two positions were chosen. The positions I was situated in the Lower Elbe between Brunsbüttel and Cuxhaven, and II in the Outer Elbe, northeastwards from the Island of Scharhörn (see Fig. 1). This manuscript is intended to provide information concerning those investigations. Nearly 50 similar investigations using radioactive tracers have been carried out in the coastal areas of the North Sea, since 1960, by the Coastal Department of the Federal

Institute for Hydraulic Engineering at Hamburg. The methods of labelling applied thereby, the introduction onto the sea bottom or the river bottom as well as the measurement of the radioactivity and its spreading over the bottom, is comprehensively reported in (1), (3), and (6).

In the case of all hitherto existing investigations, the main point was merely to qualitatively comprehend the sand movements; therefore, to gain evidence about the main direction of movement of the sand. At the present time, there are investigations in operation that will enable quantitative statements to be made in the future; therefore, evidence about the amounts of radioactive materials transported in the various directions. A method for that has been given by MUNDSCHENK (4). For this method, a new, particularly heavy measurement sledge has been constructed by the Coastal Department of the Federal Institute for Hydraulic Engineering. This sledge is illustrated in Figs. 4 and 5. Fig. 4 is a side elevation of the sledge, which - during measurement operations - is dragged over the bed of the waterway behind a tow-boat.

Fig. 4: The new measurement sledge, lateral view

Fig. 5 : The measurement sledge from below

Fig. 5 shows the underside of the sledge, and - at the same time - provides a clear impression of its size. The measuring probe can be seen at the rear end. This measurement sledge has proved itself to be very good. It is extraordinarily stable, and will reright itself alone if it has tipped over. The distance of the probe from the bottom remains practically always constant, which is of special significance for the comparatability of the measurement values, especially in the case of quantitative investigations. The registration of the measurement values is carried out on board of the towing ship by means of a tape printer. This measurement sledge was also used in the investigations (described in this manuscript) which were carried out in the Lower and the Outer Elbe, although the

spreading of the radioactive sand was to be only qualitatively recorded.

The investigation area I lies westwards of the Neufelder Sand (see Fig. 1). The Medemrinne (Medem Channel), a subsidiary channel of the Lower Elbe, has sufficient depths to be able to be negotiated by deep-draught hopper dredgers. The Channel is separated from the actual navigational channel by a sand ridge. Current measurements gave a rather larger flood stream velocity when compared with that of the ebb stream velocity: on the other hand, the ebb stream duration was larger than that of the flood stream. Fig. 6 shows the tidal curve and the graph of the current velocity at the eastern end of the Medem Channel, as it was measured in the model experiment. On the basis of the current, velocities, nothing can be definitely concluded as to how the sand movements take place. In the model, at the two positions (Point A) at the eastern end of the Medem Channel and 3 km to the East of that (Point B); each time, in succession, 25 g of radioactive bed material was deposited and the spreading was measured after 15o model tides. In Fig. 7, the areas in which radioactive material could be identified are shown as being darker. From this, it could be seen that there was a clear movement in the direction of the extensive sand plate which lies in the direction of the flood - the Neufelder Sand. A sand transportation in the navigational channel was not observed.

In spring 1973, in the immediate vicinity of the model deposition Point A, an amount of 1o kg of sand was introduced on the river bed in the field. This sand was labelled with 3 Curie Scandium 46 (Sc 46, half-life value 84 days). The stratification of the isotope on the surface of the sand grains direct took place by a chemical method (2) without preliminary preparation of the sand with waterglass (Na_2SiO_3). The spreading of the material was measured by

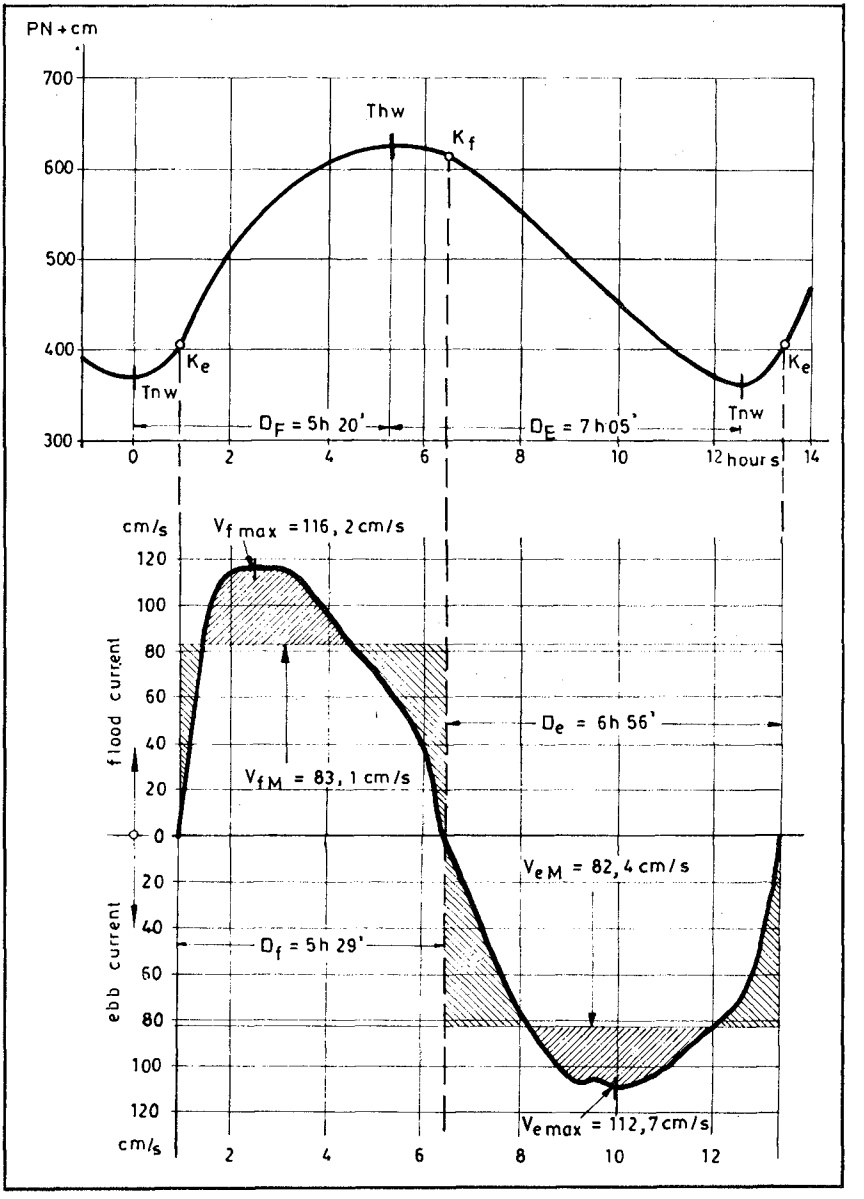

Fig. 6: Tidal curve and graph of the current velocity in the dumping area of the Medemrinne (Model measurements)

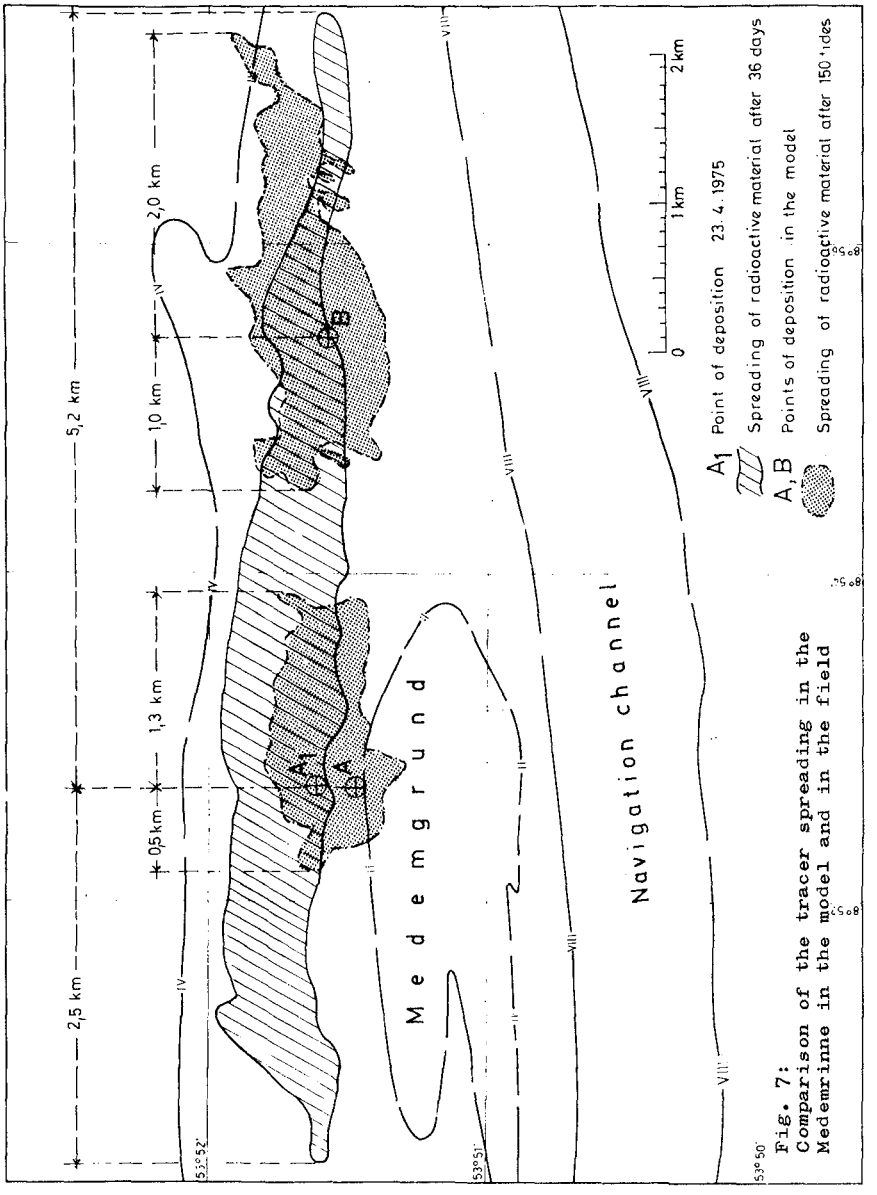

Fig. 7:
Comparison of the tracer spreading in the Medemrinne in the model and in the field

means of a scintillation counter. The counting equipment was built into the heavy measurement sledge (shown in Figs. 4 and 5) which was towed by the ship over the bottom. Furthermore, for control and for precise demarcation of the area in which radioactive sand was detectable, extensive bottom samples were taken and were γ-spectrometrically investigated by means of a multi-channel analyzer. The area in which radioactive sand in the field could be detected within 36 days is shown cross-hatched in Fig. 7.

The investigations revealed a good harmony between the spreading direction of the radioactive tracer in the model and in the field. Not only in the field, but also in the model, a predominating transportation in the direction of the flood stream took place in the direction of the Neufelder Sand. No radioactive material was found in the navigational channel. During the whole of the investigation period of 36 days, the activity in the close proximity of the introduction point remained the highest. In comparison, considerable differences in the spreading period in the model and of that in the field could be recognized. To begin with, if one considers the introduction points A and A1: in the model the largest spreading in the flood stream direction measured after 15o tides was 1.3 km; in the ebb stream direction only o.5 km. The spreading stretch, therefore, was 2.6 times larger in the flood stream direction than that in the ebb stream direction. In the field experiment, the introduction point lay 25o m more northwards. Already, after 36 days or 72 tides, radioactive material was found at a distance of 5.2 km in the flood stream direction and 2.5 km in the ebb stream direction. Therefore, the spreading in the flood stream direction was 2.1 times greater than that in the ebb stream direction.

The model introduction point B was at the eastern end of the spreading area detected in the field. The material deposited here, therefore, spread out in the flood stream

direction double so far as in the ebb stream direction (2.o km and 1.o km). The spreading direction was also in good conformity with that established in the field experiment.

Fig. 8 shows the radioactivity as measured in the field (after 3 and 4 weeks) in the longitudinal reach of the spreading. The points are the measurement values calculated on the day of the introduction. The dashed line evens out these values and provides a picture of the distribution of the radioactivity. The logarithmical scale, which is based upon this illustration, is shown on the left of Fig. 8, the dimension is Nanocurie (nCi). The staged curve shows the distribution of the radioactivity in the model experiment, the scale is given on the right of the figure, the dimension is Impulses per Minute. Nanocurie and Impulses per Minute are not to be compared direct, it is intended only to present the form of both distribution curves vis-à-vis to one another in Fig. 8. One can quite clearly recognise that, in both cases, the rise on the left (that is, to the West of the introduction point) is very steep. The maximum is somewhat displaced towards the right. The main body of the radioactive bed material, in the model experiment, had obviously shifted intensely towards the right (East), and a second maximum had built itself up. The more intense shift towards the East, in the direction of the flood current, was also produced by the distribution curve in the field.

The comparison of the experiments revealed that the spreading took place in the field substantially quicker than in the model experiment. The relationship between the extents of the spreading in both the ebb and flood stream directions, indeed, were about the same size both in the model and in the field. However, it was positive that in about half the number of tides in the field the distance from the introduction point in which radioactive

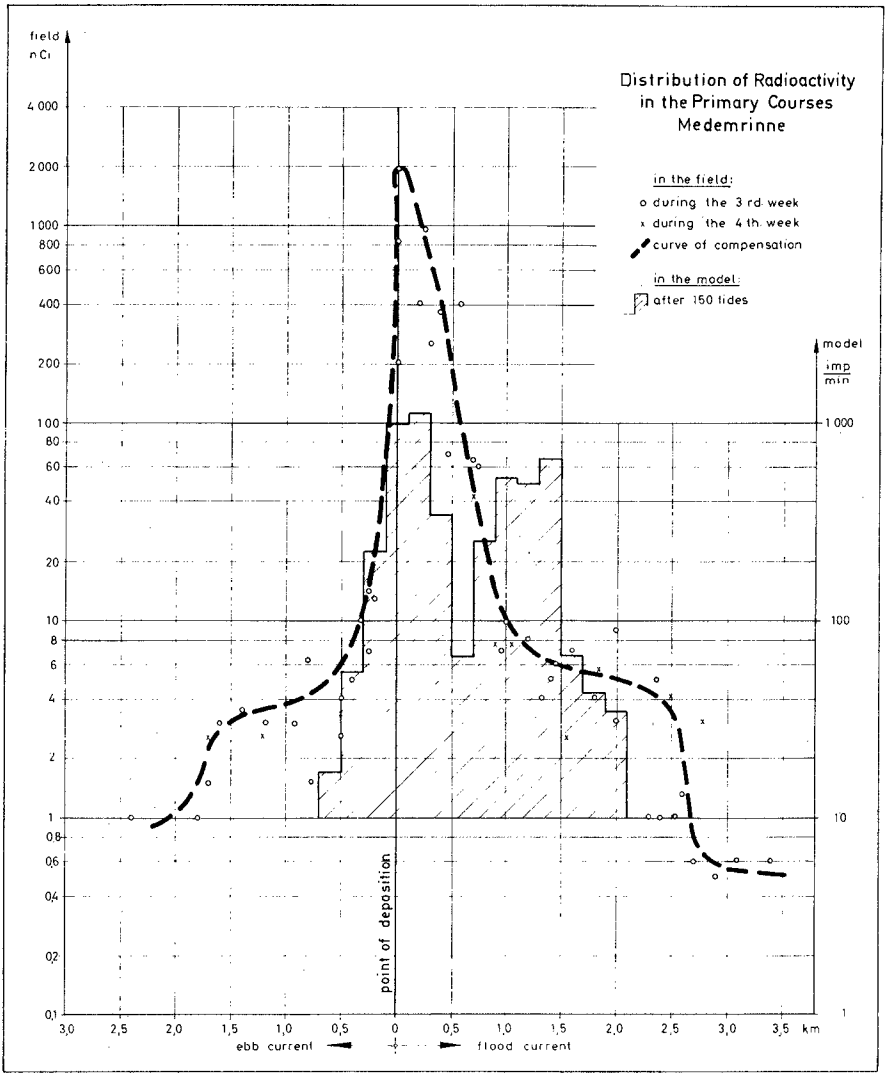

Fig. 8: Spreading of the tracer in the Medemrinne in the model and in the field (Distribution of the radioactivity in the main spreading direction)

material could still be detected was four times greater in the flood stream direction and five times greater in the ebb stream direction, than those in the model experiment. Thereby, one must still bear in mind that, in the so-called morphological Model Time Scale, a model tide represents a larger span of time than a tide in the field. These great differences in the spreading velocity are to be traced back, primarily, to differences between the transportation behaviour of the model bed material and that of the natural sand in the field. The model bed material is transported predominantly as bedload: on the other hand, a larger part of the sand in the field - in suspension. In particular, the radioactive amounts of sand furthest away from the introduction points and which were found only at individual positions, would seem to have reached their deposition location in suspension. Only in a part of the stretch where the sand could be detected as enclosed strips, could the radioactive sand have been transported as bedload, during the relatively short period of observation.

A further investigation in the Outer Elbe was carried out in autumn 1975. The investigation area II lay at the westerly end of the Norderrinne (Northern Channel) which is separated by the Neuen Leuchter Grund from the Mittelrinne (Central Channel) which serves as the main navigational channel (see Fig. 1). Thereby, the deposition point was situated in the vicinity of the introduction point 1 (which is described in (8)) in the model with a moveable bed. In this investigation, the isotope Chromium 51 (Cr 51, half-life value 28 days) was used, and the enrichment was made after previous preparation of the sand with waterglass (1). 1oo kg of sand with an activity of 2o Curie was used. Chromium 51 is not so ideally suited for investigations of this type as is Scandium 46, because Chromium 51 has a shorter half-life value and a less energy-rich γ-radiation. As Fig. 9 shows, the ebb stream velocity predominated quite obviously in the vicinity of the introduction

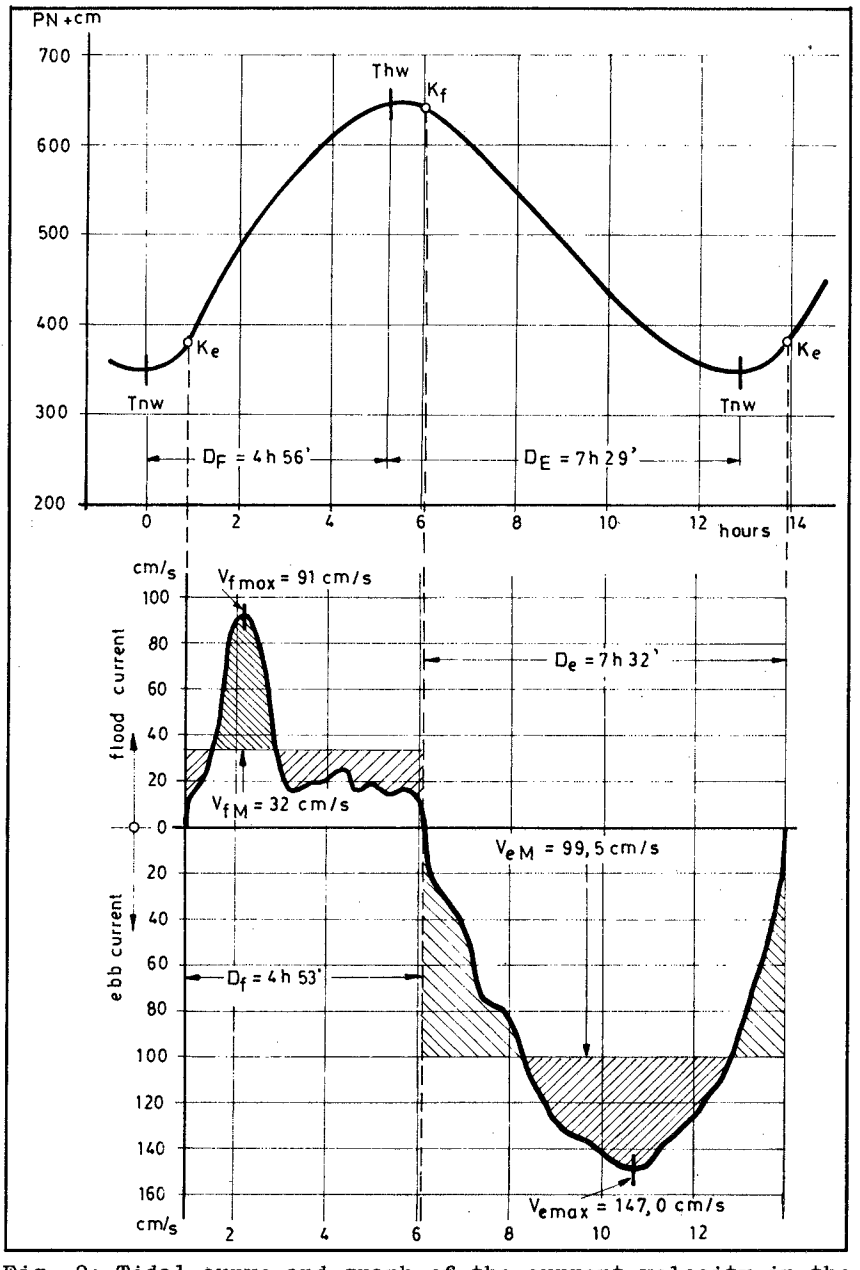

Fig. 9: Tidal curve and graph of the current velocity in the dumping area of the Northern Channel (Model measurements)

point. Correspondingly, a predominant transportation of the sand in the direction of the ebb stream was also to be expected. The spreading of the radioactive bed material, which was measured after 15o model tides, is illustrated in Fig. 1o as dark area. The area where radioactive sand could be detected already five days or ten tides after the introduction in the field, is shown as cross-hatching. Here, also the transportation directions show good harmony, practically no transportation occurred in the flood stream direction. It is particularly interesting that, three weeks after the introduction, a limited spot with heavily increased radioactivity at the edge of the main navigation channel was to be found at 8 km distance from the introduction point. This position is shown in double-hatching in Fig.1o. Sand deposits build up abundantly at this position. The investigations in the Northern Channel of the Outer Elbe confirm the results which were obtained during the investigations in the Medem Channel. Here, also, the spreading in the field occured very much more quickly than in the model experiment, which is to be traced back to transportation in suspension. The radioactive material which was found at 8 km distance away, must have been transported exclusively in suspension.

The investigations have shown that experiments using radioactive tracers in a model with a moveable bed can give valuabel indications concerning the sediment transportation to be expected in the field. In particular, it permits the determination of the direction of main movement. In the field, however, larger transportation distances are attained in a shorter time, because, in part, the transportation takes place in suspension. In the model experiments, the deposition of the whole of the amount of the radioactive material introduced could be recorded exactly. To date, that is not yet possible in investigations carried out in the field. As, in the only qualitative field investigations, however, the same main transportation directions resulted

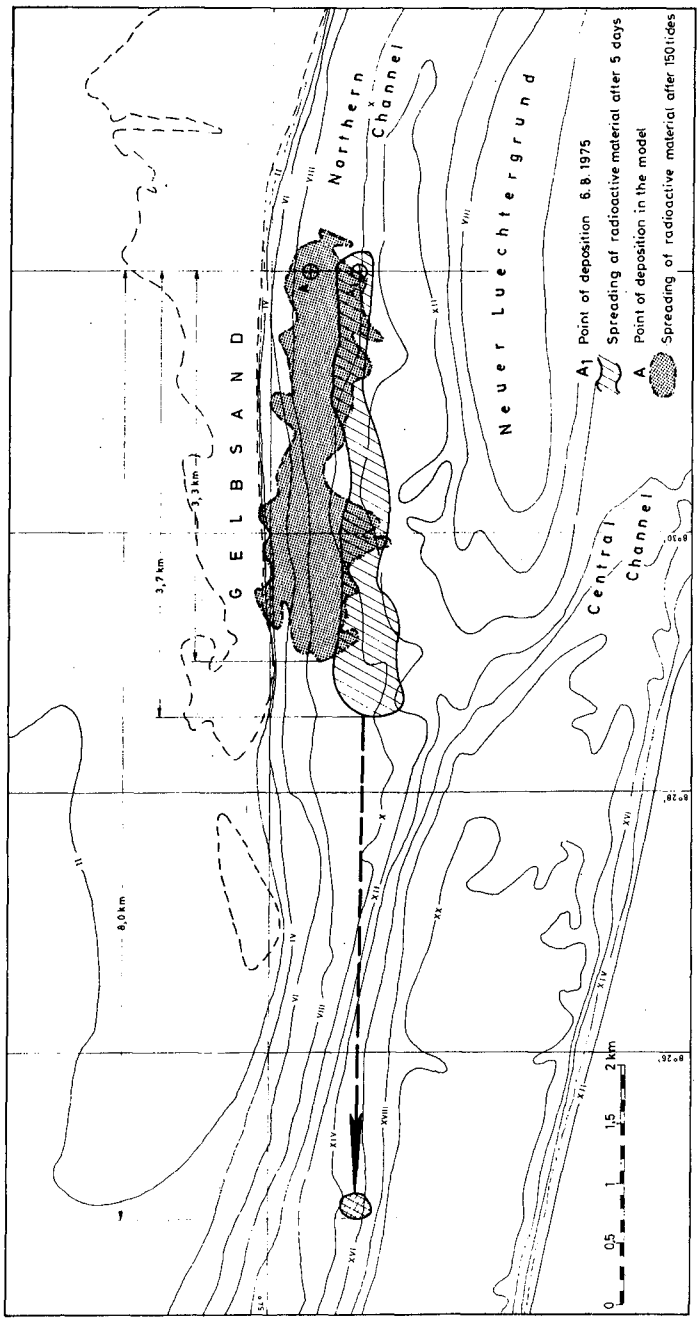

Fig. 10: Comparison of the tracer spreading in the Northern Channel in the model and in the field

as in the model experiment, and as the shape of the distribution curves was also similar, it is to be supposed that thereby an indication is given about the amount transported. In the area in which the higher radioactivity was measured in the fiel, in spite of the greater possibilities of a mixing and over-enrichment with inactive sands, the heaviest sand transportation is to be expected.

Further comparisons between model experiments and investigations in the field must yet clarify details, especially also the different transportation of the radioactive sand in the field, not only quantitatively but also qualitatively. Such investigations are planned for the future.

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