HARBASINS

HARBASINS Report:

Spatial Balance of Habitats in the Weser Estuary

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NLWKN

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Table of Content

Table of Figures

Table of Tables

1. Introduction

The Lower Saxony Department of Environment has assigned the coastal research station the Lower Saxony Water Management, Coastal Defence and Nature Conservation Agency to develop a concept for the identification of heavily modified water bodies (HMWB) in the transitional waters of the Weser estuary according to The Water Framework Directive of the European Community (EC-WFD). The main goal of the model project „Weser Estuary“ is to attain an objective containment of spatial effects of structural interferences of the waters with respect to annex II, 1.4 of the EC-WFD. Significant hydrodynamic and morphologic changes are examined in the Weser estuary over long-term developments for the identification of potential heavily modified water bodies.

2. Investigation Area

The waterway of the Weser estuary extends from the North Sea to the ports of Bremerhaven, Nordenham and Brake reaching the city of Bremen. The Weser can be divided into two different sections: as morphologically and as causes due to waterway engineering. This is on the one hand the Outer Weser with a length of approximately 60 km, which covers the far estuary of the North Sea extending to Bremerhaven. On the other hand, the second section, the Lower Weser, is likewise about 60 km long and includes the river section from Bremerhaven to Bremen at the Wilhelm-Kaisen bridge (WETZEL 1987). It is to be noted for this investigation that the Weser estuary has the most strongest regulated tidal changes in the world (RAMACHER 1974).

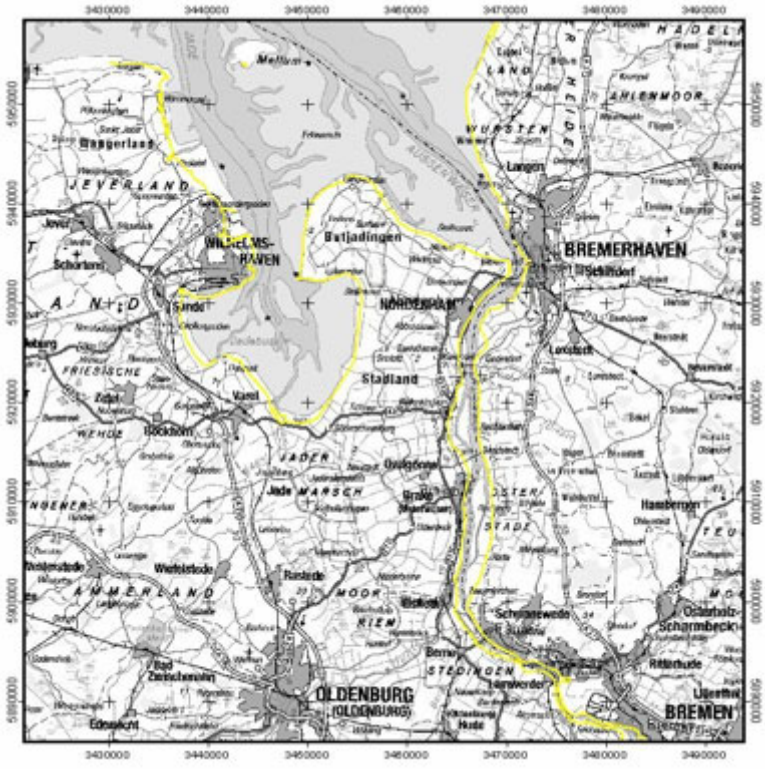

Fig. 1: Investigation area of the Weser Estuary

3. Methodology

3.1. Procedures

When looking at a historical perspective of the littoral areas in the Weser estuary, different conditions of this body of water were compared at three separate time ranges. In the year 1888, the major Weser correction was done by Ludwig Franzius who was head of the Building Permit Agency. This interference, now known as the “Franzius correction”, represents the strongest human impact on the Lower Weser estuary. The conditions documented in the recordings of Ludwig Franzius from the year 1887 (FRANZIUS 1888) can be used as natural reference condition. As a compari-

son, the water situations of the Lower Weser from 1972 before the SKN-9-m-development as well as those of the year 2000, regarded as a representation of today's conditions, are in reference to the surface sizes of different habitat. For a more exact investigation of the Weser Estuary, it is necessary to divide this body of water into sections of the Outer and Lower Weser as well as the prevailing area sections according to the EC-WFD. The Outer Weser was divided therefore into the areas of coastal and transitional waters.

3.2. Data Basis

The data needed for the evaluation were taken from different sources, which are represented as an overview in Table 1.

Tab. 1: Source of Data

Outer Weser

Year	Data Source
1860	Historical Maps No. 8 to 14 (HOMEIER 1962)
1960	Historical Maps No. 8 to 14 (HOMEIER 1962)
2000	• Topography model of the existing Jade-Weser model [KNAACK ET AL 2006] • Mean low and high tide water levels (LASSEN & SIEFERT 1991)

Lower Weser

Year	Data Source
1887	• Depth maps (FRANZIUS 1888) • Mean low and high tide water levels (FRANZIUS 1888)
1972	• Soundings of the Water and Navigational Agency of Bremerhaven and Bremen • Mean low and high tide water levels (WSD - NORD WEST)
2000	• Topography model of the existing Jade-Weser model (KNAACK ET AL 2006) • Mean low and high tide water levels (WSD - NORD WEST)

3.3. Definition of Littoral Surfaces

The coastal seam (littoral) of marsh coasts are subdivided according to a habitat investigation into the levels subtidal, intertidal and supratidal. These levels (fig. 2) are defined as follows:

- Subtidal: Area below MLW -2.00 m
  (Level: Deep water zone)
  Area between MLW and MLW -2.00 m
  (Level: Shallow water zone)
- Intertidal: Area between MLW - MHW
  (Level: Low-tide flat zone)
- Supratidal: Area between MHW - MHW +0.5 m
  (Level: Siltation Zone)
  Area above MHW + 0.5 m to the toe of the dyke
  (Level: Marsh or Foreland)

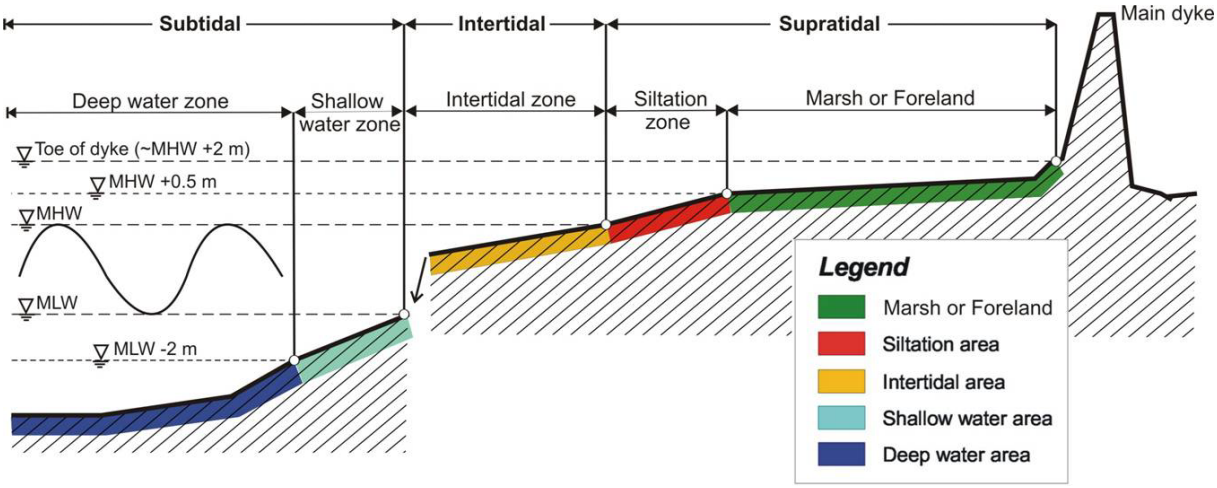

Fig. 2: Classification of the littoral environment

The areas at the defined levels as stated above will be balanced in the following chapters.

4. Spatial Habitat Balance in the Weser Esturay

4.1. Spatial Habitat Balance in the Outer Weser Estuary

4.1.1. Data Basis and Conversion

At the investigation of the existing areas of the Outer Weser, the region under consideration is from the North Sea to Bremerhaven where the transition from Lower and Outer Weser meet. The calculation of the areas in the Outer Weser are evaluated for the years 1860 (representative of 1887) and 1960 (representative of 1972) by means of polygons, since the historical maps of Homeier (HOMEIER 1962) document only the boundaries of areas and incorporate no depth data. The areas of the water condition of the year 2000 however, were determined with regular 5 x 5 m grids, whereas the water levels of the mean low and high tides for the year 2000 in the Wadden Sea of Lower Saxony were assumed according to LASSEN & SIEFERT (1991) (fig. 3). A conformed area structure was made for the comparison of his-

torical data. Furthermore the subtidal levels in the coastal waters were supplemented with extrapolated data, in order to make calculation in accordance with the water body compartments of the EC-WFD.

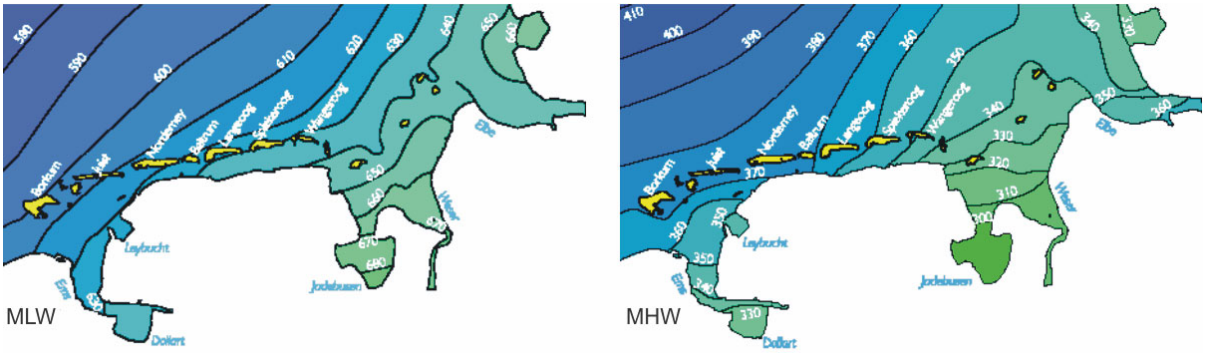

Fig. 3: Mean Low and Mean High Tide Water Levels in the Wadden Sea of Lower Saxony based on NN-5m by LASSEN & SIEFERT [NIEMEYER & KAISER 1996]

4.1.2. Coastal Waters of the Outer Weser Estuary

The The compilation of the historical maps No. 8 to 14 (HOMEIER 1962) for the situations 1860, 1960 as well as an adapted structure for the year 2000 (fig. 4 and 5) were used as a basis for determining the area of the appropriate habitats (fig. 6). For the year 2000, the higher data density was used for a more differentiated representation including that of the shallow water zone and the siltation zone. In the following, the area situations are pointed out for the years 1860, 1960 and 2000.

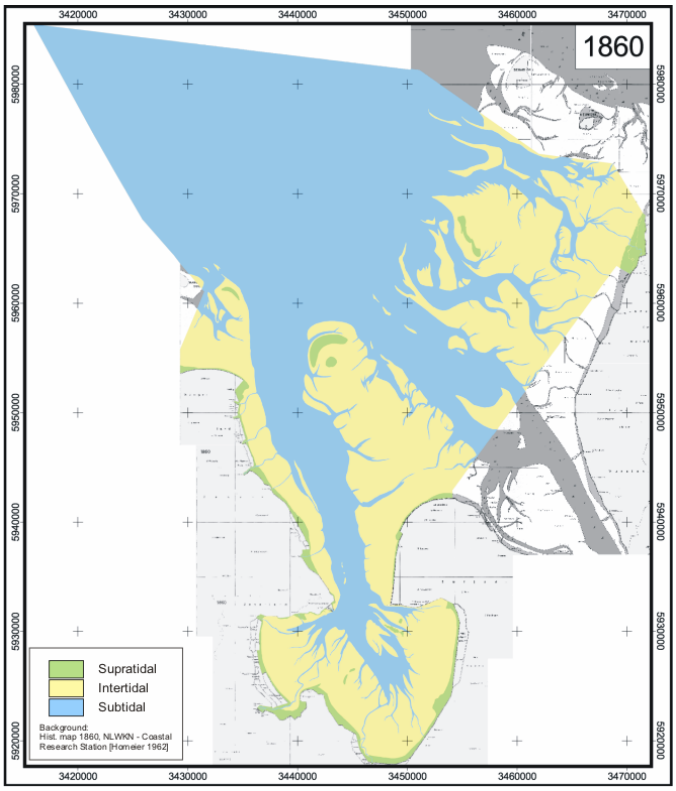

Fig. 4: Littoral habitats of the situation of 1860 in the Outer Weser Estuary (Area: Coastal Waters)

The area of the Outer Weser coastal waters has decreased in comparison to the existing area of 1860 up to the year 2000 from 1676 km² to 1623 km². The first half of this area loss of 52 km² originated between 1860 and 1960, whereas the second half occurred over a period of only 40 years. This area difference is essentially attributed to transformations or movements of summer dykes or main dykes.

However, subtidal areas (fig. 4 and 5) increased during the same period from 1045 km² to 1097 km² (fig. 6) which corresponds to an increase of a total of 52 km². The area increase occurred continuously over the two given periods of time so that a steady increase of the subtidal area was registered over the last 140 years.
In the intertidal, a decrease was determined of 591 km² in 1860 to 486 km² in the year 2000. Therefore

the area of the intertidal has decreased about 105 km² (fig. 6). Also the decrease of this area occurred continuously over the three given time periods with a uniform trend.

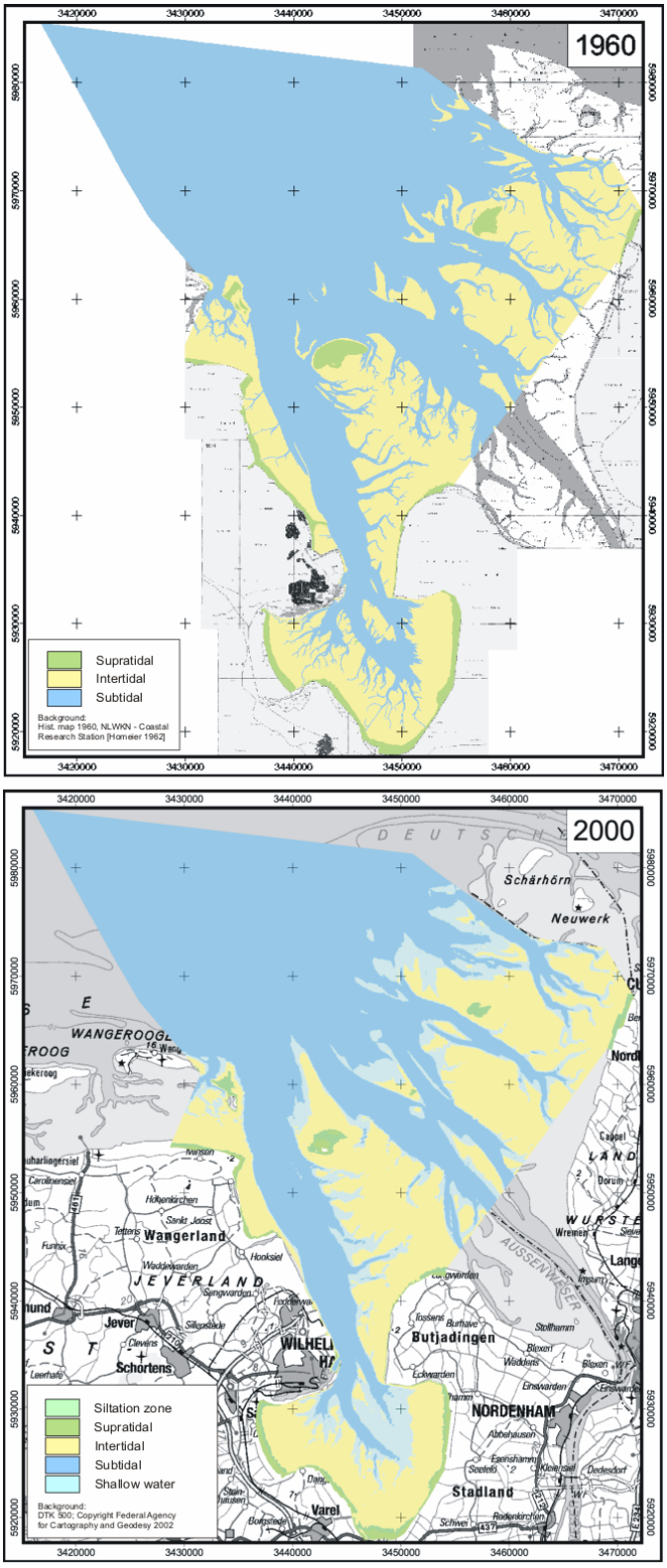

Fig. 5: Littoral habitats of the situation of 1960 and 2000 in the Outer Weser Estuary (Area: Coastal Waters)

The supratidal area amounted to in 1860 as well as in 2000, an area of about 40 km². It is noted that in 1960 the area had increased at first to 43 km² and then decreased in 2000 again down to 40 km². Indeed it is to be stated that in contrast to the conditions of 1860 and 1960, another analysis method was applied in the year 2000 and therefore the results are limited regarding their comparability. However, the results indicate on a whole that no essential changes have appeared for the complete considered period (fig. 6).

For the condition in 2000, a finer subdivision of the sub- and supratidal could be applied on account of the available data material. With respect to this, 192 km² from the large subtidal area registered at 1097 km², can be assigned to the shallow waters. Therefore 17.5% of the complete sub-tidal area of the coastal waters are to be looked at as shallow waters. When considering the supratidal total area of 40 km², 21 km² can be classified to the siltation zone which takes up thus a 52.5% portion of the supra-tidal area. Indeed an essential portion of this that lies in the low-tides flats will never become a part of the foreland.

Zone	Area [km²]				
	1860	1960	2000	Part	2000
Subtidal	1044.92	1070.18	1096.77	Shallow water	192.40
Intertidal	591.1	537.16	486.12		
Supratidal	39.48	43.14	40.32	Siltation zone	20.94
Sum:	1675.5	1650.48	1623.21		

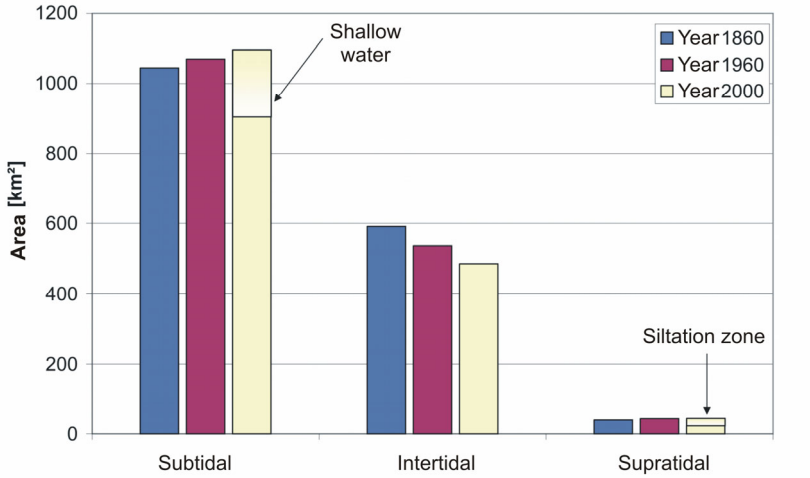

Fig. 6: Development of the habitat surfaces in the Outer Weser Estuary for the situations of 1860, 1960 and 2000 (Area: Coastal Waters)

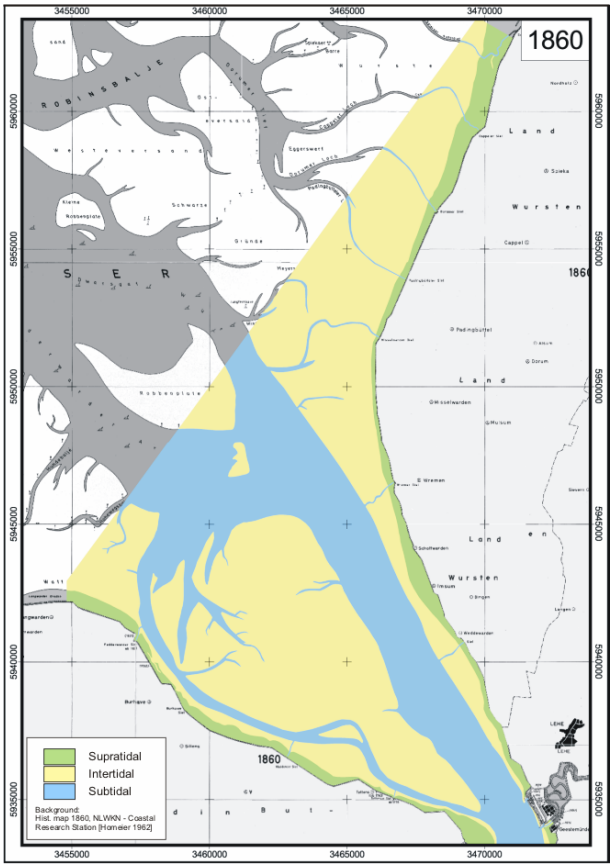

Fig. 7: Littoral habitats of the situation of 1860 in the Outer Weser Estuary (Area: Transitional Waters)

4.1.3. Transitional Waters of the Outer Weser Estuary

The transitional waters of the Outer Weser according to the definition of the EC-WFD is shown on the same basis (fig. 7 and 8) as the coastal waters with analogous shades to allow a comprehensive optical comparison. The harbor area of Bremerhaven has deliberately not been taken into consideration in this case, for the reason that its architectural development is not of interest to this investigation and unimportant for the other ascertained results.

In the case of the investigation of the total area of the transitional waters, there proves to be a reduction of the area of approximately 14 km² from the beginning area of 204 km² in the year 1860 and finally to 190 km² in the year 2000. In the course of which the total habitat area decreased between 1860 and 1960 approximately 7 km² and during the following 40 years it decreased about another 7 km ².

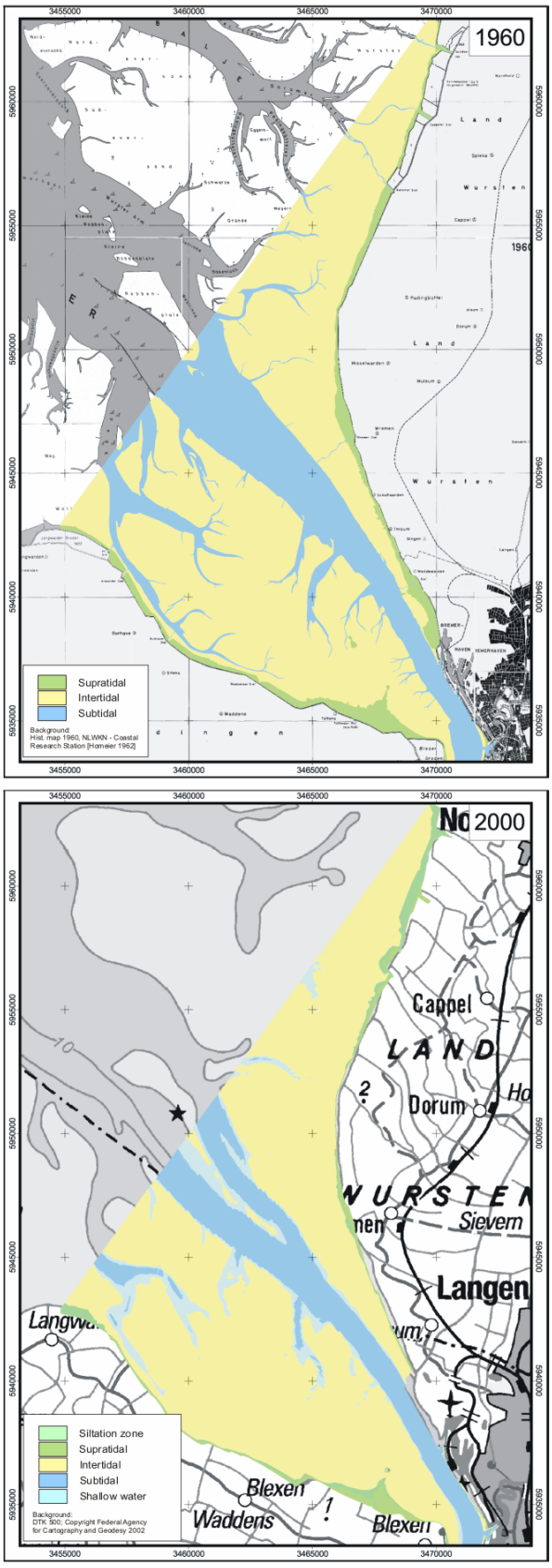

Fig. 8: Littoral habitats of the situations of 1960 and 2000 in the Outer Weser Estuary (Area: Transitional Waters)

The subtidal area of the transitional waters shows from 1860 an area of 69 km² up until the year 2000 an area of 44 km² thus an obvious reduction of the investigated area of about 25 km². Already up until the year 1960, there was a distinct decrease determined of approximately 18 km² (fig. 9).
In the intertidal area, however, an increase of 119 km² was observed in the year 1860 and increased to 137 km² in the year 2000. Therefore the area of the intertidal expanded to approximately 18 km² in the investigation time period whereas the largest increase of 16 km² occurred between 1860 and 1960 (fig. 9).

The area above the mean high tide level shows a reduction of the area from 16 km² in 1860 to 9 km² in 2000 which was caused by the seaward advancement of the dyke line, in particular around and near the locations of Spieka-Neufeld, Cappel-Neufeld and Dorumer Siel. In this case also the larger changes took place between 1860 and 1960 (fig. 9).

Analogously for the evaluations of the coastal waters of the Outer Weser, a finer subdivision of the sub- and supratidal areas were done with the area data of 2000.

In the subtidal area of the transitional waters, 15 km² can be allocated to the shallow water zone from the 44 km² of the total investigated area. This part corresponds to 34% of the subtidal area in the transitional waters.

From the massive 9 km² supratidal area, 5 km² of this total area is classified as the siltation zone. The 53.5% percentile of the supratidal area indicates the enclosure of other areas located up to the mean spring high tide water level which do not lie directly before salt marshes.

Zone	Area [km²]				
	1860	1960	2000	Part	2000
Subtidal	68.99	51.24	44.3	Shallow water	14.55
Intertidal	119	134.56	137.04		
Supratidal	16.11	10.96	8.75	Siltation zone	4.65
Sum:	204.1	196.76	190.09		

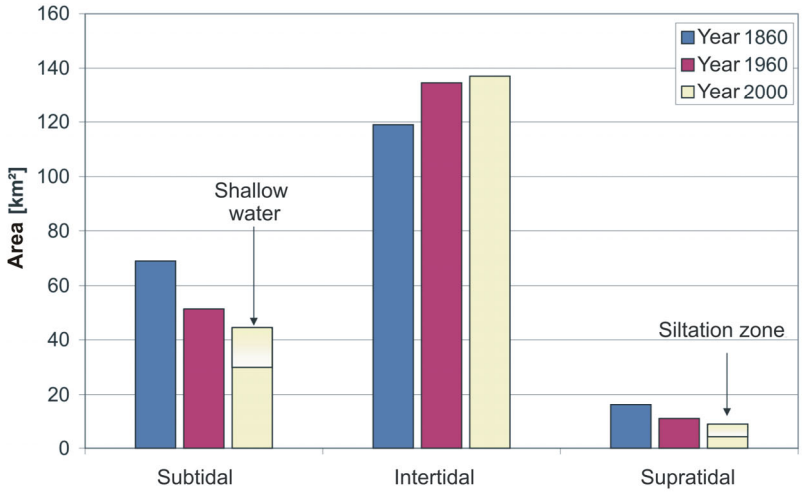

Fig. 9: Development of the habitat Surfaces in the Outer Weser Estuary for the situations 1860,1960 and 2000 (Area: Transitional Waters)

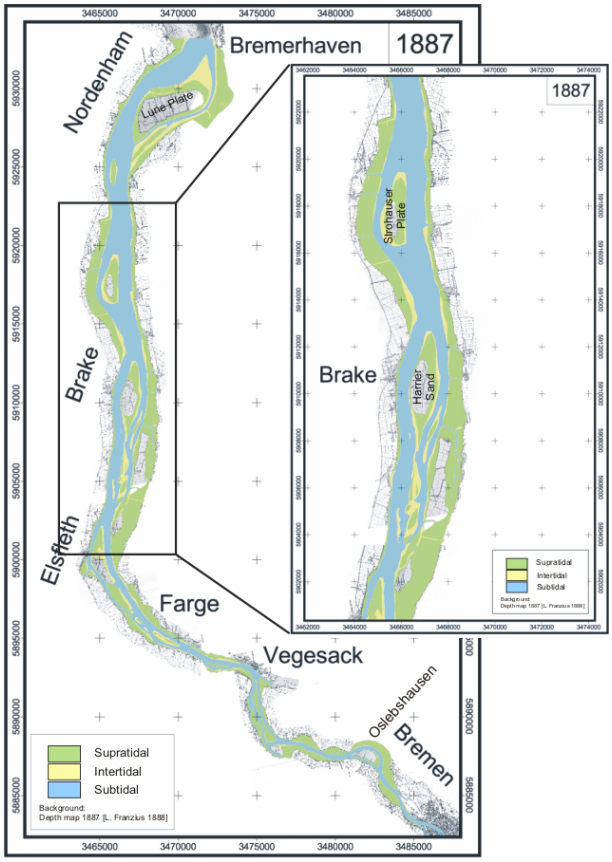

Fig. 10: Littoral habitats of the situation of 1860 in the Lower Weser Estuary

4.2. Spatial Habitat Balance in the Lower Weser Estuary

The area investigations of the Lower Weser habitats were methodically determined analogous to the calculations of the upper Weser with a regular 5 x 5m grid for the area from Bremerhaven (65 km) to Bremen (0 km - "Wilhelm Kaisen-Bridge"). The mean low and high tide water levels required for the area balancing were taken for the conditions of 1887 from the layouts of Ludwig Franzius (FRANZIUS 1888) and for the conditions in 1972 as well as in the year 2000 from the German yearbook of hydrology.

For the years 1972 and 2000, a refined division of the tidal areas can be carried out when the subtidal shallow water zone and the supratidal siltation zone between the mean high tide and the mean spring high tide are additionally distinguished. This differentiation cannot be done for the area comparisons with the conditions of 1887

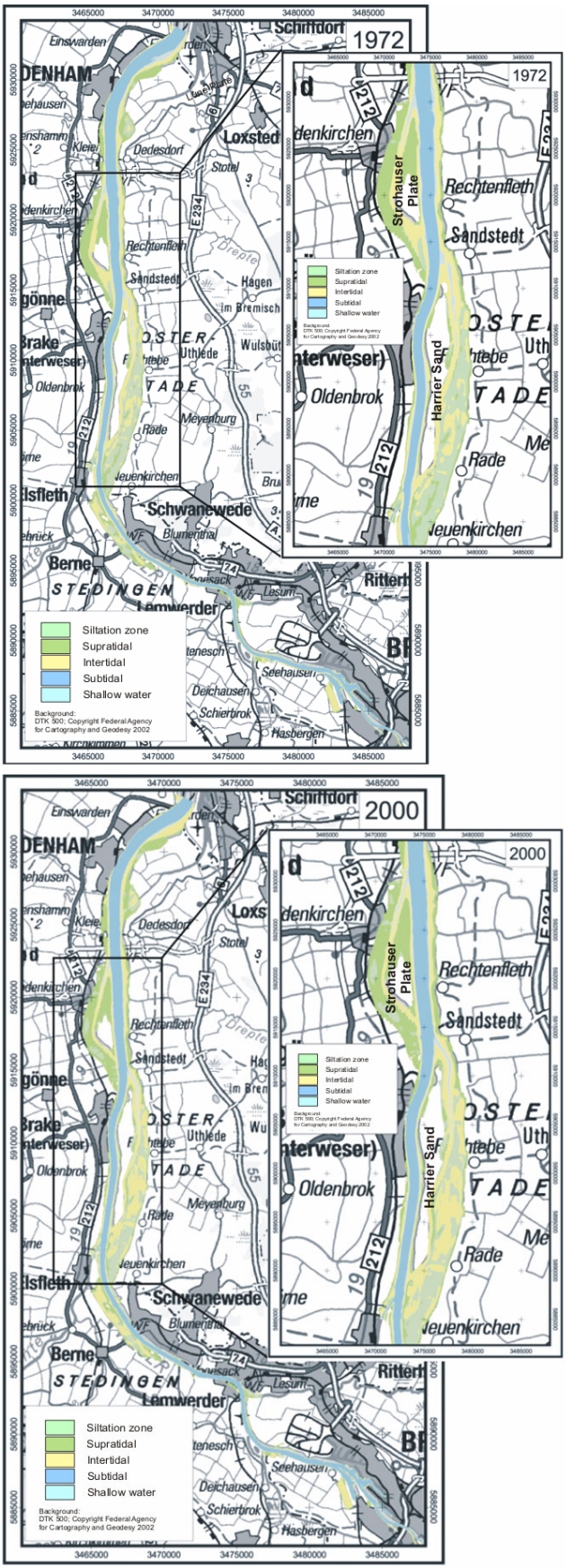

Fig. 11: Littoral habitats of the situations of 1960 and 2000 in the Lower Weser Estuary

because of an unavailable suitable date base.

The marsh waters of the Lower Weser have a huge number of islands and sand bars which are partially spared of floods through dykes (fig. 10). Therefore these structures are to be excluded from the spatial balance: The Lune Plate, the Harrier Sand, the Strohauser Plate as well as areas around the locations of Elsfleth and Oslebshausen.

The massive changes in the Lower Weser during the investigation period from 1887 to 2000 become obvious in the cartographic comparison of the different habitat zones (fig. 10 and 11). To emphasize the special intensive transformations of the tidal areas from 1887 until today, the regions around the Strohauser Plate and the Harrier Sand are specifically shown as an enlargement (fig. 10 and 11).

The area showed a reduction of the total area from 118 km² to 91 km² on the basis of the ascertained areas from the year 1887 to 2000. This resulted as an area loss of 27 km² which can be explained to a great extent by the building of dykes for example in the regions of Blexer Bogens and the Lune Plate.

In the subtidal area, a reduction was determined from 57 km² in the year 1887 to 37 km² in the year 2000. This corresponds to a decrease of the subtidal area of 20 km². This loss originated predominantly before 1972, after this the changes were relatively slight. However, the change for the shallow water area is comparatively large in relation to the entire change in the subtidal during the period from 1972 to 2000. The intertidal showed for the complete investigation period an increase of 12 km² in the year 1887 and also an increase of 22 km² in the year 2000. This resulted therefore in a growth of 10 km² in the intertidal area.

This increase originated predominantly in the period between 1887 and 1972. Afterwards the area of the intertidal increased only slightly (Abb.12). The spatial balance confirms as a whole the phenomenon that estuarine dredging and deepening increases the intertidal area at the expense of subtidal areas and in particular at the expense of the shallow water area. This particularly becomes clear in the disproportionate decrease between 1972 and 2000 (fig. 12). Altogether the area increase of the intertidal reflects the inclination of the loss of the subtidal. Indeed, an area loss was ascertained in both the intertidal and subtidal areas: only half of the area losses in the subtidal are reflected as an area profit in the intertidal (fig. 12).

Zone		Area [km²]				
		1887	1972		2000	
Subtidal	Deep water zone	56.8	37.22	30.79	36.52	31.45
	Shallow water zone			6.43		5.07
Intertidal	Low-tide flat zone	12.17	20.31	20.31	21.65	21.65
Supratidal	Siltation zone	49.01	31.97	13.73	32.42	12.29
	Marsh or Foreland			18.24		20.13
sum		117.98	89.5		90.59	

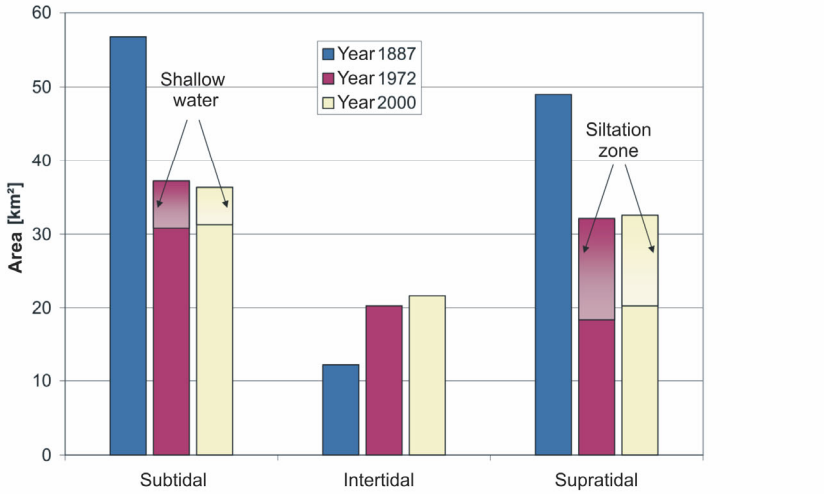

Fig. 12: Development of the habitat surfaces in the Lower Weser Estuary for the situations of 1860, 1960 and 2000

In the area above the mean high tide water level, a decrease of the investigated area was determined at 49 km² in 1887 to 32 km² in 2000. As a result, a total area loss of 17 km² arose in the supratidal (fig. 12). Also in this case, the decrease in area had taken place predominantly between 1887 and 1972.

The portion of the shallow zone in the sub-tidal area amounted to 6.4 km² from 37 km² at 17% in the year 1972. For the year 2000, the sub-tidal was registered at a total of 37 km² from which 5 km² is classified to the shallow water area which corresponds to a proportional part in the subtidal area of 14%. The supratidal had in 1972 a size of 32 km². The area portion of the siltation zone amounted to 14 km² which equals to as 44%. In the year 2000 the subtidal is likewise large at 32 km². The subtidal area of the range between the mean high tide and the mean spring high tide amounts to 12 km². The proportional interest has dropped therefore, to 37.5%.

Remarkably for the interval from 1972 to 2000 is that analogous, the shallow water zone decreases over proportionally to the supratidal siltation zone.

5. Summary

The investigation of the area situation of the Outer Weser coastal waters has resulted in the comparison of the conditions in 1860 and 2000 to a reduction of 3% in which half of the area loss originated between 1960 and 2000. The coastal waters showed an area enlargement in the subtidal of 5% during the investigation period. In the supratidal, there were no observed essential area changes. However, the area of the intertidal decreased to an area portion of approximately 18% during the investigated time periods. In this case also, half of the area loss occurred between 1960 and 2000.

In the transitional waters of the Outer Weser, the analysis proved a reduction of 7%. Hence, there was an observed area decrease of 36% in the subtidal range and an observed area increase of 15% in the intertidal area. The supratidal registered an area decrease of 46% which was caused by seaward advance of the dyke line done in the areas of Spieka-Neufeld, Cappel-Neufeld and Dorumer Siel. With the growth of the intertidal and the decrease in the subtidal – in reference to the complete investigation period - the changes between 1960 and 2000 were shown as over proportional high.

The littoral area situation of the Lower Weser was proved by the investigation to have major changes in the area balance which were caused by the interventions of Franzius during the first Weser correction. The reduction of 23% of the total area is especially striking, on this occasion. Thus considering the investigation period of 140 years, the area of the subtidal was reduced to approximately 36% as well as the area of the supratidal had a reduction of approximately 34%. However, the area of the intertidal on the other hand increased to approximately 78%.

In the coastal waters of the Outer Weser, in accordance with the classification by the Water Framework Directive of the European Community which also includes Jade and Jade Bay, as well as in the transitional waters of the Weser, there were distinct changes determined for both investigation periods in 1860/1960 and 1960/2000. Also it is to be assumed that the most changes took place during the first period from the beginning of the 20th century since starting from this time on appreciable anthropogene interventions occurred (NIEMEYER ET AL 1996). The effectiveness becomes also clear by the fact that the changes of the intertidal are over proportionally high in the investigation period of 1960/2000 measured over the complete investigation period.

In the Lower Weser, however, the changes are much more dominant in the first investigation period of 1887/1972 than between 1972 and 2000. This is attributed in particular to the lasting effect of the Franzius correction which was successfully designed to cause a morphodynamical follow-up other than just the virtual immediate change of the topography (NIEMEYER ET AL 1996). Even the considerable changes by the hydrodynamics SKN-9m development after 1972, in comparison to the changes in the preceding investigation period, had only sustainable consequences to the change of littoral areas.

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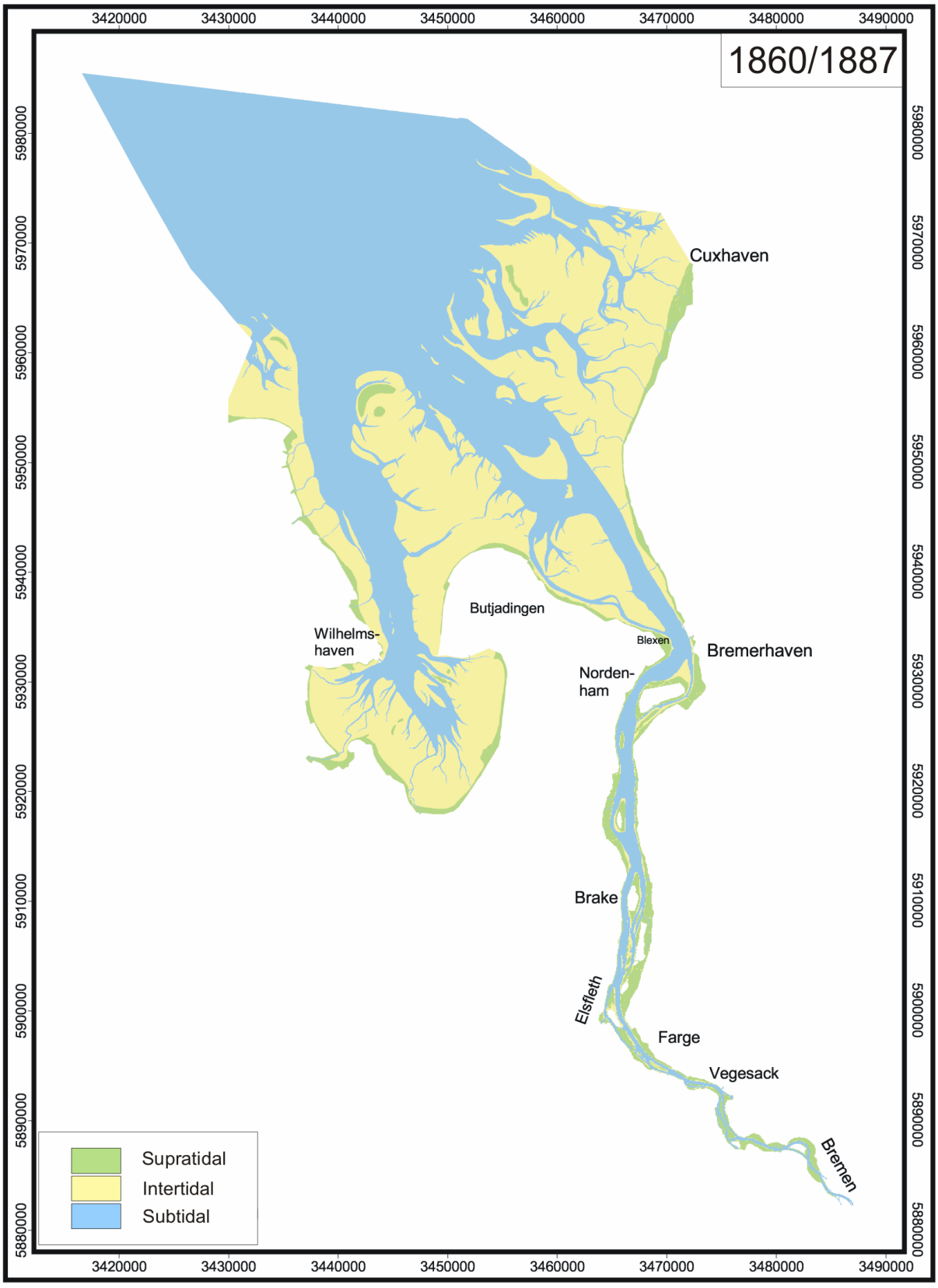
7. Appendix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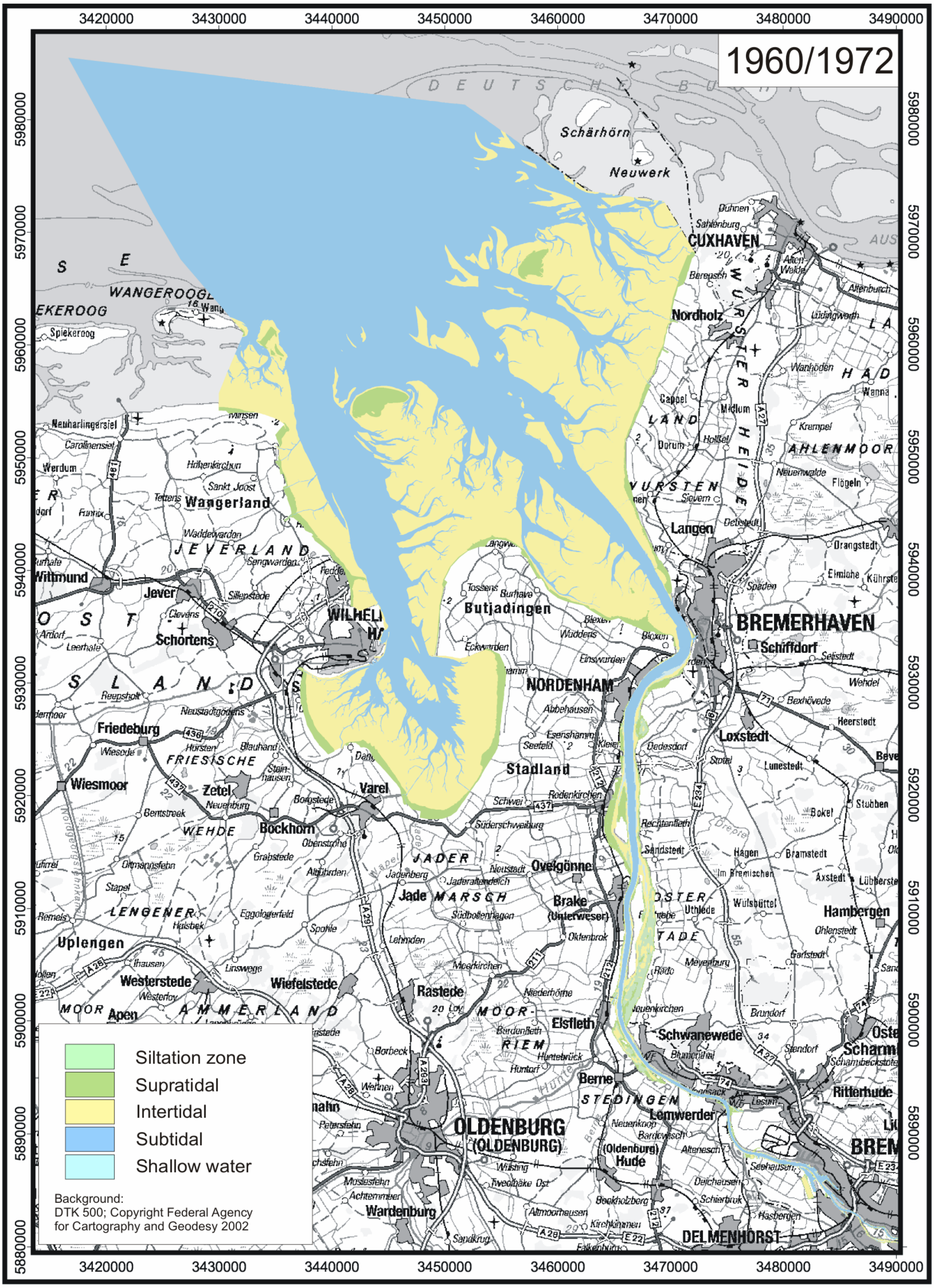
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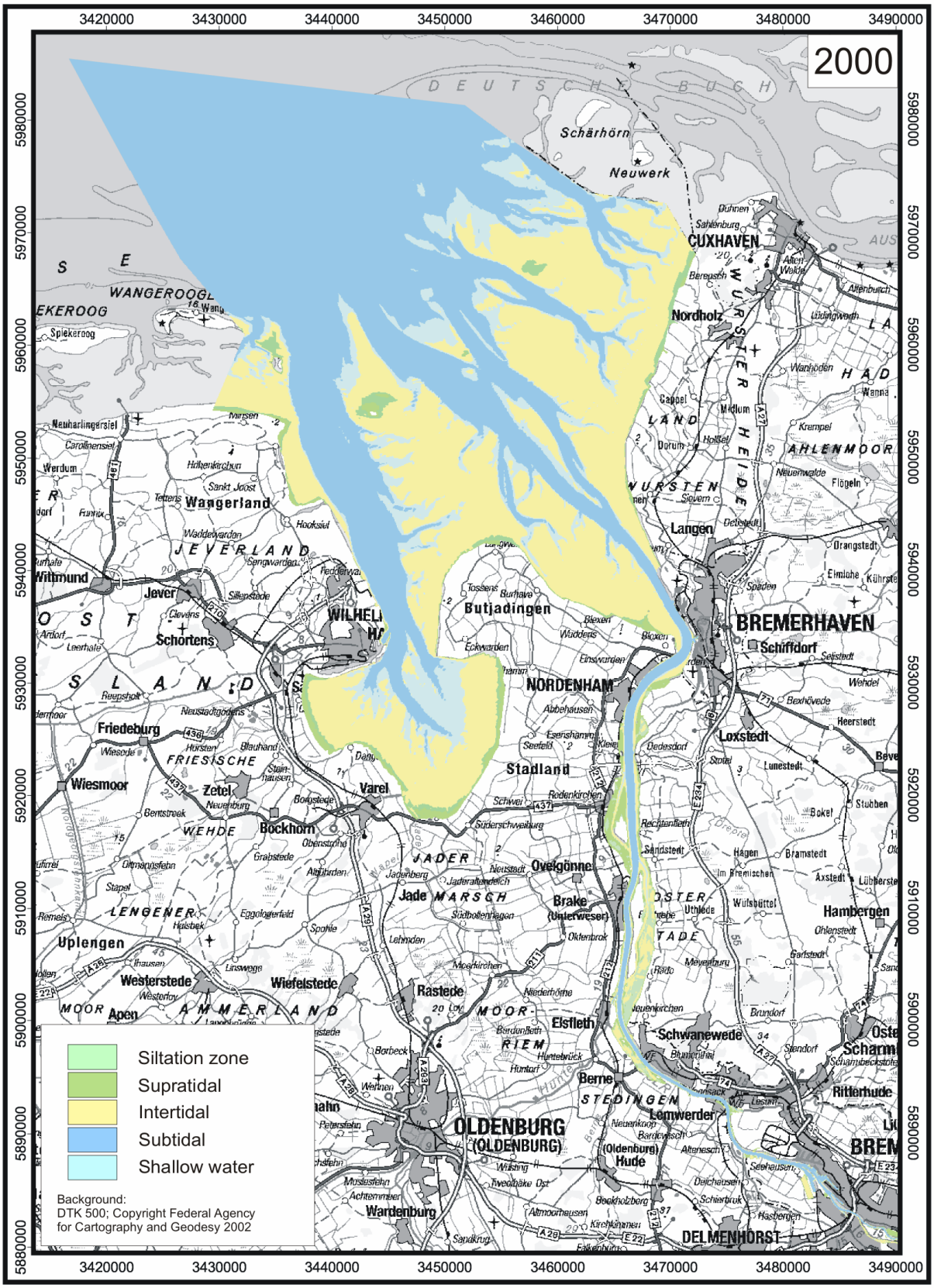
Nordholz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WANGEROOGE
Spiekeroog
Wangerland
JEVERLAND
Wittmund
Jever
Schortens
WILHELMSHAVEN
Butjadingen
BREMERHAVEN
Schiffdorf
NORDENHAM
Langen
Friedeburg
Wiesmoor
Zetel
Varel
Stadland
Loxstedt
Bockhorn
Ovelgönne
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Uplengen
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Schwanewede
Berne
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OLDENBURG (OLDENBURG)
Hude
Ritterhude
Wardenburg
DELMENHORST
Siltation zone
Supratidal
Intertidal
Subtidal
Shallow water
Background:
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