Ministerie van de Vlaamse Gemeenschap
Departement Leefmilieu en Infrastructuur
Administratie Waterinfrastructuur en Zeewezen
Dienst der Kusthavens - Hydrografie

OOSTENDE

SYNOPSIS OF THE TIDAL OBSERVATIONS ALONG THE BELGIAN COAST CONCLUSIONS WITH RESPECT TO THE HIGH WATER, THE MEAN SEA AND THE LOW WATER LEVELS.

by

C. VAN CAUWENBERGHE

Coastal Hydrographic Service -Ostend - Belgium

- ***Rapport nr. 37bis van de Hydrografische Dienst der Kust.***
- ***Final report of the contract EPOC - CP - 0015 - Participant 23 - Dienst der Kusthavens - Hydrografie - Oostende.***

DIENST DER KUSTHAVENS
HYDROGRAFIE
OOSTENDE.

SYNOPSIS OF THE TIDAL OBSERVATIONS ALONG THE BELGIAN COAST - CONCLUSIONS WITH RESPECT TO THE HIGH WATER,THE MEAN SEA LEVEL AND THE LOW WATER LEVELS.

by Ing.C.Van Cauwenberghe.

* * *
* *
*

1.INTRODUCTION.

Many scientists accept that the increase in carbon dioxide (CO_2) and other gases, concentrated in the atmosphere, which are generated by industry, may, in a not too distant future, lead to irreversible global changes in sea level, i.e. may produce the so called "greenhouse effect".
The analysis of reliable past, and more recent, tidal elevation data, such as those of High Water (HW), Mean Sea Level (MSL) and Low Water (LW), can yield information about this development.
The prognosis of future events should be based on a wide range of climatic research and applied to the production of climatic models.

2.THE QUALITY OF THE DATA.

Before attempting to analyse the data, we must consider its value and usefulness. The observations need to have been reliable and to have been obtained over extended and uninterrupted periods.
The Annexes 1, 2 and 3 give a synopsis of the periods of the tidal observations along the Belgian coast, i.e. for Oostende, Zeebrugge and Nieuwpoort; here the periods, for which a harmonic analysis occurred, are also indicated.
As can be seen from these, there are significant gaps in these series, particularly for Oostende.
In the case of Oostende (see Annex 1), reasonably good observations began as long ago as 1820, but unfortunately the data are lost; all the other earlier records, predating World War I, were carefully examined.
The usefulness of those records were judged to be:

(1)For the period 1835-1852, the monthly values of HW/LW are based on continuous records, read from a tide-gauge, close to a lock in the harbour of Oostende (Ref 3) and near to a reliable benchmark, to which the gauge was referred. This benchmark was incorporated in a quay wall.

Because only monthly mean values of HW/LW were available, mean tide levels (i.e.the mean of HW and LW) could be calculated. The difference between this level and MSL along the Belgian coastline is nearly constant;e.g. for the period 1949-1988 the difference is +0,063 m.

So, knowing the correct mean tide levels, we were also able to determine the MSL-value for each year of the period concerned.

(2)The period 1878-1914 is NOT useful for this study, because there are too many interruptions in the data and because the reference datum is uncertain.
There are some data for the periods 1878-1885 and 1902-1914, which are unfortunately frequently interrupted.
Comparing the yearly values for these periods with those of Vlissingen (The Netherlands), we found sometimes differences of more than 10 cm, whereas only 3 or 4 mm are the normal values for years with reliable observations.

(3)From 1925 till now, the records of the years 1925, 1926 and most of the years during World War II (1940, 1941, 1942 and 1944) are very discontinuous; so we decided not to use them in this study, except when using the technique of moving averages (see 3.2).
For Nieuwpoort and Zeebrugge continuous data are only available respectively from 1967 and 1962 onwards.

3.LOCAL TRENDS FOR HW, MSL AND LW.

As periods of 25 and 30 years for Nieuwpoort and Zeebrugge are rather short, we decided not to use this information for the time being. Only the records of Oostende were considered for further examination.

3.1.Linear curve fittings.

Annex 4 represents the values of HW, MSL and LW.
These data are referred to TAW (Tweede Algemeene Waterpassing), being the Belgian National Reference Level.
Best fit calculations through these 3 annual values (linear, exponential, logarithmic, binomial) are also available, but only the equation of the least squares linear fit, is indicated in the same Annex.
For the 3 values a linear increase of 0,01 m/decade can be noted, if the two periods are taken into account: 1835-1852 and 1927-1991 (less the 4 years of the World WarII).
On the other hand, if only the last period, less the years as mentionned, is considered, we find for HW, MSL and LW a rise of 0,02 m - 0,015 m and 0,01 m/decade.

From the Dutch Rijkswaterstaat we kindly received the corresponding information for Vlissingen, for a reliable period of 102 years (1890-1991). We transformed the data by referring these to TAW as well.
In the Annex 5 we see some increases of 0,03 m - 0,02 m and 0,015 m/decade for the 3 levels, as mentionned before.

3.2.Cyclic curve fittings.

To understand why this method of curve fitting is used, it is necessary to explain the movement of the moon's node on the ecliptic (solar orbit).

The point, where the moon crosses the ecliptic from the south to the north/the north to the south is called the ascending node/the descending node. The length of the ascending node has the vernal equinox (first point of Aries) as reference; with values of 90° and 270° as length of the ascending node, the tidal range has a mean value, while with 0° and 180° the tidal range has a minimum / maximum value.
The regression of the ascending node is just the movement westwards along the ecliptic. Due to the regression of both of the nodes, the obliquity of the lunar orbit to the celestial equator will change progressivily with each orbit between a variable maximum and a minimum value (i.e. 23°27'+ 05°09'= 28°36' or 23°27'- 05°09'= 18°18') with a periodicity of 18,61 years.
In other words, the declination of the moon is characterised generally by 2 periodicities, first the lunation-period of 29,53 mean solar days (synodic period), due to the rotation of the moon around the earth (which, on its turn, moves around the sun), and secondly the period of 18,61 years, which is called the nodal cycle.

The Annexes 6 and 7 show the values of HW and LW for Oostende with the fittings of a cyclic trend; for reasons of comparison the similar curves for Vlissingen also have been given in the Annexes 8 and 9.
For Oostende nearly the same increase of 2 mm/year for HW and 1 mm/year can be noted, while for Vlissingen again the annual increase amounts to nearly 3 mm/year for HW and to 1 mm/year for LW.

3.3. Moving averages.

Further it was considered that the use of moving averages could be interesting in order to eliminate the oscillations and afterwards to detect any acceleration in the increase of HW, MSL and LW levels; also the similar values of Vlissingen have been added in the Annexes 10, 11, 12, 13, 14 and 15, where successively groups of observations of 1, 7, 13, and 19 years have been taken into consideration for the period 1927-1991.
In none of the pictures of both places we see up to now any significant indication of an acceleration in the increase of the values concerned.

* * *

These conclusions on the rise of the 3 levels only are valid if the land is not subject to crustal movements from isostatic or eustatic origin.
However, geologists in our country have good reasons to believe that Oostende has had a rather high degree of stability of the substratum since the quaternary period.
Probably this statement is not valid for Vlissingen, where indeed we see a greater increase in the levels, due to the subsidence of land.

As time passes by, it will be highly desirable to pay attention to the evolution of the sea levels very closely.

REFERENCES

1. J.LAUWERS. Les marées du port d'Ostende. Annales des Travaux Publics de Belgique. Aout 1930.
2. L.JONES et R.HEIDERSCHEIDT. Surfaces de niveau zéro belges et zéro hydrographique H. Annales des Travaux Publics de Belgique. Juin 1952.
3. J.HENRIONET. Notice sur les travaux topographiques exécutés au Dépot de la Guerre de Belgique. Archives de l'Institut Géographique Militaire. Bruxelles, 1876.
4. A.STESSELS. Discussion des observations de la marée et ses effects dans l'Escaut. Annales des Travaux Publics de Belgique. Tome XXX, Deuxième Cahier. 1872.
5. M.BOVIE. Etude sur la régime de la marée au port d'Ostende. Annales des Travaux Publics de Belgique. Tome XLIV, 1887.
6. P.MELCHIOR et P.PAQUET. Les constantes des marées océaniques au port d'Ostende de 1882 à 1964. Koninklijke Academie van België-Mededelingen van de Klasse der Wetenschappen-5e Reeks-Boek LIV-1968, 10.
7. J.LAUWERS. Les marées des ports d'Ostende, de Zeebrugge et de Nieuwpoort. Annales des Travaux Publics de Belgique. Avril - Juin 1949.
8. C.VAN CAUWENBERGHE. Overzicht van de tijwaarnemingen langs de Belgische kust. Periode:1941-1970 voor Oostende, 1959-1970 voor Zeebrugge en Nieuwpoort. Tijdschrift der Openbare Werken van België. Nr.4, 1977.
9. P.MELCHIOR, P.PAQUET et C.VAN CAUWENBERGHE. Analyse harmonique de vingt années océaniques à Ostende. Koninklijke Academie van België. Mededelingen van de Klasse der Wetenschappen-5e Reeks-Boek LIII-1967,2.
10. C.VAN CAUWENBERGHE. Overzicht van de tijwaarnemingen langs de Belgische kust. Periode: 1972-1980 voor Nieuwpoort, Oostende en Zeebrugge. Tijdschrift der Openbare Werken van België. Nr.5, 1985.
11. C.VAN CAUWENBERGHE. Overzicht van de tijwaarnemingen langs de Belgische kust. Periode: 1981-1990 voor Nieuwpoort, Oostende en Zeebrugge. Will be published later on in "Infrastructuur in het Leefmilieu" of the "Ministerie van de Vlaamse Gemeenschap".

Ostend, 04 March 1993

Ing.C.Van Cauwenberghe

Head of the Coastal Hydrographic Service

DIENST DER KUSTHAVENS
HYDROGRAFIE
OOSTENDE

Annex 1

PERIODS OF

THE TIDAL OBSERVATIONS

for **OOSTENDE** (Belgium).

Period	Tide pole(a) or automatic tide gauge(b)	Harmonic analysis	References/Remarks
1820-1834	(a)	No	Ref 1 & 2 Data are lost
1835-1853	(a)	No	Ref 3 Only monthly mean values available
1866-1871	(a)	No	Ref 4 Data are lost
1878-1914	(b)	Yes for 1882-1888 and for 1894-1912	Ref 5 & 6 Many interruptions Reference level not well known
1925-1940	(b)	No	Ref 1 & 7 Interruptions for 1925, 1926 & 1940
1941-1970	(b)	Yes for 1943-1968	Ref 7, 8 & 9 Interruptions for 1941, 1942 & 1944
1971-1980	(b)	Yes for 1976-1980	Ref 10 Continuous records
1981-1991	(b)	Yes for 1981-1991	Ref 11 Continuous records

DIENST DER KUSTHAVENS
HYDROGRAFIE
OOSTENDE

Annex 2

PERIODS OF

THE TIDAL OBSERVATIONS

for **ZEEBRUGGE** (Belgium).

Period	Tide pole(a) or automatic tide gauge(b)	Harmonic Analysis	References/Remarks
1932-1939	(b)	No	Ref 7 Interruptions for 1932
1941-1943	(b)	Yes for 1943	Ref 7 Interruptions from 1940 to 1943
1959-1970	(b)	Yes for 1963-1966	Ref 8 Interruptions from 1959 to 1961
1971-1980	(b)	No	Ref 10 Continuous records
1981-1991	(b)	Yes for 1983	Ref 11 Continuous records

DIENST DER KUSTHAVENS
HYDROGRAFIE
OOSTENDE

Annex 3

PERIODS OF

THE TIDAL OBSERVATIONS

for **NIEUWPOORT** (Belgium).

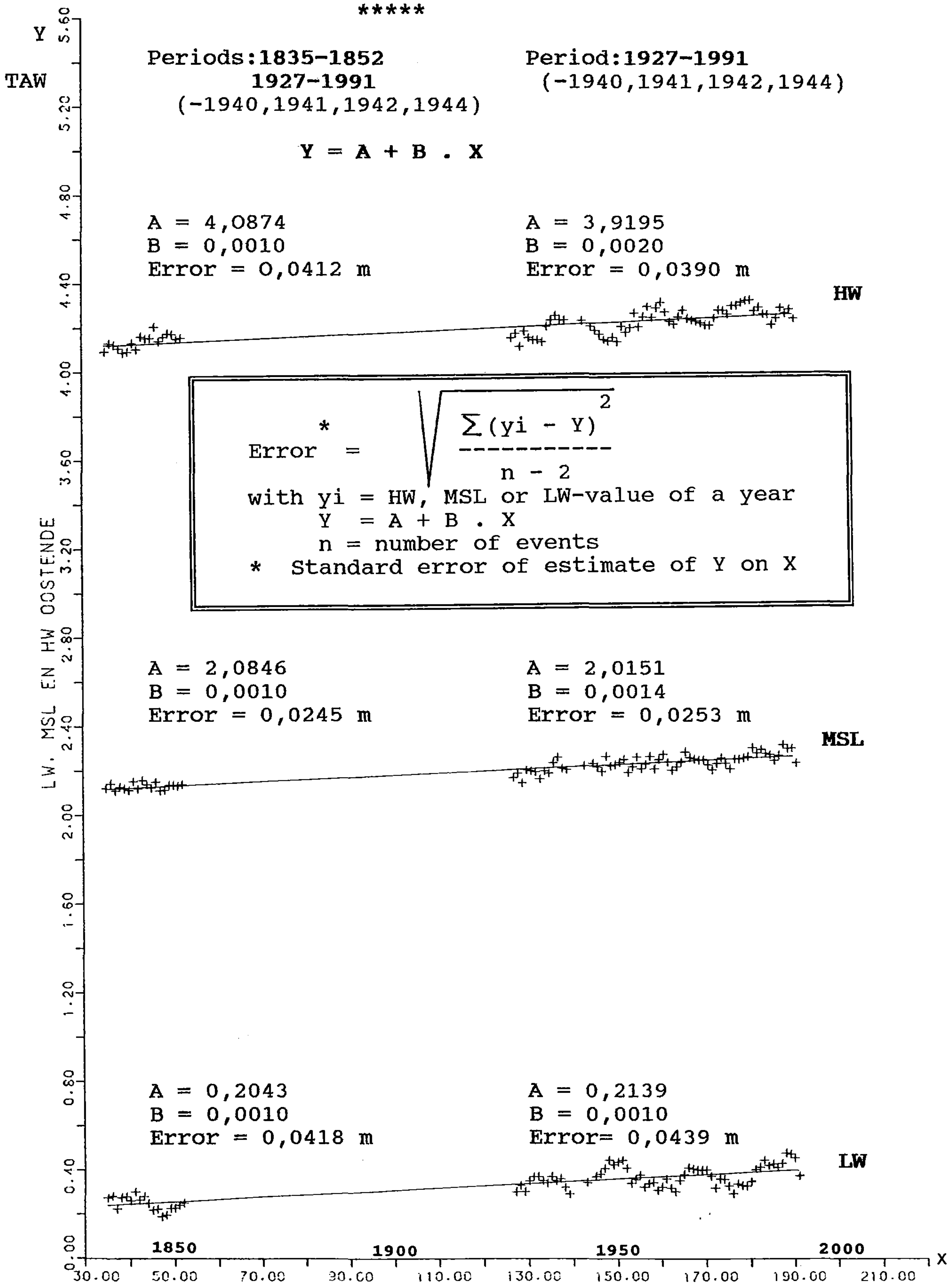
Period	Tide pole(a) or automatic tide gauge(b)	Harmonic Analysis	References/Remarks
1933-1938	(b)	No	Ref 7 Interruptions for 1933, 1937 & 1938
1941-1943	(b)	Yes for 1943	Ref 7 Interruptions for 1942 & 1943
1959-1970	(b)	Yes for 1967-1969	Ref 8 Interruptions for 1959, 1961 & from 1963 to 1966
1971-1980	(b)	No	Ref 10 Continuous records
1981-1991	(b)	Yes for 1983	Ref 11 Continuous records

DIENST DER KUSTHAVENS
HYDROGRAFIE
<u>OOSTENDE</u>

Annex 4

LINEAR TRENDS calculated on the Annual Values of **HW, MSL and LW** for **OOSTENDE** (Belgium).

*****

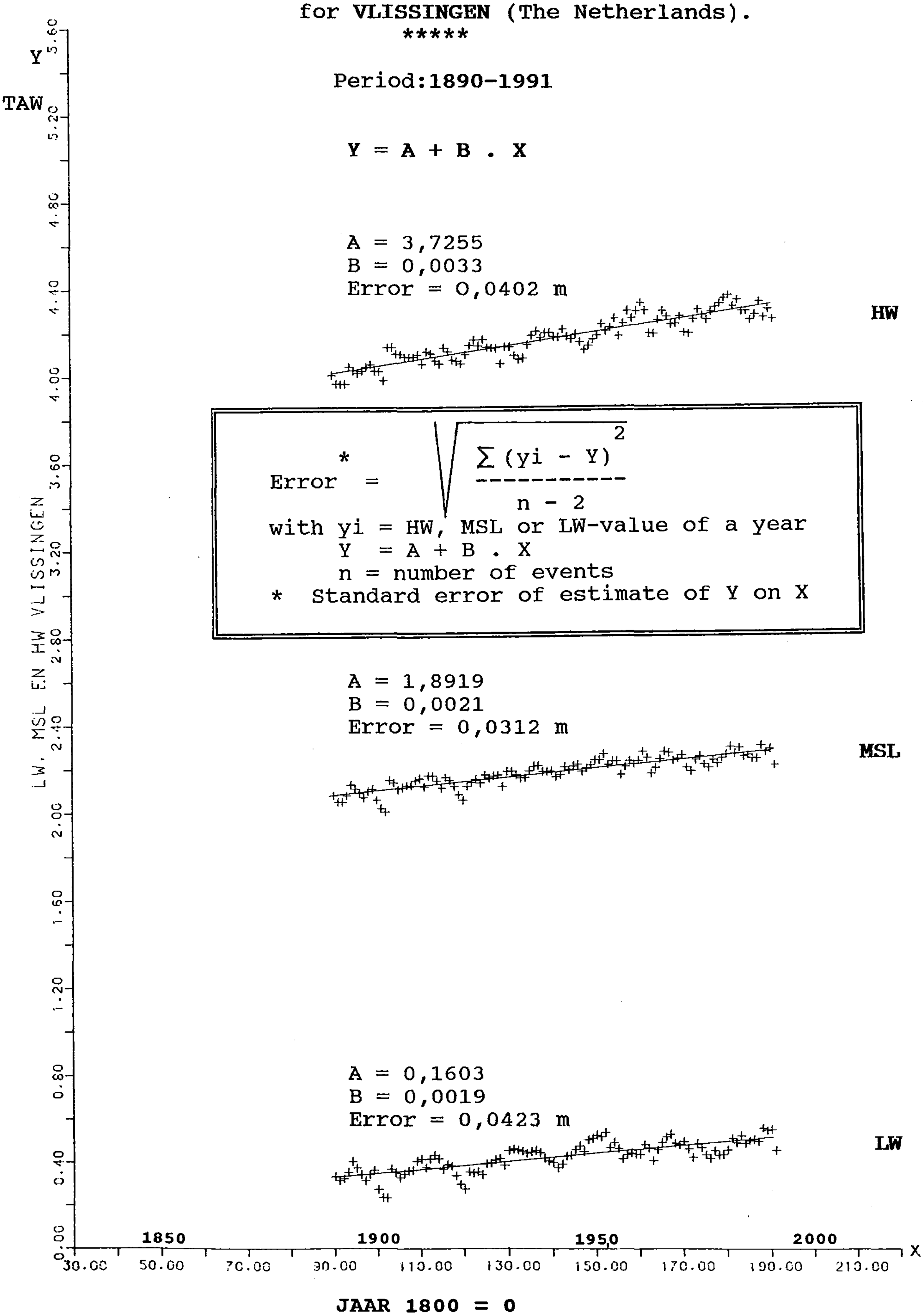


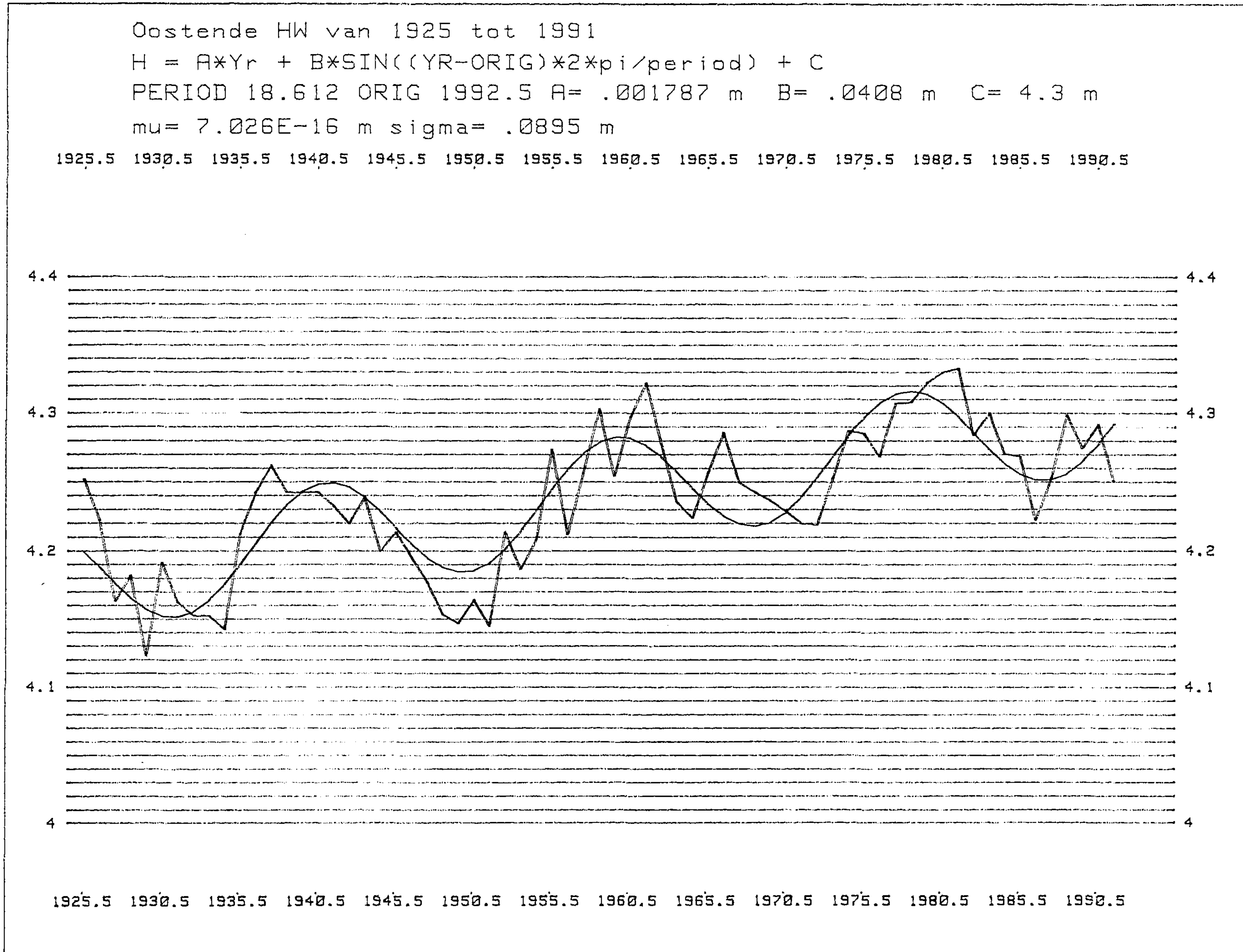
JAAR 1800 = 0

DIENST DER KUSTHAVENS
HYDROGRAFIE
<u>OOSTENDE</u>

Annex 5

LINEAR TRENDS calculated on the Annual Values of **HW, MSL and LW** for **VLISSINGEN** (The Netherlands).





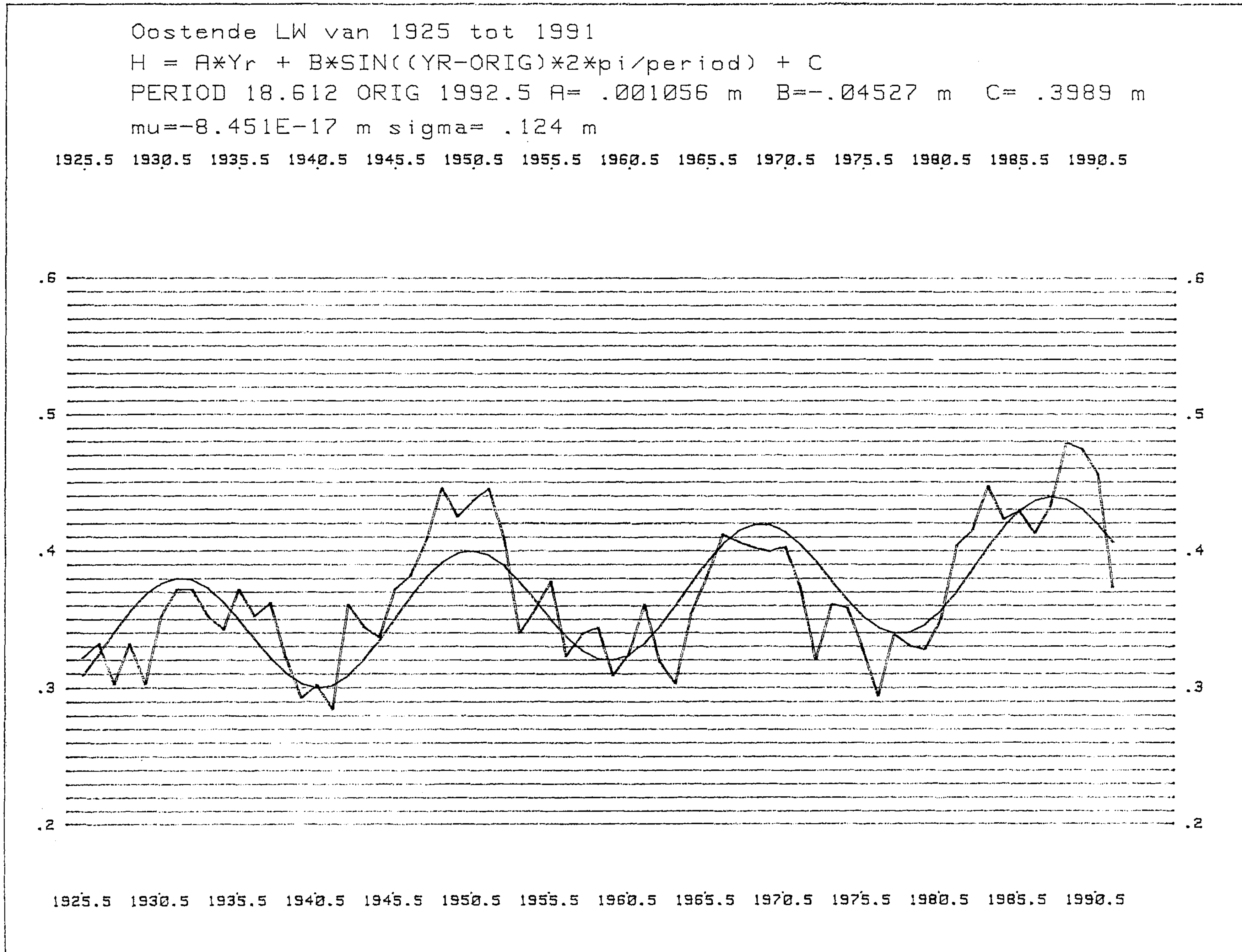
DIENST DER KUSTHAVENS
HYDROGRAFIE
OOSTENDE

CYCLIC TREND
calculated on
the Annual Values of **HW**
for **OOSTENDE** (Belgium).
****
Period:1925-1991

Annex 6

DIENST DER KUSTHAVENS
HYDROGRAFIE
OOSTENDE

CYCLIC TREND
calculated on
the Annual Values of **LW**
for **OOSTENDE** (Belgium).
****
Period:1925-1991



Annex 7

DIENST DER KUSTHAVENS
HYDROGRAFIE
OOSTENDE

Annex 8

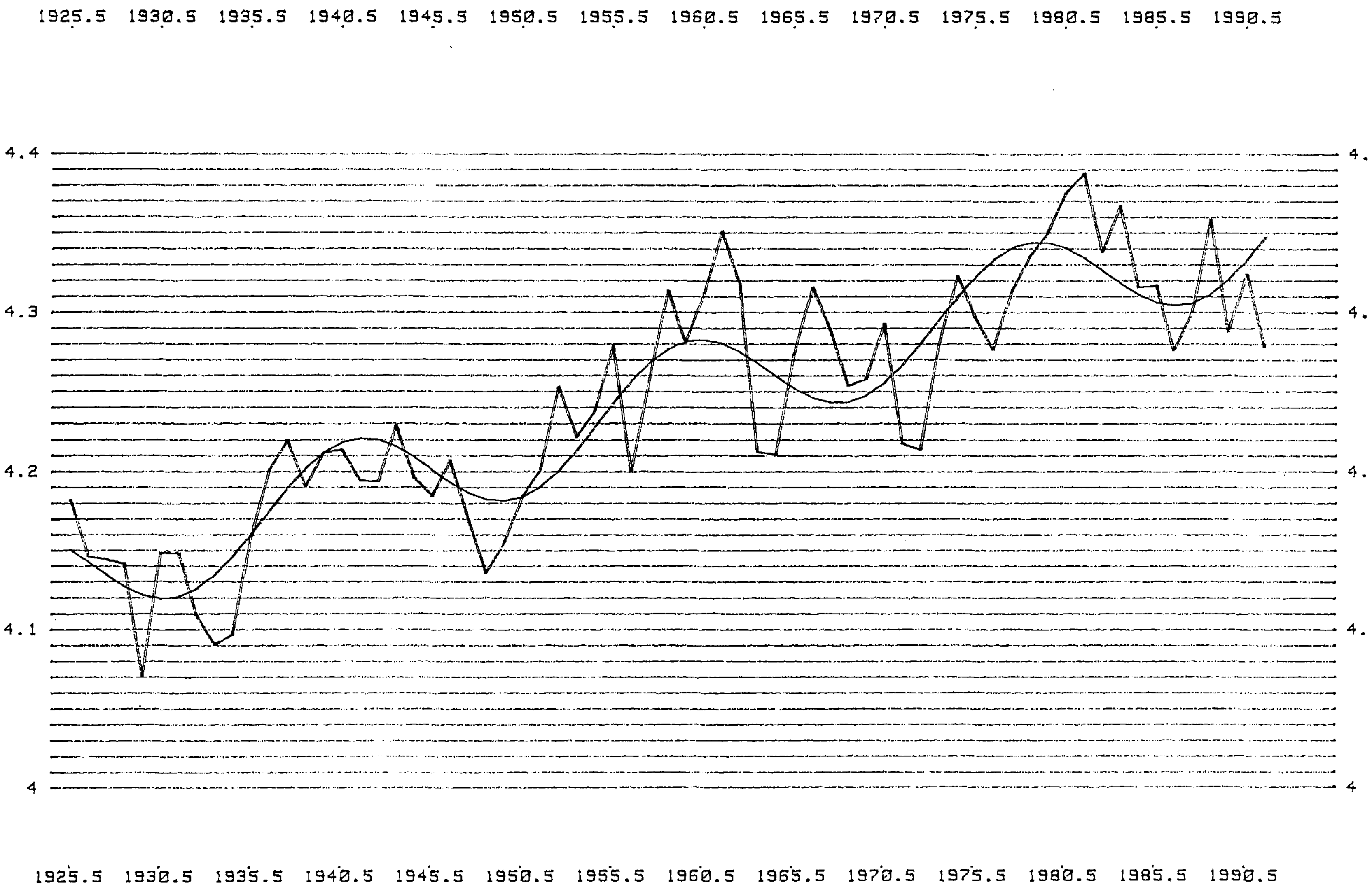
CYCLIC TREND
calculated on
the Annual Values of **HW**
for **VLISSINGEN** (The Netherlands).
***
Period:1925-1991

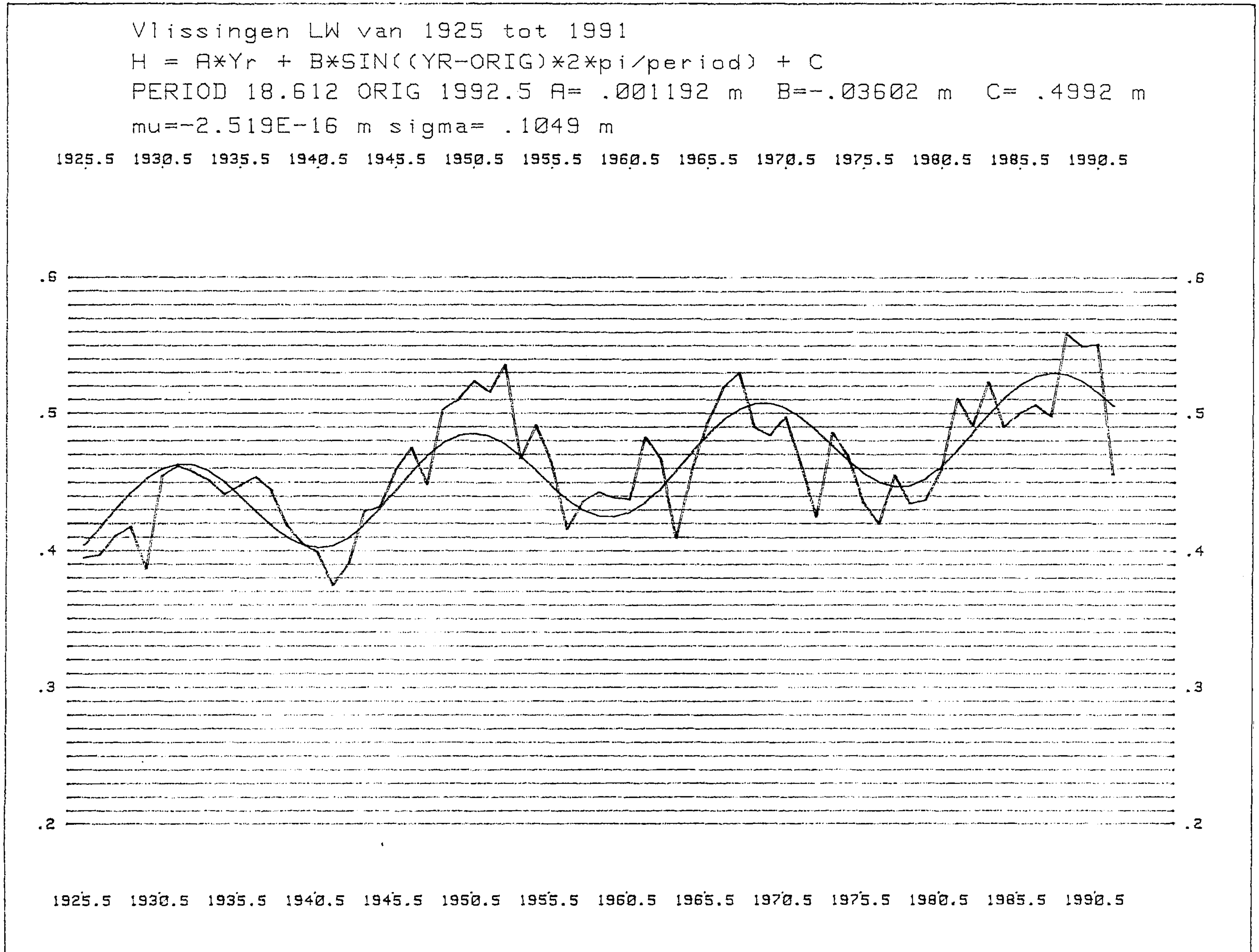
Vlissingen HW van 1925 tot 1991

H = A*Yr + B*SIN((YR-ORIG)*2*pi/period) + C

PERIOD 18.612 ORIG 1992.5 A= .003309 m B= .03418 m C= 4.355 m

mu= 3.049E-16 m sigma= .07301 m





DIENST DER KUSTHAVENS
HYDROGRAFIE
<u>OOSTENDE</u>

CYCLIC TREND
calculated on
the Annual Valued of **LW**
for **VLISSINGEN** (The Netherlands).
****
Period:1925-1991

Annex 9

DIENST DER KUSTHAVENS
HYDROGRAFIE
<u>OOSTENDE</u>

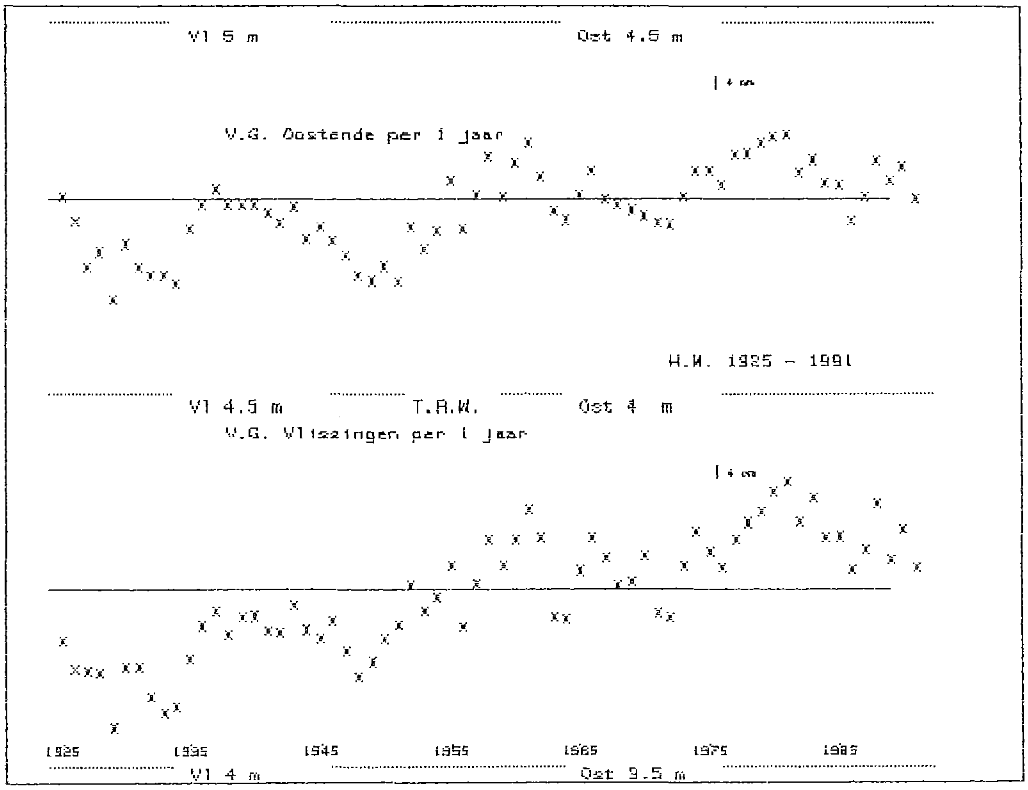
Annex 10

MOVING AVERAGES
calculated on
the Annual Values of **HW**
for **OOSTENDE** (Belgium) and for **VLISSINGEN** (The Netherlands).

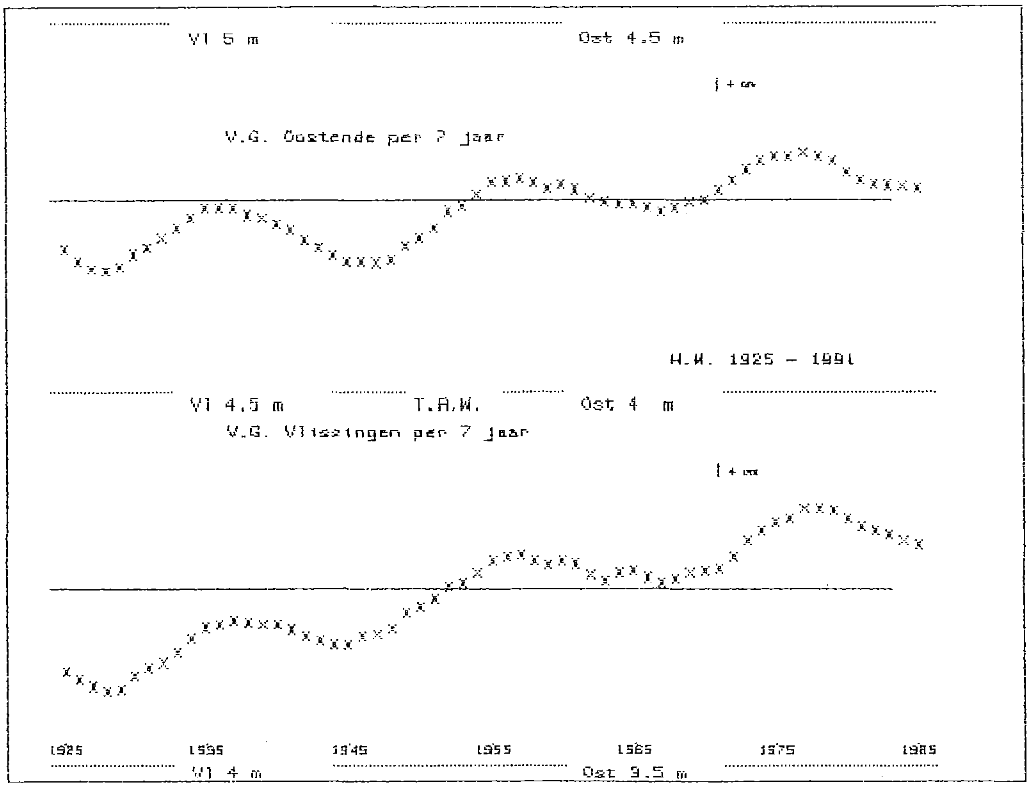
****

Period:1925-1991

1 year



7 years



DIENST DER KUSTHAVENS
HYDROGRAFIE
<u>OOSTENDE</u>

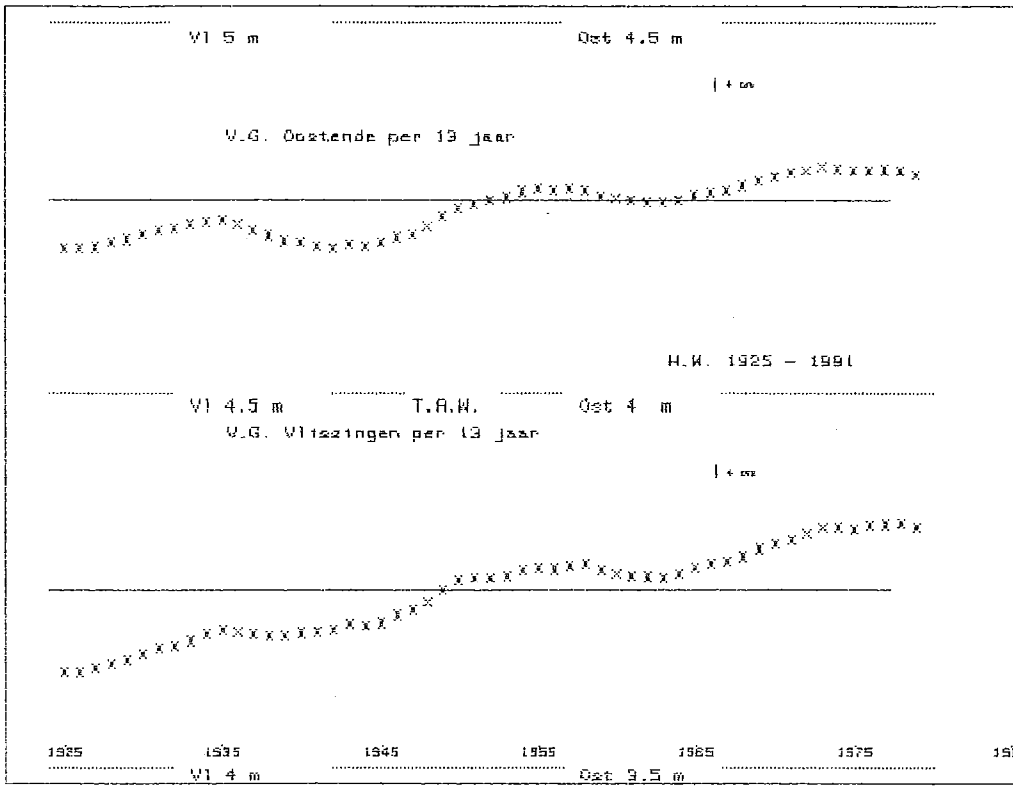
Annex 11

MOVING AVERAGES calculated on the Annual Values of **HW** for **OOSTENDE** (Belgium) and for **VLISSINGEN** (The Netherlands).

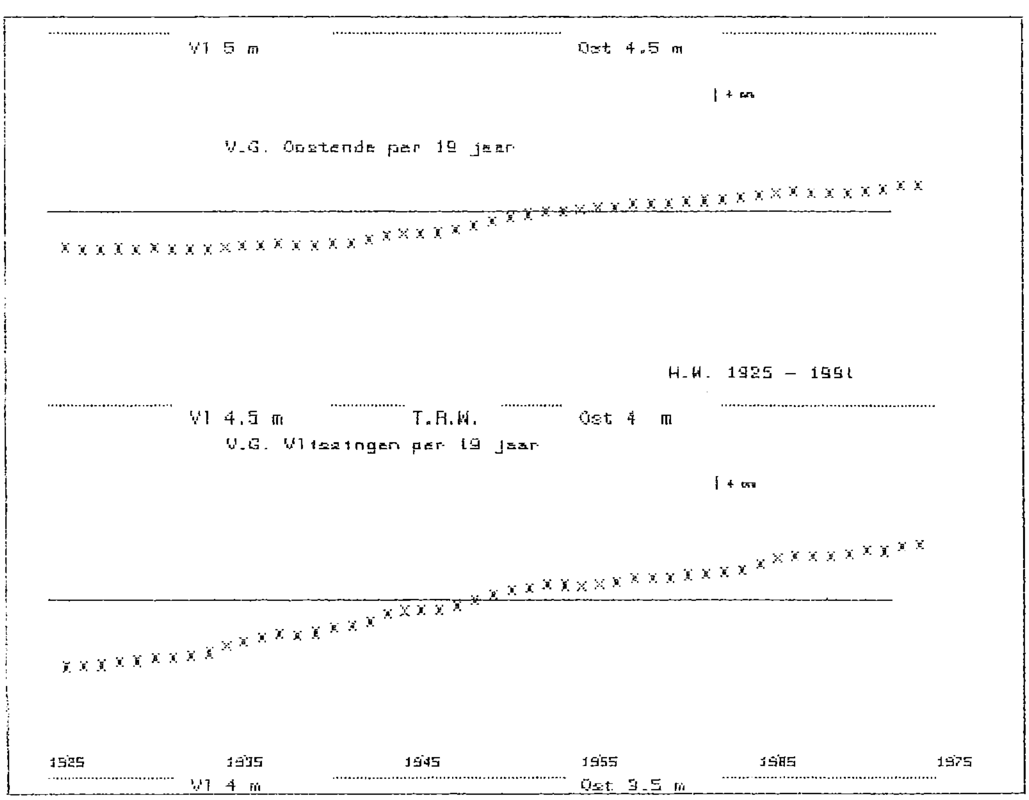
****

Period:1925-1991

13 years



19 years



DIENST DER KUSTHAVENS
HYDROGRAFIE
<u>OOSTENDE</u>

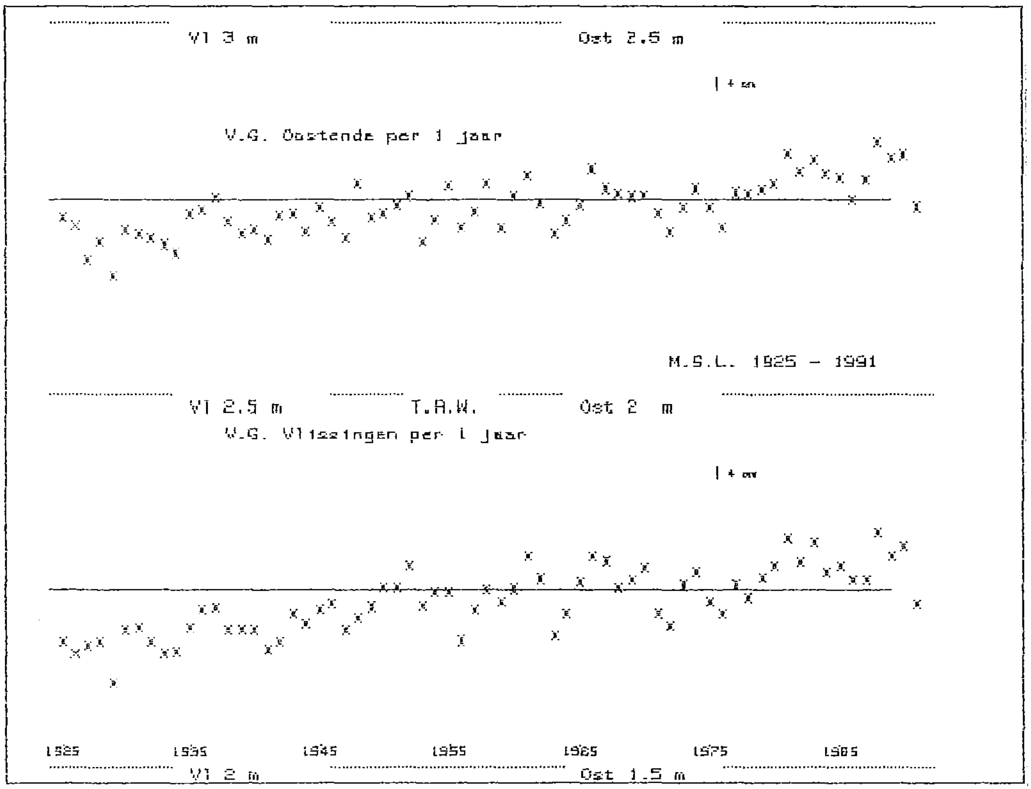
Annex 12

MOVING AVERAGES calculated on the Annual Values of MSL for OOSTENDE (Belgium) and for VLISSINGEN (The Netherlands).

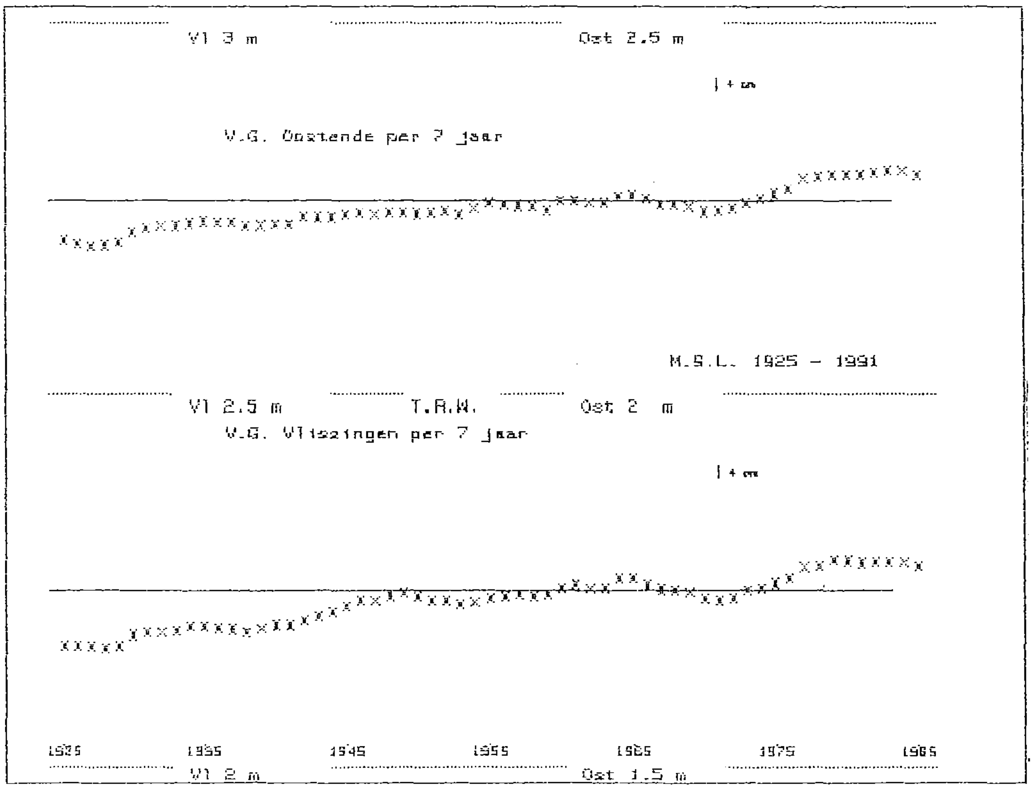
****

Period:1925-1991

1 year



7 years

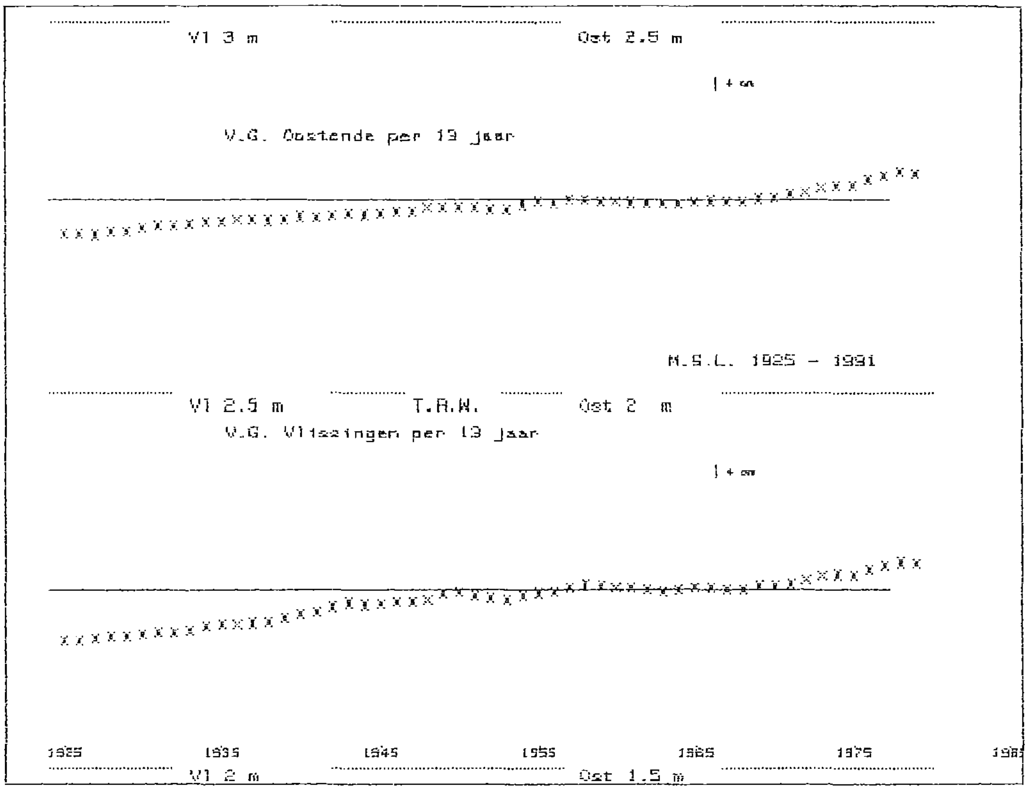


DIENST DER KUSTHAVENS
HYDROGRAFIE
OOSTENDE

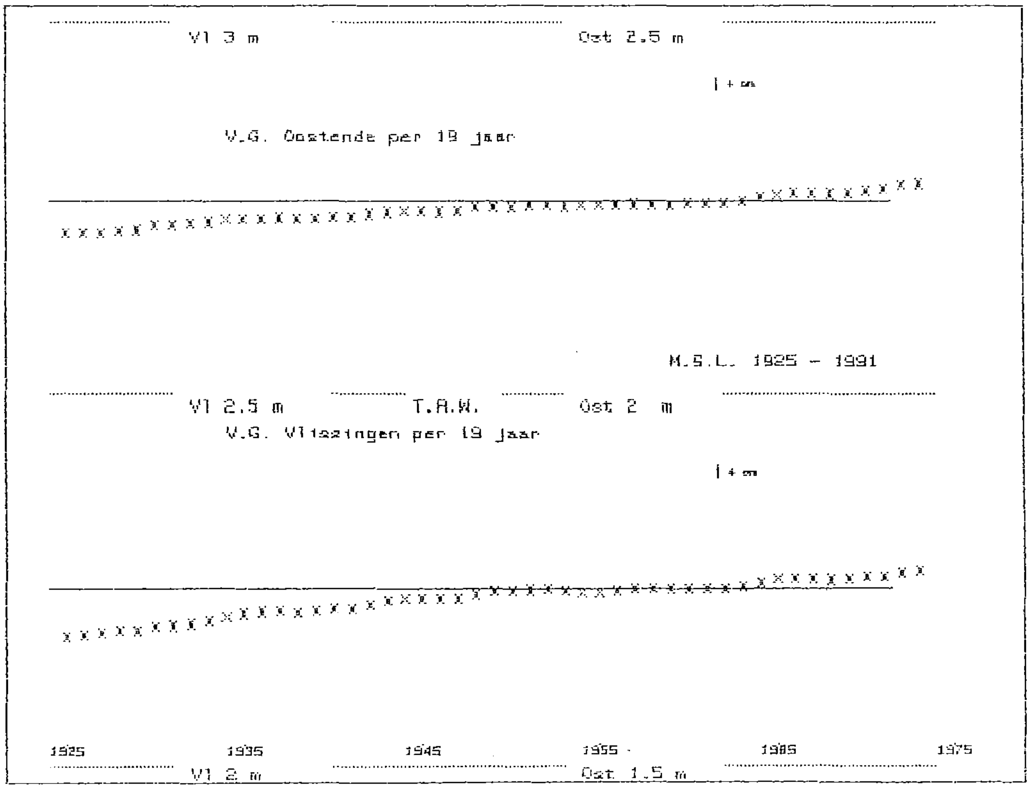
Annex 13

MOVING AVERAGES
calculated on
the Annual Values of **MSL**
for **OOSTENDE** (Belgium) and for **VLISSINGEN** (The Netherlands).
****
Period:**1925-1991**

13 years



19 years

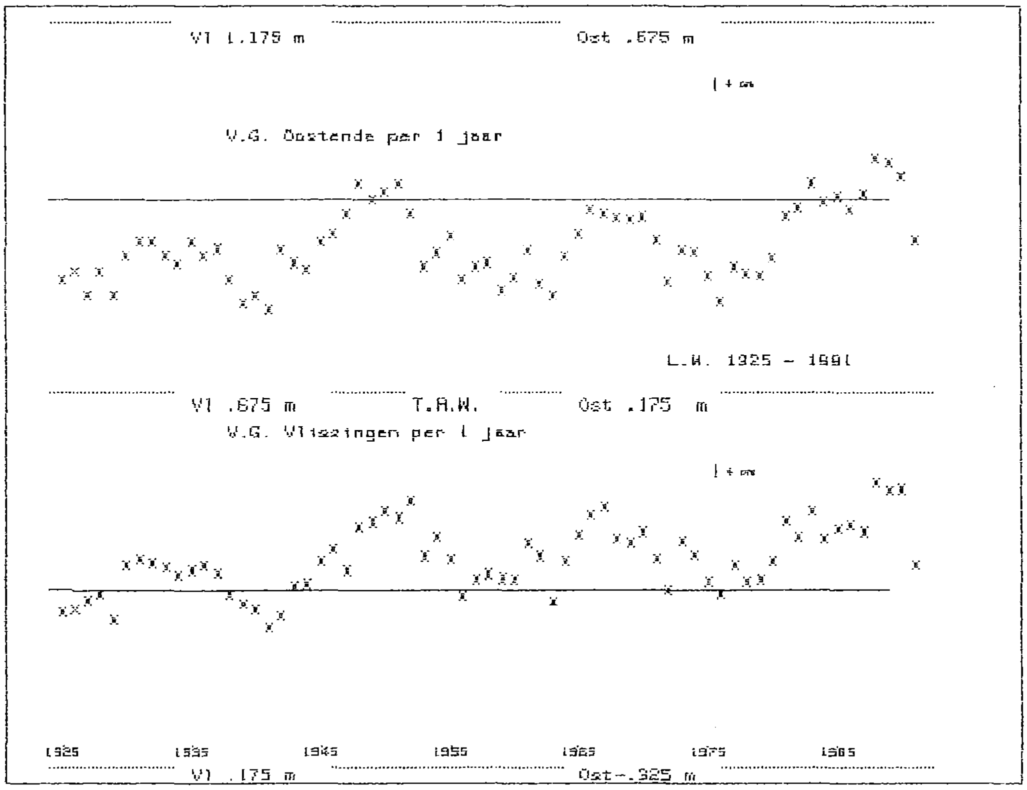


DIENST DER KUSTHAVENS
HYDROGRAFIE
<u>OOSTENDE</u>

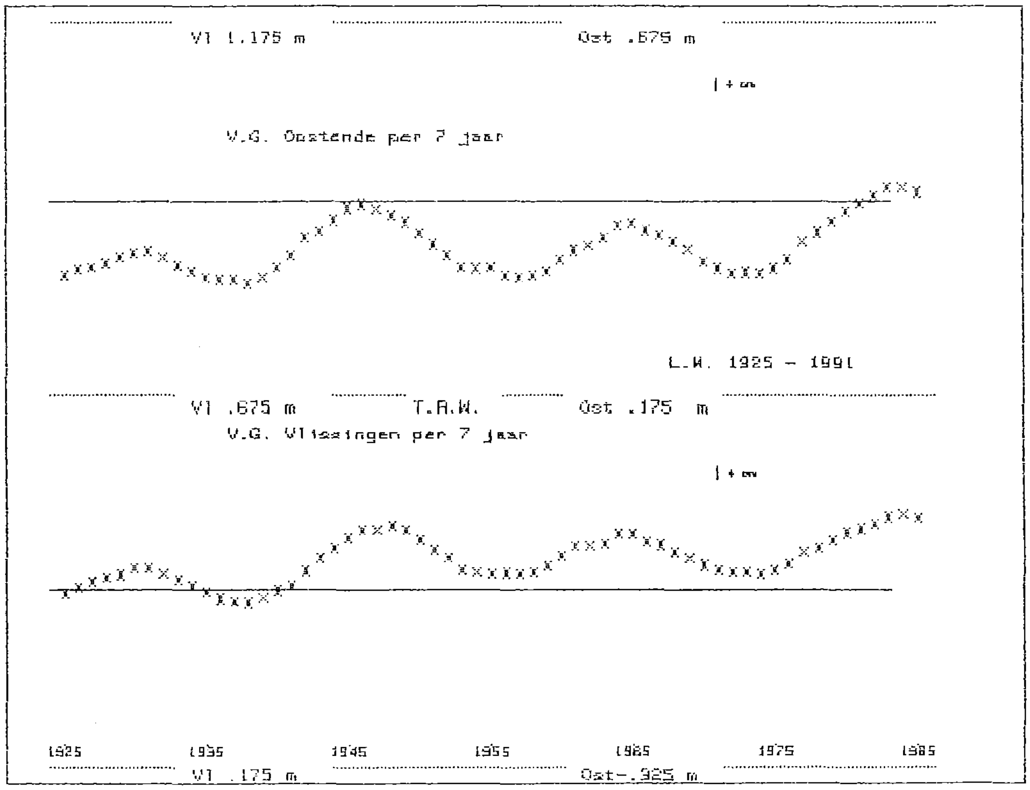
Annex 14

MOVING AVERAGES
calculated on
the Annual Values of **LW**
for **OOSTENDE** (Belgium) and for **VLISSINGEN** (The Netherlands).
****
Period:**1925-1991**

1 year



7 years

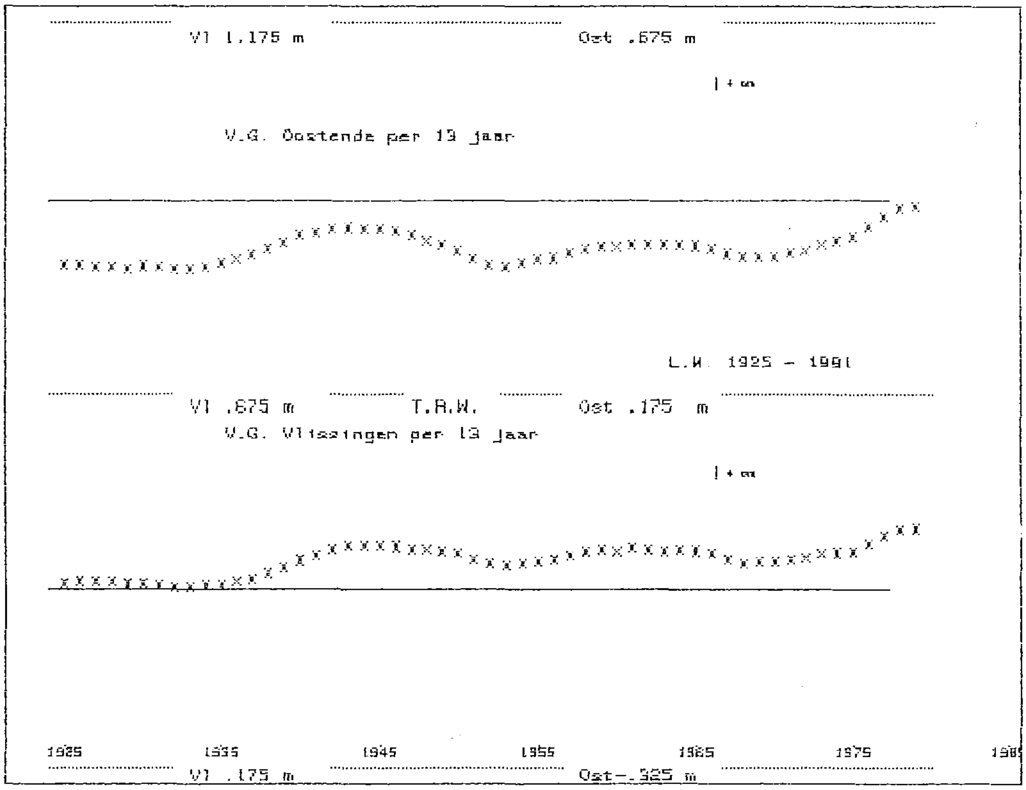


DIENST DER KUSTHAVENS
HYDROGRAFIE
OOSTENDE

Annex 15

MOVING AVERAGES
calculated on
the Annual Values of **LW**
for **OOSTENDE** (Belgium) and for **VLISSINGEN** (The Netherlands).
****
Period:**1925-1991**

13 years



19 years