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HARMONIC TIDAL PREDICTIONS ALONG THE BELGIAN COAST

by

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DIENST DER KUSTHAVENS
HYDROGRAFIE
OOSTENDE

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INTRODUCTION

In the harmonic method of tidal prediction, the predicted astronomical tidal height about mean sea level (MSL) y at time t, y(t), is based on the following formula (**ref. 1**) :

$$y(t) = \sum_i F_i * H_i * \cos(VO_i + U_i + N_i * t - G_i) \tag{1}$$

Here H_i is the amplitude of het i-th tidal constituent or astronomical component
and where : G_i = the phase lag of the i-th constituent on the equilibrium tide;
VO_i = the equilibrium phase of the same i-th constituent;
F_i and U_i = its nodal corrections on the amplitude and phase;
N_i = its angular speed, atronomically defined.

Normally a height datum, different from MSL, will be needed, e.g. the national reference level like TAW or a local hydrographic chart datum. For applying the necessary correction here **Annex 1** will be useful for the Belgian coast.

THE DIFFERENT TIDAL PREDICTION MODELS

As soon as the Coastal Hydrographic Service was computerised (in 1983) three tidal predictions models were developed following the formula (1) : VORDA - VORJA1 (in 1984), VORDA - VORJA2 (in 1987) and VORDA - VORJA3 (in 1990).

1. The resemblances in the programming mainly are related to the calculation of VO_i and to the choise of the nodal corrections F_i and U_i.

1.1. The argument of the equilibrium phase VO_i is computed as a function of the following so-called variables of Brown (**ref. 1, 2, 3**)

τ : mean lunar time (expressed as an angle)

S : mean longitude of the moon

K: mean longitude of the sun

P : mean longitude of the lunar perigee

PS: mean longitude of het solar perigee

L' = -L where L is the longitude of the ascending node of the moon (value changed in sign in order to obtain uniformity in the formulae; L is the only one of the 6 variables, that increases towards the west).

The formulae of this 6 variables are based on Brown's theory, mentionned in **ref. 2**.

Here we used the formula, mentionned in ref. 4

where : $\tau = K - S + 180°$ (for 0.00h. G.M.T.)

$$\left.\begin{aligned} S &= 270°,434358 + 481.267°,88314137 * T - 0,001133 * T^2 + 1,9 \times 10^{-6} * T^3 \\ K &= 279°,69668 + 36.000°,768925485 * T + 3,03 \times 10^{-4} * T^2 \\ P &= 334°,329653 + 4.069°,0340329575 * T - 0,010325 * T^2 - 1,2 \times 10^{-5} * T^3 \\ L' &= -259°,183275 + 1.934°,142008355 * T - 0,002078 * T^2 - 2 \times 10^{-6} * T^3 \\ PS &= 281°,22083 + 1°,7191733100 * T + 0,000453 * T^2 + 3 \times 10^{-6} * T^3 \end{aligned}\right\} \quad (2)$$

Here T is expressed in "Julian centuries" of 36.525 mean solar days (equals 100 years) from 31/12/1899 - 12.00 h. GMT or mean noon of the Greenwich origin.

E.W. Schwiderski **(ref. 4)** published a very practical formula for T as a function of D, being the number of days from 31/12/1974 - 00.00 h. GMT till the concerned day (e.g. D = 1 for 01/01/1975 - 00.00 h. GMT) :

$$T = \frac{27.392,500528 + 1,0000000356 * D}{36525} \quad (3)$$

with $D = d + 365 (y - 1975) + \mathrm{Int}\,[(y-1973)/4]$

where : d = day number of the year (e.g. d= 1 for January 1)

y = year number $\geqslant$ 1975

Int [x] = integral part of x

Now we come to the point where the exact formula for VO_i can be given as a function of τ, S, K, P, L' and PS :

$$VO_i = A_i * \tau + B_i * S + C_i * K + D_i * P + E_i * L' + F_i * PS + n.90° \quad (4)$$

In this multinominal the integer coefficients A, B, C, D, E and F are to be derived from the so called argument numbers or Doodson numbers **(ref. 1 and 2)**, composed as follows :

$$A_i\,(B_i + 5)\,(C_i + 5)\,.\,(D_i + 5)\,(E_i + 5)\,(F_i + 5) \quad (5)$$

E.g. for S2 with 273.555 as Doodson-number :

$$VO_{S2} = 2 * (K-S + 180°) + 2 * S - 2 * K + 0 * P + O * L' + 0 * PS + 0 * 90° = 0°$$

Here n. 90° is a term where n equals 0 or 1 or 2 or 3 following ref. 5

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In the 3 models VO_i is calculated once a day.

1.2. For the nodal corrections F_i and U_i, the values of Horn have been used for the 3 models, as explained in ref. 6 and 7 and as far as they have been tabled in ref. 8.
The values in the tables (ref. 8) only have been given for the first of January; for that reason a subroutine program for interpolations with divided differences is employed (ref. 9). Here too the interpolation subroutine occurs once a day.

2. The differences between the 3 models mainly concern the choise of the harmonic constituents and, only for VORDA-VORJA3, the application of a correction on the F_{M2} and F_{S2}— values of Horn.

2.1. VORDA - VORJA 1 still uses the classical 60 harmonic constituents, as they were a matter of common knowledge till the middle of the sixties. These data for Oostende, Zeebrugge and Nieuwpoort were the results of a harmonic analysis, based on the method, described by G.W. Lennon (ref. 10), carried out in the Royal Observatory in Brussels and based on the post-World-War II - observations of the Coastal Hydrographic Service - Oostende (ref. 11).

The Annex 2 shows the listings of concerned constituents, used in VORDA - VORJA 1.

2.2. Towards the end of the sixties, it became clear that, for shallow water tides (as we have along the Belgian coast), some new tidal terms could be identified. In the Tidal Institute and Observatory Birkenhead (U.K.) it led to the development of the Extended Harmonic Method (EHM) of analysing and predicting shallow water tides, based on 114 components (ref. 12).
For the Belgian coast we still had to wait for a long time before a more extensive analysis was possible.
Hourly tidal records of 1983 (being a mean year in the nodal cycle with L = 90° on 14/03/1983) benevolently were analysed in 1986 with the HATYAN 30 - program by the Rijkswaterstaat - Dienst Informatieverwerking.
As a result of this analysis, 195 constituents for each coastal harbour (Nieuwpoort, Oostende and Zeebrugge) were available now.
Afterwards a selection has been made in order to retain only the components, higher than 1,5 cm., 57 in number. These were introduced in the VORDA - VORJA 2 - program.
Compared with the first program now 21 new constituents were added, while, on the other hand some 24 others were deleted in accordance to the criterion, mentionned before.
Annex 3 representents the data, chosen for VORDA - VORJA 2.

2.3. For VORDA - VORJA 3 once again the choise in the harmonic components for Oostende has been changed and, as stated sub 2, a correction on two F- values was implemented :

2.3.1. From 1989-1990 on, the tidal data of Oostende for some more recent years were analysed in Belgium, first for the period 1981-1988 with the program ANZ of the KU Leuven (Katholieke Universiteit Leuven) - **ref. 13** - and afterwards for the period 1981-1989 in our own service with the program HARTIS.

The last one was a creation of the BMM (Beheerseenheid Mathematisch Model - Noordzee en Schelde-estuarium - Ministerie van Volksgezondheid) **(ref. 14)** which, with the agreement of this service, has been implemented on our own computer-system.

At the same time the 2 last programs could be controlled on quality for 1983, because meanwhile the tidal analysis for this year was carried out by 2 more qualified institutions abroad (Delft Hydraulics Laboratory and POL or the Proudman Oceanographic Laboratory).

This abondance of analysed data allowed us to conclude which components are stable and which are rather variable in time.

Concerning the choise of the components for VORDA - VORJA 3, we took for M2 and S2 the mean of the different results of analysis for 1983; for the other constituents the mean of the 2 periods were taken into account after implementing the following formulae on the components of the 2 series :

$$\left.\begin{aligned} H_i * \cos G_i &= \sum H_i * \cos G_i/n \\ H_i * \sin G_i &= \sum H_i * \sin G_i/n \end{aligned}\right\} \quad (5)$$

By calculating the mean (μ) and the standard deviation (σ) on the different H_i- and G_i-values, we often see a big scatter; statistically this phenomenon also has been analysed by Y. Adam and A. Pollentier **(ref. 14 and 15)** and by I. Hermans **(ref. 13)**.

Introducing a very rigid criterion, namely :

$$H_i > 1{,}25 \text{ cm}$$

$$\sigma_{G_i} < 20° \quad ,$$

compared with VORDA - VORJA 2, now a lot of components are to be deleted (14 in all) such as all the long periodic species, except for SA (7 in all), 2 diurnal components (RO1 and M1), only 1 semi-diurnal constituent (OQ2), 1 quarter diurnal species (3MK4), 2 of the sixth diurnal type (2NM6, 2MNU6) and 1 eight diurnal component (MSNK8); on the other hand SO3, used in VORDA - VORJA 1, is fished up again, while 4 more new constituents have been added (2MK2, MNU4, 3MO5, 2MSK8).

The **Annex** 4 represents a list of the harmonic constituents, - 48 in number - used in VORDA - VORJA 3; also an ordering following the magnitude of the amplitudes is made in the same Annex. The last sequence is very similar to the listings of I. Hermans as given in **Annex 5** (ref. 13).

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2.3.2. The nodal corrections F_i and U_i, as used in the formula (1), are factors varying in a period of 18,6 years, being the nodal cycle; these variables are thus dependent on the longitude of the ascending node of the moon or L.

In 1.2. we mentionned that, so far, the nodal corrections of Horn for the 3 models were applied. In the **Annexes 6 and 7**, where uncorrected and corrected values of H_{M2} and H_{S2} for 15 years have been shown (results of the HARTIS-program), we can see that the nodal corrections (here these of Godin (**ref. 16**)) are not adequate for our regions; in fact for M2 there is a degree of over-correction, while for S2 we can ascertain the contrary. With the nodal corrections of Horn this phenomenon is very similar. As indicated by M. Amin (**ref. 17**), probably this changes of nodal corrections from their equilibrium values are mostly due to bottom friction for the shallow-water regions around the North Sea. In the Netherlands mainly C. Landsheer and J. Doekes (**ref. 18, 19 and 20**) found some additional corrections to apply on the nodal corrections of the amplitudes of the most important components (mainly M2, S2).

In VORDA - VORJA 3 experimentally we did the same for the amplitudes of M2 and S2 for Oostende :

- for M2 : in stead of using F_{M2} of the Horn-tables we took :
  $0{,}60 * (F_{M2}$ of the Horn-tables $- 1) + 1$
- for S2 : in stead of using F_{S2} of the Horn-tables we took :
  $- 0{,}60 * (F_{M2}$ of the Horn-tables $- 1) + 1$

Probably in the near future more refined adjustments on the nodal corrections of several other components can be introduced, after studying the results of some more years of harmonic analysis.

The **Annex 8** represents the tidal predictions with VORDA - VORJA 3 for 1 month.

EVALUATION OF THE DIFFERENT METHODS

Some results of a comparison between computed sea levels (HW/LW and hourly heights) over certain periods and observed sea levels (also HW/LW and hourly heights) over the same periods were presented already in **ref. 21**; the **Annexes 9 and 10** show 2 examples of this comparison for Oostende, where, besides VORDA-VORJA1, VORDA - VORJA2 and POL, also 2 methods of the KU Leuven were considered.

As later on the results of VORDA - VORJA 3 became available, the **Annex 9** could be extended with the mean and standard deviation of the differences, determined with the last method.

Here I want to stress thas since World War II the tidal predictions of POL (formerly IOS) has been used in the Belgian Tide Tables; particularly for Oostende these data are obtained by the so called Harmonic Shallow Water Correction Method (**ref. 22**).

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The **Annexes 11 and** 12 represent some more examples of quality control for Oostende :
Annex 11 is related to HW/LW controls for Oostende, on days with excellent weather conditions during summer 1989.
Annex 12 concerns 2 complete years (1989 and 1990) for Oostende, where, once more, the HW/LW (heights and times) are quality controlled .
In **Annex** 13 the means and standard deviations of the differences between the computed and observed hourly heights are given for :
(1) the year 1989;
(2) some periods of the summer 1989 (good weather conditions).
Finally **Annex** 14 - simular to **Annex** 12 - gives the evaluation of VORDA - VORJA 2 and of the so called POL-predictions for Zeebrugge, the last being derived from the Oostende predictions.
A general conclusion of all these quality controls is that VORDA - VORJA 3 most often gives the best results.
The tidal predictions for Oostende of POL, used so far, may be discontinued before long.

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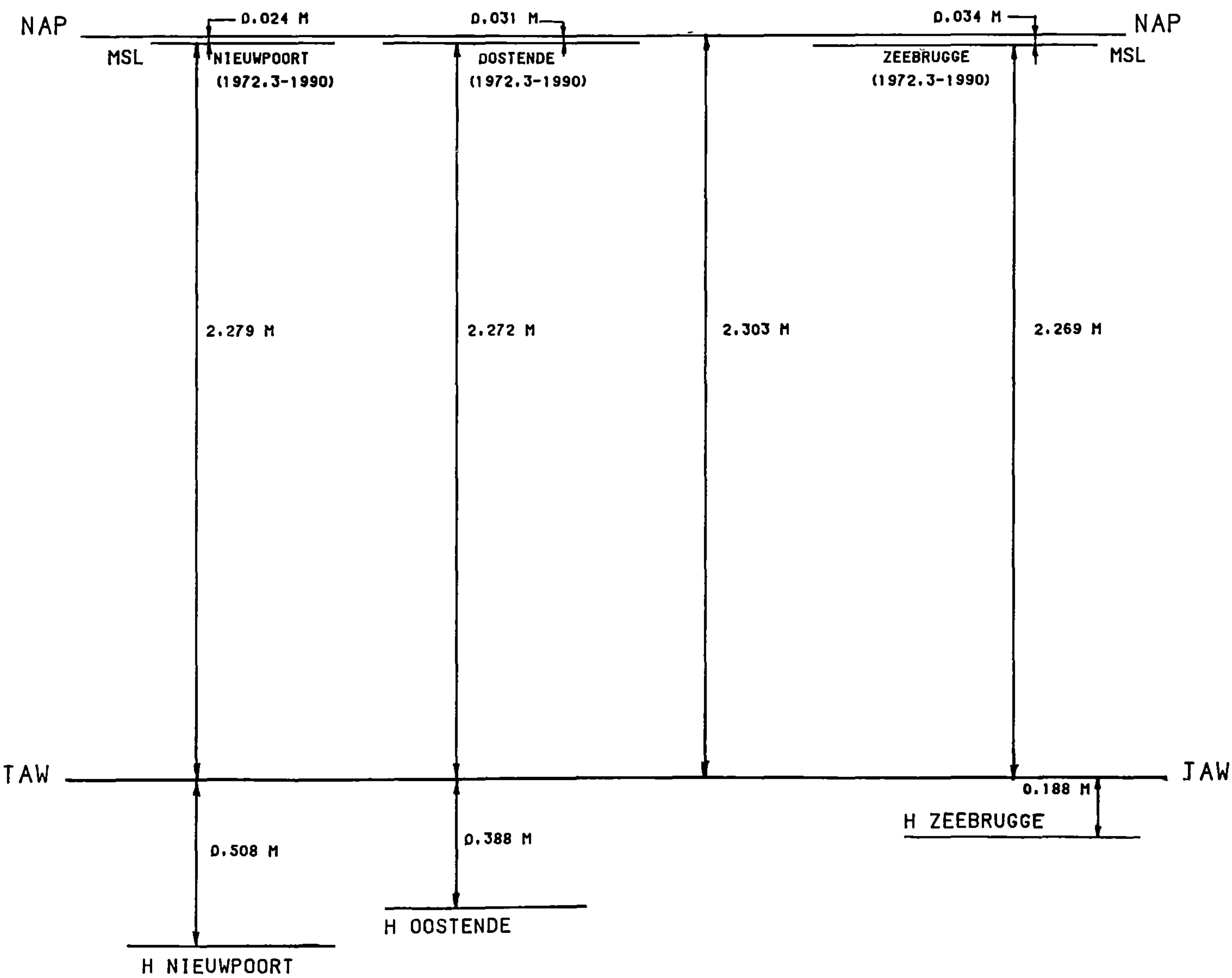
OOSTENDE

REFERENCE LEVELS ALONG THE BELGIAN COAST



LEGEND: NAP: "NORMAAL AMSTERDAMS PEIL" OR HEIGHT DATUM IN THE NETHERLANDS

MSL: MEAN SEA LEVEL

TAW: "TWEEDE ALGEMENE WATERPASSING" OR NATIONAL REFERENCE LEVEL IN BELGIUM

H : MEAN LOWLOWWATERSPRING OR CHART DATUM

DIENST DER KUSTHAVENS
HYDROGRAFIE
OOSTENDE

HARMONIC TIDAL CONSTITUENTS (60)USED

Origin : Royal Observatory, Brussel, Belgium

	Angular Speed	NIEUWPOORT(1967) H_i	NIEUWPOORT(1967) G_i	OOSTENDE(1944-1964) H_i	OOSTENDE(1944-1964) G_i	ZEEBRUGGE(1963-196 H_i	ZEEBRUGGE(1963-196 G_i
SA	0.0410667	0.0730	232.890	0.0687	214.516	0.0732	200.027
SSA	0.0821373	0.0390	31.790	0.0163	191.794	0.0217	146.373
MM	0.5543747	0.0400	358.990	0.0065	352.567	0.0114	240.087
MSF	1.0158958	0.0310	347.760	0.0309	51.373	0.0199	82.916
MF	1.0980330	0.0180	253.860	0.0114	156.975	0.0138	162.129
2Q1	12.8542862	0.0130	315.550	0.0085	71.084	0.0056	76.660
SIG1	12.9271398	0.0060	236.470	0.0012	257.655	0.0031	176.411
Q1	13.3986609	0.0410	107.920	0.0320	118.528	0.0333	114.346
RHO1	13.4715145	0.0070	100.030	0.0077	120.116	0.0069	139.413
O1	13.9430356	0.0970	160.870	0.0948	167.537	0.1032	170.766
MP1	14.0251729	0.0060	186.910	0.0051	27.634	0.0065	98.023
M1	14.4966939	0.0070	210.590	0.0022	37.001	0.0058	89.847
CHI1	14.5695476	0.0020	2.170	0.0006	294.181	0.0017	101.978
PI1	14.9178647	0.0080	275.770	0.0027	197.076	0.0052	309.453
P1	14.9589314	0.0320	328.090	0.0234	326.309	0.0316	328.233
S1	15.0000000	0.0070	231.670	0.0040	322.543	0.0043	335.493
K1	15.0410686	0.0560	354.940	0.0551	349.237	0.0631	349.805
PSI1	15.0821353	0.0110	306.640	0.0026	219.566	0.0048	259.446
PHI1	15.1232059	0.0020	101.600	0.0024	15.265	0.0031	48.773
THE1	15.5125897	0.0080	284.420	0.0007	64.588	0.0037	300.376
J1	15.5854433	0.0080	220.290	0.0033	136.795	0.0046	169.608
SO1	16.0569664	0.0020	22.570	0.0046	88.360	0.0050	106.977
OO1	16.1391017	0.0080	255.490	0.0015	128.493	0.0054	163.303
OQ2	27.3416965	0.0130	298.580	0.0126	289.833	0.0126	303.280
MNS2	27.4238338	0.0320	99.980	0.0248	98.952	0.0244	113.774
2N2	27.8953548	0.0170	206.160	0.0396	305.149	0.0415	328.262
MU2	27.9682085	0.0980	101.250	0.0994	113.641	0.0999	130.557
N2	28.4397295	0.3380	336.720	0.3055	341.189	0.2793	350.076
NU2	28.5125832	0.0840	322.750	0.0907	335.576	0.0852	341.883
OP2	28.9019670	0.0320	346.500	0.0122	348.576	0.0151	351.529
M2	28.9841042	1.9370	0.280	1.7956	5.263	1.6462	14.725
MKS2	29.0662415	0.0120	178.220	0.0138	180.544	0.0131	219.894
LDA2	29.4556253	0.0470	10.450	0.0526	16.423	0.0543	26.454
L2	29.5284789	0.1660	358.080	0.1213	21.172	0.1119	31.890
T2	29.9589333	0.0270	40.830	0.0287	44.363	0.0231	52.480
S2	30.0000000	0.5770	53.680	0.5242	57.684	0.4704	67.882
R2	30.0410667	0.0120	97.550	0.0051	108.371	0.0051	94.376
K2	30.0821373	0.1640	55.370	0.1522	56.895	0.1424	67.714
MSN2	30.5443747	0.0340	271.470	0.0286	263.675	0.2970	272.051
KJ2	30.6265120	0.0060	223.540	0.0019	251.218	0.0047	327.573
2SM2	31.0158958	0.0430	269.210	0.0351	285.205	0.0333	295.965
MO3	42.9271398	0.0250	67.220	0.0281	78.355	0.0292	91.100
M3	43.4761564	0.0180	72.180	0.0073	68.354	0.0027	147.547
SO3	43.9430356	0.0140	160.180	0.0120	149.291	0.0136	164.583
MK3	44.0251729	0.0140	224.790	0.0223	228.610	0.0251	247.645
SK3	45.0410686	0.0100	249.160	0.0089	268.875	0.0098	298.724
MN4	57.4238338	0.0520	280.440	0.0339	311.898	0.0339	0.208
M4	57.9682085	0.1300	308.270	0.1048	335.321	0.0974	23.134
SN4	58.4397295	0.0050	164.820	0.0048	80.719	0.0074	132.491
MS4	58.9841042	0.0640	12.030	0.0643	37.353	0.0697	78.939
MK4	59.0662415	0.0180	0.920	0.0189	38.599	0.0214	81.102
S4	60.0000000	0.0050	200.530	0.0036	163.061	0.0061	166.026
SK4	60.0821373	0.0020	172.980	0.0026	138.895	0.0017	206.015
2MN6	86.4079380	0.0340	241.850	0.0372	275.161	0.0482	306.600
M6	86.9523127	0.0520	272.810	0.0679	298.675	0.0876	335.588
MSN6	87.4238338	0.0110	319.350	0.0175	334.585	0.0242	15.553
2MS6	87.9682085	0.0530	324.010	0.0696	345.439	0.0912	21.250
2MK6	88.0503458	0.0130	316.390	0.0185	346.963	0.0239	18.277
2SM6	88.9841042	0.0090	42.420	0.0127	49.277	0.0217	79.170
MSK6	89.0662415	0.0050	29.910	0.0096	18.362	0.0133	82.761

H_i - values in metres

G_i - values are referred to GMT

DIENST DER KUSTHAVENS
HYDROGRAFIE
OOSTENDE

HARMONIC CONSTITUENTS (57) USED IN VORDA-VORJA 2

Origin : Rijkswaterstaat - Dienst Informatieverwerking

	Angular Speed	NIEUWPOORT(1983) H_i	NIEUWPOORT(1983) G_i	OOSTENDE(1983) H_i	OOSTENDE(1983) G_i	ZEEBRUGGE(1983) H_i	ZEEBRUGGE(1983) G_i
SA	0.041069	0.0626	258.000	0.0560	228.000	0.0635	240.000
SSA	0.082137	0.0332	85.400	0.0374	84.400	0.0279	85.300
MSM	0.471521	0.0192	65.900	0.0194	71.000	0.0209	59.300
MM	0.544375	0.0441	71.100	0.0447	66.000	0.0486	66.900
MSF	1.015896	0.0368	63.500	0.0388	51.700	0.0338	64.900
MF	1.098033	0.0374	256.800	0.0371	251.500	0.0402	255.800
Q1	13.398661	0.0236	131.100	0.0257	133.600	0.0258	133.600
RO1	13.471514	0.0175	214.800	0.0179	210.800	0.0188	214.100
O1	13.943036	0.0808	176.300	0.0843	177.400	0.0907	180.700
M1	14.496694	0.0144	159.300	0.0159	161.900	0.0161	162.100
P1	14.958931	0.0285	331.200	0.0307	329.600	0.0344	329.700
K1	15.041069	0.0496	7.800	0.0550	4.300	0.0606	4.800
OQ2	27.341696	0.0156	287.200	0.0167	293.200	0.0167	299.900
MNS2	27.423834	0.0232	96.900	0.0205	104.500	0.0212	115.700
2N2	27.895355	0.0717	3.000	0.0641	7.300	0.0607	18.600
MU2	27.968208	0.0979	133.000	0.0987	140.500	0.1003	153.000
N2	28.439730	0.3195	4.400	0.3011	8.200	0.2739	17.600
NU2	28.512583	0.0885	356.500	0.0838	1.000	0.0826	12.200
M2	28.984104	1.9114	29.100	1.8019	33.500	1.6670	42.600
LBDA2	29.455625	0.0500	43.300	0.0470	51.200	0.0453	62.700
2MN2	29.528479	0.1355	225.000	0.1307	232.000	0.1282	241.600
T2	29.958933	0.0252	70.800	0.0218	73.600	0.0221	79.100
S2	30.000000	0.5628	82.900	0.5260	87.600	0.4754	97.200
K2	30.082137	0.1672	85.200	0.1530	90.600	0.1404	99.100
MSN2	30.544375	0.0272	273.600	0.0274	286.100	0.0265	294.900
2SM2	31.015896	0.0435	307.700	0.0414	313.900	0.0392	327.700
MO3	42.927140	0.0280	114.600	0.0280	120.700	0.0285	133.400
MK3	44.025173	0.0200	279.500	0.0209	282.300	0.0224	291.300
3MS4	56.952313	0.0231	93.800	0.0211	108.000	0.0200	141.300
MN4	57.423834	0.0420	342.100	0.0350	3.700	0.0310	50.000
M4	57.968208	0.1363	9.300	0.1149	30.900	0.1029	73.400
3MN4	58.512583	0.0244	206.600	0.0235	227.000	0.0222	261.600
MS4	58.984104	0.0849	72.600	0.0744	97.000	0.0749	139.000
MK4	59.066241	0.0267	76.200	0.0238	102.600	0.0234	142.900
2MN6	86.407938	0.0294	337.400	0.0380	356.100	0.0483	28.900
M6	86.952313	0.0535	2.300	0.0686	22.700	0.0885	54.500
MSN6	87.423834	0.0137	37.700	0.0165	55.400	0.0202	84.200
2MS6	87.968208	0.0596	49.800	0.0752	69.800	0.0938	101.600
2MK6	88.050346	0.0167	54.400	0.0208	78.500	0.0274	107.300
2SM6	88.984104	0.0142	121.100	0.0165	138.600	0.0196	168.900
3MN8	115.392042	0.0281	285.300	0.0264	302.700	0.0202	352.900
M8	115.936417	0.0382	320.100	0.0355	338.700	0.0287	29.300
2MSN8	116.407938	0.0233	337.200	0.0212	354.500	0.0156	44.800
3MS8	116.952313	0.0592	2.300	0.0543	21.700	0.0430	72.500
2MS8	117.968208	0.0234	62.400	0.0212	80.800	0.0159	132.900
4MS10	145.936417	0.0197	323.300	0.0153	3.200	0.0141	101.900
SNU2	1.487417	0.0331	357.300	0.0328	356.400	0.0324	352.800
SN	1.560270	0.0175	215.800	0.0172	214.400	0.0220	211.800
3MKS2	26.870175	0.0163	241.400	0.0162	245.900	0.0157	258.500
3MS2	26.952313	0.0258	261.000	0.0243	267.600	0.0251	277.600
SKM2	31.098033	0.0238	299.100	0.0227	307.500	0.0230	319.800
3MK4	56.870173	0.0160	68.900	0.0133	86.900	0.0115	127.000
2NM6	85.863563	0.0100	314.800	0.0134	340.700	0.0189	12.600
2MNU6	86.480792	0.0071	281.200	0.0095	314.700	0.0151	0.700
3MSN6	88.512583	0.0125	242.800	0.0166	269.300	0.0225	303.800
3MK8	117.034430	0.0164	9.300	0.0155	29.000	0.0116	78.700
MSNK8	117.505971	0.0172	81.700	0.0161	104.000	0.0128	153.100

H_i - values in metres

G_i - values are referred to MET

Annex 4

DIENST DER KUSTHAVENS
HYDROGRAFIE
OOSTENDE

HARMONIC CONSTITUENTS(48) USED IN VORDA-VORJA 3

Origin : 1981-1988 analysed with ANZ - KUL
1981-1989 analysed with HARTIS-BMM

OOSTENDE

	Angular Speed	H_i	G_i	Sequence number
SA	0.041069	0.0700	294.600	13
Q1	13.398661	0.0350	116.200	23
O1	13.943036	0.0950	165.300	08
P1	14.958931	0.0280	327.000	25
K1	15.041069	0.0560	349.400	14
MNS2	27.423834	0.0230	93.800	30
2N2	27.895355	0.0360	318.000	22
MU2	27.968208	0.1010	111.800	07
N2	28.439730	0.3110	340.500	03
NU2	28.512583	0.0900	334.300	09
M2	28.984104	1.8000	4.600	01
LBDA2	29.455625	0.0550	15.700	15
T2	29.958933	0.0250	42.800	29
S2	30.000000	0.5260	57.800	02
K2	30.082137	0.1550	57.800	04
MSN2	30.544375	0.0300	258.200	24
2SM2	31.015896	0.0400	282.500	18
MO3	42.927140	0.0280	78.300	26
SO3	43.943036	0.0120	151.500	48
MK3	44.025173	0.0210	234.200	34
MN4	57.423834	0.0360	308.900	21
M4	57.968208	0.1150	332.100	06
MS4	58.984104	0.0730	37.200	11
MK4	59.066241	0.0220	37.700	32
M6	86.952313	0.0710	294.300	12
MSN6	87.423834	0.0190	334.700	38
2MN6	86.407938	0.0390	271.100	19
2MS6	87.968208	0.0740	344.300	10
2MK6	88.050346	0.0200	344.300	36
2SM6	88.984104	0.0170	45.200	39
3M(KS)2	26.870175	0.0140	240.400	43
3MS2	26.952313	0.0280	238.000	27
SKM2	31.098033	0.0200	279.600	35
3MSN6	88.512583	0.0150	174.000	42
3MK8	117.034450	0.0140	269.000	44
2MN2	29.528479	0.1270	200.600	05
3MS4	56.952313	0.0190	51.600	37
3MN4	58.512583	0.0150	157.200	41
3MN8	115.392042	0.0270	188.900	28
M8	115.936417	0.0380	216.200	20
2MSN8	116.407938	0.0230	246.400	31
3MS8	116.952313	0.0550	264.300	16
2(MS)8	117.968208	0.0210	320.400	33
2MSK8	118.050346	0.0130	325.300	47
4MS10	145.936417	0.0160	217.500	40
2MK2	27.886071	0.0430	115.100	17
MNU4	57.496688	0.0130	274.300	46
3MO5	73.009277	0.0130	83.600	45

H_i values in metres

G_i values are referred to GMT

Sequence number : ordering according to the magnitude of the H_i-values

	A B C D E F	Argument-getal	n	Darwin-notatie
1)	2 0 0 0 0 0	255.555	0	M2
	2 2-2 0 0 0	273.555	0	S2
	2-1 0 1 0 0	245.655	0	N2
	4 0 0 0 0 0	455.555	0	M4
	2 2 0 0 0 0	275.555	0	K2
	2 1 0-1 0 0	265.455	2	L2
	6 2-2 0 0 0	673.555	0	2MS6
	4 2-2 0 0 0	473.555	0	MS4
	1-1 0 0 0 0	145.555	-1	O1
10)	6 0 0 0 0 0	655.555	0	M6
	8 2-2 0 0 0	873.555	0	3MS8
	2-1 2-1 0 0	247.455	0	NU2
	2-2 2 0 0 0	237.555	0	MU2
	1 1 0 0 0 0	165.555	1	K1
	2 4-4 0 0 0	291.555	0	2SM2
	6-1 0 1 0 0	645.655	0	2MN6
	8 0 0 0 0 0	855.555	0	M8
	4-1 0 1 0 0	445.655	0	MN4
	3-1 0 0 0 0	345.555	-1	MO3
20)	2 1-2 1 0 0	263.655	2	LAMB2
	2-4 4 0 0 0	219.555	0	3M2S2
	1-2 0 1 0 0	135.655	-1	Q1
	8-1 0 1 0 0	845.655	0	3MN8
	4 2 0 0 0 0	475.555	0	MK4
	1 1-2 0 0 0	163.555	-1	P1
	2 4-2 0 0 0	293.555	0	SKM2
	6 2 0 0 0 0	675.555	0	2MK6
	3 1 0 0 0 0	365.555	1	MK3
	8 1-2 1 0 0	863.655	0	2MSN8
30)	8 4-4 0 0 0	891.555	0	2(MS)8
	4-2 2 0 0 0	437.555	0	3MS4
	6 1-2 1 0 0	663.655	0	MSN6
	2 3-2-1 0 0	283.455	0	MSN2
	2-2 0 2 0 0	235.755	0	2N2
	6 4-4 0 0 0	691.555	0	2SM6
	8 2 0 0 0 0	875.555	0	3MK8
	2-4 2 0 0 0	217.555	0	3M(SK)2
	10 2-2 0 0 0	X73.555	0	4MS10
	6 3-2-1 0 0	683.455	0	3MSN6
40)	8 4-2 0 0 0	893.555	0	2MSK8
41)	2 2-3 0 0 1	272.556	0	T2
	4 1 0-1 0 0	465.455	0	3MN4
	5 1 0 0 0 0	565.555	1	3MO5
	3 1-2 0 0 0	363.555	-1	SO3
	2-3 2 1 0 0	227.655	0	EPS2
	4-1 2-1 0 0	447.455	0	MV4
	3-2 0 1 0 0	335.655	-1	MQ3
	2 0-1 0 0 1	254.556	0	MA2
	6-2 0 2 0 0	635.755	0	2NM6
50)	6 4-2 0 0 0	693.555	0	MSK6
	5-1 0 0 0 0	545.555	-1	3MK5
	8-2 0 2 0 0	835.755	0	2(MN)8
	2-3 0 1 0 0	225.655	2	OQ2
	4 3-2-1 0 0	483.455	0	2MSN4
	0 0 1 0 0-1	056.554	0	Sa
	3 0 0 0 0 0	355.555	2	M3
	10 1-2 1 0 0	X63.655	0	3MSN10
	8 1 0 1 0 0	865.655	0	2MNK8
	6 1 0-1 0 0	665.455	0	4MN6
60)	6-1 2-1 0 0	647.455	0	2MV6
	10 4-4 0 0 0	X91.555	0	3M2S10
	6-2 2 0 0 0	637.555	0	4MS6
	2 0-2 0 0 0	253.555	2	OP2
	5 1-2 0 0 0	563.555	-1	MSO5
	10 0 0 0 0 0	X55.555	0	M10
	12 2-2 0 0 0	T73.555	0	5MS12
	3 3-2 0 0 0	383.555	1	SK3
	2-3 4-1 0 0	229.455	0	MVS2
	4-3 2 1 0 0	427.655	0	2MNS4
70)	5 3-2 0 0 0	583.555	0	MSK5
	2-5 4 1 0 0	209.655	0	2MN2S2
	10-1 0 1 0 0	X45.655	0	4MN10
	0 2-2 0 0 0	073.555	0	MSf
	2 0 1 0 0-1	256.554	0	MB2
	1-2 2-1 0 0	137.455	-1	RO1
	2 0 2 0 0 0	257.555	0	DELT2
	0 0 2 0 0 0	057.555	0	Ssa
	0 3-2-1 0 0	083.455	0	SN
	0 3-4 1 0 0	081.655	0	SV
80)	0 1 0-1 0 0	065.455	0	Mm

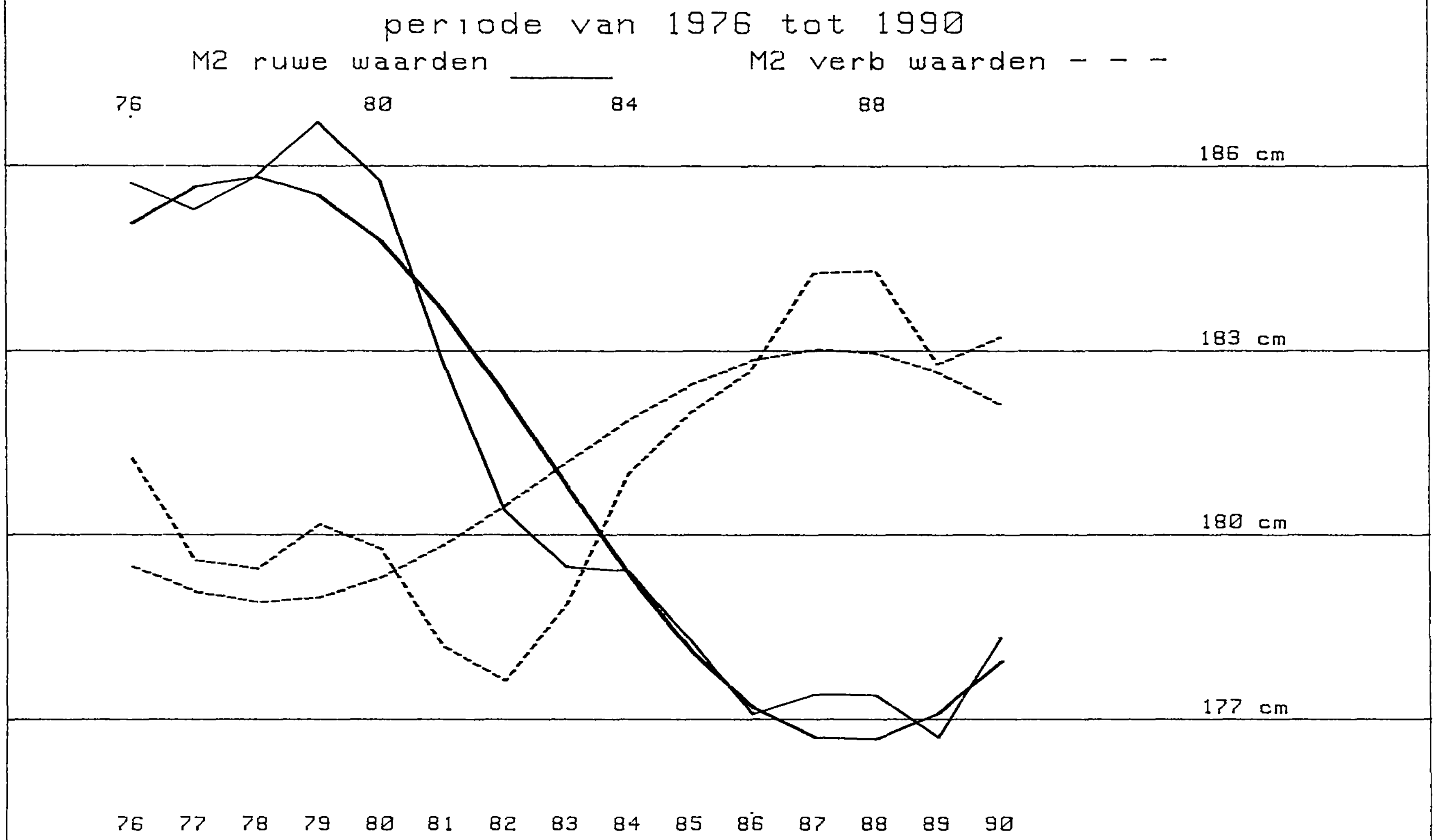
Tabel IX: Optimale volgorde van 80 getijcomponenten voor Oostende (bron : I. HERMANS (1989c)) - See also ref 13
optimum ordering of the constituents for Oostende

Annex 6

ANNUAL VALUES OF H_{M2} FOR OSTEND
(WITH CYCLIC CURVE FITTING)

uncorrected
corrected

PERIOD : 1976-1990



H=A*(Jr-92)+B*SIN(((JR-92)/PERIOD)*360)+C

PERIOD 18.61 Jaar | A=-.03151 cm | B=-2.206 cm | C= 180.67 cm
verb waarden - - - gemidd.verschil .106 cm ST AFW 24.65 cm B / ST AFW = .0895

PERIOD 18.61 Jaar | A=-.09284 cm | B= 4.159 cm | C= 180.37 cm
ruwe waarden ______ gemidd.verschil-1.764E-12 cm ST AFW 1.164 cm B / ST AFW = 3.57

DIENST DER KUSTHAVENS
HYDROGRAFIE
OOSTENDE

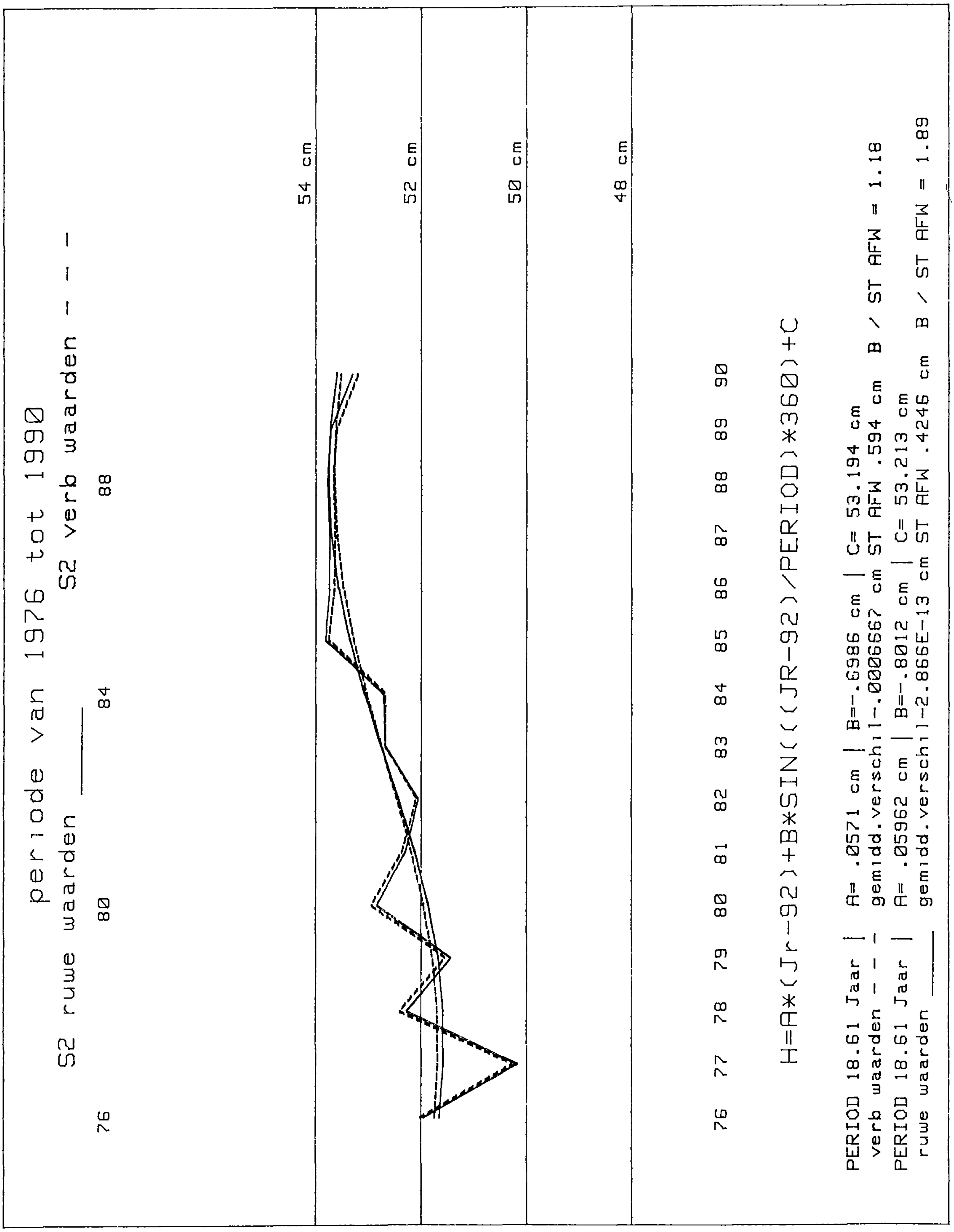
Annex 7

ANNUAL VALUES OF H_{S2} FOR OSTEND

(WITH CYCLIC CURVE FITTING)

———————— uncorrected
- - - - - - - - - corrected

PERIOD : 1976-1990



DIENST DER KUSTHAVENS
HYDROGRAFIE
OOSTENDE

EXEMPLE OF A MONTHLY TIDAL PREDICTION WITH VORDA-VORJA 3

DIENST DER KUSTHAVENS

HYDROGRAFIE OOSTENDE

VOORSPELDE GETIJEN : OOSTENDE

APRIL 1991

DATUM	HOOGWATER h.min	HOOGWATER m	LAAGWATER h.min	LAAGWATER m	DATUM	HOOGWATER h.min	HOOGWATER m	LAAGWATER h.min	LAAGWATER m
1	2.00	4.67	8.47	-0.19	16	1.36	4.83	8.26	-0.26
	14.24	4.58	21.00	0.06		13.59	4.79	20.43	-0.10
2	2.37	4.66	9.23	-0.09	17	2.17	4.89	9.07	-0.24
	15.01	4.50	21.33	0.09		14.41	4.73	21.25	-0.09
3	3.15	4.57	9.56	0.08	18	3.00	4.85	9.49	-0.13
	15.37	4.36	22.05	0.18		15.24	4.58	22.08	-0.02
4	3.51	4.42	10.26	0.28	19	3.46	4.71	10.34	0.06
	16.11	4.18	22.35	0.33		16.12	4.35	22.55	0.12
5	4.26	4.21	10.55	0.51	20	4.38	4.48	11.24	0.30
	16.45	3.96	23.06	0.53		17.09	4.07	23.53	0.29
6	5.05	3.94	11.29	0.77	21	5.45	4.19	---	---
	17.25	3.68	23.52	0.80		18.25	3.80	12.27	0.56
7	5.59	3.63	---	---	22	7.08	3.97	1.05	0.44
	18.41	3.36	12.42	1.06		19.47	3.66	13.40	0.74
8	7.33	3.37	1.51	0.99	23	8.30	3.91	2.19	0.47
	20.18	3.23	14.21	1.15		21.05	3.72	14.55	0.80
9	8.59	3.39	3.03	0.93	24	9.49	4.04	3.39	0.40
	21.35	3.36	15.28	1.08		22.14	3.92	16.29	0.70
10	10.08	3.63	4.09	0.79	25	10.52	4.22	4.59	0.20
	22.32	3.63	16.34	0.90		23.08	4.13	17.33	0.50
11	10.58	3.94	5.10	0.53	26	11.39	4.34	5.52	0.04
	23.14	3.92	17.29	0.67		23.49	4.27	18.16	0.37
12	11.36	4.22	5.55	0.32	27	---	---	6.35	-0.03
	23.48	4.19	18.09	0.46		12.17	4.39	18.53	0.29
13	---	---	6.32	0.11	28	0.26	4.37	7.12	-0.02
	12.09	4.46	18.45	0.27		12.51	4.41	19.27	0.23
14	0.21	4.45	7.08	-0.06	29	1.02	4.44	7.47	0.02
	12.43	4.65	19.23	0.10		13.26	4.41	20.02	0.18
15	0.57	4.67	7.46	-0.19	30	1.39	4.48	8.22	0.07
	13.20	4.77	20.02	-0.03		14.03	4.40	20.35	0.13

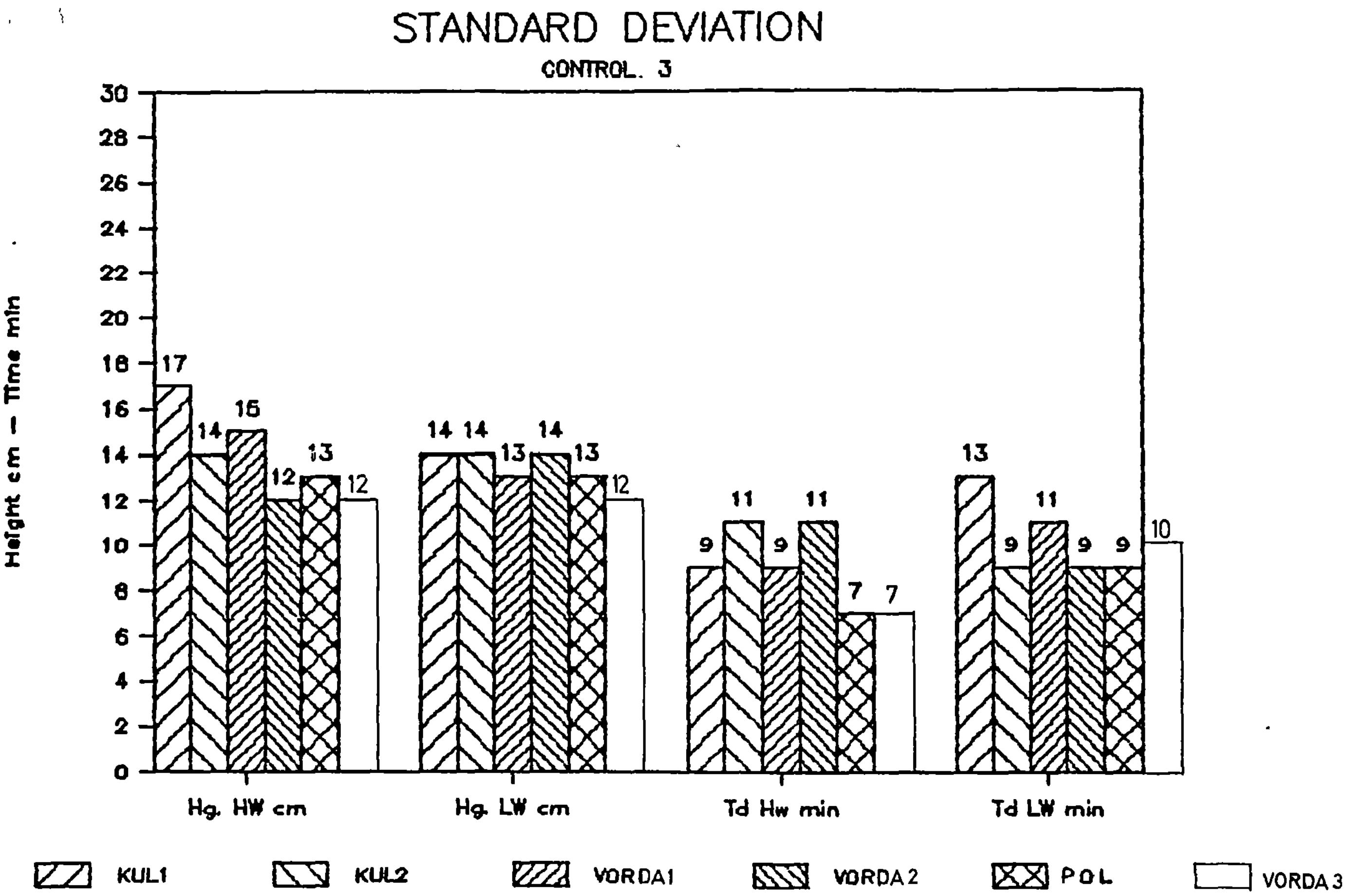
TIJDEN (h.min) in M.E.T. HOOGTEN (meter) t.o.v. T.A.W.
HOOGTE t.o.v. G.L.L.W.S. = HOOGTE t.o.v. T.A.W. + 0.39 m

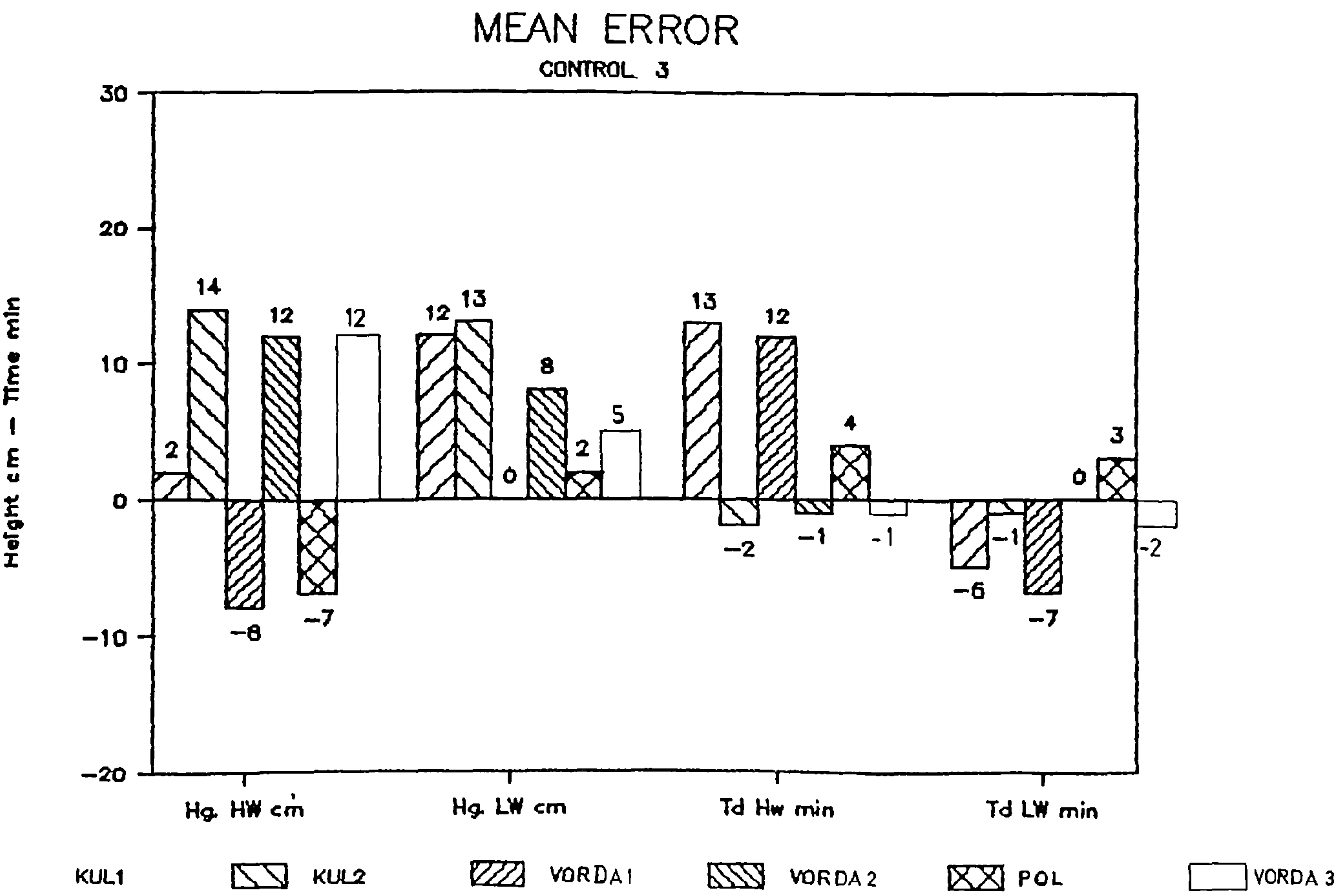
Hoogste H.W.= 4.89 Laagste H.W.= 3.23
Hoogste L.W.= 1.15 Laagste L.W.=-0.26

Gemiddeld Hoogwater = 4.206 met 58 waarnemingen
Gemiddeld Laagwater = 0.319 met 58 waarnemingen

QUALITY CONTROL ON TIDAL PREDICTIONS

HW/LW(heights and times) for OSTEND
Period : from 15/09/86 to 15/10/86

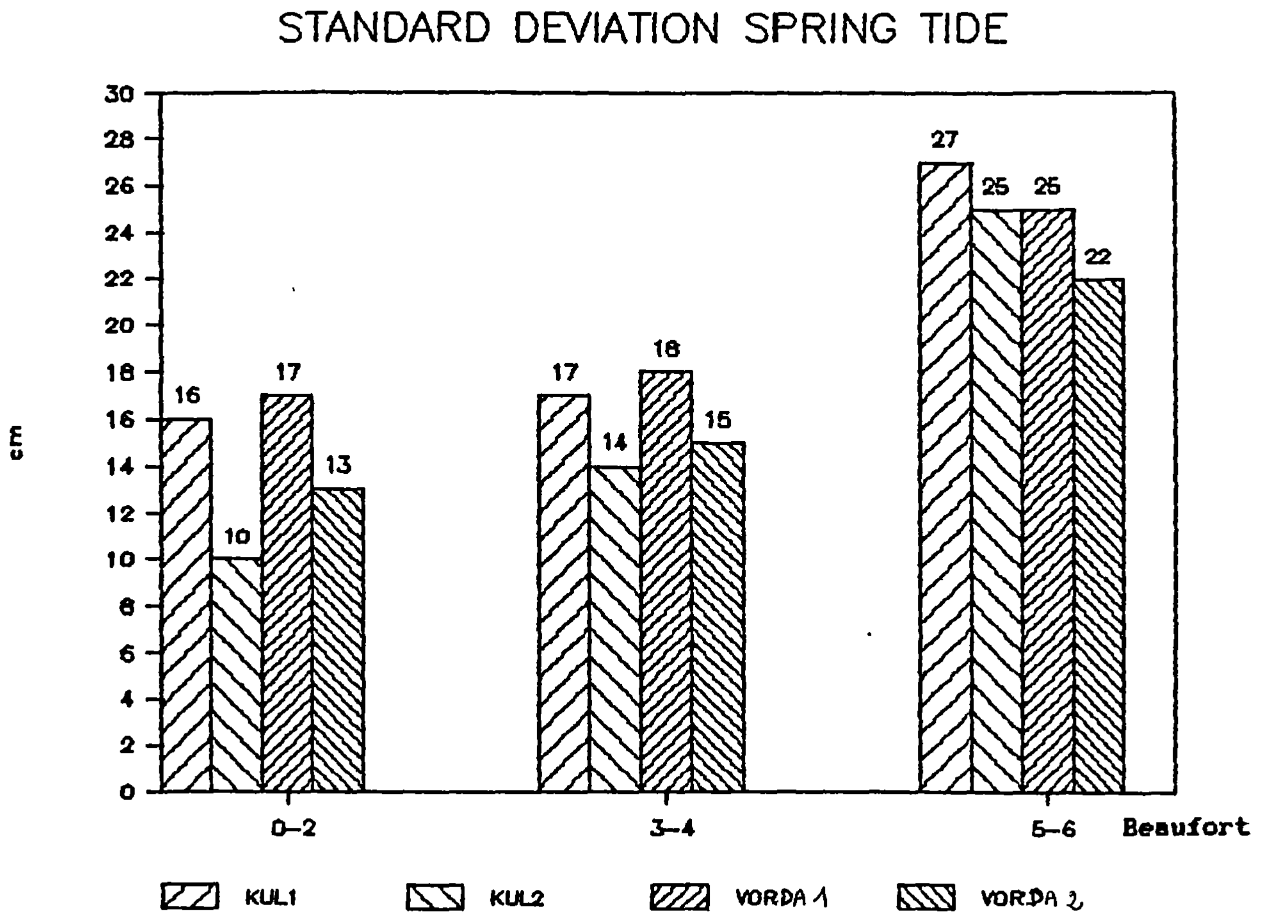


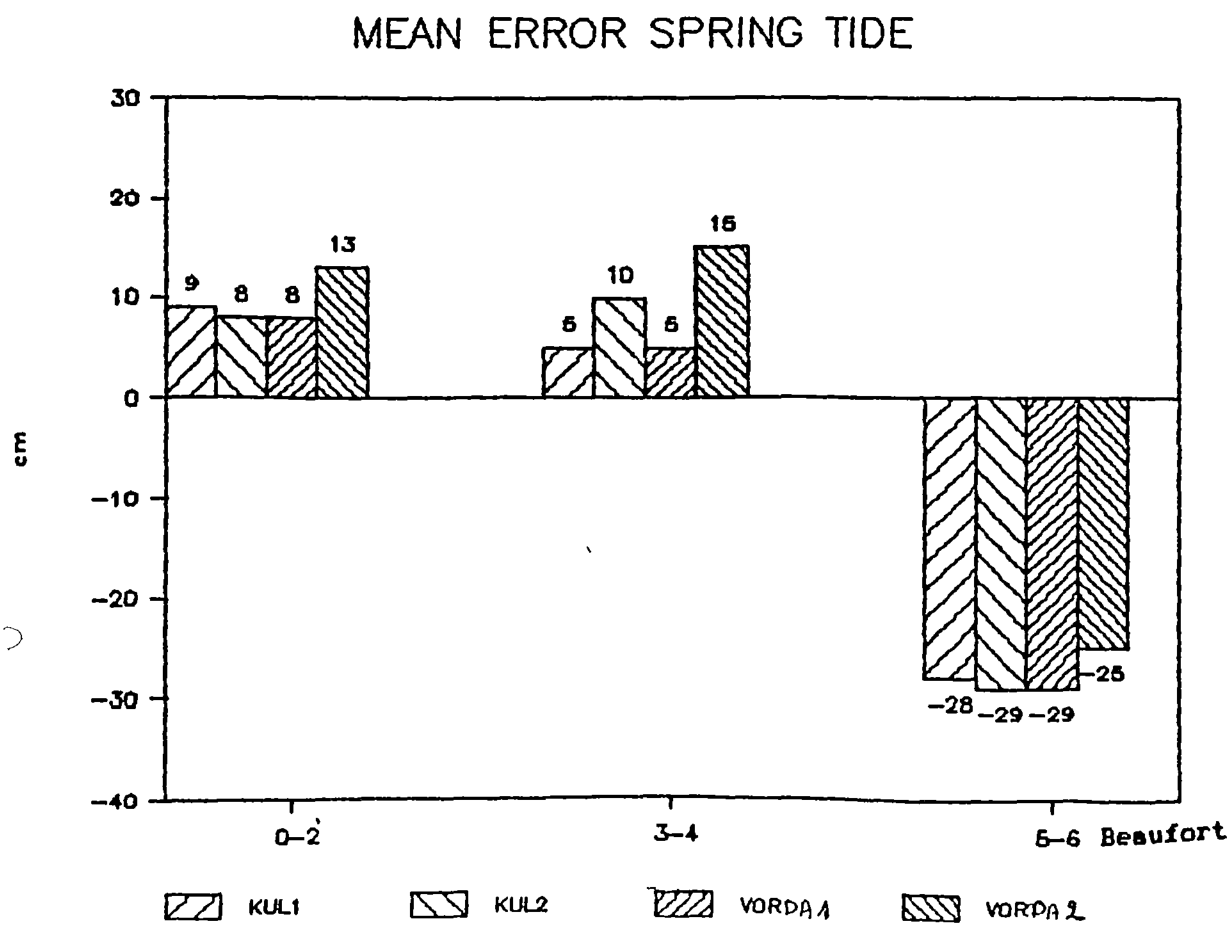


QUALITY CONTROL ON TIDAL PREDICTIONS

3 types of weather

(hourly heights) for OSTEND
Tidal type : SPRINGTIDE
Periods : 08-09/03/85 windstrength 0-2
01-02/02/87 3-4
21-22/11/87 5-6



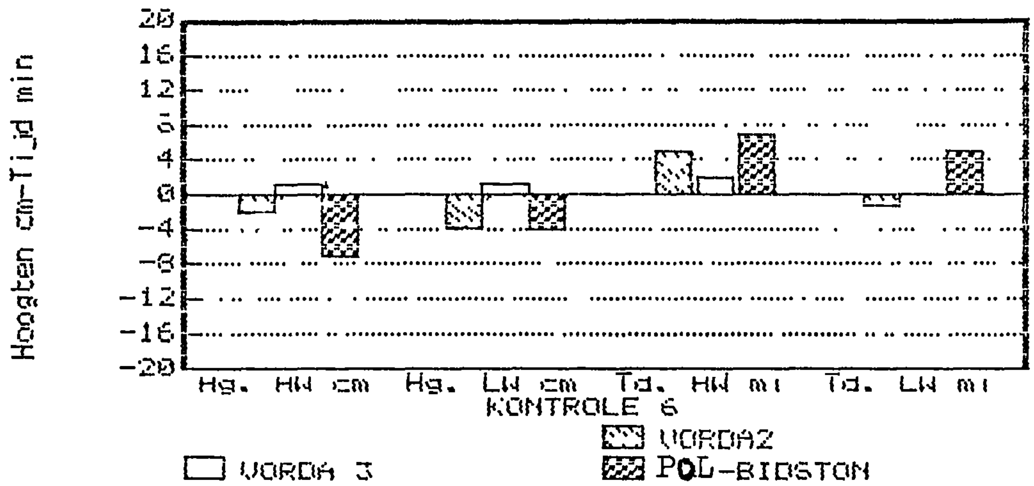


DIENST DER KUSTHAVENS
HYDROGRAFIE
OOSTENDE

QUALITY CONTROL ON TIDAL PREDICTIONS

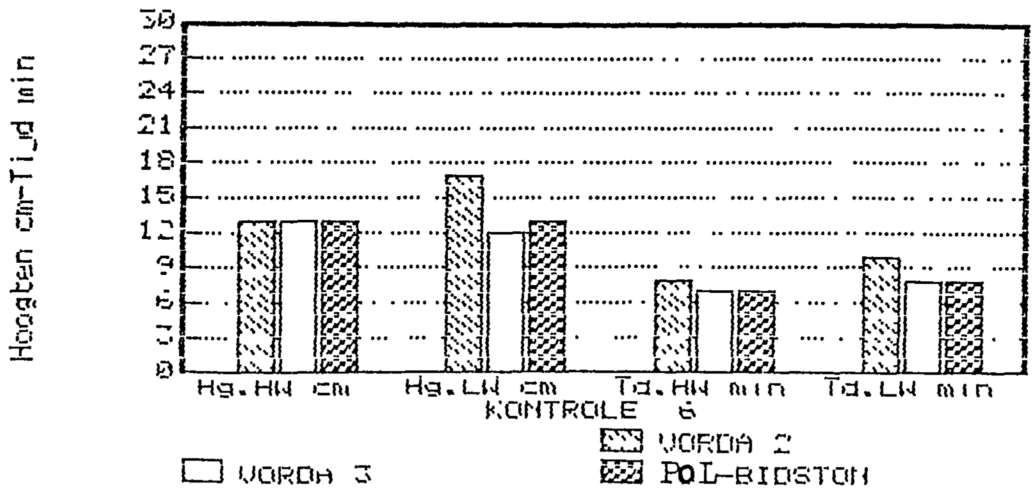
HW/LW(heights and times) for OSTEND
Periods : 23-24-25/6/89
6-7-8-9-10-11-12-13-22-23-24-25-27-28-29/7/89
2-3-4-5-6-7-8-18-19-20-21-22-23/8/89
4-5-6-7-17-18-19-20-21/9/89

GEMIDDELDE AFWIJKING GETIJVOORSPELLING (mean)



	VORDA2	VORDA 3	IOS-BIDSTON
Hg. HW cm	-2	+1	-7
Hg. LW cm	-4	+1	-4
d. HW min	5	2	7
Td. LW min	-1	0	5

STANDAARDAFWIJKING GETIJVOORSPELLING (stand.dev.)



	VORDA 2	VORDA 3	IOS-BIDSTON
Hg.HW cm	13	13	13
Hg.LW cm	17	12	13
Td.HW min	8	7	7
Td.LW min	10	8	8

DIENST DER KUSTHAVENS
HYDROGRAFIE
OOSTENDE

QUALITY CONTROL ON TIDAL PREDICTIONS

HW/LN (heights and times) for OOSTENDE
Years : 1989 en 1990

Year 1989

VOORSPEL. H.D. - DIGITIZER HOOG-EN LAAGWATER (VORDA2)
PERIODE: 1- 1-89 tot en met 31-12-89

PARAMETERS TIJD (hh.mm)		PARAMETERS GETIJ (cm)	
GEMIDDELDE =	0.02	GEMIDDELDE =	-1,28
VARIANTIE =	2.16	VARIANTIE =	474.61
STANDAARDAFWIJKING =	0.12	STANDAARDAFWIJKING =	21.79

VOORSPEL. H.D. - DIGITIZER HOOG-EN LAAGWATER (VORDA3)
PERIODE: 1- 1-89 tot en met 31-12-89

PARAMETERS TIJD (hh.mm)		PARAMETERS GETIJ (cm)	
GEMIDDELDE =	0.02	GEMIDDELDE =	-2,06
VARIANTIE =	1.39	VARIANTIE =	407.34
STANDAARDAFWIJKING =	0.10	STANDAARDAFWIJKING =	20.18

VOORSPEL. BIDSTON - DIGITIZER HOOG-EN LAAGWATER (POL)
PERIODE: 1- 1-89 tot en met 31-12-89

PARAMETERS TIJD (hh.mm)		PARAMETERS GETIJ (cm)	
GEMIDDELDE =	0.05	GEMIDDELDE =	-10.16
VARIANTIE =	1.26	VARIANTIE =	495.13
STANDAARDAFWIJKING =	0.09	STANDAARDAFWIJKING =	22.25

Year 1990

VOORSPEL. H.D. - DIGITIZER HOOG-EN LAAGWATER (VORDA2)
PERIODE: 1- 1-90 tot en met 31-12-90

PARAMETERS TIJD (hh.mm)		PARAMETERS GETIJ (cm)	
GEMIDDELDE =	0.03	GEMIDDELDE =	-1,17
VARIANTIE =	2.21	VARIANTIE =	693.40
STANDAARDAFWIJKING =	0.12	STANDAARDAFWIJKING =	26.33

VOORSPEL. H.D. - DIGITIZER HOOG-EN LAAGWATER (VORDA3)
PERIODE: 1- 1-90 tot en met 31-12-90

PARAMETERS TIJD (hh.mm)		PARAMETERS GETIJ (cm)	
GEMIDDELDE =	0.02	GEMIDDELDE =	-1,92
VARIANTIE =	2.01	VARIANTIE =	620.25
STANDAARDAFWIJKING =	0.11	STANDAARDAFWIJKING =	24.90

VOORSPEL. BIDSTON - DIGITIZER HOOG-EN LAAGWATER (POL)
PERIODE: 1- 1-90 tot en met 31-12-90

PARAMETERS TIJD (hh.mm)		PARAMETERS GETIJ (cm)	
GEMIDDELDE =	0.01	GEMIDDELDE =	1.85
VARIANTIE =	2.18	VARIANTIE =	698.21
STANDAARDAFWIJKING =	0.12	STANDAARDAFWIJKING =	26.42

DIENST DER KUSTHAVENS
HYDROGRAFIE
OOSTENDE

QUALITY CONTROL ON TIDAL PREDICTIONS

Hourly Heights for OOSTENDE

1) Year 1989

METHOD	Mean	Standard deviation
VORDA 2	-3,3 cm	23,3 cm
VORDA 3	-3,3 cm	21,4 cm

2) Summer 1989 (excellent weather conditions)

PERIODS	VORDA 2		VORDA 3		
	Mean	Standard deviation	Mean	Standard deviation	Number of days
Juni 1989:23/6 t.e.m.25/6	+1,5cm	12,7cm	+1,55cm	10,1cm	3
Juli 1989:06/7 " 13/7	-5,9cm	18,3cm	+0,3 cm	12,6cm	8
22/7 " 25/7	-2,1cm	8,2cm	+3,21cm	7,9cm	4
27/7 " 29/7	-1,9cm	11,1cm	+3,9 cm	9,3cm	3
August 1989 : 02/8 t.e.m.8/8	-9,3cm	15,4cm	-6,3 cm	10,1cm	7
18/8 " 23/8	-3,6cm	11,5cm	+1,7 cm	9,0cm	6
September 1989:4/9 " 7/9	+0,20cm	12,8cm	+8,8 cm	8,7cm	4
17/9 " 21/9	-7,0 cm	20,2	-6,7 cm	17,8cm	5
					40 days

DIENST DER KUSTHAVENS
HYDROGRAFIE
OOSTENDE

QUALITY CONTROL ON TIDAL PREDICTIONS

HW/LW (heights and times) for ZEEBRUGGE

Years 1989 en 1990

VOORSPEL. H.D. - DIGITIZER HOOG-EN LAAGWATER (VORDA2)
PERIODE: 1- 1-89 tot en met 31-12-89

PARAMETERS TIJD (hh.mm)		PARAMETERS GETIJ (cm)		
GEMIDDELDE =	0.00	GEMIDDELDE =	+0,26	Year 1989
VARIANTIE =	2.27	VARIANTIE =	505.87	
STANDAARDAFWIJKING =	0.12	STANDAARDAFWIJKING =	22.49	

VOORSPEL. BIDSTON - DIGITIZER HOOG-EN LAAGWATER
PERIODE: 1- 1-89 tot en met 31-12-89

PARAMETERS TIJD (hh.mm)		PARAMETERS GETIJ (cm)	
GEMIDDELDE =	0.03	GEMIDDELDE =	-5.32
VARIANTIE =	1.35	VARIANTIE =	513.88
STANDAARDAFWIJKING =	0.10	STANDAARDAFWIJKING =	22.67

VOORSPEL. H.D. - DIGITIZER HOOG-EN LAAGWATER (VORDA2)
PERIODE: 1- 1-90 tot en met 31-12-90

PARAMETERS TIJD (hh.mm)		PARAMETERS GETIJ (cm)		
GEMIDDELDE =	0.01	GEMIDDELDE =	-0,42	Year 1990
VARIANTIE =	2.37	VARIANTIE =	737.56	
STANDAARDAFWIJKING =	0.13	STANDAARDAFWIJKING =	27.16	

VOORSPEL. BIDSTON - DIGITIZER HOOG-EN LAAGWATER
PERIODE: 1- 1-90 tot en met 31-12-90

PARAMETERS TIJD (hh.mm)		PARAMETERS GETIJ (cm)	
GEMIDDELDE =	0.00	GEMIDDELDE =	5.49
VARIANTIE =	2.23	VARIANTIE =	756.17
STANDAARDAFWIJKING =	0.12	STANDAARDAFWIJKING =	27.50