VIIIth IHO TIDAL COMMITTEE MEETING
Halifax, Canada 23 – 25 October 2007

Final Report

1. OPENING

The meeting was opened at 0900 on 23rd October 2007 in the Maritime Museum of the Atlantic at Halifax, Nova Scotia. The list of participants is given in Annex A.

Mr Steve Forbes, Director of the Atlantic Region of the Canadian Hydrographic Service (CHS), welcomed the delegates attending the VIIIth Meeting of the IHO Tidal Committee (TC). He wished them a successful and enjoyable meeting, and outlined the interests of the CHS. He went on to emphasize the need to keep abreast of environmental changes both locally in Canada and on a global basis. He mentioned particularly the impact of such changes on commercial maritime interests.

Lt Cdr Steve Shipman (IHB) expressed the appreciation of the IHO for Canada agreeing to host the VIIIth TC Meeting.

The Chairman also thanked Mr Forbes for kindly hosting the TC Meeting, and the Maritime Museum for providing such excellent facilities. He extended special thanks to Mr Charles O'Reilly for his invaluable help and support in the preparation for the meeting.

The Chairman extended a warm welcome to the delegates from Brasil, France, Norway and Spain representing their countries for the first time.

During the morning of the 23rd a Tidal Seminar was held with presentations made by delegates from USA and UK. A detailed list of the subjects presented is given in Annex B.

2. ADMINISTRATIVE ARRANGEMENTS

2.1 Adoption of the Agenda

The Agenda was presented to delegates for consideration and accepted without modification. See Annex C.

2.2 Conduct of the Sessions

The timetable was presented and explained to the delegates. See Annex D.

Apologies for absence were received from Chile, China, Germany and Japan.

2.3 Report on Intersessional Activities

The Chairman mentioned the work undertaken in connection with the completion of the Task Identification Form he submitted to the IHB and the work he undertook in the summary of the presentation of Secondary Port Data in National Tide Tables. He then outlined the detailed work done at UKHO in the creation of the Exchange Format for Harmonic Constants.

He referred to the CL issued by the IHB in respect of Technical Resolution A6.2, and the draft CL prepared for a new Technical Resolution on the Naming Convention for Chart Datum.

He mentioned the contact made with the Chairman of the CSPCWG at the UKHO by the IHB concerning the proposed amendments to the relevant articles in M-4. He concluded by highlighting the presentation of the TC Report to the XVIIth IHC which had been well received.

2.4 Minutes of the VIIth IHO TC Meeting

The Minutes of the VIIth IHO TC Meeting were accepted without amendment.

2.5 Matters arising from the VIIth IHO TC Meeting

There were no matters arising out of the VIIth IHO TC Meeting other than the intersessional activities mentioned in 2.3 above. All Action Items from the VIIth TC Meeting had been successfully completed and would be reflected in the agenda items for this meeting.

3. PROGRAMME MATTERS

3.1 Update on Standard Constituent List

The Chairman advised the TC members of the state of the latest Standard Constituent List. He acknowledged the support and expertise of Bernard Simon who assisted him in the completion of the list, especially with regard to the Nodal Corrections.

He encouraged member states to submit new HC's but emphasized the need to include XDO's and Nodal Corrections in addition to the name and speed of any new HC's. He stated that UKHO would act as custodian of the list on behalf of the IHO and maintain it with regard to any new HC's submitted by MS with a view to updating the IHO website accordingly.

3.2 Format for Exchange of Harmonic Constants

Mr Chris Jones (United Kingdom) presented the work done at the UKHO on the creation of a proposed format for the Exchange of Harmonic Constants. Details of this presentation and the Product Specification are held on the IHO website and are also given in Annexes E1 and E2.

After discussion between delegates concern was expressed over the possibility of virus contamination in the XML files. Hopefully normal virus checking software might give the level of acceptable protection, but confirmation will be provided from UKHO IT staff that XML files will be thoroughly virus checked.

When the new format has been thoroughly tested and accepted by MS it would then be logical to adopt a similar XML format for the exchange of annual tidal predictions, replacing the existing ASCII format currently in use.

3.3 Digital Tide Tables

The Chairman emphasized the need for MS to respond positively to the recommendation outlined in Agenda Item 5.6 of IHOTC 2, which was re-iterated in the Chairman's report to the XVIIth IHC, by considering the production of national digital tide tables which have both functionality and intelligence built into them.

He advised the TC that it may only be a matter of 5-10 years before all major shipping vessels will be using digital tide tables in preference to paper tide tables and it is incumbent upon MS to be prepared for this event.

The TC concluded that a CL should be issued by the IHB to establish the status of digital tide tables produced by MS. Where a MS has not produced a digital tide table they will be requested to declare their intentions to do so. Where a MS does not necessarily have the resources to develop their own digital tide tables then they may wish to consider the co-production under license of an established digital tide table of another MS, for example UK's TotalTide or France's WorldTide.

3.4 Tide Table Construction

The Chairman explained the rationale behind the summary he produced into the principles for predictions using Secondary Port Data in national tide tables. The details are given in Annex F.

After considerable discussion between delegates questions were raised as to the preference for using a range ratio rather than direct height differences applied to the Standard Port predictions. It was concluded that the respective methodologies had developed as a result of historic precedent, and provided the results continued to yield acceptable predictions then there should be no requirement to change the status quo to a unified system.

3.5 Naming Convention for Chart Datum

The draft CL prepared by Lt Cdr Steve Shipman (IHB) was discussed at length and eventually accepted without amendment. The full details are given in Annex G. He agreed to arrange for the issue of the CL at the earliest opportunity.

3.6 Vertical Reference Framework

Lt Cdr Steve Shipman (IHB) presented the summary of the work done by the IAG and FIG in connection with vertical reference frames. The details are given in Annex H.

Because the work of the IAG was written by and for geodesists he succeeded in having an entire section on Chart Datum included in order to expand their understanding of the vertical datum aspects of hydrography. He drew attention to FIG Publication No 37 emphasizing the value of the guidance it contained on vertical reference surfaces for hydrography.

The Chairman expressed the deep appreciation of the TC for his continued representation of members' interests on these two influential international bodies.

3.7 Update on IOC/GLOSS Programme

The TC was grateful to Professor Keith Thompson from Dalhousie University for presenting a comprehensive update on the IOC/GLOSS programme. Full details of the presentation are given in Annex I, which revealed a deceleration in the rate of MSL rise over the latter half of the 80 year record at Halifax.

Lt Cdr Steve Shipman (IHB) attended the GE-X Meeting in Paris in June 2007 and gave a brief summary of the outcome, details of which are given in Annex J.

3.8 Global Sea Level Rise effects

The Chairman had carried out extensive research into the changes in tidal ranges at the major ports around the UK since the previous TC meeting. The comparison between 1997 and 2007 was deliberately chosen as the astronomical tide raising forces for both these years were virtually identical, thereby ensuring that any changes in tidal range detected could not be attributable to the variations in astronomical influences. The reduction in tidal range was seen to be greatest at those ports with the largest tidal range. For details see Annex K.

This topic generated vigorous debate and was recognized as a very complex issue influenced by several potential factors such as crustal movements, changes in seabed topography and not least of all changes in the resonant frequency of the ocean.

No other MS reported any significant changes in tidal range, but USA presented the results of their research at Annex L. However, the Chairman emphasized the need for each MS to monitor changes in tidal ranges over the coming years in the interests of environmental impact assessment. The TC concluded that this would be an excellent topic to put before the GLOSS Group of Experts for further research in line with oceanographic considerations.

3.9 Matters arising from the XVIIth IHC

Lt Cdr Steve Shipman (IHB) presented the written report of the IHO TC to the XVIIth IHC. The conference welcomed the report and several expressions of gratitude for the work of the TC were made from the floor. The Conference endorsed the report and approved the recommendations listed, namely the amendment to IHO Technical Resolution A6.8, tasking the TC to develop standards for digital tide tables, and endorsing the continuing liaison with IOC/GLOSS.

The IHC report tasked the TC to maintain the Standard List of Harmonic Constituents and to review the tidal-related IHO Technical Resolutions. The

Chairman of the TC was tasked, with IHB support as needed, to organize, prepare and conduct meetings in 2009, 2010 and 2012. He was also tasked to coordinate and execute the detail of approved IHO WP items, providing guidance and advice to relevant organizations, bodies and MS.

3.10 IHO Committees Structure

The XVIIth IHC held in Monaco in May 2007 approved the reorganization of the committee structure of the IHO. The revised structure will come into force no later than 1st January 2009. Details of this new structure are shown in the organizational diagram in Annex M.

Lt Cdr Steve Shipman (IHB) explained that the new structure would call for far greater regulatory control and that the existing 5-yearly Conference is to be replaced by a 3-yearly Assembly to approve the WP and budget for each 3 year period. There is to be a Council composed of MS which will meet on a yearly basis. However, these changes to the convention need to be ratified by a two-thirds majority of MS.

The TC were invited by the IHO to review their TOR's and consider a more concise title for the Group. The draft TOR's (see Annex N) were studied in detail and agreed by all delegates, with the new title proposed as Tidal Working Group (TWG).

3.11 IHO Capacity Building Programme

With respect to the IHO, "Capacity Building" is defined as the process by which the organization assesses and assists in sustainable development and improvement of the States, to meet the objectives of the IHO and the hydrography, cartography and marine safety obligations and recommendations described in UNCLOS, SOLAS V and other international instruments.

The XVIIth IHC confirmed that Capacity Building was a strategic issue for the IHO. The Chairman of the IHO Capacity Building Committee wrote to the Chairs of all IHO Committees and Working Groups seeking information as to their ability to assist in training programmes for Capacity Building.

The TC were invited to consider how it could best respond to this request. The Chairman encouraged MS to look at the possibility of providing training course material and/or presentational material to meet the request. This resulted in vigorous lengthy debate amongst the delegates, however it would be for Regional IHO Commissions to define their requirements in the first instance in priority order before any such material is offered up.

3.12 Review of relevant IHO Technical Resolutions

All existing Technical Resolutions A2.5, A2.8, A2.9 & A6.1 - A6.9 ; G1.1, G1.2, G2.1 & G3.1 - G3.3 ; and K1.7 were reviewed in detail, resulting in the following proposed amendments (added text in italics);

A2.5, Paragraph 1

> It is resolved that heights on shore, including elevations of lights, should be referred to a HW datum. *Heights should be referred to Mean Sea Level (MSL) where the tidal range is not appreciable*. The datum used should be clearly stated on all charts.

A2.5, Note (ii)

> In non-tidal waters, in order to allow the development of regional solutions, it is recommended that *an appropriate long term* range of low/high water definitions of the lower/upper 94-100 percentile be adopted.

A2.5, Paragraph 4, last sentence

> It is further resolved that such observations should relate to *an appropriate* geocentric reference system, *such as* the World Geodetic System 1984 (WGS84), *or the International Terrestrial Reference System (ITRS)*.

A2.9, Paragraph 6

> It is resolved that velocities shall be given in knots *to one decimal place*.

A6.4, delete Paragraph 3(b).

K1.7, delete in entirety.

Lt Cdr Steve Shipman (IHB) undertook to arrange for the issue of a CL showing these amendments for each of the above Technical Resolutions.

3.13 Review of relevant IHO Charting Specifications

All Charting Specifications B-302 – 303, B-310, B-380, B-405 – 408 and B-471.6 were reviewed in detail, resulting in the following proposals to be put to the Chairman of the CSPCWG :

B-302.2 - the **Comments** to be reviewed in the light of the proposed amendments to Technical Resolution A2.5.

B-407.2 – add the following words in italics to the first sentence:

> **Stations** (locations) at which tidal streams have been observed *or determined from tidal models* and for which the data has been charted must be assigned reference letters A, B, C,… in some regular order.

Lt Cdr Steve Shipman (IHB) undertook to contact the Chairman of the CSPCWG accordingly.

3.14 French Manual of Tides

The completed French Manual of Tides written by Bernard Simon was presented at the meeting. It consists of 10 chapters and 5 annexes and is available at a cost of 50 euros. It is currently being translated into English, albeit slowly, and Lt Cdr Steve Shipman (IHB) is acting as the technical point of contact. He has requested that the English texts be supplied chapter by chapter for proof reading, whereupon they will be circulated around appropriate MS for checking. IOC experts have also offered to assist with the proof reading.

4. Any Other Business

The TC were invited by the IHO to submit any tidal topics that would be suitable for secondees at the IHB to take on. After a brief discussion it was considered that no appropriate topics from the TC's WP were available at the present time. However, the Chairman recommended that this matter be kept under review at subsequent meetings.

5. Review of Action Items

Item 3.1 – the UK delegate to act as custodian of the Standard Constituent List and maintain it on behalf of the IHO.

Item 3.2 – the UK delegate to provide confirmation from UKHO IT staff that XML files would be virus checked.

Item 3.3 – Lt Cdr Steve Shipman (IHB) to arrange for the issue of a CL to determine the status of digital tide tables amongst MS.

Item 3.5 – Lt Cdr Steve Shipman (IHB) to arrange for the issue of a CL on the Naming Convention for Chart Datum.

Item 3.12 – Lt Cdr Steve Shipman (IHB) to arrange for the issue of a CL for the amendments to the Technical Resolutions A2.5, A2.9, A6.4 and K1.7 in M-3.

Item 3.13 – Lt Cdr Steve Shipman (IHB) to contact the Chairman of the CSPCWG concerning articles B-302.2 and B-407.2 of the Charting Specifications M-4.

6. Resignation and Election of Chairman

The incumbent Chairman, Commander John Page (United Kingdom), who had been in post for three years, placed his resignation before the Committee and called for the consideration and election of a new Chairperson.

After a brief discussion, Mr Stephen Gill (United States) volunteered to take up the position. The TC then asked Lt Cdr Steve Shipman (IHB) to put forward his name for due consideration by MS in accordance with the normal procedures of the IHO.

7. Venue and Date of VIIth IHO TC Meeting

The TC confirmed after a brief discussion that future meetings should continue to be held in countries where the presence of the TC could contribute much needed tidal expertise. It was concluded that the IXth Meeting should be held in Brasil in April 2009. China and India, in that priority order, would be considered as alternative venues.

8. Adoption of Draft Report

The draft report was prepared and discussed in detail. Subsequent amendments would be incorporated in the final draft and circulated to delegates for comment at the earliest opportunity. The Final Report would then be posted in the IHO website.

9. Closing Remarks

The Chairman thanked the Canadian Hydrographic Service for the excellent facilities arranged for the meeting, and also for the generosity of their hospitality throughout the time in Halifax.

He thanked the delegates for their valuable contributions to all the discussions, which had lead to an extremely productive and fruitful meeting.

He expressed his pride at being Chairman of the Tidal Committee, and wished his successor every good fortune in the post, which he hoped would provide him with an equally stimulating experience as he had enjoyed.

Mr Stephen Gill (United States) then voiced the appreciation of the TC for the dedicated work, energy and leadership that Commander John Page had exercised throughout his term of office.

The VIIIth TC Meeting was then closed at 1100 on 25^{th} October 2007.

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TIDAL SEMINAR

- **Advances in Vertical Datum Transformation Tools and use of Interpretation Tidal Models for Hydrographic Surveys at NOAA**
  Mr Stephen Gill, National Oceanic and Atmospheric Administration

- **Exchange Format for the Transfer of Tidal Harmonic Constants**
  Mr Chris Jones, United Kingdom Hydrographic Office

Agenda

1. Opening

a. Welcoming address

2. Administrative Arrangements

a. Adoption of the Agenda
b. Conduct of the Sessions
c. Report on Intersessional Activities
d. Minutes of the VIIth IHO TC Meeting
e. Matters arising from the VIIth IHO TC Meeting

3. Programme Matters

3.1 Update on Standard Constituent List
3.2 Format for Exchange of Harmonic Constants
3.3 Digital Tide Tables
3.4 Tide Table Construction
3.5 Naming Convention for Chart Datum
3.6 Vertical Reference Framework
3.7 Update on IOC/GLOSS Programme
3.8 Global Sea Level Rise effects
3.9 Matters Arising from the XVIIth IHC
3.10 IHO Committees Structure
3.11 IHO Capacity Building Programme
3.12 Review of relevant IHO Technical Resolutions
3.13 Review of relevant IHO Charting Specifications
3.14 French Manual of Tides

4. Any Other Business

5. Review of Action Items

6. Resignation and Election of Chairman

7. Venue and date of the IXth IHO TC Meeting

8. Adoption of Draft Report

9. Closing Remarks

VIIIth IHO TIDAL COMMITTEE MEETING
HALIFAX, CANADA 23-25 OCTOBER 2007

TIMETABLE

	OCTOBER 23	OCTOBER 24	OCTOBER 25
09.00 - 09:30	**1. Opening** Welcoming address	**<u>Program Matters continued:</u>** 3.7 Update on IOC/GLOSS Program 3.8 Global Sea Level Rise effects	**<u>Program Matters continued:</u>** **5. Review of Action Items** **6. Resignation and Election of Chairman** **7. Venue and date of the IXth IHO TC Meeting**
09:30 - 11:00	**TIDAL SEMINAR**		
11:00 - 11:20	Tea/coffee break	Tea/coffee break	Tea/coffee break
11:20 - 13.00	**TC Meeting commences** **2. Administrative Arrangements** Adoption of the Agenda / Conduct of the Sessions Report of Intersessional Activities Minutes of VIIth IHO TC Meeting Matters arising from VIIth IHO TC Meeting **3. Program Matters** 3.1 Update on Standard Constituent List 3.2 Format for Exchange of Harmonic Constants	**<u>Program Matters continued:</u>** 3.9 Matters arising from the XVIIth IHC 3.10 IHO Committees Structure 3.11 IHO Capacity Building Programme	**7. Adoption of Draft Report** **8. Closing Remarks**
13:00 - 13:15	Official photograph		
13:00 - 14:00	Lunch break	Lunch break	Lunch break
14:00 – 15:20	**<u>Program Matters continued:</u>** 3.3 Digital Tide Tables 3.4 Tide Table Construction	**<u>Program Matters continued:</u>** 3.12 Review of relevant IHO Technical Resolutions 3.13 Review of relevant IHO Charting Specifications 3.14 French Manual of Tides	**Tour of the Museum and CSS Acadia** **(1400 – 1600)**
15:20 - 15:40	Tea/coffee break	Tea/coffee break	
15:40 - 17:00	**<u>Program Matters continued:</u>** 3.5 Naming Convention for Chart Datum 3.6 Vertical Reference Framework	**<u>Program Matters continue:</u>** **4. Any Other Business**	
17:00	End of first day session	End of second day session	
19:00 - 22:00	--	---	Official Dinner at Salty's Seafood Restaurant.

Digital Exchange of Harmonic Constants

Christopher Jones

United Kingdom Hydrographic Office

Background

- Harmonic Constant (HC) data is passed freely between Foreign Government Hydrographic Offices (FGHO's) on request......BUT......
- .....it is frequently in a variety of differing digital formats and layouts

Some Examples….

Brazil

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|35341.0300000060719843009198430114TERMINAL ALUMAR                     02407S044218W+030
0MSF    001.0158958                   1    -1 00011.7200030.38
1O1     013.9430356                           00010.9000216.96
1P1     014.9589314                           00004.0600252.36
1K1     015.0410686                           00012.2600255.23
12N2    027.8953549                           00005.5100180.37
1MU2    027.9682084                           00010.8500271.59
1N2     028.4397295                           00041.7700193.75
1NU2    028.5125831                           00007.9400195.54
1M2     028.9841042                           00218.7200207.12
1LAMBD2 029.4556253                           00001.5300225.07
1L2     029.5284789                           00016.4500176.92
1T2     029.9589333                           00003.5300244.26
1S2     030.0000000                           00059.7600245.81
1K2     030.0821373                           00016.2500248.94
0MO3    042.9271398   1               1       00002.3600314.60
1M3     043.4761563                           00002.3500307.75
0MK3    044.0251728           1       1       00004.2600016.26
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0MS4    058.9841042                   1     1 00006.1400277.20
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0MNO5   071.3668693   1         1     1       00000.5500317.31
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0MSK5   074.0251728           1       1     1 00000.6200216.63
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02MN6   086.4079380               1   2       00002.5900290.85
0M6     086.9523127                   3       00005.0200311.64
0MSN6   087.4238337               1   1     1 00001.1900350.90
02MS6   087.9682084                   2     1 00004.3900341.33
0MKL6   088.5967204                   1 1    100000.8500241.09
02SM6   088.9841042                   1     2 00001.2400053.40
02SMK7  104.0251728           1       1     2 00000.7500088.61
0M8     115.9364169                   4       00000.5500320.94
03MS8   116.9523127                   3     1 00000.7300000.77
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Spain

15 arrecife GMT 2857 1334

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6	MF	.00305009	15	197/1297	0.0129	5.27
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8	2Q1	.03570635	15	197/1297	0.0046	200.94
9	SIG1	.03590872	15	197/1297	0.0034	219.80
10	Q1	.03721850	15	197/1297	0.0184	244.70
11	RHO1	.03742087	15	197/1297	0.0023	250.49
12	O1	.03873065	15	197/1297	0.0509	296.64
13	TAU1	.03895881	15	197/1297	0.0015	33.86
14	BET1	.04004044	15	197/1297	0.0010	61.34
15	NO1	.04026860	15	197/1297	0.0068	33.51
16	CHI1	.04047097	15	197/1297	0.0013	112.74
17	P1	.04155259	15	197/1297	0.0211	27.00
18	K1	.04178075	15	197/1297	0.0696	44.23
19	PHI1	.04200891	15	197/1297	0.0009	60.76
20	THE1	.04309053	15	197/1297	0.0012	96.23
21	J1	.04329290	15	197/1297	0.0012	78.84
22	SO1	.04460268	15	197/1297	0.0012	117.27
23	OO1	.04483084	15	197/1297	0.0027	125.05
24	UPS1	.04634299	15	197/1297	0.0004	73.13
25	OQ2	.07597495	15	197/1297	0.0054	347.65
26	EPS2	.07617731	15	197/1297	0.0076	335.88
27	2N2	.07748710	15	197/1297	0.0262	8.79
28	MU2	.07768947	15	197/1297	0.0333	356.02
29	N2	.07899925	15	197/1297	0.1739	21.11
30	NU2	.07920162	15	197/1297	0.0324	25.54
31	M2	.08051140	15	197/1297	0.8337	36.00
32	MKS2	.08073956	15	197/1297	0.0127	68.62

Netherlands

Bath
(N 51 24 E 4 13)
Harmonic constituents computed from hourly levels 1997...2000
(SA and SM from hourly levels 1976...1994)
Mean level = 2.79 meter above chart datum
Resp. name, phase angle (g) in degree (time zone : MET = UT + 1 hour),
amplitude (H) in meter, speed in degrees per hour, and Extended Doodson Number

SA	219.20	.06550	.041069	056555
SM	45.80	.08250	1.015896	073555
Q1	169.87	.03812	13.398661	135655
O1	214.13	.11095	13.943036	145555
M1C	148.71	.00810	14.492052	155555
P1	18.74	.03790	14.958931	163555
S1	8.47	.01076	15.000000	164555
K1	32.92	.07017	15.041069	165555
3MKS2	305.83	.02433	26.870174	217555
3MS2	304.03	.04844	26.952312	219555
OQ2	354.34	.01561	27.341696	225655
MNS2	170.12	.04209	27.423834	227655
2ML2S2	339.94	.03023	27.496687	229455
NLK2	21.11	.05082	27.886070	235555
MU2	187.27	.20563	27.968208	237555
N2	68.82	.34417	28.439730	245655
NU2	54.72	.12188	28.512583	247455
MSK2	263.17	.02979	28.901966	253555
MPS2	152.04	.03604	28.943035	254555
M2	92.03	2.10941	28.984104	255555
MSP2	146.56	.00771	29.025173	256555
MKS2	260.15	.01820	29.066240	257555
LABDA2	104.14	.06988	29.455626	263655
2MN2	286.76	.18402	29.528479	265455
T2	138.40	.03415	29.958933	272556
S2	155.65	.54475	30.000000	273555
K2	156.43	.15648	30.082136	275555
MSN2	.10	.03611	30.544374	283455
2SM2	22.23	.04873	31.015896	291555
SKM2	34.47	.02409	31.098034	293555
NO3	185.98	.01874	42.382767	335655
2MK3	224.94	.04165	42.927139	345555
2MP3	242.64	.00679	43.009277	347555
SO3	311.44	.02151	43.943035	363555
MK3	30.67	.03419	44.025173	365555
SK3	91.24	.01331	45.041069	383555

Germany

506 Cuxhaven Steubenhoef 15 53 52N 008 43E

1	Z0	.00000000	506	1	1/12		1184.0000	.00	515.3334	.00
2	SSA	.00022816	506	1	1/12	1	4.6340	93.79	4.6340	252.59
3	MSM	.00130978	506	1	1/12	1	3.1439	311.62	3.1439	129.43
4	MM	.00151215	506	1	1/12	1	10.7527	243.08	10.7527	148.50
5	MSF	.00282193	506	1	1/12	1	.8476	89.67	.8476	172.91
6	MF	.00305009	506	1	1/12	1	5.7937	344.11	5.7937	226.15
7	ALP1	.03439657	506	1	1/12	1	.3806	140.38	.3859	70.02
8	2Q1	.03570635	506	1	1/12	1	.4287	162.65	.4518	270.38
9	SIG1	.03590872	506	1	1/12	1	.9406	34.37	.9471	227.67
10	Q1	.03721850	506	1	1/12	1	2.3069	210.85	2.3621	222.75
11	RHO1	.03742087	506	1	1/12	1	1.1721	220.42	1.1367	316.36
12	O1	.03873065	506	1	1/12	1	9.5686	264.02	9.5837	180.29
13	TAU1	.03895881	506	1	1/12	1	.6317	217.04	.6707	108.91
14	BET1	.04004043	506	1	1/12	1	1.0199	254.58	1.0219	166.76
15	NO1	.04026859	506	1	1/12	1	1.1642	274.65	1.1208	339.00
16	CHI1	.04047097	506	1	1/12	1	.4777	330.59	.4827	156.24
17	P1	.04155259	506	1	1/12	1	3.1869	55.59	3.1881	66.76
18	K1	.04178075	506	1	1/12	1	7.0270	56.86	7.0419	55.13
19	PHI1	.04200891	506	1	1/12	1	.8369	162.94	.8647	307.35
20	THE1	.04309053	506	1	1/12	1	.5503	239.48	.5328	59.31
21	J1	.04329290	506	1	1/12	1	.3004	212.75	.3245	116.85
22	SO1	.04460268	506	1	1/12	1	.3930	260.35	.3936	343.96
23	OO1	.04483084	506	1	1/12	1	.4093	130.14	.4031	28.56
24	UPS1	.04634299	506	1	1/12	1	.4783	255.08	.4870	64.27
25	OQ2	.07597494	506	1	1/12	1	1.7487	326.48	2.0141	177.79
26	EPS2	.07617731	506	1	1/12	1	3.1475	46.92	3.3648	340.13
27	2N2	.07748710	506	1	1/12	1	4.5215	354.13	5.0346	106.78
28	MU2	.07768947	506	1	1/12	1	13.5897	101.04	13.8726	297.51
29	N2	.07899925	506	1	1/12	1	22.0550	341.58	22.1392	354.79
30	NU2	.07920162	506	1	1/12	1	8.0515	325.00	8.1679	65.81
31	M2	.08051140	506	1	1/12		1136.7370	10.92	137.4238	289.74
32	MKS2	.08073957	506	1	1/12	1	1.8893	133.49	1.8652	228.88
33	LDA2	.08182118	506	1	1/12	1	5.4992	26.27	5.5305	303.38
34	L2	.08202355	506	1	1/12	1	11.5236	36.96	12.1924	27.60
35	S2	.08333334	506	1	1/12	1	34.6370	80.17	34.6344	80.04
36	K2	.08356149	506	1	1/12	1	10.5368	83.92	10.3515	260.37
37	MSN2	.08484548	506	1	1/12	1	2.6139	268.63	2.6369	174.11
38	ETA2	.08507364	506	1	1/12	1	.0862	351.21	.0974	75.50
39	MO3	.11924210	506	1	1/12	1	1.4782	189.39	1.4879	24.48
40	M3	.12076710	506	1	1/12	1	.4448	250.61	.4481	308.95
41	SO3	.12206400	506	1	1/12	1	.8740	287.35	.8753	203.49
42	MK3	.12229210	506	1	1/12	1	.9571	316.81	.9640	233.89

France

Calais

temps en usage: UT +1.0 h
L=50 58N G= 1 51E

longues periodes

onde	nb argument	vitesse (°/h)	amplitude (cm)	situation (°)
NIV MOY	055555	0.00000000	406.58	0.03
SA	056555	0.04106864	8.41	221.82
SSA	057555	0.08213728	2.33	94.68
MSM	063655	0.47152109	0.58	63.24
MM	065455	0.54437469	1.16	218.11
MSF	073555	1.01589578	1.76	186.92
MF	075555	1.09803306	0.91	351.46

diurnes

onde	nb argument	vitesse (°/h)	amplitude (cm)	situation (°)
2Q1	125755	12.85428619	0.68	111.68
SIGMA1	127555	12.92713980	0.22	253.43
Q1	135655	13.39866088	1.67	114.21
RHO1	137455	13.47151449	0.55	136.04
O1	145555	13.94303558	5.52	155.01
MS1	146555	13.98410422	1.42	61.95

Canada

```
WaterLevConstit 00065 SAINT JOHN                                      0/00/00||
!Computed    45 16.00  N  66 04.00  W                        +04    0000:00   ||
        60 0365days 100.0%                                          0000:00 06||
Stephenson,FE                                                               ||
Reference v2.2 002                                                         0||
                                  0   0                                     ||
01 Const Name [Ref Nam]     0       TW                                      ||
02 Nominal Period hours     1       3W                                      ||
03 Amplitude     metres     2       4W                                      ||
04 Phase Lag[g]     deg     1       2W                                      ||
05 Doodson Numbers          0       TW                                      ||
06 Security                 0       TW                                      ||
Tides & Currents, IOS    Shore                                              ||
00065const.wlev                                        fl__00065cyyddda.wlev ||
**                                                                          ||
Constitutents from Crawford's analysis at IOS (Jan 2/97)                    ||
Z0 changed from 4.4100 to previous "Bluebook" value of 4.4200 m BdLB 9 Jan 97||
Checked against Crawford's results ok BdLB 9 Jan 1997                       ||
Doodson numbers as defined by Godin's The Analysis of Tides. pp 25-27       ||
                                                                            ||
                                                                            ||
                                                                            ||
                                                                            ||
                                                                            ||
Z0       0.000  4.4200   0.00  0  0  0  0  0  0 46
SA    8766.231  0.0240 108.00  0  0  1  0  0 -1 21
SSA   4382.906  0.0510 114.10  0  0  2  0  0  0 5e
MM     661.309  0.0100 205.70  0  1  0 -1  0  0 29
MSF    354.367  0.0080 211.50  0  2 -2  0  0  0 54
MF     327.859  0.0090 242.60  0  2  0  0  0  0 2e
SIG1    27.848  0.0030 124.90  1 -3  2  0  0  0 53
Q1      26.868  0.0190 102.80  1 -2  0  1  0  0 50
RHO1    26.723  0.0050 105.80  1 -2  2 -1  0  0 51
```

UK

IPS1 Tides - Harmonic constants

Run by jonescy at 10:59:40 on 17/05/2007

No: 0089 Name: DOVER STANDARD PORT

Time Zone: GMT Position: 51 07 N 001 19 E

Authority: HO 19 YRS 1979-2006 Units: METRES

Z0: +3.758

A0:

Key: S = Suspect
I = Inferred

Shallow Water Corrections

	"H"	"g"
F4:f4	0.0464	278.7
F6:f6	0.0041	186.1

Constituents

Name	"H"	"g"	Name	"H"	"g"	Name	"H"	"g"
Sa	0.065	211.8	2MS3	0.001	265.5	MSN6	0.014	141.7
Ssa	0.023	094.7	2MP3	0.005	141.0	4MN6	0.009	274.8
Mnum	0.005	263.4	M3	0.011	035.3	MNK6	0.001	101.4
Mm	0.007	184.7	MP3	0.003	352.4	2(MS)K6	0.002	303.2
Msf	0.015	220.1	MS3	0.003	341.6	2MT6	0.003	140.5
Mf	0.018	236.1	MK3	0.015	008.9	2MS6	0.060	150.0
Q1	0.023	121.0	2MQ3	0.003	102.2	2MK6	0.017	154.2
rho1	0.006	121.7	SP3	0.003	078.0	2SM6	0.012	217.1
O1	0.057	180.2	S3	0.001	191.3	MSK6	0.007	218.7
MS1	0.001	100.2	SK3	0.007	081.3	S6	0.002	017.7
MP1	0.003	216.7	3MK4	0.008	302.8	2MNO7	0.003	068.6
M1	0.003	192.5	3MS4	0.024	292.1	2NMK7	0.001	045.7
chi1	0.002	033.3	MSNK4	0.003	028.0	M7	0.002	141.1
pi1	0.003	054.3	MN4	0.092	197.2	2MSO7	0.003	167.2
P1	0.021	022.1	Mnu4	0.024	181.2	2(MN)8	0.006	318.2
S1	0.006	239.1	2MSK4	0.009	004.2	5MS8	0.003	095.1
K1	0.049	042.4	MA4	0.007	168.9	3MN8	0.016	343.8
psi1	0.002	315.8	M4	0.255	221.1	3Mnu8	0.005	328.2

Exchange of data is important between FGHO's

- Ensures that the most up-to-date information is used in tidal / navigational products
- The less manual intervention the better – reduces the likelihood of random human error

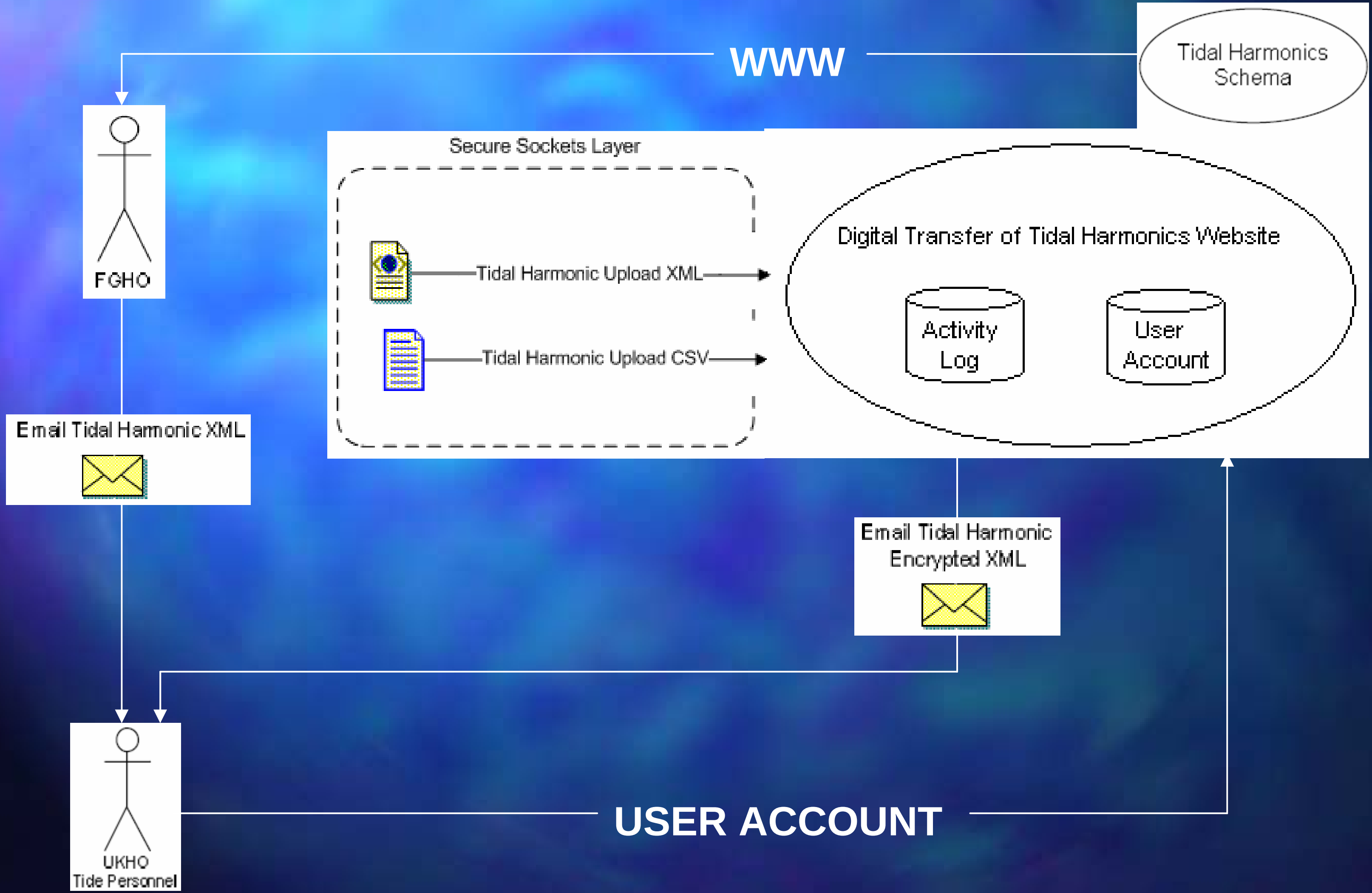
Proposal

- To develop a new way of exchanging HC's between FGHO's
- A convenient way of transferring data - like that of the International Exchange format for predictions (ASCII)
- Web application will transfer tidal harmonic constants in an XML format

The project

- IHO Tidal Committee (TC) tasked the IHO Transfer Standard Maintenance and Application Development Working Group (TSMAD) to develop a standard transfer mechanism for harmonic constants
- Draft Product Specification prepared
- Aim - to develop a web application that will output an Extensible Mark-up Language (XML) file for transfer between FGHO's

How will it work?

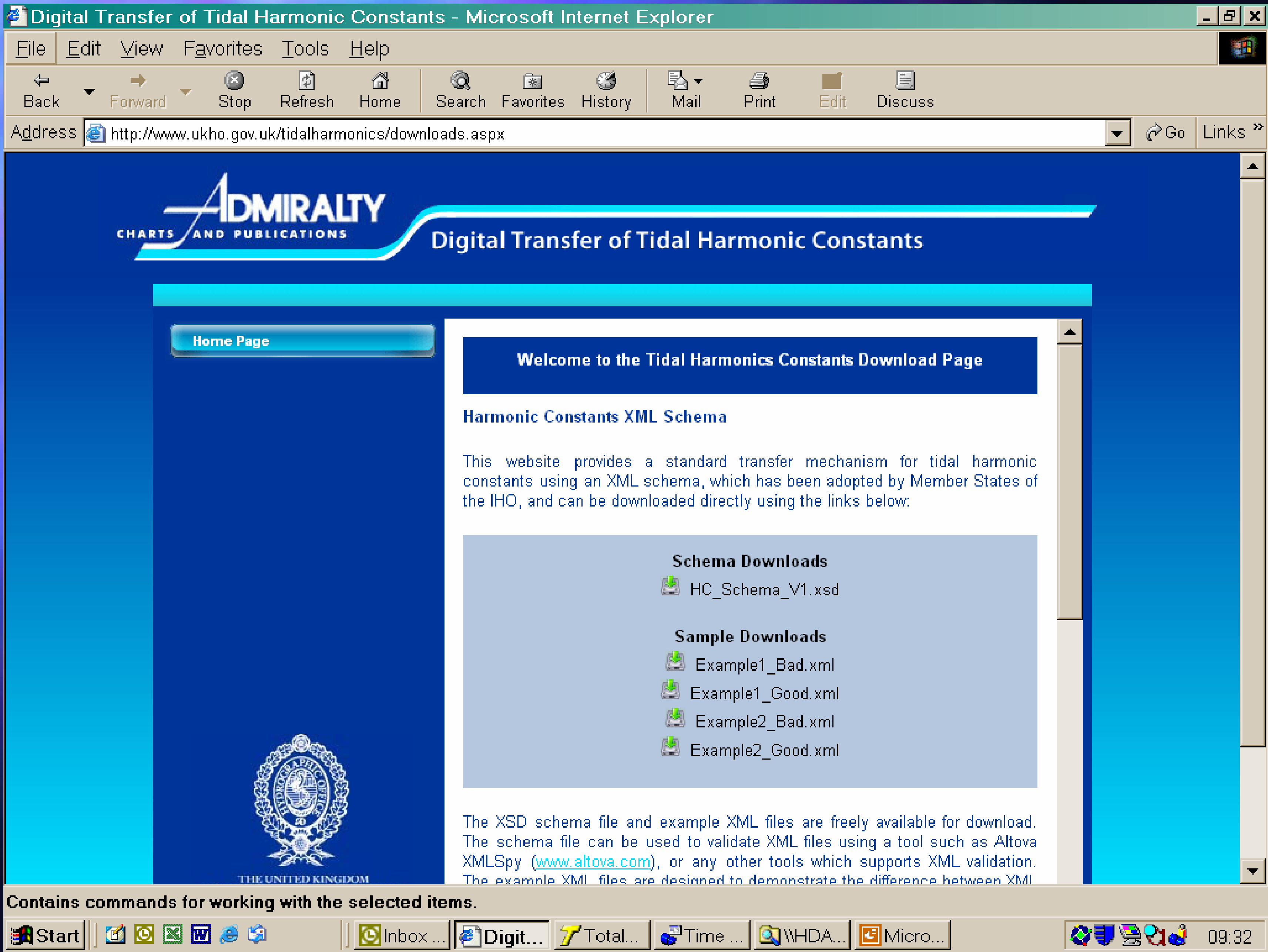


Product Specification: Gives details of.....

- Header Information and Data Record
- Precision of Phase Angle (g) and Amplitude (H) relative to observation period
- Extended Doodson Number (XDO)
- Computation of the Astronomical Argument and use of the XDO
- General information on the major tidal constituents
- Reproduces the Standard List of Tidal Harmonic Constituents (as published on the IHO website)
- Application and Computation of Nodal Corrections
- Derivation of Speeds and values of Nodal Corrections from Constituent Names

Web Link

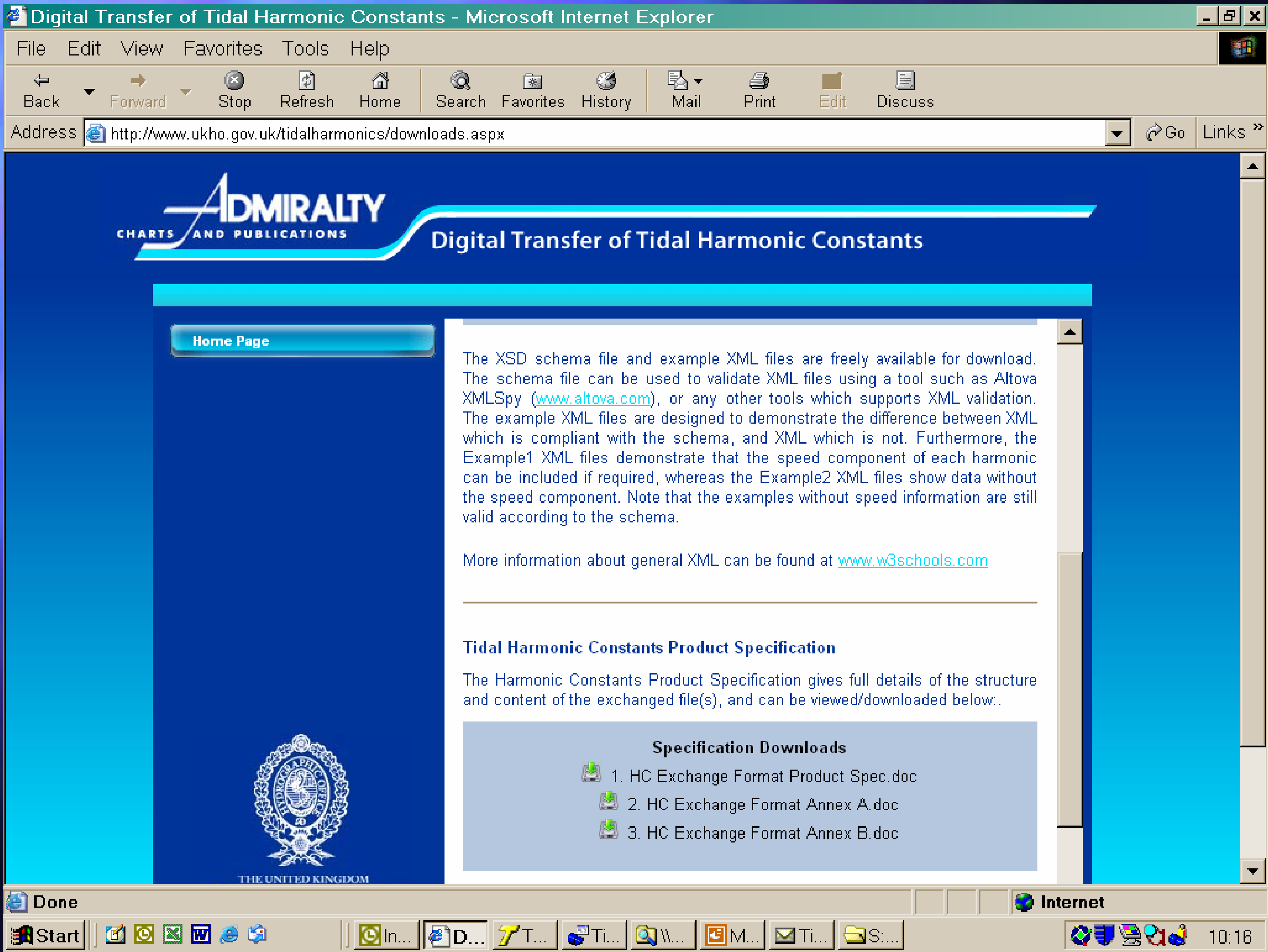
http://www.ukho.gov.uk/
tidalharmonics/downloads.aspx



United Kingdom Hydrographic Office

Schema Downloads

- Schema Download ‘HC_Schema_V1.xsd’
- Example 1_Good.xml = Well formed, valid against the schema, and contains speeds of each harmonic constituent.
- Example 1_Bad.xml = Well formed, not valid against the schema, and contains speeds of each harmonic constituent.
- Example 2_Good.xml = Well formed, valid against the schema, does not contain speeds of each harmonic constituent.
- Example 2_Bad.xml = Well formed, not valid against the schema, does not contain speeds of each harmonic constituent.
- There are no non-well-formed files available for download, as well-formedness is a by-product of valid XML.


Digital Transfer of Tidal Harmonic Constants - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Forward Stop Refresh Home Search Favorites History Mail Print Edit Discuss
Address http://www.ukho.gov.uk/tidalharmonics/downloads.aspx
Go Links
ADMIRALTY
CHARTS AND PUBLICATIONS
Digital Transfer of Tidal Harmonic Constants
Home Page
The XSD schema file and example XML files are freely available for download. The schema file can be used to validate XML files using a tool such as Altova XMLSpy (www.altova.com), or any other tools which supports XML validation. The example XML files are designed to demonstrate the difference between XML which is compliant with the schema, and XML which is not. Furthermore, the Example1 XML files demonstrate that the speed component of each harmonic can be included if required, whereas the Example2 XML files show data without the speed component. Note that the examples without speed information are still valid according to the schema.
More information about general XML can be found at www.w3schools.com
Tidal Harmonic Constants Product Specification
The Harmonic Constants Product Specification gives full details of the structure and content of the exchanged file(s), and can be viewed/downloaded below:.
Specification Downloads
1. HC Exchange Format Product Spec.doc
2. HC Exchange Format Annex A.doc
3. HC Exchange Format Annex B.doc
THE UNITED KINGDOM
Done
Internet
Start
10:16

- The XSD schema file and example XML files are freely available for download.
- The schema file can be used to validate XML files using a tool such as Altova XMLSpy (www.altova.com), or any other tools which supports XML validation.
- The example XML files are designed to demonstrate the difference between XML which is compliant with the schema, and XML which is not.
- Furthermore, the Example1 XML files demonstrate that the speed component of each harmonic can be included if required, whereas the Example2 XML files show data without the speed component. Note that the examples without speed information are still valid according to the schema.
- More information about general XML can be found at www.w3schools.com

HARMONIC CONSTANTS
Product Specification

Edition 1.0

Contents

1. Introduction

1.1 General

The tide is a periodical movement in the level of the surface of the sea or ocean, due to the gravitational attraction between the Earth, Moon and Sun. By collating and analysing tidal data it is possible to derive harmonic constants that can be used in the prediction of sea levels.

The Harmonic Constants Product Specification sets out the rules which have to be followed when transferring tidal harmonic data.

1.2 Definitions

Harmonic analysis The mathematical process by which the observed tide or tidal current at any place is separated into basic harmonic constituents.

Harmonic Constituents One of the harmonic elements in a mathematical expression of the tide-producing force, and in corresponding formulae for the tide or tidal stream. Each constituent represents a periodic change of relative position of the Earth, Sun and Moon.

Harmonic Constants The amplitude (H) and phase lag (g) of each harmonic constituent of the tide or tidal stream at any place, in a specific time zone.

Species of Tide

Long Period Includes all tidal oscillations with periods ranging from 1 to 2 days through to 19 years.

Diurnal A tidal cycle with a period lasting approximately a day, on average 24 hours 50 minutes.

Semidiurnal A tidal cycle roughly occupying half a day, on average 12hours 25 minutes.

2. General Information

2.1 Observation of the Tide

Observations of sea level are made by automated tide gauges over a period of time at specific locations. The two main tidal features recorded are the tidal range, measured as the height between successive high and low levels and the period, the time laps between one high (or low) level and the next high (or low) level. Tidal analysis of the data collected produces calculated constants which can be used to compute predicted sea-levels. Analysis of the data also provides researchers with information on changes in Mean Sea Level which is used for impact analysis. In reality these calculated constants can only be approximate as the observation period often varies from a year to a month. These observations are also subject to errors induced by natural meteorological occurrences. The principal factors being atmospheric pressure and the winds acting on the sea surface to create storm surges.

2.2 Harmonic Analysis

In general, a simple Harmonic term can be expressed in the form:

$$X(t) = H_n \cos (\sigma_n t - g_n)$$

Where X = Value of the variable quantity at time t
H_n = Amplitude of oscillation
g_n = Phase lag
σ_n = Angular speed
t = Time

The amplitudes and phase lags are the parameters determined by analysis which define the tidal regime for the place of observation.

Note: A full list of Harmonic Constituents with their respective Speeds and Extended Doodson Numbers (XDO) is given in Annex B.

3. Header Information

3.1 Port Name
Full port or tidal station name with no abbreviations, this is a mandatory field.

3.2 Country
IHO Country code, this is a mandatory field.

3.3 Position
A Latitude and Longitude position of observation station quoted as DDD-MM.MM together with the correct suffix dependant on the hemisphere (N-S) and the direction from the Greenwich Meridian (E-W), this is a mandatory field.

3.4 Time Zone
The difference in hours and minutes to Universal Time (UT) using standard International Maritime convention (e.g. Greece -0200; Belize +0600), this is a mandatory field.

3.5 Units
The unit of measure used to specify the Amplitude (H), this is a mandatory field.

3.6 Observation
The start and end dates of the observation period quoted as YYYY-MM-DD, this is a mandatory field.

3.7 Comments
Any useful comments and remarks that will assist processing of the data, this is not a mandatory field.

4. Data Record

4.1 Constituent Name
As specified in Annex B, no variations are allowable, this is a mandatory field.

4.2 Phase Angle (g)
The phase lag of a tidal constituent at a particular place in degrees, this is a mandatory field.

4.3 Amplitude (H)
The amplitude of a tidal constituent for a given place in metres, this is a mandatory field.

4.4 Speed
The speed of a constituent has been calculated from relevant astronomical theory, this is a mandatory field.

4.5 Extended Doodson Number (XDO)
A seven-digit numerical and alphabetical system devised as a convenient way of expressing the Harmonic Constituents in order of speed, this is not a mandatory field but is highly desirable.

5. Accuracy

5.1 Calculation

The overall accuracy of the derived constants is intrinsically linked to the length of the observation period. By increasing the observation period we can gather more measurements therefore reducing the inherent error in the derived values.

So that the calculated data is not misinterpreted as of a higher quality it is important to restrict the precision of the calculated g and H values to reflect the length of observation. The table below shows how many decimal places each derived constant should be quoted to with respect to the length of observation.

Time	Phase Angle (g)	Amplitude (H)
≥ 1 Year	X.X	X.XXX
< 1 Year or ≥ 3 x 30 days	X.X	X.XXX
< 3 x 30 days	X	X.XX

6. Extended Doodson Number (XDO)

6.1 Introduction

The XDO refers to a seven digit numbering system devised by Dr. A. T. Doodson in the 1920's as a convenient way of expressing the Harmonic Constituents in order of speed, which then in turn becomes a useful way of obtaining the phase and speed of any constituent within a computer environment. Each number represents a *multiplier* which is applied to the individual speeds of the Orbital Elements:-

The numbering system effectively 'runs-out' after the ninth-diurnal, therefore an alphabetical system continues through the tenth to fourteenth- diurnal.

The XDO, both numerical and alphabetical, is shown in the full list of IHO Harmonic Constituents (Annex B)

6.2 Computation of the Astronomical Argument (*E*) - Use of Extended Doodson Number (XDO)

1. The value of *E*, at 00hr, for any constituent can be derived from the values for Orbital Elements. For example the phase of the constituent known as R_2 can be expressed as:

$$h - p' + 180°$$

2. In practice it has been found convenient to include an additional term (h–s). The multiplier for this term is the species to which the constituent belongs. R_2 is a semi-diurnal constituent so the multiplier for this term is 2. Simple algebra means that E of R_2 can now be expressed as :

$$2(h-s) + 2s - h - p' + 180°$$

3. If the coefficients for the term (*h* - *s*), for each of the Orbital Elements in turn and for the number of right angles to be applied, are written in sequence, *E* of R_2 can be expressed as :

Parameter	*(h–s)*	*s*	*h*	*p*	*N*	*p′*	90°
Coefficient	+2	+2	-1	0	0	-1	+2

4. To avoid the use of negative numbers 5 is normally added to each coefficient, except the first. *E* of R_2 now becomes:

Parameter	*(h–s)*	*s*	*h*	*p*	*N*	*p′*	90°
Coefficient	2	7	4	5	5	4	7

5. In the 1920s, Dr. Doodson realised that the first three digits of this number (274 in the case of R_2) were a convenient way of tabulating harmonic constituents in order of speed and he called this the Doodson Number. What he could not have foreseen was that the full number forms a convenient shorthand for obtaining the phase and speed of any constituent within programs on electronic computers. The full number is referred to as the Extended Doodson Number (XDO).

6. Comparatively recently, electronic computers have enabled the use of constituents which overflow the above system and the UK Hydrographic Office has replaced it with an alphabetical system in which Z represents 0, the letters A to P represent coefficients of 1 to 15 respectively while R to Y represent -8 to -1. Substituting the values in Para 2.7, the XDO for R_2 now becomes :

Parameter	*(h - s)*	*s*	*h*	*p*	*N*	*p′*	90°
Coefficient	B	B	Y	Z	Z	Y	B

7. Tidal Harmonic Constant Data File Format

7.1 Header Record

Field	Name	Description
1-2	Name	Port or tidal station name
2-3	Country	IHO Country code
3-4	Latitude N - S	DDD-MM.MM
4-5	Longitude E - W	DDD-MM.MM
5-6	Time Zone	+/-HHMM Maritime Convention
6-7	Observation Start	YYYY-MM-DD
7-8	Observation End	YYYY-MM-DD
8-9	Comment	Comment or remarks

7.2 Harmonic Constants Record

Field	Name	Description			
1-2	Sa	Phase Angle of Sa constant in degrees	Amplitude of Sa in meters	Speed of Sa in degrees per mean solar hour	XDO value Numerical or alphabetical
2-3	Ssa	Phase Angle of Ssa constant in degrees	Amplitude of Ssa in meters	Speed of Ssa in degrees per mean solar hour	XDO value Numerical or alphabetical
3-4	Sta	Phase Angle of Sta constant in degrees	Amplitude of Sta in meters	Speed of Sta in degrees per mean solar hour	XDO value Numerical or alphabetical

HARMONIC CONSTANTS
Annex A

Edition 1.0

Contents

1. Introduction

1.1 General

The following documentation gives a brief explanation of the most commonly used Harmonic constituents.

1.2 Major Tidal Constituents
Lunar

M_2	The semi-diurnal constituent of a fictitious moon, which moves in a circular orbit in the plane of the equator
N_2 & L_2	Modulate $M_{2,}$ converting the circular orbit of the fictitious moon into an elliptical one in the plane of the equator
ν_2 , $\lambda_{2,}$ μ_2 & S_2	Modulate $M_{2,}$ allowing for the fact that the real moon's orbit is not elliptical, but pear shaped, since the sun attracts it more at new moon than at full moon. This S_2 is not the main semi-diurnal constituent of the mean sun.
K_2	Modulates $M_{2,}$ converting the orbit from the plane of the equator into the mean plane of the real moon.
K_1 & O_1	The diurnal constituents of a fictitious moon which has a fixed circular orbit in the mean plane of the real moon
J_1, M_1 & Q_1	Modulate K_1 & $O_{1,}$ allowing for the fact that the moon's orbit is not circular, but elliptical. M_1 is the sum of two constituents, which cannot easily be separated.
M_f & M_m	'Long Period' lunar constituents, with periods of about a fortnight and one month respectively. They have very small amplitudes, and are often masked by meteorological and shallow water effects.

1.3 Major Tidal Constituents
Solar

S_2	The semi-diurnal constituent of the mean sun, which moves in a circular orbit in the plane of the equator
T_2	Modulates S_2 allowing for the fact that the sun's orbit is an ellipse. Another constituent, which operates with T_2, is so small that it is not named and is neglected.
K_2	Modulates $S_{2,}$ allowing for the fact that the sun's orbit is in the plane of the ecliptic. Another constituent, which operates with it, is so small that it is not named and is neglected. This K_2 has the same speed as the moon's $K_{2,}$ and the two are combined.

K_1 & P_1 The diurnal constituents of a fictitious sun which has a circular orbit in the plane of the ecliptic. This K_1 has the same speed as the moon's $K_{1,}$ and the two are combined.

S_{sa} & S_a 'Long Period' solar constituents, with periods of about six months and one year respectively. They have very small amplitudes, and in practice cannot usually be distinguished from changes in MSL caused by prevailing winds and monsoons.

1.4 Major Tidal Constituents Shallow Water

M_4 The second harmonic of M_2 with twice its speed.

MS_4 A quarter diurnal constituent produced from M_2 & $S_{2.}$ It has a speed equal to the sum of their two speeds.

M_6 The third harmonic of M_2 with three times it's speed.

$2MS_6$ A sixth diurnal constituent produced from M_2 and S_2. It has a speed equal to the sum of twice the speed of M_2 plus the speed of S_2

There are of course many other shallow water constituents with high harmonic frequencies, as shown in Annex B.

HARMONIC CONSTANTS
Annex B

Edition 1.0

Contents

Long Term Constituents

Zo	0.000 000	0 555 555	Z ZZZ ZZZ	z
Sa	0.041 067	0 565 545	Z ZAZ ZYZ	z
Sa	0.041 069	0 565 555	Z ZAZ ZZZ	z
Ssa	0.082 137	0 575 555	Z ZBZ ZZZ	z
Sta	0.123 204	0 585 544	Z ZCZ ZYY	x
MSm	0.471 521	0 636 555	Z AXA ZZZ	x
Mnum (Mνm)	0.471 521	0 636 555	Z AXA ZZZ	x
Mm	0.544 375	0 654 555	Z AZY ZZZ	y
MSf	1.015 896	0 735 555	Z BXZ ZZZ	b
MSo	1.015 896	0 735 555	Z BXZ ZZZ	b
SM	1.015 896	0 735 555	Z BXZ ZZZ	x
Mf	1.098 033	0 755 555	Z BZZ ZZZ	y
KOo	1.098 033	0 755 555	Z BZZ ZZZ	x
MKo	1.098 033	0 755 555	Z BZZ ZZZ	x
Snu2 (Sν2)	1.487 417	0 816 555	Z CVA ZZZ	x
SN	1.560 270	0 834 555	Z CXY ZZZ	x
MStm	1.569 554	0 836 555	Z CXA ZZZ	x
Mfm	1.642 408	0 854 555	Z CZY ZZZ	a
2SM	2.031 792	0 915 555	Z DVZ ZZZ	c
MSqm	2.113 929	0 935 555	Z DXZ ZZZ	b
Mqm	2.186 782	0 953 555	Z DZX ZZZ	m
2SMN	2.576 166	--------------	Z EVY ZZZ	x

Diurnal Constituents

2Q1	12.854 286	1 257 554	A WZB ZZY	o
NJ1	12.854 286	1 257 554	A WZB ZZY	x
nuJ1 (νJ1)	12.927 140	1 275 554	A WBZ ZZY	o
sigma1 (σ1)	12.927 140	1 275 554	A WBZ ZZY	o
Q1	13.398 661	1 356 554	A XZA ZZY	o
NK1	13.398 661	1 356 555	A XZA ZZZ	x
rho1 (ρ1)	13.471 515	1 374 554	A XBY ZZY	o
nuK1 (νK1)	13.471 515	1 374 554	A XBY ZZY	x
O1	13.943 036	1 455 554	A YZZ ZZY	y
MK1	13.943 036	1 455 554	A YZZ ZZY	x
MS1	13.984 104	1 465 557	A YAZ ZZB	x
MP1	14.025 173	1 475 555	A YBZ ZZZ	m
MP1	14.025 173	1 475 556	A YBZ ZZA	m
tau1 (τ1)	14.025 173	1 475 556	A YBZ ZZA	k
M1B	14.487 410	1 554 554	A ZZY ZZY	y
M1B	14.487 410	1 554 556	A ZZY ZZA	Y
M1C	14.492 052	1 555 555	A ZZZ ZZZ	Y
M1	14.492 052	1 555 556	A ZZZ ZZA	Y
M1	14.492 052	1 555 557	A ZZZ ZZB	Y
NO1	14.496 694	1 556 556	A ZZA ZZA	X
M1A	14.496 694	1 556 556	A ZZA ZZA	Y
M1	14.496 694	1 556 556	A ZZA ZZA	y
LP1	14.569 548	1 574 554	A ZBY ZZY	x
chi1 (χ1)	14.569 548	1 574 556	A ZBY ZZA	j
pi1 (π1)	14.917 865	1 625 564	A AWZ ZAY	z
TK1	14.917 865	1 625 564	A AWZ ZAY	x
P1	14.958 931	1 635 554	A AXZ ZZY	z
SK1	14.958 931	1 635 555	A AXZ ZZZ	x
S1	15.000 000	1 645 555	A AYZ ZZZ	z
S1	15.000 000	1 645 557	A AYZ ZZB	z

S1	15.000 002	1 645 566	A AYZ ZAA	z
SP1	15.041 069	1 655 555	A AZZ ZZZ	x
K1	15.041 069	1 655 555	A AZZ ZZZ	y
MO1	15.041 069	1 655 555	A AZZ ZZZ	x
K1	15.041 069	1 655 556	A AZZ ZZA	y
RP1	15.082 135	1 665 544	A AAZ ZYY	x
psi1 (ψ1)	15.082 135	1 665 546	A AAZ ZYA	z
phi1 (Φ1)	15.123 206	1 675 556	A ABZ ZZA	j
KP1	15.123 206	1 675 556	A ABZ ZZA	x
lambdaO1 (λO1)	15.512 590	1 736 554	A BXA ZZY	x
theta1 (θ1)	15.512 590	1 736 556	A BXA ZZA	j
MQ1	15.585 443	1 754 555	A BZY ZZZ	x
J1	15.585 443	1 754 556	A BZY ZZA	y
2PO1	15.974 827	1 815 554	A CVZ ZZY	x
SO1	16.056 964	1 835 555	A CXZ ZZZ	x
SO1	16.056 964	1 835 556	A CXZ ZZA	x
OO1	16.139 102	1 855 556	A CZZ ZZA	d
ups1 (υ1)	16.683 476	1 954 556	A DZY ZZA	d
KQ1	16.683 476	1 954 556	A DZY ZZA	x

Semi-Diurnal Constituents

2MN2S2	26.407 938	2 096 555	B UDA ZZZ	x
3M(SK)2	26.870 175	2 175 555	B VBZ ZZZ	x
3MKS2	26.870 175	2 175 555	B VBZ ZZZ	x
2NS2	26.879 459	2 177 555	B VBB ZZZ	x
3M2S2	26.952 313	2 195 555	B VDZ ZZZ	x
3MS2	26.952 313	2 195 555	B VDZ ZZZ	x
2NK2S2	26.961 596	2 197 555	B VDB ZZZ	x
OQ2	27.341 696	2 256 555	B WZA ZZZ	x
MNK2	27.341 696	2 256 555	B WZA ZZZ	x
OQ2	27.341 696	2 256 557	B WZA ZZB	x
MNS2	27.423 834	2 276 555	B WBA ZZZ	x
eps2 (ε2)	27.423 834	2 276 555	B WBA ZZZ	m
MnuS2 (MνS2)	27.496 687	2 294 555	B WDY ZZZ	x
2ML2S2	27.496 687	2 294 557	B WDY ZZB	x
MNK2S2	27.505 971	2 296 555	B WDA ZZZ	x
2MS2K2	27.803 934	2 335 555	B XXZ ZZZ	x
2MK2	27.886 071	2 355 555	B XZZ ZZZ	x
O2	27.886 071	2 355 555	B XZZ ZZZ	x
NLK2	27.886 071	2 355 557	B XZZ ZZB	x
2N2	27.895 355	2 357 555	B XZB ZZZ	m
mu2 (μ2)	27.968 208	2 375 555	B XBZ ZZZ	m
2MS2	27.968 208	2 375 555	B XBZ ZZZ	x
SNK2	28.357 592	2 436 555	B YXA ZZZ	x
NA2	28.398 661	2 446 555	B YYA ZZZ	f
NA2	28.398 663	2 446 565	B YYA ZAZ	f
N2	28.439 730	2 456 555	B YZA ZZZ	m
KQ2	28.439 730	2 456 555	B YZA ZZZ	x
NB2	28.480 796	2 466 545	B YAA ZYZ	f
NA2*	28.480 798	2 466 555	B YAA ZZZ	f
nu2 (ν2)	28.512 583	2 474 555	B YBY ZZZ	m
2KN2S2	28.604 004	2 496 555	B YDA ZZZ	x
MSK2	28.901 967	2 535 555	B ZXZ ZZZ	x
OP2	28.901 967	2 535 555	B ZXZ ZZZ	x
OP2	28.901 967	2 535 557	B ZXZ ZZB	x

gamma2 (γ2)	28.911 251	2 537 557	B ZXB ZZB	y
MA2	28.943 036	2 545 555	B ZYZ ZZZ	f
MPS2	28.943 036	2 545 556	B ZYZ ZZA	x
alpha2 (α2)	28.943 038	2 545 567	B ZYZ ZAB	y
M(SK)2	28.943 038	2 545 567	B ZYZ ZAB	x
M2	28.984 104	2 555 555	B ZZZ ZZZ	y
KO2	28.984 104	2 555 555	B ZZZ ZZZ	x
M(KS)2	29.025 171	2 565 545	B ZAZ ZYZ	x
MSP2	29.025 173	2 565 554	B ZAZ ZZY	x
MB2	29.025 173	2 565 555	B ZAZ ZZZ	f
MA2*	29.025 173	2 565 555	B ZAZ ZZZ	f
MKS2	29.066 242	2 575 555	B ZBZ ZZZ	x
delta2 (δ2)	29.066 242	2 575 555	B ZBZ ZZZ	y
M2(KS)2	29.148 379	2 595 555	B ZDZ ZZZ	x
2KM2S2	29.148 379	2 595 555	B ZDZ ZZZ	x
2SN(MK)2	29.373 488	2 616 555	B AVA ZZZ	x
lambda2 (λ2)	29.455 625	2 636 557	B AXA ZZB	m
L2	29.528 479	2 654 557	B AZY ZZB	y
2MN2	29.528 479	2 654 557	B AZY ZZB	x
L2A	29.528 479	2 654 557	B AZY ZZB	p
L2B	29.537 763	2 656 555	B AZA ZZZ	q
NKM2	29.537 763	2 656 555	B AZA ZZZ	x
2SK2	29.917 863	2 715 555	B BVZ ZZZ	x
T2	29.958 933	2 725 565	B BWZ ZAZ	z
S2	30.000 000	2 735 555	B BXZ ZZZ	z
KP2	30.000 000	2 735 555	B BXZ ZZZ	x
R2	30.041 067	2 745 547	B BYZ ZYB	z
K2	30.082 137	2 755 555	B BZZ ZZZ	y
MSnu2 (MSν2)	30.471 521	2 816 555	B CVA ZZZ	x
MSN2	30.544 375	2 834 555	B CXY ZZZ	x
xi2 (ξ2)	30.553 658	2 836 555	B CXA ZZZ	y
eta2 (η2)	30.626 512	2 854 555	B CZY ZZZ	y
KJ2	30.626 512	2 854 557	B CZY ZZB	x
2KM(SN)2	30.708 649	2 874 555	B CBY ZZZ	x
2SM2	31.015 896	2 915 555	B DVZ ZZZ	x
2MS2N2	31.088 749	2 933 555	B DXX ZZZ	x
SKM2	31.098 033	2 935 555	B DXZ ZZZ	x
2Snu2 (2Sν2)	31.487 417	--------------	B ETA ZZZ	x
3(SM)N2	31.487 417	--------------	B ETA ZZZ	x
2SN2	31.560 270	--------------	B EVY ZZZ	x
SKN2	31.642 408	--------------	B EXY ZZZ	x
3S2M2	32.031 792	--------------	B FTZ ZZZ	x
2SK2M2	32.113 929	--------------	B FVZ ZZZ	x

Third-Diurnal Constituents

MQ3	42.382 765	3 356 554	C XZA ZZY	x
NO3	42.382 765	3 356 554	C XZA ZZY	x
MQ3	42.382 765	3 356 555	C XZA ZZZ	x
NO3	42.382 765	3 356 555	C XZA ZZZ	x
MO3	42.927 140	3 455 554	C YZZ ZZY	x
2MK3	42.927 140	3 455 554	C YZZ ZZY	x

MO3	42.927 140	3 455 555	C YZZ ZZZ	x
2NKM3	42.936 423	3 457 556	C YZB ZZA	x
2MS3	42.968 208	3 465 557	C YAZ ZZB	x
2MP3	43.009 277	3 475 556	C YBZ ZZA	x
M3	43.476 156	3 555 557	C ZZZ ZZB	g
NK3	43.480 798	3 556 555	C ZZA ZZZ	x
NK3	43.480 798	3 556 556	C ZZA ZZA	x
SO3	43.943 036	3 635 554	C AXZ ZZY	x
MP3	43.943 036	3 635 554	C AXZ ZZY	x
MP3	43.943 036	3 635 555	C AXZ ZZZ	x
MS3	43.984 104	3 645 557	C AYZ ZZB	x
MK3	44.025 173	3 655 555	C AZZ ZZZ	x
MK3	44.025 173	3 655 556	C AZZ ZZA	x
NSO3	44.496 694	3 736 556	C BXA ZZA	x
2MQ3	44.569 548	3 754 556	C BZY ZZA	x
SP3	44.958 931	3 815 554	C CVZ ZZY	x
SP3	44.958 931	3 815 555	C CVZ ZZZ	x
S3	45.000 000	3 825 557	C CWZ ZZB	x
SK3	45.041 069	3 835 555	C CXZ ZZZ	x
SK3	45.041 069	3 835 556	C CXZ ZZA	x
K3	45.123 206	3 855 555	C CZZ ZZZ	x
K3	45.123 206	3 855 556	C CZZ ZZA	x
2SO3	46.056 964	-------------	C EVZ ZZA	x

Quarter-Diurnal Constituents

4MS4	55.936 417	4 195 555	D VDZ ZZZ	x
4M2S4	55.936 417	4 195 555	D VDZ ZZZ	x
2MNK4	56.325 801	4 256 555	D WZA ZZZ	x
3NM4	56.335 084	4 258 555	D WZC ZZZ	x
2MNS4	56.407 938	4 276 555	D WBA ZZZ	x
2MnuS4 (2MνS4)	56.480 792	4 294 555	D WDY ZZZ	x
3MK4	56.870 175	4 355 555	D XZZ ZZZ	x
MNLK4	56.870 175	4 355 557	D XZZ ZZB	x
N4	56.879 459	4 357 555	D XZB ZZZ	x
2N4	56.879 459	4 357 555	D XZB ZZZ	x
3MS4	56.952 313	4 375 555	D XBZ ZZZ	x
2NKS4	56.961 596	4 377 555	D XBB ZZZ	x
MSNK4	57.341 696	4 436 555	D YXA ZZZ	x
MN4	57.423 834	4 456 555	D YZA ZZZ	x
Mnu4 (Mν4)	57.496 687	4 474 555	D YBY ZZZ	x
2MLS4	57.496 687	4 474 557	D YBY ZZB	x
MNKS4	57.505 971	4 476 555	D YBA ZZZ	x
2MSK4	57.886 071	4 535 555	D ZXZ ZZZ	x
MA4	57.927 140	4 545 555	D ZYZ ZZZ	x
M4	57.968 208	4 555 555	D ZZZ ZZZ	x
2MRS4	58.009 275	4 565 547	D ZAZ ZYB	x
2MKS4	58.050 346	4 575 555	D ZBZ ZZZ	x
SN4	58.439 730	4 636 555	D AXA ZZZ	x
3MN4	58.512 583	4 654 555	D AZY ZZZ	x
ML4	58.512 583	4 654 555	D AZY ZZZ	x
ML4	58.512 583	4 654 557	D AZY ZZB	x
KN4	58.521 867	4 656 555	D AZA ZZZ	x
NK4	58.521 867	4 656 555	D AZA ZZZ	x
2SMK4	58.901 967	4 715 555	D BVZ ZZZ	x
M2SK4	58.901 967	4 715 555	D BVZ ZZZ	x

MT4	58.943 038	4 725 565	D BWZ ZAZ	x
MS4	58.984 104	4 735 555	D BXZ ZZZ	x
MR4	59.025 171	4 745 547	D BYZ ZYB	x
MK4	59.066 242	4 755 555	D BZZ ZZZ	x
2SNM4	59.455 625	4 816 555	D CVA ZZZ	x
2MSN4	59.528 479	4 834 555	D CXY ZZZ	x
2MSN4	59.528 479	4 834 557	D CXY ZZB	x
SL4	59.528 479	4 834 557	D CXY ZZB	x
2MKN4	59.610 616	4 854 555	D CZY ZZZ	x
ST4	59.958.933	4 905 565	D DUZ ZAZ	x
S4	60.000 000	4 915 555	D DVZ ZZZ	x
SK4	60.082 137	4 935 555	D DXZ ZZZ	x
K4	60.164 275	4 955 555	D DZZ ZZZ	x
3SM4	61.015 896	-------------	D FTZ ZZZ	x
2SKM4	61.098 033	-------------	D FVZ ZZZ	x

Fifth-Diurnal Constituents

MNO5	71.366 869	5 356 554	E XZA ZZY	x
2MQ5	71.366 869	5 356 554	E XZA ZZY	x
2NKMS5	71.453 648	5 377 556	E XBB ZZA	x
3MK5	71.911 244	5 455 554	E YZZ ZZY	x
2MO5	71.911 244	5 455 554	E YZZ ZZY	x
2NK5	71.920 528	5 457 556	E YZB ZZA	x
3MS5	71.952 313	5 465 557	E YAZ ZZB	x
3MP5	71.993 381	5 475 556	E YBZ ZZA	x
NSO5	72.382 765	5 536 554	E ZXA ZZY	x
M5	72.460 261	5 555 556	E ZZZ ZZA	g
M5	72.460 261	5 555 557	E ZZZ ZZB	g
M5	72.464 902	5 556 556	E ZZA ZZA	g
MNK5	72.464 902	5 556 556	E ZZA ZZA	x
MB5	72.501 329	5 565 556	E ZAZ ZZA	x
MSO5	72.927 140	5 635 554	E AXZ ZZY	x
2MP5	72.927 140	5 635 554	E AXZ ZZY	x
2MS5	72.968 208	5 645 557	E AYZ ZZB	x
3MO5	73.009 277	5 655 556	E AZZ ZZA	x
2MK5	73.009 277	5 655 556	E AZZ ZZA	x
NSK5	73.471 515	5 734 556	E BXY ZZA	x
3MQ5	73.553 652	5 754 556	E BZY ZZA	x
MSP5	73.943 036	5 815 554	E CVZ ZZY	x
MSK5	74.025 173	5 835 555	E CXZ ZZZ	x
MSK5	74.025 173	5 835 556	E CXZ ZZA	x
3KM5	74.107 310	5 855 554	E CZZ ZZY	x
2SP5	74.958 931	-------------	E ETZ ZZY	x
2SK5	75.041 069	-------------	E EVZ ZZA	x
(SK)K5	75.123 206	-------------	E EXZ ZZA	x

Sixth-Diurnal Constituents

2(MN)K6	84.765 530	6 157 555	F VZB ZZZ	x
5MKS6	84.838 384	6 175 555	F VBZ ZZZ	x
2(MN)S6	84.847 668	6 177 555	F VBB ZZZ	x
5M2S6	84.920 521	6 195 555	F VDZ ZZZ	x
3MNK6	85.309 905	6 256 555	F WZA ZZZ	x
N6	85.319 189	6 258 555	F WZC ZZZ	x
3MNS6	85.392 042	6 276 555	F WBA ZZZ	x
3NKS6	85.401 326	6 278 555	F WBC ZZZ	x
3MnuS6 (3MνS6)	85.464 896	6 294 555	F WDY ZZZ	x

4MK6	85.854 280	6 355 555	F XZZ ZZZ	x
2NM6	85.863 563	6 357 555	F XZB ZZZ	x
M2N6	85.863 563	6 357 555	F XZB ZZZ	x
4MS6	85.936 417	6 375 555	F XBZ ZZZ	x
2NMKS6	85.945 701	6 377 555	F XBB ZZZ	x
2MSNK6	86.325 801	6 436 555	F YXA ZZZ	x
2MN6	86.407 938	6 456 555	F YZA ZZZ	x
2Mnu6 (2Mν6)	86.480 792	6 474 555	F YBY ZZZ	x
2MNO6	86.480 792	6 474 555	F YBY ZZZ	x
2MNKS6	86.490 075	6 476 555	F YBA ZZZ	x
3MSK6	86.870 175	6 535 555	F ZXZ ZZZ	x
MA6	86.911 244	6 545 555	F ZYZ ZZZ	x
M6	86.952 313	6 555 555	F ZZZ ZZZ	x
3MKS6	87.034 450	6 575 555	F ZBZ ZZZ	x
MTN6	87.382 767	6 626 565	F AWA ZAZ	x
MSN6	87.423 834	6 636 555	F AXA ZZZ	x
4MN6	87.496 687	6 654 555	F AZY ZZZ	x
2ML6	87.496 687	6 654 557	F AZY ZZB	x
MNK6	87.505 971	6 656 555	F AZA ZZZ	x
MKN6	87.505 971	6 656 555	F AZA ZZZ	x
MKnu6 (MKν6)	87.578 825	6 674 555	F ABY ZZZ	x
2(MS)K6	87.886 071	6 715 555	F BVZ ZZZ	x
2MT6	87.927 142	6 725 565	F BWZ ZAZ	x
2MS6	87.968 208	6 735 555	F BXZ ZZZ	x
2MK6	88.050 346	6 755 555	F BZZ ZZZ	x
2SN6	88.439 730	6 816 555	F CVA ZZZ	x
3MTN6	88.471 517	6 824 565	F CWY ZAZ	x
3MSN6	88.512 583	6 834 555	F CXY ZZZ	x
MSL6	88.512 583	6 834 557	F CXY ZZB	x
NSK6	88.521 867	6 836 555	F CXA ZZZ	x
SNK6	88.521 867	6 836 555	F CXA ZZZ	x
MKL6	88.594 720	6 854 557	F CZY ZZB	x
3MKN6	88.594 720	6 854 555	F CZY ZZZ	x
MST6	88.943 038	6 905 565	F DUZ ZAZ	x
2SM6	88.984 104	6 915 555	F DVZ ZZZ	x
MSK6	89.066 242	6 935 555	F DXZ ZZZ	x
SKM6	89.066 242	6 935 555	F DXZ ZZZ	x
2KM6	89.148 379	6 955 555	F DZZ ZZZ	x
2MSTN6	89.487 412	--------------	F EUY ZAZ	x
2(MS)N6	89.528 479	--------------	F EVY ZZZ	x
2MSKN6	89.610 616	--------------	F EXY ZZZ	x
S6	90.000 000	--------------	F FTZ ZZZ	x

Seventh-Diurnal Constituents

2MNO7	100.350 974	7 356 554	G XZA ZZY	x
3MQ7	100.350 974	7 356 554	G XZA ZZY	x
4MK7	100.895 348	7 455 554	G YZZ ZZY	x
2NMK7	100.904 632	7 457 556	G YZB ZZA	x
MNSO7	101.366 869	7 536 554	G ZXA ZZY	x
M7	101.444 365	7 555 557	G ZZZ ZZB	g
M7	101.449 007	7 556 556	G ZZA ZZA	g
2MNK7	101.449 007	7 556 556	G ZZA ZZA	x
MNKO7	101.449 007	7 556 556	G ZZA ZZA	x
2MSO7	101.911 244	7 635 554	G AXZ ZZY	x
3MK7	101.993 381	7 655 556	G AZZ ZZA	x
MSKO7	103.009 277	7 835 554	G CXZ ZZY	x

Eighth-Diurnal Constituents

3M2NS8	113.831 772	8 177 555	H VBB ZZZ	x
4MNS8	114.376 146	8 276 555	H WBA ZZZ	x
5MK8	114.838 384	8 355 555	H XZZ ZZZ	x
2(MN)8	114.847 668	8 357 555	H XZB ZZZ	x
5MS8	114.920 521	8 375 555	H XBZ ZZZ	x
2(MN)KS8	114.929 805	8 377 555	H XBB ZZZ	x
3MSNK8	115.309 905	8 436 555	H YXA ZZZ	x
3MN8	115.392 042	8 456 555	H YZA ZZZ	x
3Mnu8 (3Mν8)	115.464 896	8 474 555	H YBY ZZZ	x
3MNKS8	115.474 180	8 476 555	H YBA ZZZ	x
4MSK8	115.854 280	8 535 555	H ZXZ ZZZ	x
MA8	115.895 348	8 545 555	H ZYZ ZZZ	x
M8	115.936 417	8 555 555	H ZZZ ZZZ	x
4MKS8	116.018 554	8 575 555	H ZBZ ZZZ	x
2MSN8	116.407 938	8 636 555	H AXA ZZZ	x
3ML8	116.480 792	8 654 555	H AZY ZZZ	x
2MNK8	116.490 075	8 656 555	H AZA ZZZ	x
3M2SK8	116.870 175	8 715 555	H BVZ ZZZ	x
2(NS)8	116.879 459	8 717 555	H BVB ZZZ	x
3MT8	116.911 246	8 725 565	H BWZ ZAZ	x
3MS8	116.952 313	8 735 555	H BXZ ZZZ	x
3MK8	117.034 450	8 755 555	H BZZ ZZZ	x
2SNM8	117.423 834	8 816 555	H CVA ZZZ	x
2SMN8	117.423 834	8 816 555	H CVA ZZZ	x
2MSL8	117.496 687	8 834 557	H CXY ZZB	x
MSNK8	117.505 971	8 836 555	H CXA ZZZ	x
4MSN8	117.578 825	8 854 555	H CZY ZZZ	x
2MST8	117.927 142	8 905 565	H DUZ ZAZ	x
2(MS)8	117.968 208	8 915 555	H DVZ ZZZ	x
2MSK8	118.050 346	8 935 555	H DXZ ZZZ	x
2(MK)8	118.132 483	8 955 555	H DZZ ZZZ	x
3SN8	118.439.730	--------------	H ETA ZZZ	x
2SML8	118.512 583	--------------	H EVY ZZB	x
2SKN8	118.521 867	--------------	H EVA ZZZ	x
MSKL8	118.594 720	--------------	H EXY ZZB	x
3SM8	118.984 104	--------------	H FTZ ZZZ	x
2SMK8	119.066 242	--------------	H FVZ ZZZ	x
S8	120.000 000	--------------	H HRZ ZZZ	x

Ninth-Diurnal Constituents

3MNO9	129.335 076	9 356 554	I XZA ZZY	x
2M2NK9	129.888 738	9 457 556	I YZB ZZA	x
2(MN)K9	129.888 738	9 457 556	I YZB ZZA	x
MA9	130.387 400	9 545 555	I ZYZ ZZZ	x
3MNK9	130.433 113	9 556 556	I ZZA ZZA	x
4MK9	130.977 488	9 655 556	I AZZ ZZA	x
3MSK9	131.993 383	9 835 556	I CXZ ZZA	x

Tenth-Diurnal Constituents

5MNS10	143.360 251	--------------	J WBA ZZZ	x
3M2N10	143.831 772	--------------	J XZB ZZZ	x

6MS10	143.904 625	--------------	J XBZ ZZZ	x
3M2NKS10	143.913 909	--------------	J XBB ZZZ	x
4MSNK10	144.294 009	--------------	J YXA ZZZ	x
4MN10	144.376 146	--------------	J YZA ZZZ	x
4Mnu10 (4Mν10)	144.449 000	--------------	J YBY ZZZ	x
5MSK10	144.838 384	--------------	J ZXZ ZZZ	x
M10	144.920 521	--------------	J ZZZ ZZZ	x
5MKS10	145.002 658	--------------	J ZBZ ZZZ	x
3MSN10	145.392 042	--------------	J AXA ZZZ	x
6MN10	145.464 896	--------------	J AZY ZZZ	x
4ML10	145.464 896	--------------	J AZY ZZB	x
3MNK10	145.474 180	--------------	J AZA ZZZ	x
2(SN)M10	145.863 563	--------------	J BVB ZZZ	x
4MS10	145.936 417	--------------	J BXZ ZZZ	x
4MK10	146.018 554	--------------	J BZZ ZZZ	x
2(MS)N10	146.407 938	--------------	J CVA ZZZ	x
2MNSK10	146.490 075	--------------	J CXA ZZZ	x
5MSN10	146.562 929	--------------	J CZY ZZZ	x
3M2S10	146.952 313	--------------	J DVZ ZZZ	x
3MSK10	147.034 450	--------------	J DXZ ZZZ	x
3SMN10	147.423 834	--------------	J ETA ZZZ	x
2SMKN10	147.505 971	--------------	J EVA ZZZ	x
4M2SN10	147.578 825	--------------	J EXY ZZZ	x
3S2M10	147.968 208	--------------	J FTZ ZZZ	x
2(MS)K10	148.050 346	--------------	J FVZ ZZZ	x

Eleventh-Diurnal Constituent

4MSK11	160.977 486	--------------	K CXZ ZZA	x

Twelfth-Diurnal Constituents

5M2NS12	171.799 980	--------------	L VBB ZZZ	x
3(MN)12	172.271 501	--------------	L WZC ZZZ	x
6MNS12	172.344 355	--------------	L WBA ZZZ	x
4M2N12	172.815 876	--------------	L XZB ZZZ	x
7MS12	172.888 730	--------------	L XBZ ZZZ	x
4M2NKS12	172.898 013	--------------	L XBB ZZZ	x
5MSNK12	173.278 113	--------------	L YXA ZZZ	x
3N2MS12	173.362 457	--------------	L YZA YZZ	x
5MN12	173.360 251	--------------	L YZA ZZZ	x
5Mnu12 (5Mν12)	173.433 104	--------------	L YBY ZZZ	x
6MSK12	173.822 488	--------------	L ZXZ ZZZ	x
3M2SN12	173.831 772	--------------	L ZXB ZZZ	x
MA12	173.863 557	--------------	L ZYZ ZZZ	x
M12	173.904 625	--------------	L ZZZ ZZZ	x
4MSN12	174.376 146	--------------	L AXA ZZZ	x
4ML12	174.449 000	--------------	L AZY ZZB	x
4MNK12	174.458 284	--------------	L AZA ZZZ	x
2(MSN)12	174.847 668	--------------	L BVB ZZZ	x
5MT12	174.879 455	--------------	L BWZ ZAZ	x
5MS12	174.920 521	--------------	L BXZ ZZZ	x
5MK12	175.002 658	--------------	L BZZ ZZZ	x
3M2SN12	175.392 042	--------------	L CVA ZZZ	x
6MSN12	175.464 896	--------------	L CXY ZZZ	x

3MNKS12	175.474 180	--------------	L CXA ZZZ	x
5MSN12	175.547 033	--------------	L CZY ZZZ	x
4MST12	175.895 350	--------------	L DUZ ZAZ	x
4M2S12	175.936 417	--------------	L DVZ ZZZ	x
4MSK12	176.018 554	--------------	L DXZ ZZZ	x
3(MS)12	176.952 313	--------------	L FTZ ZZZ	x
3M2SK12	177.034 450	--------------	L FVZ ZZZ	x

Fourteenth-Diurnal Constituents

5MSN14	203.360 251	--------------	N AXA ZZZ	x
5MNK14	203.442 388	--------------	N AZA ZZZ	x
6MS14	203.904 625	--------------	N BXZ ZZZ	x

2. Nodal Corrections - Application

x indicates that the corrections should be derived from the name of the constituent using the principles set out in Annex B.

y indicates that reference should be made to Annex A which shows the derivations most commonly used for specific individual constituents.

z indicates that $u = 0$ and $f = 1$

a u and f are same as Mm

b u of MSf and MSo = $-u$ of M2
f of MSf and MSo = f of M2

c u of 2SM = $-2(u$ of M2)
f of 2SM = $(f$ of M2$)^2$

d u and f are same as KQ1

e u and f are same as K2

f there are theoretical reasons why u and f of MA2 , MB2 , NA2 , NB2 (and alternative names) should be the same as those for M2. The constituents are so small that there will be no significant error if values of $u = 0$ and $f = 1$ are used either in analysis or prediction, and this is often the case.

g apart from M1, the constituents MS (where "S" is an odd species) have values of :

$$u = - S\ (1.07 \sin N)$$

$$f = (\sqrt{f \text{ of M2}}\ )^{S}$$

these values are also used in place of the normal ones for M1 where this forms part of a compound constituent.

j *u* and *f* are same as J1

k *u* and *f* are same as K1

m *u* and *f* are same as M2

o *u* and *f* are same as O1

p *u* and *f* are same as 2MN2

q *u* and *f* are same as NKM2

Appendix A

Computation of Nodal Corrections *u* and *f*

The nodal corrections ***u*** and ***f*** must be derived from the Orbital Elements (p and N) using the appropriate formulae as follows :

M1B :

$$f.\sin u = 2.783 \sin 2p + 0.558 \sin (2p - N) + 0.184 \sin N$$
$$f.\cos u = 1 + 2.783 \cos 2p + 0.558 \cos (2p - N) + 0.184 \cos N$$

M1 :

$$f.\sin u = \sin p + 0.2 \sin (p - N)$$
$$f.\cos u = 2 [\cos p + 0.2 \cos (p - N)]$$

M1A :

$$f.\sin u = - 0.3593 \sin 2p - 0.2 \sin N - 0.066 \sin (2p - N)$$
$$f.\cos u = 1 + 0.3593 \cos 2p + 0.2 \cos N + 0.066 \cos (2p - N)$$

gamma 2 :

$$f.\sin u = 0.147 \sin 2(N - p)$$
$$f.\cos u = 1 + 0.147 \cos 2(N - p)$$

alpha 2 :

$$f.\sin u = - 0.0446 \sin (p - p')$$
$$f.\cos u = 1 - 0.0446 \cos (p - p')$$

delta 2 :
(B ZBZ ZZZ)

$$f.\sin u = 0.477 \sin N$$
$$f.\cos u = 1 - 0.477 \cos N$$

xi 2 / eta 2 :

$$f.\sin u = - 0.439 \sin N$$
$$f.\cos u = 1 + 0.439 \cos N$$

L2 :

$$f.\sin u = - 0.2505 \sin 2p - 0.1102 \sin (2p - N) - 0.0156 \sin (2p - 2N) - 0.037 \sin N$$
$$f.\cos u = 1 - 0.2505 \cos 2p - 0.1102 \cos (2p - N) - 0.0156 \cos (2p - 2N) - 0.037 \cos N$$

From these formulae the values of ***u*** and ***f*** can be derived

The formulae for the following fundamental constituents are :

u of Mm = 0
f of Mm = $1 - 0.1311 \cos N + 0.0538 \cos 2p + 0.0205 \cos (2p - N)$

u of Mf = $-23.7 \sin N + 2.7 \sin 2N - 0.4 \sin 3N$
f of Mf = $1.084 + 0.415 \cos N + 0.039 \cos 2N$

u of O1 = $10.80 \sin N - 1.34 \sin 2N + 0.19 \sin 3N$
f of O1 = $1.0176 + 0.1871 \cos N - 0.0147 \cos 2N$

u of K1 = $-8.86 \sin N + 0.68 \sin 2N - 0.07 \sin 3N$
f of K1 = $1.0060 + 0.1150 \cos N - 0.0088 \cos 2N + 0.0006 \cos 3N$

u of J1 = $-12.94 \sin N + 1.34 \sin 2N - 0.19 \sin 3N$
f of J1 = $1.1029 + 0.1676 \cos N - 0.0170 \cos 2N + 0.0016 \cos 3N$

u of M2 = $-2.14 \sin N$
f of M2 = $1.0007 - 0.0373 \cos N + 0.0002 \cos 2N$

u of K2 = $-17.74 \sin N + 0.68 \sin 2N - 0.04 \sin 3N$
f of K2 = $1.0246 + 0.2863 \cos N + 0.0083 \cos 2N - 0.0015 \cos 3N$

u of M3 = $-3.21 \sin N$
f of M3 = $(\sqrt{f \text{ of M2}})^3$

Values for all other constituents can either be derived form the above using the methods described in Annex B or else they have values of $u = 0$ and $f = 1$.

Appendix B

Derivation of Speeds and values of *u* and *f* from Constituent Names

As shown in Annex A the values of ***u*** and ***f*** have been derived from the Orbital Elements for the constituents given, but the values for other constituents can be derived from the construction of the individual constituent names using the principles below.

Speeds :

Starting from the left add all the values of the letters of the same name. Therefore, for example, MS4 = M2 + S2.
But if such addition produces the wrong number of cycles per day, then the signs of the compound constituents must be changed progressively from the right until the correct number of cycles is reached. Thus :

2MN6 = 2 x M2 + N2 resulting in the correct 6 cycles per day

however, 4MN6 = 4 x M2 + N2 which gives incorrect 10 cycles per day, therefore changing the sign of N2 produces :

4MN6 = 4 x M2 – N2 which gives the correct value of 6 cycles per day

Some other examples are :

MP1 = M2 – P1

3M2S2 = 3 x M2 – 2 x S2

Value of *u* :

When using the above principles it needs to be borne in mind that ***u*** sometimes has a value of zero.

For example, *u* of 3M2S2 = 3 x (*u* of M2) – 2 x (*u* of S2) but *u* of S2 = 0

therefore, *u* of 3M2S2 = 3 x (*u* of M2)

Likewise, *u* of MP1 = (*u* of M2) – (*u* of P1) but *u* of P1 = 0

therefore, *u* of MP1 = *u* of M2

In addition, because several astronomical constituents have the same values of ***u*** the expression may sometimes be simplified. For example, M2 and N2 have the same value for ***u*** and therefore, *u* of 2MN6 = 3 x (*u* of M2)

Value of *f* :

The values of ***f*** are obtained in basically the same manner but multiplying instead of adding the individual contributions. Furthermore, ***f*** is always obtained by multiplication and not by division even if a change of sign becomes necessary as explained above.

As with the values of ***u*** the expression if often simplified by the fact that some astronomical constituents have values of *f* = 1, and several have the same value.

For example,

f of MS4 = *f* of M2 x *f* of S2 but *f* of S2 = 1

therefore, *f* of MS4 = *f* of M2

f of 2MN6 = $(f \text{ of M2})^2$ x *f* of N2 but *f* of N2 = *f* of M2

therefore, *f* of 2MN6 = $(f \text{ of M2})^3$

f of 4MN6 = $(f \text{ of M2})^4$ x *f* of N2 but *f* of N2 = *f* of M2

therefore, *f* of 4MN6 = $(f \text{ of M2})^5$

f of MP1 = *f* of M2 x *f* of P1 but *f* of P1 = 1

therefore, *f* of MP1 = *f* of M2

f of 3M2S2 = $(f \text{ of M2})^3$ x $(f \text{ of S2})^2$ but *f* of S2 = 1

therefore, *f* of 3M2S2 = $(f \text{ of M2})^3$

Exceptions :

There are several exceptions to all the above principles. The primary ones are :

MSf this has a speed equal to (S2 – M2) and should be treated, therefore, as if it were SMf, and hence the value of ***u*** becomes (–*u* of M2). This will of course have no effect on the value of ***f***, which is always obtained by multiplication and thus equals (*f* of M2).

MA2 and MB2 :

despite their appearance neither of them, nor constituents of other species which include A and B, are compound constituents – there are no constituents A or B to form a compound. They are constituents whose speeds differ by one cycle a year from that of M2. The A in MA2 was intended to signify the Annual differences.

MB2 was originally called Ma2 but this became ambiguous when spoken, or typed on computers without lower case, and so it was initially changed to MA2*. However, this in turn was thought to be clumsy and hence MB2 was finally adopted. Although theoretically they should have the same values of ***u*** and ***f*** as M2, they are so small that they are commonly treated as having values of $u = 0$ and $f = 1$.

NA2 and NB2 :

the self same reasoning applies to these two constituents. They are constituents whose speeds differ by one cycle a year from that of N2. Although theoretically they should have the same values of ***u*** and ***f*** as N2 they are so small that they are commonly treated as having values of $u = 0$ and $f = 1$.

M3 despite the fact that it has more than 2 cycles per day it is nevertheless an astronomical constituent.

MSm found in some lists is apparently mis-named. Its speed corresponds to a name of MNum (Mνm) by which name it is referred to in the foregoing list.

Note :

Greek letters present difficulties for most computer keyboards and the solution often employed is to spell out the letter phonetically – for example, theta1 ; mu2.

Care has to be taken when using this method in order not to confuse P1 with the Greek PI 1 (= $\pi 1$). ν (nu or Nu) by virtue of its close resemblance to the letter v is often written as v or V. Thus Mν4 may be written as Mnu4 ; MNu4 ; Mv4 or MV4.

Principles for Predictions using Secondary Port Data in National Tide Tables

Country	Times	Heights	Remarks
Australia	One single mean time difference for both HW and LW applicable at Springs or Neaps.	Four absolute tidal levels given. A Ratio of Ranges between the Standard and Secondary Port is then derived and used to obtain the height at the Secondary Port.	Harmonic Constants (up to 22 where available) published. A semi-graphic solution is also available using time and height data.
Canada	One time difference for HW and one for LW applicable at Springs or Neaps.	Two height differences for HW and two for LW applicable to their own unique set of four tidal levels.	No harmonic data published.
Chile	One time difference for HW and one for LW applicable at Springs or Neaps.	One height difference for HW and one for LW applicable at Springs or Neaps, but in special cases a Ratio of Ranges between the Standard and Secondary Port is then used to derive the height at the Secondary Port.	No harmonic data published.
Denmark	In Faeroes – one time difference for HW and one for LW applicable at Springs or Neaps. In Greenland – one time difference for HW and one for LW applicable at Springs or Neaps. In Denmark – no Secondary Port data published.	In Faeroes - Differences for each of the four main tidal levels on Standard Port levels applied directly to the Standard Port heights. In Greenland – no height differences given. In Denmark – no Secondary Port Data published.	Four main Harmonic Constants given only for Standard Ports Four main Harmonic Constants only for Standard Ports. Four main Harmonic Constants given only for Standard Ports.
France	HW and LW time differences for both Springs and Neaps in European Waters, elsewhere a single HW and LW time difference applied using “concordance” methodology.	Differences for each of the four main tidal levels on Standard Port levels applied using “concordance” methodology.	A semi-graphic solution is also available using time and height data. No harmonic data published.
Japan	One single mean time difference for both HW and LW applicable at Springs or Neaps.	Four absolute tidal levels given. A Ratio of Ranges between the Standard and Secondary Port is published and used to obtain the height at the Secondary Port.	No harmonic data published.

Norway	One single mean time difference for both HW and LW applicable at Springs or Neaps.	A Ratio of Ranges between the Standard and Secondary Port is used to derive the height at the Secondary Port.	Harmonic constants (7) given for Standard and Secondary Ports. A semi-graphic solution is also available using time and height data.
New Zealand	One time difference for HW and one for LW applicable at Springs or Neaps.	Four absolute tidal levels given. A Ratio of Ranges between the Standard and Secondary Port is then derived and used to obtain the height at the Secondary Port.	No harmonic data published.
Portugal	HW and LW time differences for both Springs and Neaps.	Differences for each of the four main tidal levels on Standard Port levels, and also a Ratio of Ranges at both Springs and Neaps are given.	Four main Harmonic Constants published but for Standard Ports only.
Spain	One time difference for HW and one for LW applicable at Springs or Neaps.	One height difference for HW and one for LW applicable at Springs or Neaps.	No harmonic data published.
United Kingdom	HW and LW time differences for both Springs and Neaps using linear interpolation for times at Standard Port in European and Scandinavian Waters, elsewhere a single HW and LW time difference is used.	Differences for each of the four main tidal levels on Standard Port levels. Linear interpolation between the Standard Port daily heights used to derive the Secondary Port predicted heights.	Four main Harmonic Constants plus Shallow Water Corrections published. A semi-graphic solution is also available using time and height data.
United States	One time difference for HW and one for LW applicable at Springs or Neaps.	A mixture of one height difference for HW and one for LW, and a Ratio of Ranges between the Standard and Secondary Port is then used to derive the height at the Secondary Port.	No harmonic data published.

Notes:

1. ***The National Tide Tables of Brasil, China and South Africa contain daily predictions for Standard Ports only and do not have any Secondary Port data.***

2. ***Several Member States also publish MSL(Zo) values, tidal ranges and "Establishments" for each of their Secondary Ports, which are not necessarily required directly for the computation of the tidal prediction.***

A2.16 Naming Convention for the Vertical Datum of Charts

1. It is resolved that the vertical datum used on navigational charts, Chart Datum (CD), be defined without ambiguity in order to enable subsequent bathymetric data comparisons to be conducted in an efficient and reliable manner and for the accurate combination of datasets using different vertical datums.

2. It is recommended that a designated epoch for example CD (2006) or LAT-UK (2000) be used. The decision as to when a change in CD for a given area is necessary and the name given to that specific definition of CD remains a matter for each Member State based on their national requirements.

Vertical Reference Framework – Submitted by the IHB

IAG – International Association of Geodesy

The IAG inter-commission project ICP1.2 on vertical reference frames was tasked to prepare a proposal for the definition and realization of a global vertical reference frame (World Height System – WHS). The IHB has not been able to attend any further meetings of ICP1.2 since IHOTC7. ICP1.2 has finalised the report which will go to the IAG Congress and a copy is attached to this paper. It is not known at this point whether the project will be re-established by the Congress.

FIG – International Federation of Surveyors

As indicated at IHOTC7 the FIG Congress was held in Munich in October 2006. Captain Hugo Gorziglia and Steve Shipman attended on behalf of the IHB. Andrew Leyzack from Canada was elected as the Chair of Commission 4 (Hydrography) and the excellent liaison established with his predecessor, Adam Greenland, is continuing. The “FIG Guide on the Establishment of a Vertical Reference Surface for Hydrography” prepared by a WG of Commission 4 led by Ruth Adams from the UKHO was published as FIG Publication No.37 and presented at the Congress. This publication can be downloaded free of charge from the IHO website www.iho.int > INT Organizations > FIG.

Global Sea Level Observing System (GLOSS)

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Why Measure Sea Level?

- **Practical applications e.g define vertical datums, safe navigation, constrain models, predict flood risks**
- **Coastal management e.g. sea level used to understand past and future changes in shelf and ocean conditions**

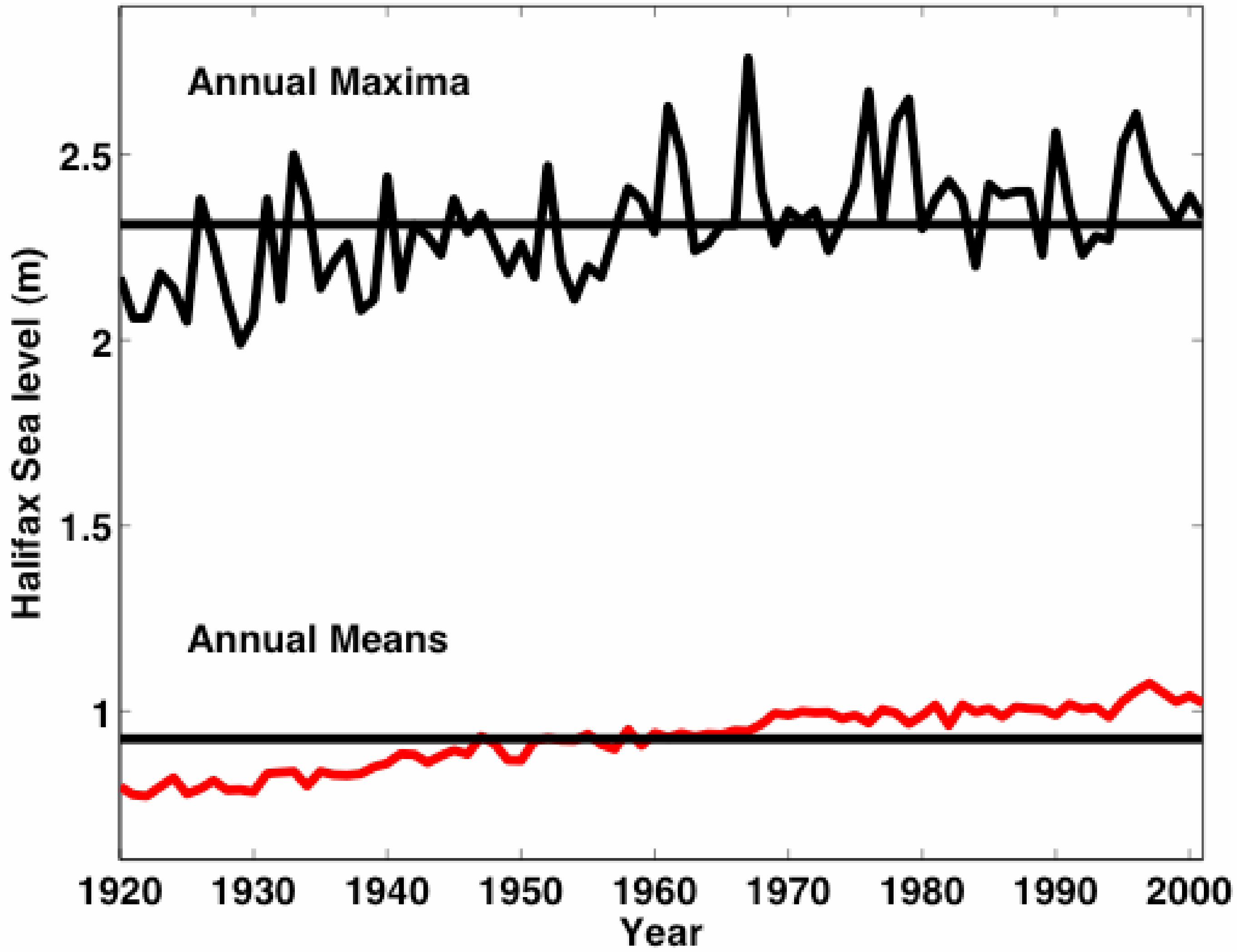
Maldives Int. Airport

Time-Scales and Causes of Sea Level Change

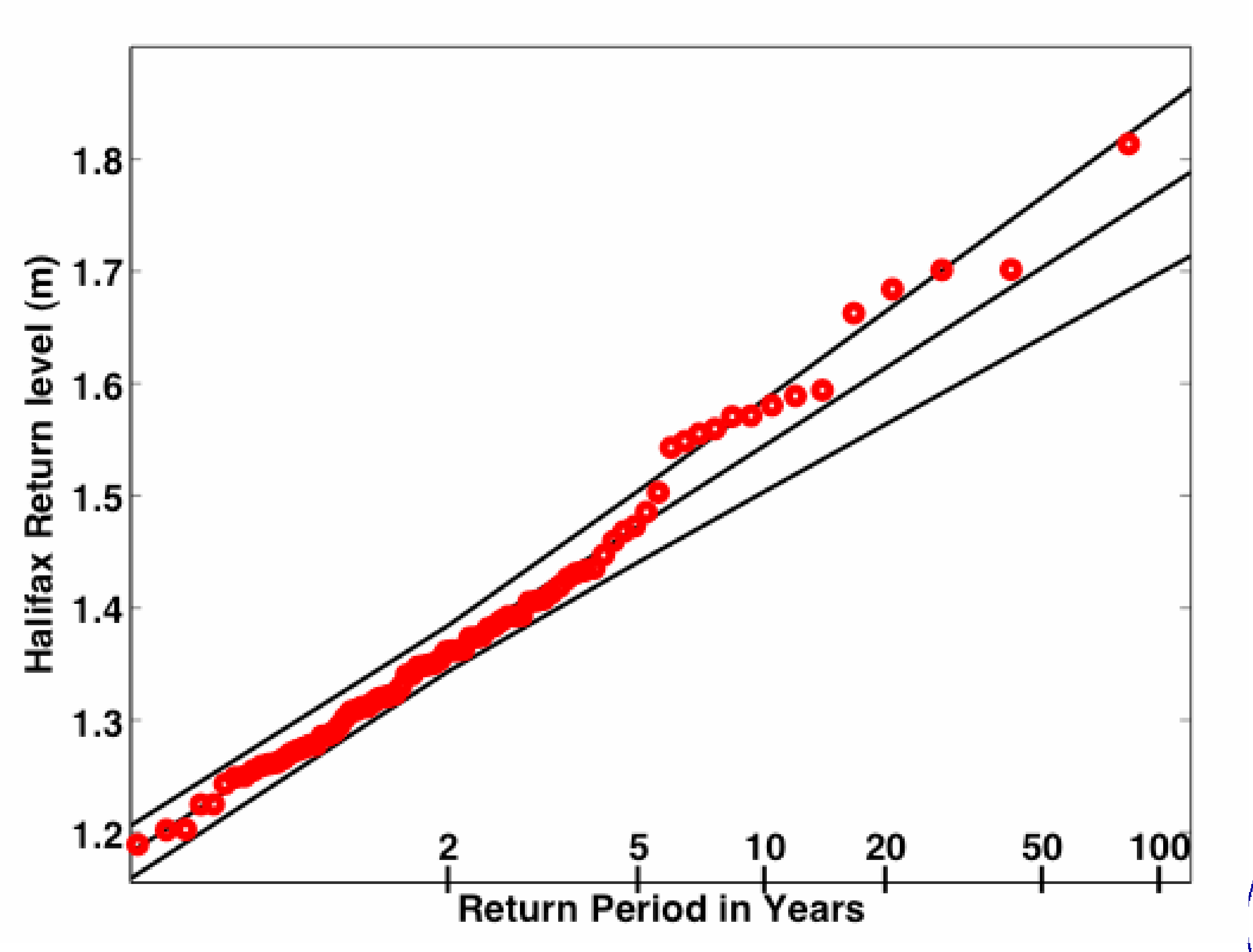
- **Seconds to minutes: waves, tsunamis**
- **Hours to days: tides and surges**
- **Seasonal: surface heating and freshwater input**
- **Interannual: ENSO, NAO**
- **Long term trends: climate variability and change, vertical crustal movement (e.g. GIA)**

GLOBAL SEA LEVEL GLOSS OBSERVING SYSTEM

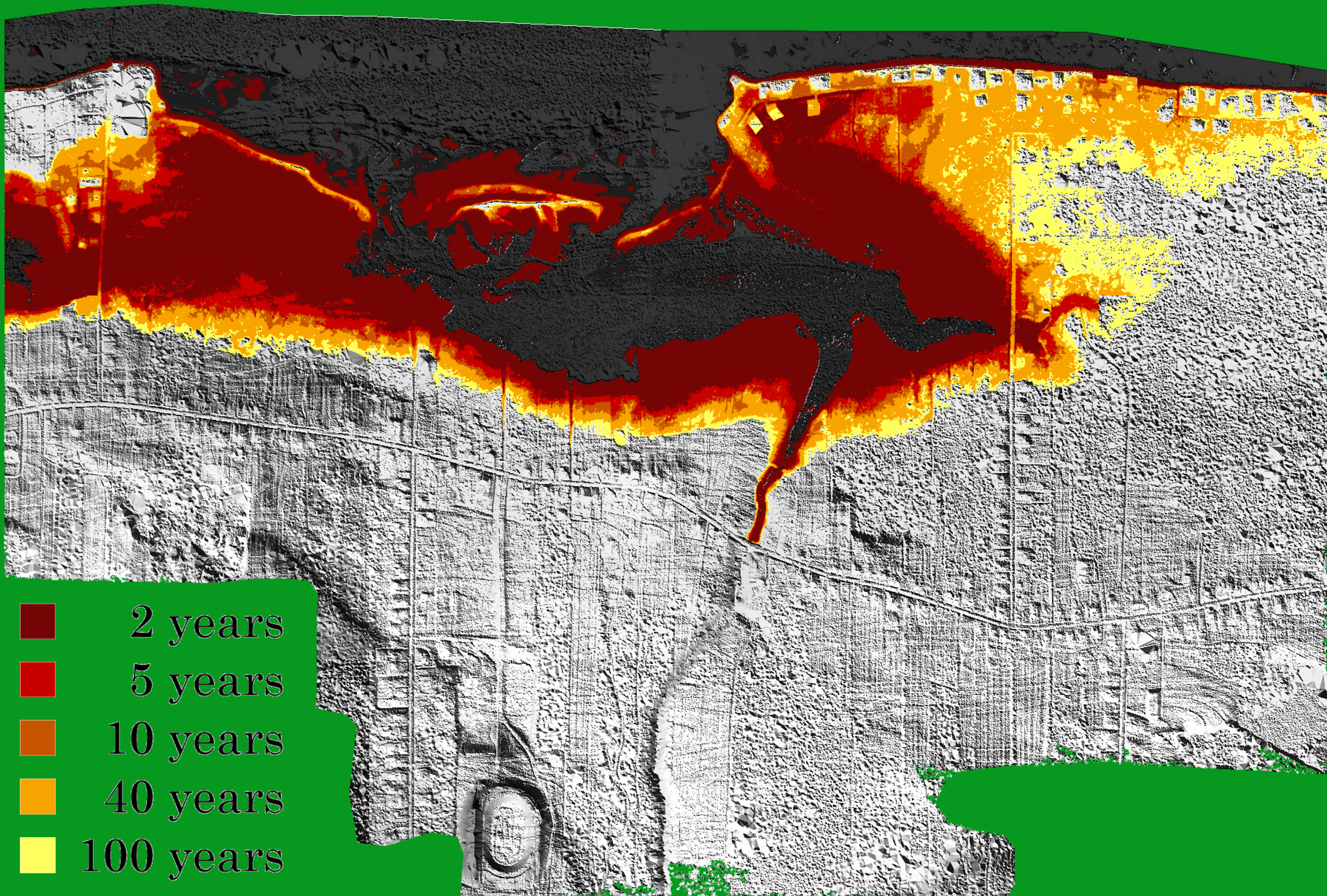
80y of Observed Sea Level at Halifax



Long Sea Level Records Allow Us to Make Plots Such As …

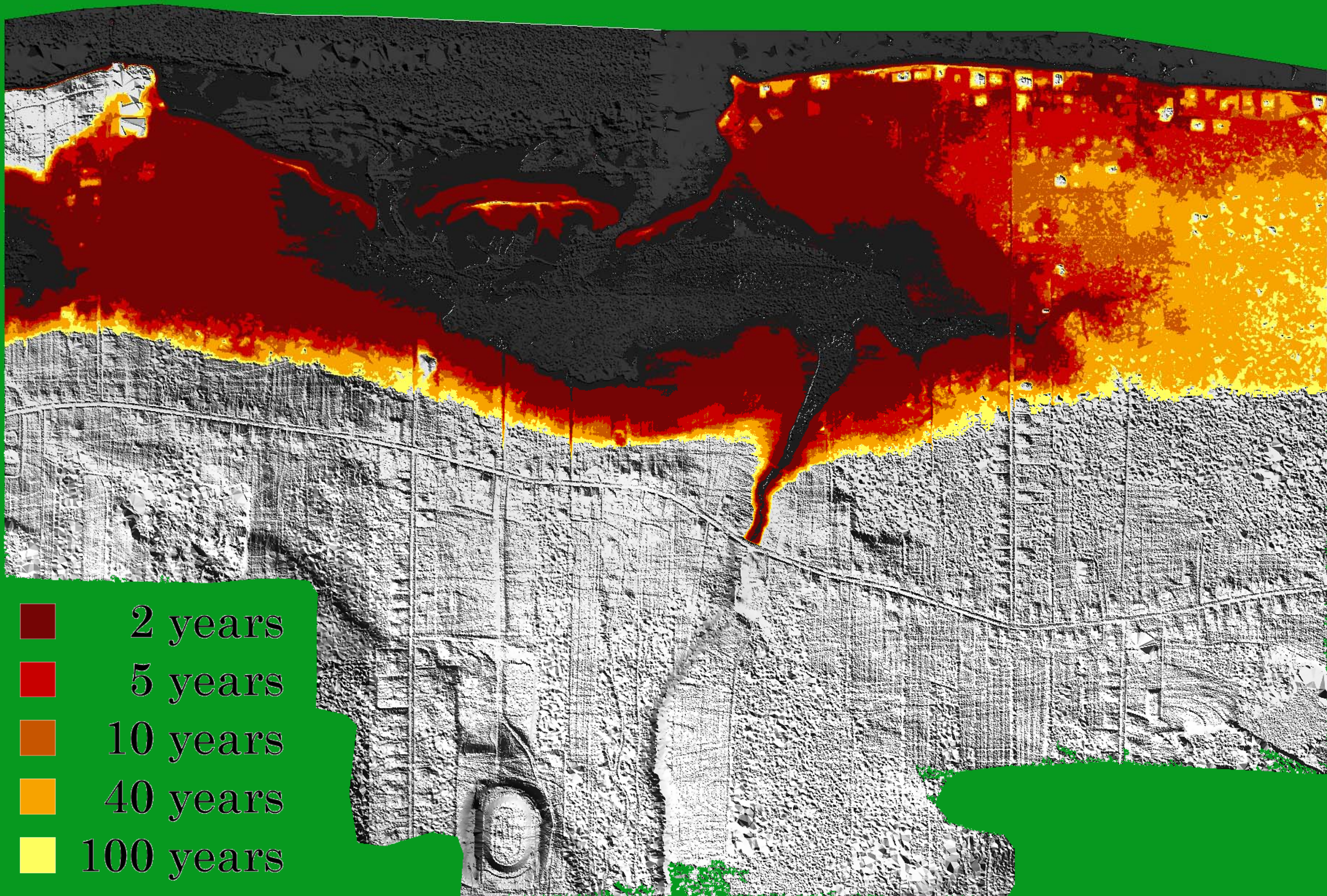


Present Day Flooding Risk
Near Shediac, NB, Canada



IHO

What Will it Be Like Next Century?



Expect present 100y return level to be breached every 10y in 100y

What is GLOSS?

- Established by IOC in mid-1980s to improve quantity and quality of sea level data sent to PSMSL and other sea level centres.
- Original aim: Develop GLOSS Core Network of 300 sea level stations for practical and ocean/climate science applications.
- Global array of gauges spaced 500-1000 km apart. Geographically balanced. Open ocean locations. Best technology.

What Data Streams Does GLOSS Generate?

1. **Delayed mode: QC'd mean sea levels to PSMSL**

2. **Delayed mode: QC'd higher-frequency data (e.g. hourly) to GLOSS Data Centre (PSMSL, UHSLC)**

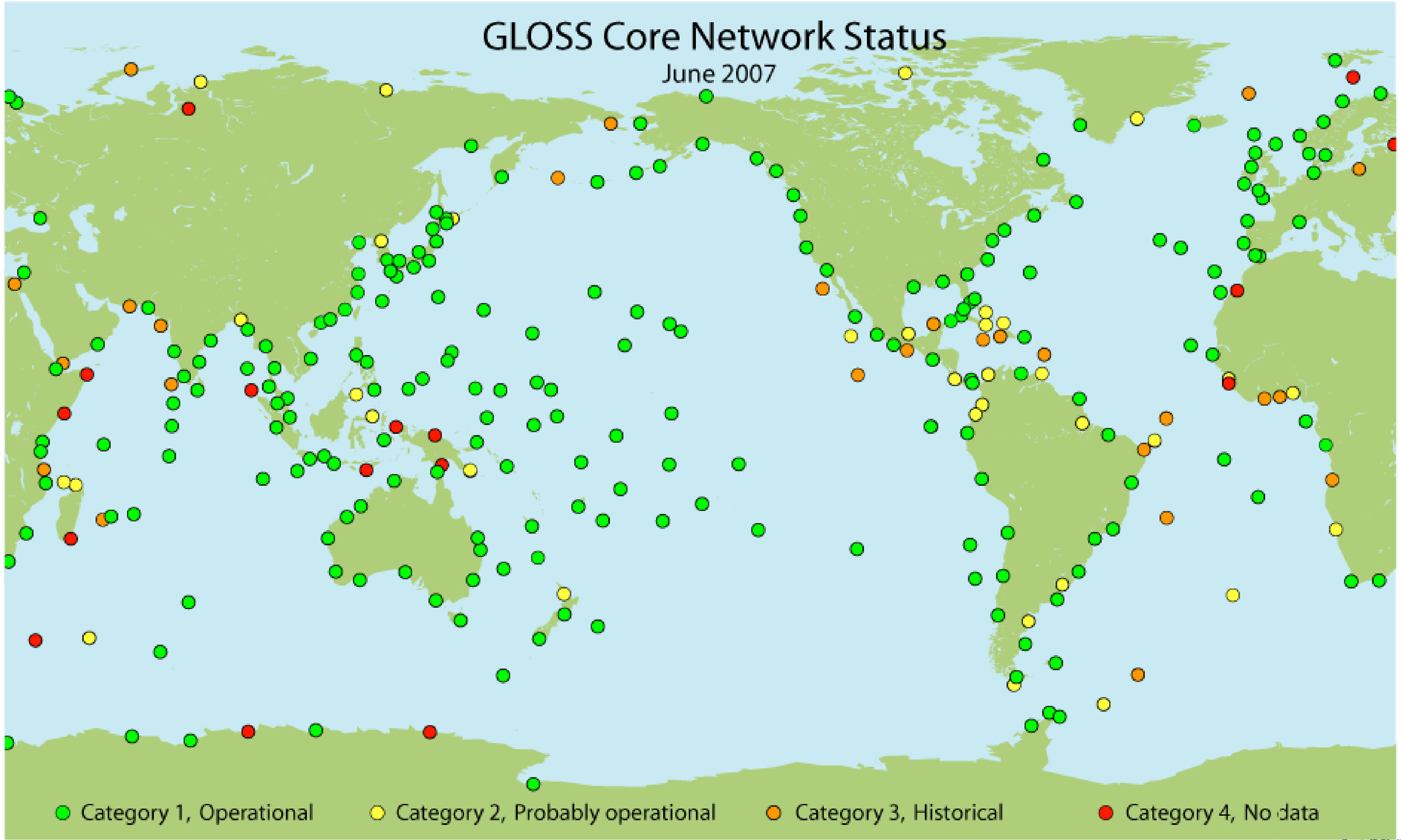
3. **Near real time: High frequency data to UHSLC and International Tsunami Warning Centers**

4. **GPS data to TIGA Centre at Potsdam (Germany) initiated by IGS/PSMSL in 2001.**

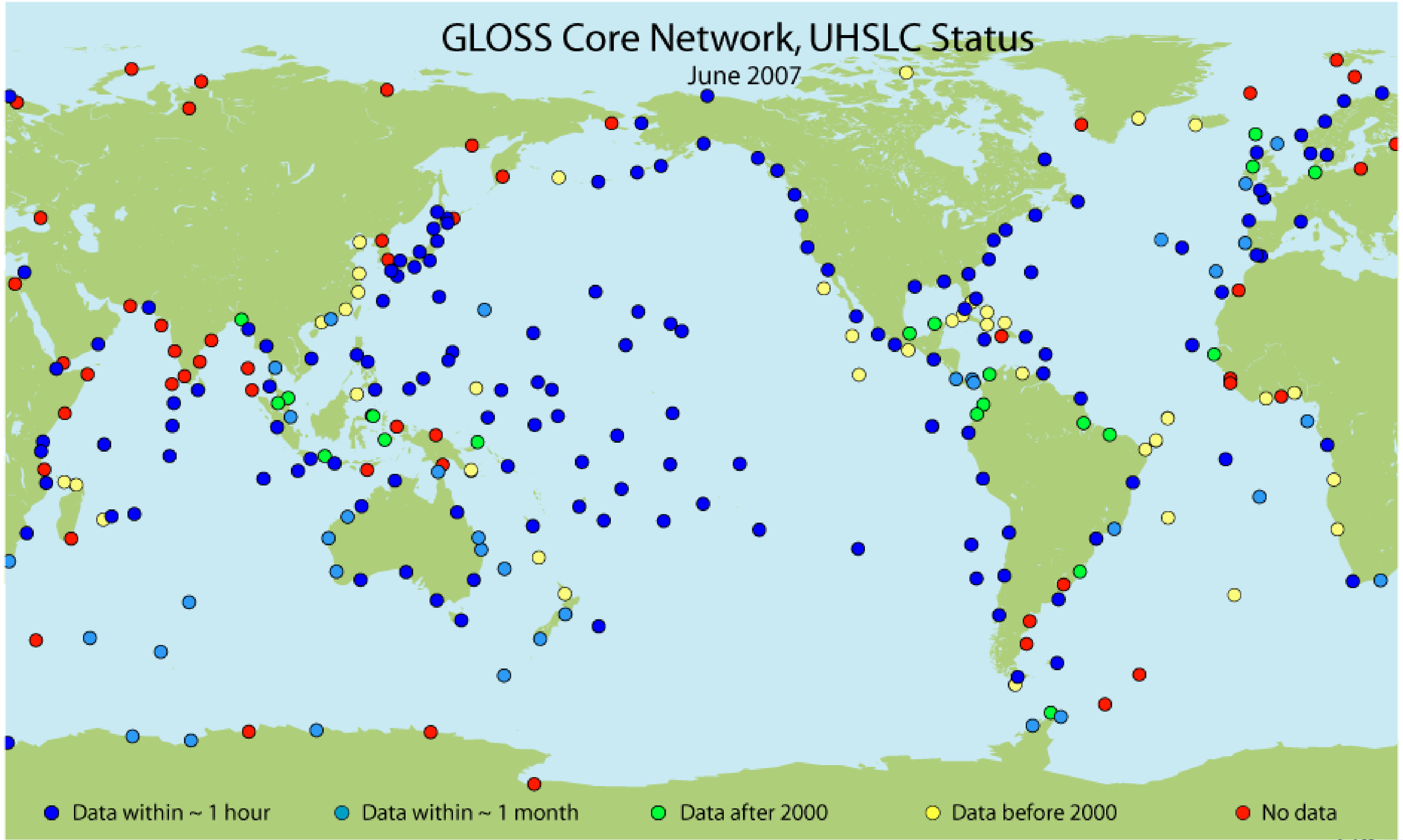
GLOSS Also Provides …

1. Coordination mechanism for global sea level observations (e.g. GLOSS Group of Experts)
2. Global data standards and archiving facilities, QC of data
3. Technical manuals and training material
4. Technical advice and special workshops on technical issues
5. Training courses on analysis and uses of sea level observations
6. Hardware (e.g. tide gauges, GPS, transmitters)

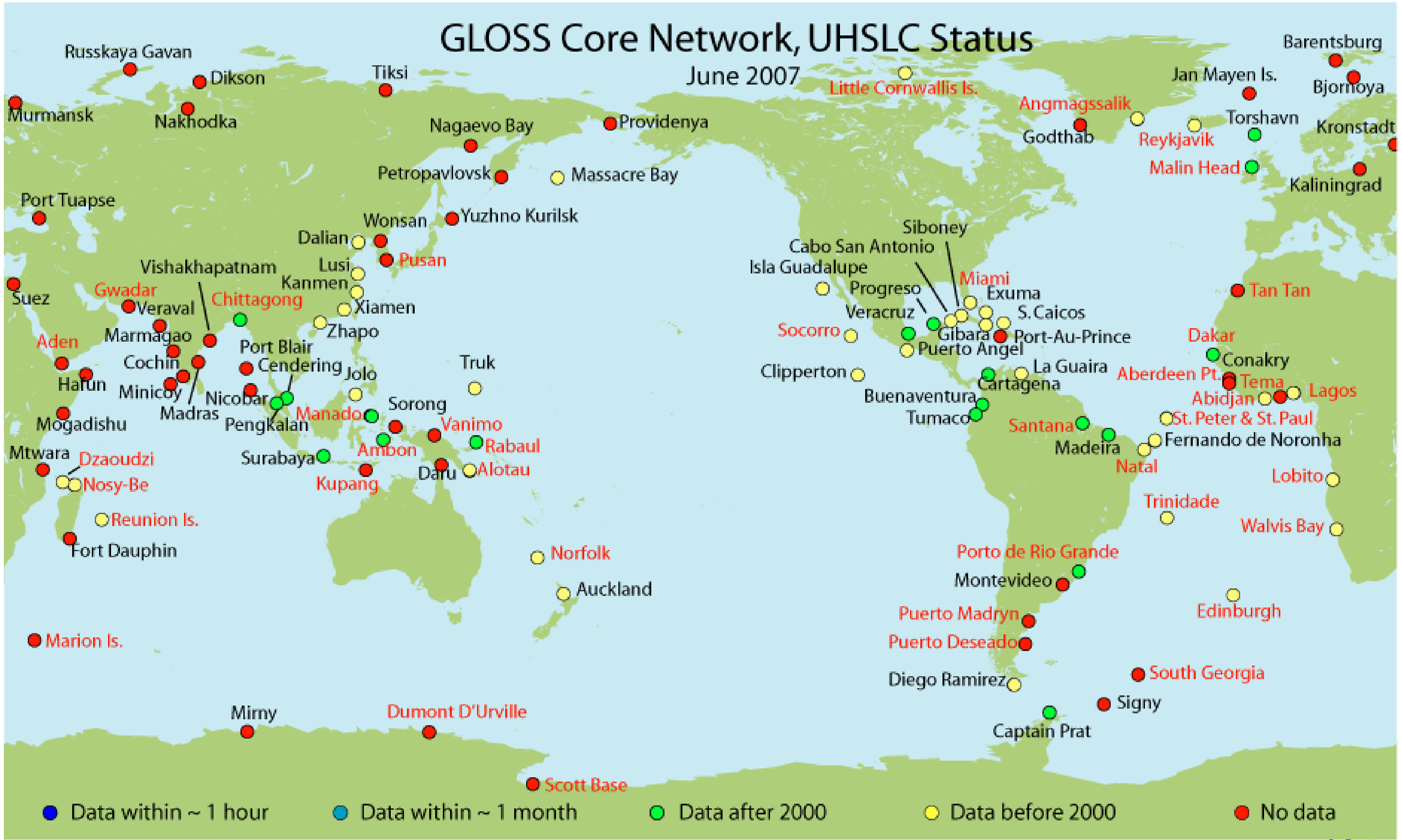
Delayed Mode Low Frequency Sea Level Stations



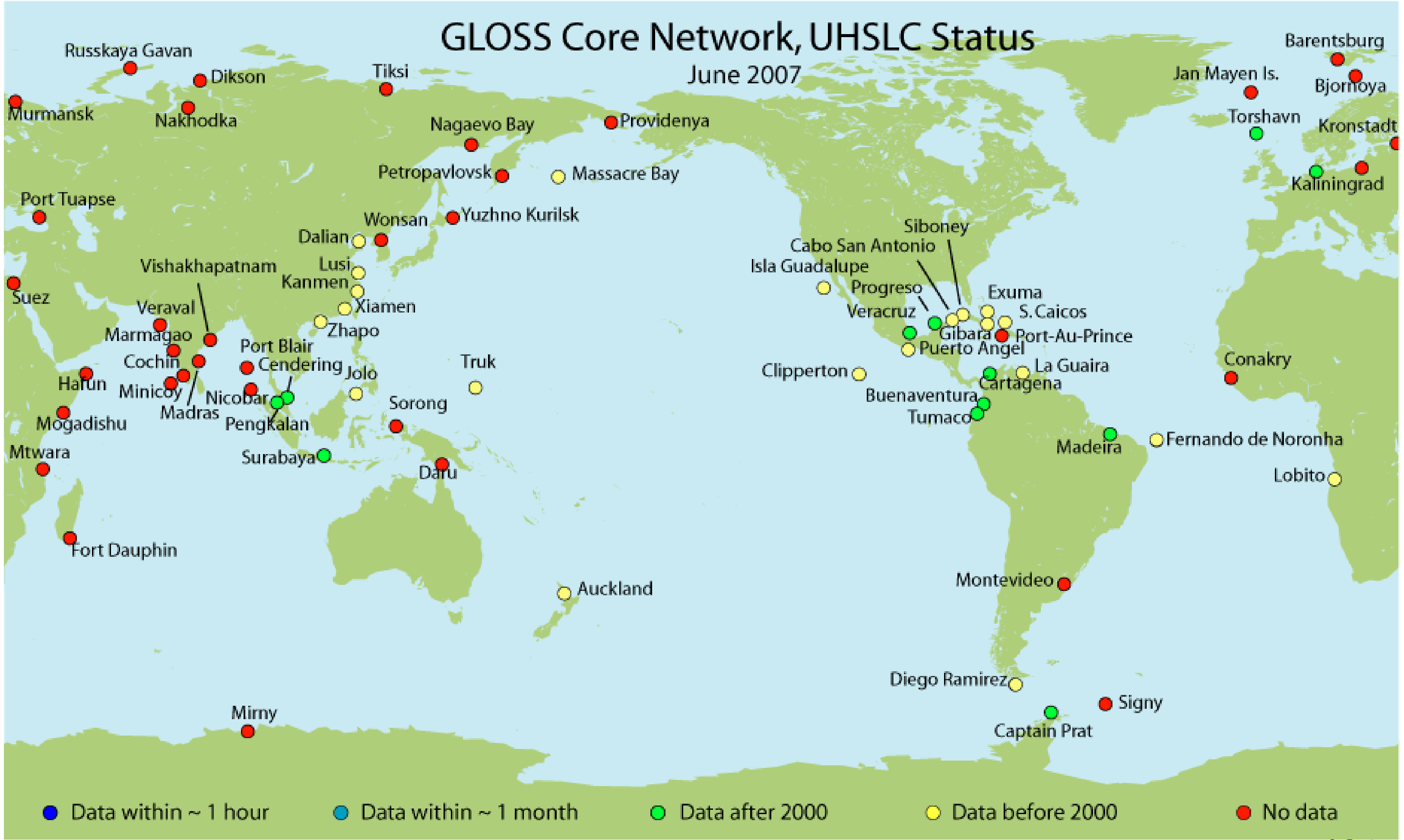
High Frequency Sea Level Stations



Planned for Upgrades for 2007-2008

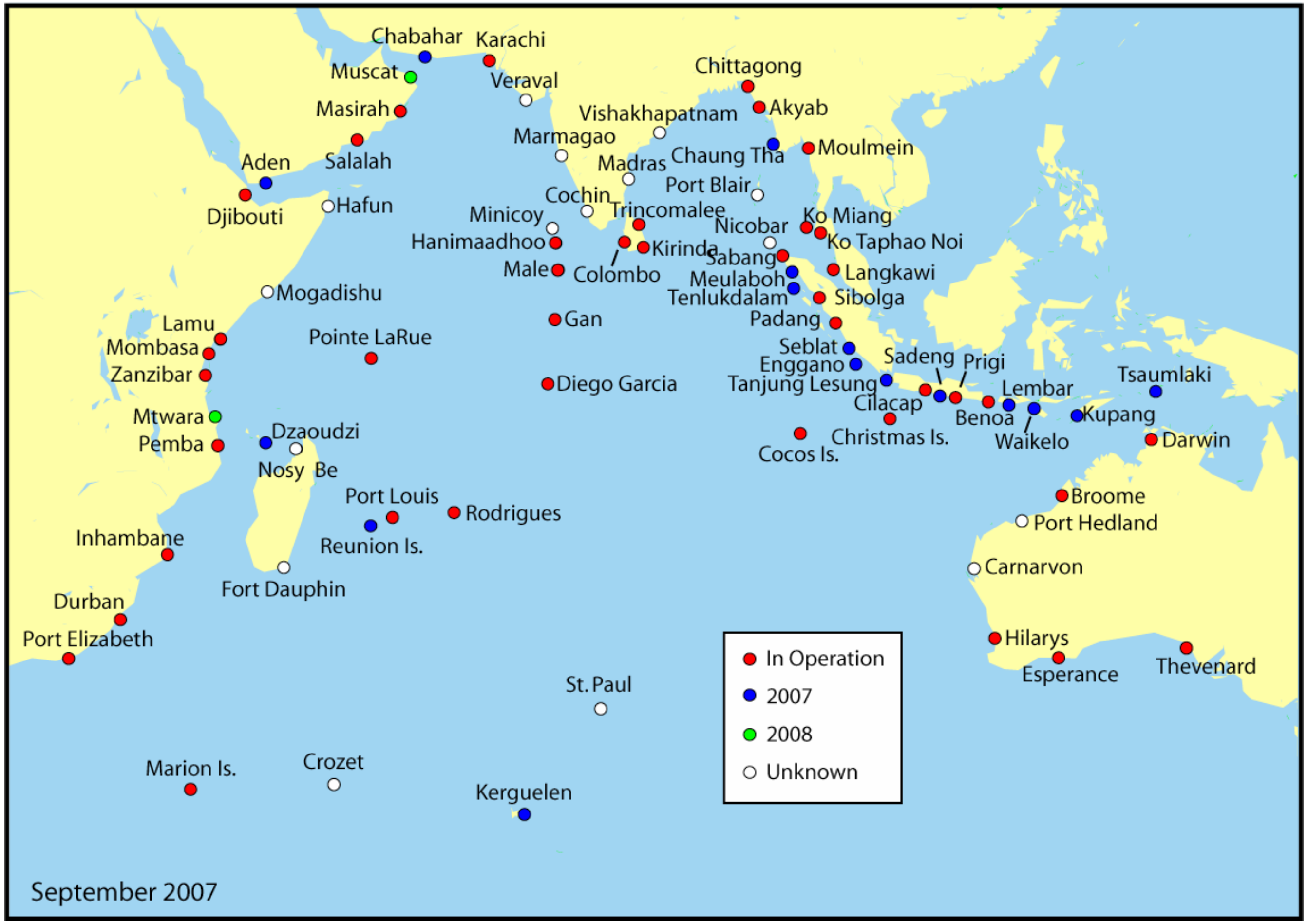


Stations Needing Upgrades and/or No Recent Provision of High Frequency Data



Status of African Tide Gauges

Status of Tide Gauge in the Indian Ocean



Recent Progress and Reports

1. **Presentations, national reports and action list from *10th GLOSS Group of Experts Meeting* (June, 2007) available at http://www.ioc-goos.org/glossge10**
2. **Presentations on *Workshop on Real-time Transmission and Processing Techniques: Improving the Global Sea Level Observing System* (June, 2007). Available from above web-site.**
3. ***Sea Level Fellowship programme* (Indian Ocean Tsunami Warning System). For details see (http://ioc.unesco.org/iocweb/docs/IOTWS-Sealevel-Fellowship-07-2ndRound.pdf)**

How Can IHO TC Assist GLOSS?

1. **Consider GLOSS requirements when upgrades are carried out by Member States (Appendix, Manual on Sea Level Observation and Analysis)**

2. **Encourage collaboration between tide gauge agencies and national GPS communities (typically geodetic/survey agencies)**

3. **Encourage data exchange/provision to GLOSS Data Centers (PSMSL, UHSLC). As status maps show, problems with high frequency data exchange from GLOSS CN stations in India, China, and Russia.**

Thanks For Your Time

Questions about scientific value of sea level observations? Please feel free to contact

keith.thompson@dal.ca

or Thorkild Aarup (IOC) at

t.aarup@unesco.org

who can also answer questions related to the organization and administration of GLOSS.

Update on IOC/GLOSS Program – Submitted by the IHB

The 10th Meeting of the IOC Global Sea Level Observing System (GLOSS) Group of Experts (GE-X) was held at the IOC headquarters in Paris from 5 – 8 June 2007. The IHOTC were represented by Steve Shipman (PAH). The 5 June was devoted to a workshop on “Real-time Transmission and Processing Techniques; improving the Global Sea Level Observing System’s contribution to multi-hazard warning systems” with the main meeting taking place from 6 - 8 June. The meeting was attended by over 62 delegates from some 30 countries. The hydrographic Offices of Brazil, Canada, Chile, France, the Islamic Republic of Iran, Mozambique, Norway, Portugal, Tunisia and the USA were represented.

The workshop was primarily dedicated to the techniques and processes for delivering and quality assuring tidal data in real-time for use in Tsunami warning systems. The main session was opened by Dr Patricio Bernal, the Executive Secretary of IOC. Sessions were devoted to:

a. Review of GLOSS Activities and action items from GE-IX (February 2005);
b. Review of the GLOSS Core network status;
c. Updating the GLOSS Implementation Plan;
d. GLOSS in the context of a Global Tsunami and other ocean-related hazards early warning system;
e. Reports from Regional GLOSS programmes;
f. National reports on Sea Level activities;
g. Reports on the linkage between GLOSS and other programmes;
h. Reports from the GLOSS data centres;
i. Reports from the GLOSS sub-committees;
j. GLOSS Training Activities; and
k. Action plan for the intercessional period 2007 – 2009.

Under item g above Steve Shipman provided a presentation on the principal activities and decisions from the 3rd EIHC, the XVIIth IHC and the 6th and 7th meetings of the IHO Tidal Committee.

The GE-X expressed its thanks to the IHO for its assistance in trying to arrange for tidal stations to be committed to the GLOSS Core network.

The papers from the GE-X meeting are available from the following URL:

http://www.ioc-goos.org/index.php?option=com_oe&task=viewEventDocs&eventID=104

Standard Ports in UK Waters Analysed Annually

Maximum Tidal Ranges (HAT - LAT)

Name	1997	MSL Zo	H of M2	2007	MSL Zo	H of M2
Devonport	5.9	3.302	1.684	5.9	3.320	1.680
Southampton	5.2	2.844	1.360	5.1	2.899	1.348
Portsmouth	5.0	2.856	1.413	5.0	2.866	1.416
Shoreham	6.9	3.315	2.148	6.8	3.384	2.141
Dover	7.2	3.740	2.249	7.1	3.758	2.249
Margate	5.1	2.619	1.603	5.0	2.610	1.647
Tilbury	7.4	3.296	2.331	7.1	3.342	2.327
London Bridge	8.0	3.629	2.529	7.8	3.655	2.475
Walton	4.7	2.195	1.422	4.6	2.221	1.427
Harwich	4.6	2.083	1.320	4.5	2.121	1.315
Spurn Head	7.5	4.079	2.115	7.4	4.068	2.141
Immingham	8.0	4.188	2.287	7.9	4.184	2.276
Rosyth	6.4	3.245	1.891	6.4	3.259	1.890
Avonmouth	15.1	6.958	4.315	14.8	6.957	4.263
St Peter Port	10.6	5.212	2.774	10.2	5.266	2.751

LONG TERM CHANGES IN TIDAL RESPONSE ASSOCIATED WITH THE DEEPENING OF NAVIGATIONAL CHANNELS

Chris E. Zervas, U.S. Department of Commerce, NOAA's National Ocean Service

Keywords: tide range, water level, dredging, mean high water, mean low water
Presented at Coastal Zone'03 Conference, U.S.A.

INTRODUCTION

NOAA's National Ocean Service (NOS) and its predecessors have been operating tide gauges to record water levels in the waterways of the United States since the 19th century. As a result, a large collection of long term water level data is available for analysis from the Center for Operational Oceanographic Products and Services (CO-OPS), a component of NOS. As each month of data is collected by CO-OPS, it is processed to obtain a set of calculated parameters that summarizes the tidal variation over the course of the month. Two important parameters are the mean high water (MHW) and the mean low water (MLW) levels for the month. The monthly mean range of tide is the difference between the MHW and the MLW. Two other important parameters are the Greenwich monthly mean high water interval (HWI) and the Greenwich monthly mean low water interval (LWI). They are defined as the mean time interval between the moon's transit over the Greenwich meridian and the following high or low water at a given location.

In this study, the monthly mean ranges, the HWIs, and the LWIs were analyzed at 116 long term NOS water level stations to identify locations where there have been significant changes in the amplitude or timing of the tide. This information will be useful in deciding where tidal parameters are changing most rapidly, thus requiring more frequent water level measurements in the surrounding area to keep tide predictions and tidal datums up-to-date with the changing tidal response.

CHANGES IN TIDAL PARAMETERS

A typical time series of the mean range of tide shows periodic variations along with a long term trend (Figure 1). The most prominent variation is the 18.6-year cycle due to the obliquity of the moon's orbit which varies between 18.5 and 28.5 . In order to get an accurate least squares estimate of the linear trend, an 18.6-year sinusoidal cycle, an average seasonal cycle, and an autoregressive coefficient of order 1 are included as variables in a linear regression. The 95% confidence intervals for the calculated trends are shown in Figure 2. It can be seen that only four stations out of the 116 long term stations analyzed have large and statistically significant trends. These stations are Philadelphia, PA, Beaufort, NC, Wilmington, NC, and Anchorage, AK. All four of these stations have mean ranges increasing at a rate greater than 3 mm/yr. As a result, these stations show significant differences in the MHW and MLW trends that were calculated using all available data up to December, 2000 (see table below). In fact, at Wilmington and Anchorage, the MHW is rising while the MLW is falling.

Water Level Station	MHW Trend (mm/yr)	MHW Standard Error (mm/yr)	MLW Trend (mm/yr)	MLW Standard Error (mm/yr)

Philadelphia, PA	4.70	0.20	0.83	0.18
Beaufort, NC	5.33	0.61	1.92	0.63
Wilmington, NC	4.33	0.22	-0.96	0.29
Anchorage, AK	2.45	0.80	-7.40	1.25

When the 18.6-year astronomical cycle and the average seasonal cycle are subtracted from the mean range, non-periodic variations are seen more clearly (Figure 3). For Philadelphia and Wilmington, the mean ranges increased by about 0.3 m up to the mid-1970s, after which they leveled off or even may have decreased slightly in the case of Philadelphia. Beaufort has experienced a steady increase in mean range amounting to about 0.1 m since the station was installed in the mid-1970s. There is more variability in the mean range for Anchorage, but it also shows an increase in mean range since the 1964 earthquake. Newly-established mean ranges based on the 1983-2001 National Tidal Datum Epoch for Philadelphia, Beaufort, and Wilmington are 1.903 m, 0.948 m, and 1.305 m, respectively. Changes in the mean range at these stations are, therefore, a large fraction of the total ranges. The established mean range for Anchorage is 7.982 m, with the change representing a much smaller percentage of the total range.

When the HWIs and LWIs of all 116 long term stations are examined, most show no long term changes in the timing of the tide since the stations were installed. However, at 16 stations, the timing of the tide has noticeably advanced over the decades, arriving at least 15 minutes earlier. The greatest rates of change in the HWIs and LWIs (Figure 4) are at three of the stations with the greatest changes in the mean range, namely Philadelphia (about 20 min and 45 min earlier), Beaufort (about 15 min and 15 min earlier), and Wilmington (about 30 min and 60 min earlier). Anchorage shows no long term change in the timing of the tide.

MODIFICATIONS TO NAVIGATIONAL CHANNELS

The amplitude and timing of the tide in bays or estuaries are driven by the tide on the adjacent continental shelf, but are significantly modified by the local bathymetry. If the bathymetry of a port region is radically changed, through dredging of navigational channels for example, there could be noticeable changes in the range and timing of the tide. The increasing maritime traffic in U.S. harbors and the growth in the size and draft of vessels visiting U.S. port facilities has lead to demands for the deepening and widening of navigational channels. The U.S. Army Corps of Engineers (USACE) has been given the responsibility by Congress for planning and implementing dredging projects necessary for deepening and widening the navigational channels in major U.S. ports. They also maintain the authorized width and depth of the navigational channels through routine maintenance dredging. Philadelphia and the Delaware River are under the jurisdiction of the Philadelphia District of the USACE. Beaufort/Morehead City harbor and Wilmington harbor are under the jurisdiction of the Wilmington District of the USACE. Information on the history of harbor and navigational channel modifications is provided on their websites (www.nap.usace.army.mil and www.saw.usace.army.mil). By the late 1800s, the Delaware River had been dredged to a depth of 18 feet. By World

War II, the USACE had deepened the navigational channel from Philadelphia to the ocean to a depth of 40 feet. The channel from Philadelphia upstream to Newbold was then dredged to a depth of 40 feet and the channel from Newbold to Trenton was dredged to 25 feet. The Philadelphia District is proposing to deepen the channel from Philadelphia to the ocean to a depth of 45 feet, but the project is presently suspended for review.

The harbor of Morehead City is connected to the Atlantic Ocean by Beaufort Inlet. The inlet was dredged to a depth of 20 feet by 1911, 30 feet by 1936, and 35 feet by 1961. In 1978, the USACE deepened the inlet to a depth of 42 feet and Morehead City harbor to a depth of 40 feet. In 1994, the inlet was further deepened to 47 feet and the harbor was deepened to 45 feet.

The Cape Fear River, up to the port of Wilmington, had been dredged to a depth of 16 feet by the late 1800s. By 1945, the navigational channel had been deepened to 32 feet and by 1950 it had been deepened to 34 feet. In 1964, the USACE deepened the ocean bar and entrance channels to 40 feet and the river channels to 38 feet. The Wilmington District has a project underway to dredge the ocean bar and entrance channels to 44 feet and the river channels to 42 feet.

SUMMARY

The long term monitoring of the tides along the U.S. coast by NOS has recorded major changes in the range and timing of the tide at only a small number of stations. Three locations, Philadelphia, Beaufort, and Wilmington, have undergone large increases in the mean range of tide and advances in the timing of the tide since the gauges were installed. This is likely a result of significant modifications to the Delaware River, Beaufort Inlet, and the Cape Fear River over the decades. The deepening of the Cape Fear River has even had the effect of slightly lowering the MLW at Wilmington. Anchorage has undergone an increase in tidal range without any advance in the timing of the tide. Further changes in the range and the timing of the tide can be expected in the future for Wilmington, as a result of the ongoing dredging project, and for Philadelphia, if the proposed dredging project goes forward.

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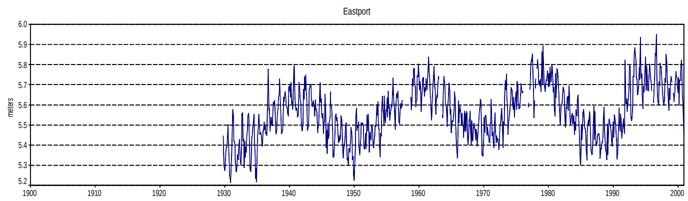


Figure 1. Monthly mean range of tide in meters at Eastport, ME.

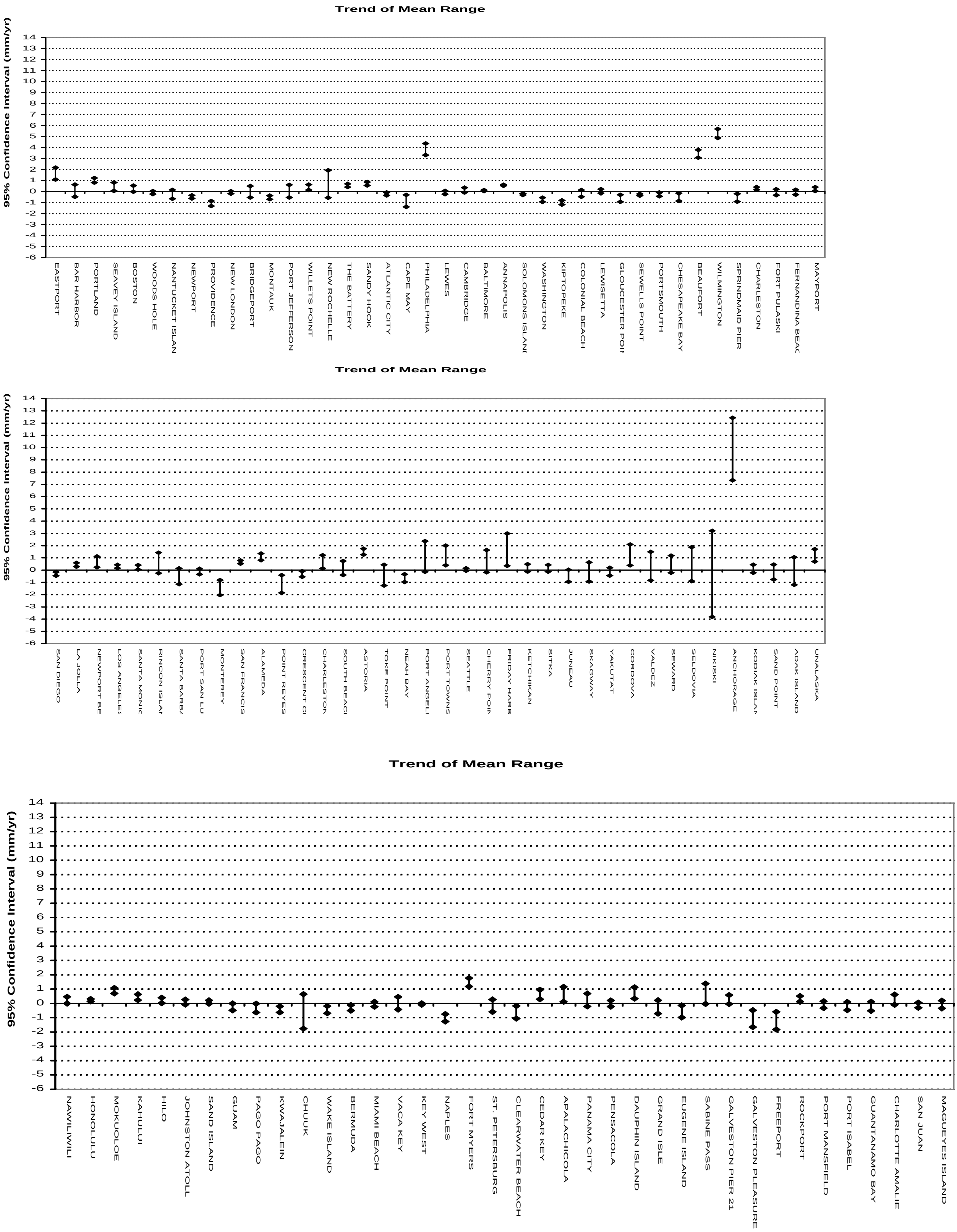


Figure 2. 95% confidence interval of linear trends in the mean range of tide (mm/yr).

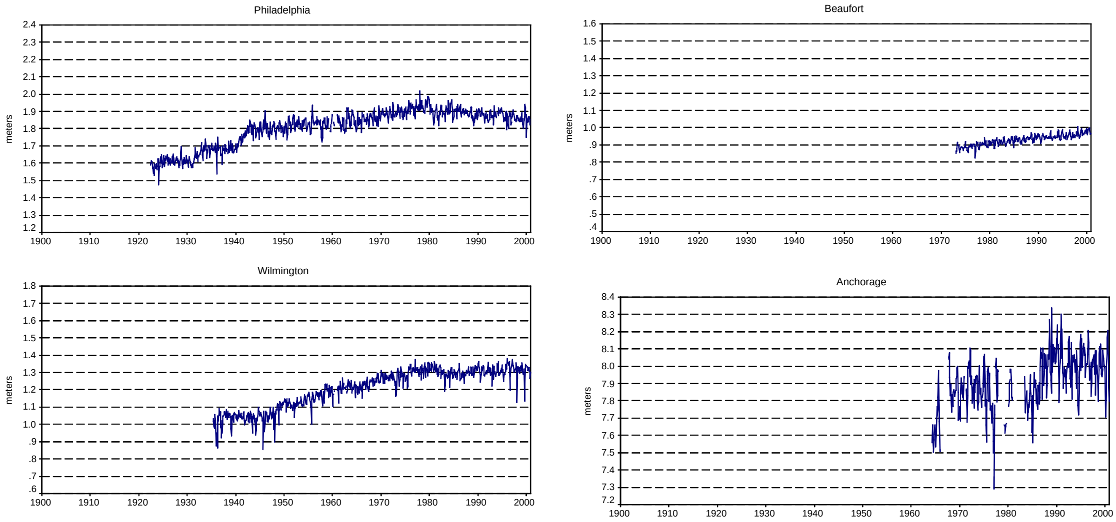


Figure 3. Mean range of tide without the 18.6-year lunar cycle or average seasonal cycle.

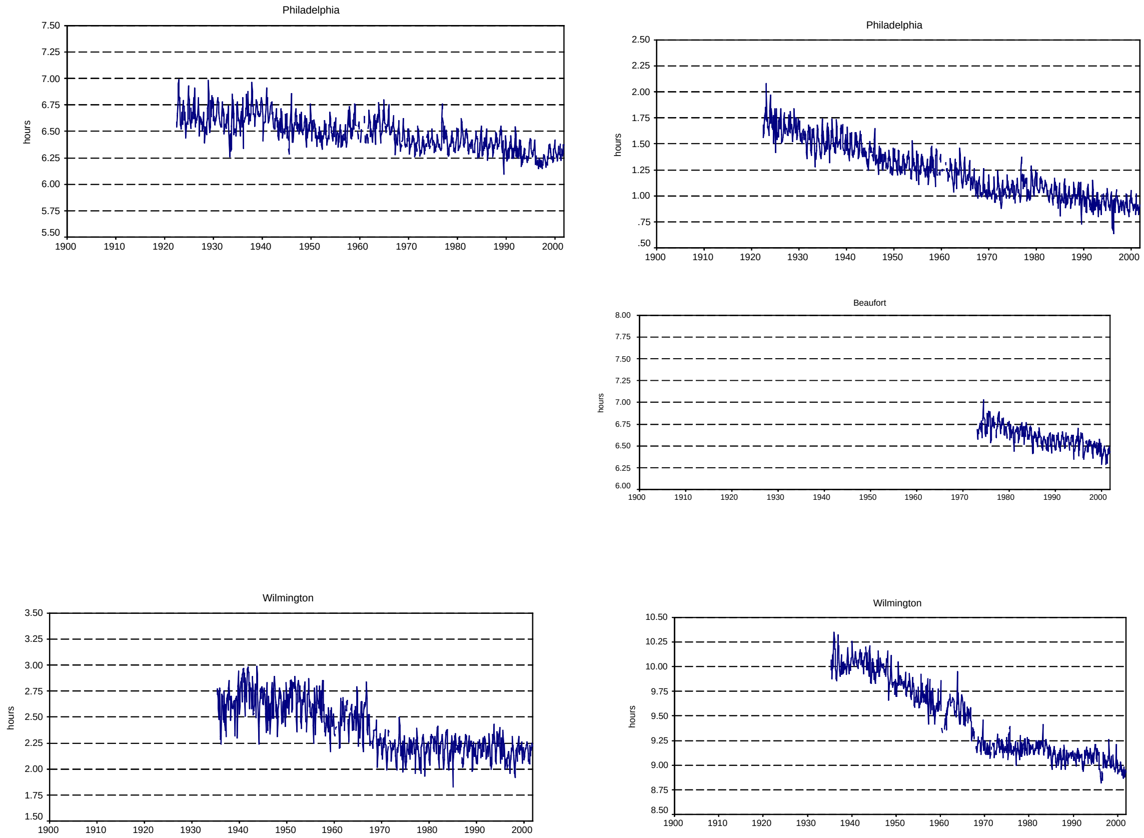
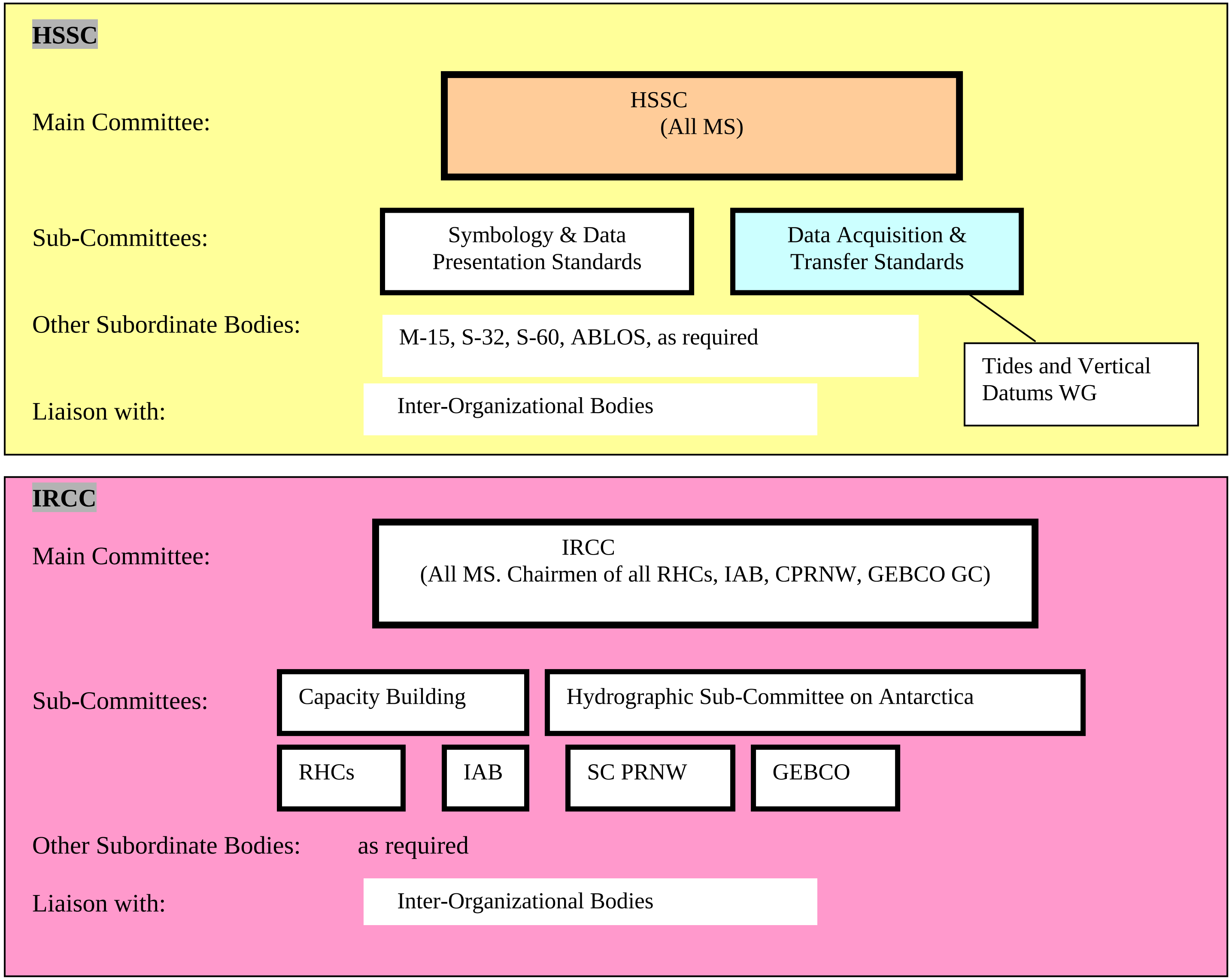


Figure 4. Monthly mean high water (left) and low water (right) intervals in hours.

FUTURE IHO COMMITTEE STRUCTURE – SUBMITTED BY THE IHB

ORGANIZATIONAL DIAGRAMS FOR HSSC AND IRCC



TIDES AND VERTICAL DATUMS WORKING GROUP (TVDWG) - Terms of Reference

1. Objective

To provide technical advice and coordination on tidal and vertical datum matters.

2. Authority

The Working Group (WG) is a subsidiary of the Data Acquisition and Transfer Standards Sub Committee (DATS) of the Hydrographic Services and Standards Committee (HSSC) and its work is subject to DATS approval.

3. Procedures

a. The WG should:

(i) monitor and develop the use of tidal data;

(ii) advise on the use of vertical datums;

(iii) advise on tidal observation, analysis and prediction;

(iv) advise on matters concerning the exchange, distribution and use of tidal and related data;

(v) propose relevant amendments and improvements to IHO Technical Resolutions (M-3) relating to tidal and vertical datums; and

(vi) propose new tidal and vertical datum topics and other applications for consideration by DATS.

b. The WG should work primarily by correspondence. The WG should attempt to meet annually, normally in connection with another convenient IHO forum.

c. The WG should liaise with other DATS and Symbology and Data Presentation Standards Sub Committee (SDPS) WG's; other IHO and international bodies as appropriate; and as instructed by DATS.

4. Composition and Chairmanship

a. The WG shall comprise representatives of IHO Member States (M/S), Expert Contributors and Accredited NGIO Observers, all of whom have expressed their willingness to participate, and a representative of the IHB.

b. Member States, Expert contributors and Accredited NGIO Observers may indicate their willingness to participate at any time. A membership list shall be maintained and confirmed annually.

c. Expert Contributor membership is open to entities and organisations that can provide a relevant and constructive contribution to the work of the WG.

d. The Chair and Vice Chair shall be a representative of a Member State. The election of the Chair and Vice-Chair should normally be decided at the first meeting following each ordinary session of the Conference (Conference to be replaced by Assembly when the revised IHO Convention enters force) and, in such case, shall be determined by vote of the Member States present and voting.

e. Decisions should generally be made by consensus. If votes are required on issues or to endorse proposals presented to the WG, only M/S may cast a vote. Votes shall be on the basis of one vote per M/S represented. In the event that votes are required between meetings or in the absence of meetings, including for elections of the Chair and vice-Chair, this shall be achieved through a postal ballot of those M/S on the current membership list.

f. If a secretary is required it should normally be drawn from a member of the WG.

g. If the Chair is unable to carry out the duties of the office, the vice-Chair shall act as the Chair with the same powers and duties.

h. Expert Contributors shall seek approval of membership from the Chair.

i. Expert Contributor membership may be withdrawn in the event that a majority of the M/S represented in the WG agree that an Expert Contributor's continued participation is irrelevant or unconstructive to the work of the WG.

j. All members shall inform the Chair in advance of their intention to attend meetings of the WG.

k. In the event that a large number of Expert Contributor members seek to attend a meeting, the Chair may restrict attendance by inviting Expert Contributors to act through one or more collective representatives.