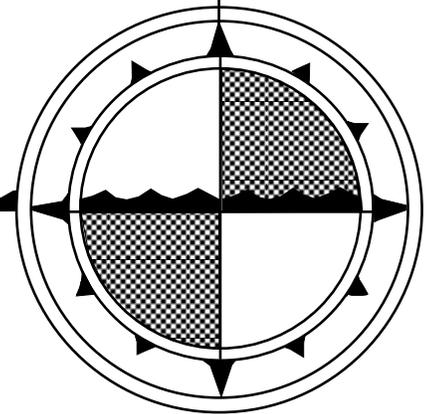# MANUAL FOR TIDAL CURRENTS
ANALYSIS AND PREDICTION

by

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TIDAL CURRENTS ANALYSIS AND PREDICTION

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CONTENTS

7 APPENDICES

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ABSTRACT

This report is intended to serve as a user's manual to G. Godin's tidal currents analysis and prediction computer programs. These programs have been revised along the lines suggested by Godin and are consistent in their methodology and constituent information with the similarly revised tidal heights package. In addition to describing input and output of these programs, the report gives an outline of the methods used, a full presentation of which can be found in Godin (1972) and Foreman (1977).

Users who wish to receive updates of these programs and manual should send their names, addresses, and type of computer used, to the author.

1 USE OF THE TIDAL CURRENTS ANALYSIS COMPUTER PROGRAM

1.1 General Description

This program analyses the hourly current meter data for a given period of time. Current ellipse parameters and Greenwich phase lags are calculated via a least squares fit method coupled with nodal modulation for only those constituents that can be resolved over the length of record. Unless specified otherwise, a standard data package of 69 constituents will be considered for inclusion in the analysis. However, up to 77 additional shallow water constituents can be requested. If the record length is such that certain important constituents are not included directly in the analysis, provision is made for inference of the current ellipse parameters of these constituents from others. A suitable compensation for the smoothing effect that moving average filters may have had on the data prior to input to this program can be made, and a synthesis of hourly tidal current values based on the analysis results and in the same units and format as the input, can be obtained during the same run. Gaps within the tidal record are permitted.

2.1 Routines Required

(1) **MAIN** ...... reads in some of data, controls most of the output and calls other routines.

(2) **INPUT** ...... reads in the hourly current data for the desired time period and checks for errors.

(3) **UCON** ...... chooses the constituents to be included in the analysis via the Rayleigh criterion.

(4) **SCFIT2** ...... finds the least squares fit to an equally spaced time series using sines and cosines of specified frequencies as fitting functions.

(5) **VUF** ...... reads required information and calculates the nodal corrections for all constituents.

(6) **INFER** ...... reads required information and calculates the current ellipse and phase parameters of inferred constituents, as well as adjusting those of the constituent used for the inference.

(7) **CHLSKY** ...... solves the symmetric positive definite matrix equation resulting from a linear least squares fit.

(8) **GDAY** ...... returns the consecutive day number from a specific origin for any given date and vice versa.

    (9) **SCLUP** ...... scales up the least squares fit results to compensate for pre-filtering.

    (10) **OUTPUT** ...... writes the hourly current data that has been constructed from analysis results, onto storage files.

    (11) **ASTR** ...... calculates ephermides for the sun and moon.

1.3 Data Input

For a computer run of the tidal currents analysis program, four files or devices are used for data input. File reference number 8 contains the tidal constituent information, file reference number 4 contains tidal station and analysis type details, and file reference numbers 10 and 11 respectively, contain the hourly north/south and east/west current components. A listing of the standard constituent information for file reference number 8 and a sample set of input for numbers 4, 10 and 11 are given in Appendices 7.1 and 7.2 respectively.

File reference number 8 expects four types of data:

(i) One card each for all possible constituents, `NAME`, to be included in the analysis along with their frequencies, `FREQ`, in cycles/h and the constituent, `KMPR`, with which they should be compared under the Rayleigh criterion. The format used is (`4X,A5,3X,F13.10,4X,A5`). Unless `NAME` is specifically designated on logical unit 4 for inclusion, a blank data field for `KMPR` results in the constituent not being included in the analysis.

A blank card terminates this data type.

(ii) Two cards specifying values for the astronomical arguments `SO,HO,PO,ENPO,PPO,DS,DH,DP,DNP,DPP` in the format (`5F13.10`).

    `SO` = mean longitude of the moon (cycles) at the reference time origin;
    `HO` = mean longitude of the sun (cycles) at the reference time origin;
    `PO` = mean longitude of the lunar perigee (cycles) at the reference time origin;
  `ENPO` = negative of the mean longitude of the ascending node (cycles) at the reference time origin;
   `PPO` = mean longitude of the solar perigee (perihelion) at the reference time origin.

`DS,DH,DP,DNP,DPP` are their respective rates of change over a 365-day period at the reference time origin.

Although these argument values are not used by the program that was revised in October 1992, in order to maintain consistency with earlier programs, they are still required as input. Polynomial approximations are now employed to more accurately evaluate the astronomical arguments and their rates of change.

(iii) At least one card for all the main tidal constituents specifying their Doodson numbers and phase shift along with as many cards as are necessary for the satellite constituents. The first card for each such constituent is in the format (`6X,A5,1X,6I3,F5.2,I4`) and contains the following information:

$$KON = \text{constituent name;}$$
$$II,JJ,KK,LL,MM,NN = \text{the six Doodson numbers for } KON;$$
$$SEMI = \text{phase correction for } KON;$$
$$NJ = \text{number of satellite constituents.}$$

A blank card terminates this data type.

If `NJ>0`, information on the satellite constituents follows, three satellites per card, in the format (11X,3(3I3,F4.2,F7.4,1X,I1,1X)). For each satellite the values read are:

LDEL,MDEL,NDEL = the last three Doodson numbers of the main constituent subtracted from the last three Doodson numbers of the satellite constituent;

    PH = phase correction of the satellite constituent relative to the main constituents;

    EE = amplitude ratio of the satellite tidal potential to that of the main constituent;

    IR = 1 if the amplitude ratio has to be multiplied by the latitude correction factor for diurnal constituents,

     = 2 if the amplitude ratio has to be multiplied by the latitude correction factor for semidiurnal constituents,

     = otherwise if no correction is required to the amplitude ratio.

(iv) One card specifying each of the shallow water constituents and the main constituents from which they are derived. The format is (6X,A5,I1,2X,4(F5.2,A5,5X)) and the respective values read are:

    KON = name of the shallow water constituent;

    NJ = number of main constituents from which it is derived;

COEF,KONCO = combination number and name of these main constituents.

The end of these shallow water constituents is denoted by a blank card.

File reference number 4 contains six types of data:

(i) One card for the variables, RAYOPT,OBSFAC,ICHK,INDPR,NSTRP, in the format (F5.2,F10.7, 3I5.

    RAYOPT = Rayleigh criterion constant value if different from 1.0;

    OBSFAC = the scaling factor which will multiply the current observations in order to produce the desired units for the ellipse major and minor semi-axes (e.g. if the hourly observations are in mm/s and the final units are to be in ft/sec, then this variable would be set to 0.0032808);

    ICHK = 0 if the hourly input data is to be checked for format errors,

     = otherwise if this checking to be waived;

    INDPR = 1 if hourly current component predictions based on the analysis results are to be calculated and written onto file reference numbers 12 and 13. If there is inference, this parameter value will also give the rms residual errors after the inference adjustments,

     = 0 if no such predictions are desired;

NSTRP = number of successive moving average filters that have been applied to the original current data.

If NSTRP>0, then TIMINT and (LSTRP(I),I=1,NSTRP) will be read on a following card, in the format (F10.5,10I5), and suitable amplitude corrections will be applied to compensate for the smoothing effect of these filters.

TIMINT = sampling interval, in minutes, of the original unfiltered record;

LSTRP(J),J=1,NSTRP = number of consecutive observations used in computing each of the NSTRP moving average filters.

(ii) One card for each possible inference pair. The format is (2(4X,A5,F13.10),4F10.3) and the respective values read are as follows:

KONAN & SIGAN = name and frequency of the analysed constituent to be used for the inference;

KONIN & SIGIN = name and frequency of the inferred constituent;

RPL & RMIN = respective ratios of KONIN to KONAN, for the positive and negative current amplitude components. The positive amplitude component is 0.5* (major semi-axis length plus minor semi-axis length) and the negative amplitude component is 0.5* (major semi-axis length minus minor semi-axis length).

ZETAP & ZETAM = respective positive and negative Greenwich phases for KONAN minus those for KONIN.

This inference information is terminated by a blank card.

(iii) One card for each shallow water constituent, other than those in the standard 69 constituent data package, to be considered for inclusion in the analysis. The Rayleigh comparison constituent is also required and the additional shallow water constituent must be found in data type (i) of file reference number 8, but have a blank data field where the Rayleigh comparison constituent is expected. The format is (6X,A5,4X,A5) and a blank card is required to terminate data of this type.

(iv) One card in the format (2X,10I2) specifying the following information on the period of the analysis:

IHHA,IDDA,IMMA,IYYA,ICCA = hour, day, month, year and century of the beginning of the analysis (measured in time ITZONE of input data (v));

IHHB,IDDB,IMMB,IYYB,ICCB = hour, day, month, year and century of the end of the analysis period.

Zero values for ICCA or ICCB are reset to 19.

(v) One card in the format (5X,I4,1X,3A6,A4,A3,1X,2I2,I3,I2,) containing the following information on the tidal station:

KSTN = tidal station number;

(NA(J),J=1,4) = tidal station name (22 characters maximum length);

ITZONE = time zone of the hourly observations;

LAD,LAM = station latitude in degrees and minutes;

`LOD,LOM` = station longitude in degrees and minutes.

If no station latitude is specified, 50°N is assumed for the nodal modulation calculations.

File reference numbers 10 and 11 respectively, contain the north/south and east/west hourly current components. Their input formats are identical and they are read individually via subroutine **INPUT**. For convenience, this format has been made similar to that employed by the tidal heights analysis program. However, if an alternative method is preferable, subroutine **INPUT** and its reference calls may simply be replaced.

The hourly current data cards for each of the current components contain the following information in the format (`I1,1X,I5,4X,I2,1X,3I2,12A5`).

$$\begin{aligned}
\texttt{KOLI} &= \text{1 or 2 indicates whether this specific card is the first or second} \\
&\quad \text{one for that day,}
\end{aligned}$$

`KOLI` =	1 or 2 indicates whether this specific card is the first or second one for that day,	
=	otherwise indicates a non-data card which is ignored;	
`JSTN` =	tidal station number;	
`IC,ID,IM,IY` =	century, day, month and year of the currents on this card. If `IC=0`, it is reset to 19;	
`(KARD(J),J=1,12)` =	hourly observations in integer form. The final constituent major and minor semi-axis lengths are in units `OBSFAC` times those of the hourly observations. Missing values should be specified as a blank field or 99999.	

When `KOLI=1`, the first hourly observation on the data card is assumed to be at 0100 h and when `KOLI=2`, it is assumed to be at 1300 h. Since all Greenwich phase angles are relative to the time zone in which the hourly observations are specified, in order to avoid possible confusion when comparing phases for tidal stations in different zones, it is recommended that observations be recorded in Greenwich mean time.

The hourly observation data cards need not begin and end so as to include exactly the analysis period. Subroutine **INPUT** ignores data outside this range.

1.4 Output

Four file reference numbers are used for the output of results from the tidal currents analysis program. File 6 is the line printer; 2 is a file that can be used for computer storage of the results, and 12 and 13 respectively, contain the north/south and east/west hourly current values constructed from the analysis results. Files 6 and 2 are required by all program runs, whereas the use of 12 and 13 is controlled by the input variable `INDRP`.

If no inference has been performed, the program will produce two pages of results on the line printer. The first of these gives the tidal station name, number and geographic coordinates; the total number of possible hourly observations in the analysis period and the total number of hourly observations, excluding gaps, in the analysis period; the starting, middle and end points of the analysis period; the sampling interval of the original data and the filters applied, or an acknowledgement that the original data is assumed to be unfiltered; and the Rayleigh criterion parameter. It also lists the constituents included in the least squares fit; their frequencies in cycles/h (although eight decimal places are given, depending on computer accuracy, less than this number may be significant); the cosine and sine coefficient values for the X (east/west) and Y (north/south) current components, along with their respective standard deviation estimates, all measured in units `OBSFAC` times those for the hourly observations; and for each of the X and

Y components, the average and standard deviation of the hourly observations, the rms residual error and the matrix condition number.

The second page repeats the tidal station and analysis period information and specifies the time zone of the Greenwich phases, and if an inference, and/or scaling compensation for pre-filtering, have/has been done. It then follows with the list of constituents included in the analysis, their frequencies and their ellipse parameters: the major and minor semi-axis lengths (measured in the same units as the cosine and sine coefficients), the angle of inclination (measured in degrees counterclockwise from east) and the Greenwich phase angles (degrees) for the current vector and its positively and negatively rotating components.

If inference has been performed in the analysis, then a third page of output is produced which, except for the addition of the inferred constituents and adjustments to those constituents used for the inference(s), is essentially the same as the second page. If the hourly current values based on the analysis results are requested, this page also gives the rms residual errors after the inference adjustments have been made.

Apart from the omission of some titles, the same information as the second (and third) page(s) of the line printer is repeated on file number 2. The list of constituent names, major and minor semi-axis lengths, angle of inclination and the three Greenwich phase lags begins on line 9 of this file, and is in the correct format for input to the tidal current prediction program, namely (4X,A5,13X,2F8.3,2F7.1).

The north/south and east/west hourly currents constructed from the analysis results, are written in the same format expected by subroutine **INPUT**. Values are specified only for the analysis period, including those intervals where there were gaps in the original record, and are in the same measurement units and scaling as the original data.

Appendix 7.3 lists the final page of line printer output resulting from the input variables of Appendix 7.2.

1.5 Program Conversion, Modifications, Storage and Dimension Guidelines

The tidal currents analysis source program and constituent data package described in this manual have been tested on various mainframe, PC and workstation computers at the Institute of Ocean Sciences, Patricia Bay. Although as much of the program as possible was written in basic FORTRAN, some changes may be required before the program and data package can be used on other installations. For example,

(i) check that the intrinsic function INT, used in subroutine **OUTPUT**, has the following definition for your installation:

INT(X) = SIGN(X)*N where N is the largest integer less than or equal to ABS(X).

Please write or call the author if any problems are encountered.

The program in its present form requires approximately 72,000 bytes for the storage of its instructions and arrays. A large part of this is due to X,Y,XP and YP, the arrays of size 9000 each that store the hourly current observations and predictions and AS, the array of size 15,000 resulting from the least squares fit for constituent component amplitudes and phases. If memory requirements are restrictive on a particular installation, array storage can be cut by reducing the dimension of X and Y in the main program to whatever is required for the proposed analysis period, by either similarly reducing XP and YP or, if there are no predictions,

setting their dimension to 2 and by reducing the size of `AS` in accordance with the number of constituents to be included in the least squares fit.

If additions are made to the standard constituent data package, the dimensions of several arrays may have to be altered. In the event of these or other changes, restrictions on the minimum dimension of all arrays are now given.

Let

MTOT	be the total number of possible constituents contained in the data package (presently 146),
M	be the number of constituents considered for inclusion in the analysis (presently 69 plus the number of shallow water constituents specifically designated for inclusion,
MCON	be the number of main constituents in the standard data package (at present 45),
MSAT	be the sum of the total number of satellites for these main constituents and the number of main constituents with no satellites (presently 162 plus 8 for the version of the constituent data package, containing no third-order satellites for both N_2 and L_2);
MSHAL	be the sum for all shallow water constituents, of the number of main constituents from which each is derived (at present 251).

Then in the main program, arrays `NAME,FREQ` and `KMPR` should have minimum dimension M+1; arrays `NAMEU,FU,CX,SX,CY,SY,ERCX,ERSX,ERCY,ERSY,AP,AM,EPSP` and `EPSM` should have minimum dimension MU; arrays `X,Y,XP` and `YP` should be large enough to contain the hourly current observations (including gaps) and predictions in the proposed analysis period (they are at present set for a maximum of 375 days); array `LSTRP` should be at least as large as the number of successive moving average filters that were applied to the original current record (at present this is set to 10) and double precision array `NA` should be large enough to hold the number of characters in the tidal station name (at present 22 characters are expected and one array dimension is 4).

In subroutines **SCLUP** and **PECON**, all arrays are passed through the argument list from the main program and thus need only be dimensioned 2.

In subroutine **GDAY**, arrays NDP and NDM should have minimum dimension 12.

In subroutine **SCFIT2**, arrays `X,XP,F,C,S,ERC` and `ERS` are passed in the argument list from the main program and so need only be dimensioned 2; array `A` should have minimum dimension $((2MU)^2 + 2MU/2)$; arrays `CW,SW,RHSC` and `RHSS` should have minimum dimension MU and array `RHS` should have minimum dimension 2MU. `AC` and `AS` should each have minimum dimension $((2MU)^2 + 2MU/2)$ and care should be taken that through their equivalence relationships, neither `AC` and `AS`, nor `RHSC` and `RHSS` overlap.

In subroutine **CHLSKY**, because arrays `A` and `F` are passed in the argument list from SCFIT2

`ZETAM` can at present accommodate a maximum of nine inferred constituents.

In subroutine **INPUT**, array `Z` is passed in the argument list from the main program and so need only be dimensioned 2 and arrays `KARD` and `IHT` should have a minimum dimension of 12.

In subroutine **OUTPUT**, arrays `XP` and `YP` are passed in the argument list from the main program and so need only be dimensioned 2; array `MONTH` should have minimum dimension 12 and arrays `ICEW` and `ICNS` should have minimum dimension 24.

2 TIDAL CURRENTS ANALYSIS PROGRAM DETAILS

2.1 Representation of Tidal Currents

The following presentation is an amalgamation of those found in Godin (1972, 1976), the unpublished notes of J. Taylor on Godin's method and the associated computer program, and Henry and Foreman (1977).

It is customary in tidal observations to measure the vertical displacement or "elevation" of the water surface and the horizontal velocity or "current" at a specified depth. The oscillatory portions of these quantities which can be ascribed to astronomical origins will be referred to as tidal heights and tidal currents[1] respectively.

The decomposition of current observations into north/south and east/west components (where the northern and eastern directions are positive), as is required by this program, is a traditional convenience lending itself to complex variable analysis. The choice of another set of rectangular coordinates would be equally justifiable as long as the positive imaginary axis, Y, is 90° counterclockwise from the positive real axis, X. This condition is satisfied in our case by setting the north/south components as the imaginary parts and the east/west components as the real parts, of a complex signal, $Z(t)$.

Assuming that each of the current components is comprised of an aperiodic constituent and tidal constituents occurring at the frequencies, σ_j, (cycles/h) for $j = 1, \ldots, M$, then the complex signal $Z(t)$ can be expressed as

$$Z(t) = X_0(t) + \sum_{j=1}^{M} X_j \cos 2\pi(\sigma_j t - \phi_j) + \left[Y_0(t) + \sum_{j=1}^{M} Y_j \cos 2\pi(\sigma_j t - \theta_j) \right].$$

Setting $CX_j = X_j \cos 2\pi\phi_j$, $SX_j = X_j \sin 2\pi\phi_j$, $CY_j = Y_j \cos 2\pi\theta_j$ and $SY_j = Y_j \sin 2\pi\theta_j$, this signal can be re-expressed initially as

$$Z(t) = X_0 + \sum_{j=1}^{M} (CX_j \cos 2\pi\sigma_j t + SX_j \sin 2\pi\sigma_j t)$$

$$+ i\left[Y_0(t) + \sum_{j=1}^{M} (CY_j \cos 2\pi\sigma_j t + SY_j \sin 2\pi\sigma_j t) \right]$$

and after some algebra as

$$Z(t) = X_0(t) + iY_0(t) + \tfrac{1}{2}\sum_{j=1}^{M} \left\{ [(CX_j + SY_j) + i(CY_j - SX_j)] \exp(2\pi i\sigma_j t) \right.$$

$$\left. + i[(CX_j - SY_j) + i(CY_j + SX_j)] \exp(-2\pi i\sigma_j t) \right\}.$$

---

[1] Godin (1972, p. 145) used "tidal stream" to indicate what is here termed "tidal current".

Dropping the constituent numbering suffix, j, and setting

$$a^+ = \left[\left(\frac{CX + SY}{2}\right)^2 + \left(\frac{CY - SX}{2}\right)^2\right]^{1/2},$$

$$a^- = \left[\left(\frac{CX - SY}{2}\right)^2 + \left(\frac{CY + SX}{2}\right)^2\right]^{1/2},$$

$$\varepsilon^+ = \arctan\left(\frac{CY - SX}{CX + SY}\right)$$

and

$$\varepsilon^- = \arctan\left(\frac{CY + SX}{CX - SY}\right),$$

the tidal currents contribution for any constituent is then seen to be

$$Z(t) = Z^+(t) + Z^-(t) = a^+ \exp(i\varepsilon^+ + 2\pi i\sigma t) + a^- \exp(i\varepsilon^- - 2\pi i\sigma t)$$

$$= \exp\left[i\left(\frac{\varepsilon^+ + \varepsilon^-}{2}\right)\right]\left\{(a^+ + a^-)\cos\left[\left(\frac{\varepsilon^+ - \varepsilon^-}{2}\right) + 2\pi\sigma t\right]\right.$$

$$\left. + i(a^+ - a^-)\sin\left[\left(\frac{\varepsilon^+ - \varepsilon^-}{2}\right) + 2\pi\sigma t\right]\right\}.$$

Examination of the first of these expressions reveals that this contribution consists of two vectors, $Z^+(t)$ and $Z^-(t)$, each rotating at the angular speed of σ cycles/h. The former vector has length, a^+, rotates counterclockwise and is at ε^+ radians counterclockwise from the positive X (east/west) axis at time, $t = 0$, while the latter has length, a^-, rotates clockwise and is at ε^- radians counterclockwise from the positive X axis at $t = 0$ (see Figures 1a and 1b). The net rotational effect is that the composite vector, $Z(t)$, moves counterclockwise if $a^+ > a^-$, clockwise if $a^+ < a^-$, and linearly if $a^+ = a^-$. From the second expression, it is seen that over a time period of $1/\sigma$ h, the path of the composite vector traces out an ellipse (or a line segment, in the degenerate case when $a^+ = a^-$) whose respective major and minor semi-axis lengths are $a^+ + a^-$ and $a^+ - a^-$ respectively and whose angle of inclination from the positive X axis is $(\varepsilon^+ + \varepsilon^-)/2$ radians.

As an aid to understanding the development and meaning of Greenwich phases for tidal currents, it is convenient to extend the concept of fictitious stars sometimes used in tidal elevation theory. Instead of regarding each tidal constituent as the result of a particular component in the tidal potential, we suppose that each pair of rotating vectors, Z^+ and Z^-, is attributable to two fictitious stars which move counterclockwise and clockwise respectively, at the same speed as the constituent in question, around the periphery of a "celestial disk" tangential to the earth at the measurement site. We suppose also that at time, t_0, the angular position of the counterclockwise rotating star, S^+, the star responsible for Z^+, is $V(t_0)$ radians counterclockwise from the positive X (east) axis, where $V(t_0)$ is the same astronomical argument, relative to Greenwich as occurs for this constituent in the tidal potential (Foreman, 1977, Section 2.3.1). Similarly, at the same time, the angular position of the clockwise rotating star, S^-, is assumed to be $V(t_0)$ radians clockwise from the positive X axis (see Figure 1c). As a consequence, the constant phase angles, g^+ and g^-, by which S^+ and S^- lead (or lag) the respective vectors, Z^+ and Z^-, can be termed Greenwich phases and are defined by

$$g^+ = V(t_0) - \varepsilon^+,$$
$$g^- = V(t_0) + \varepsilon^-.$$
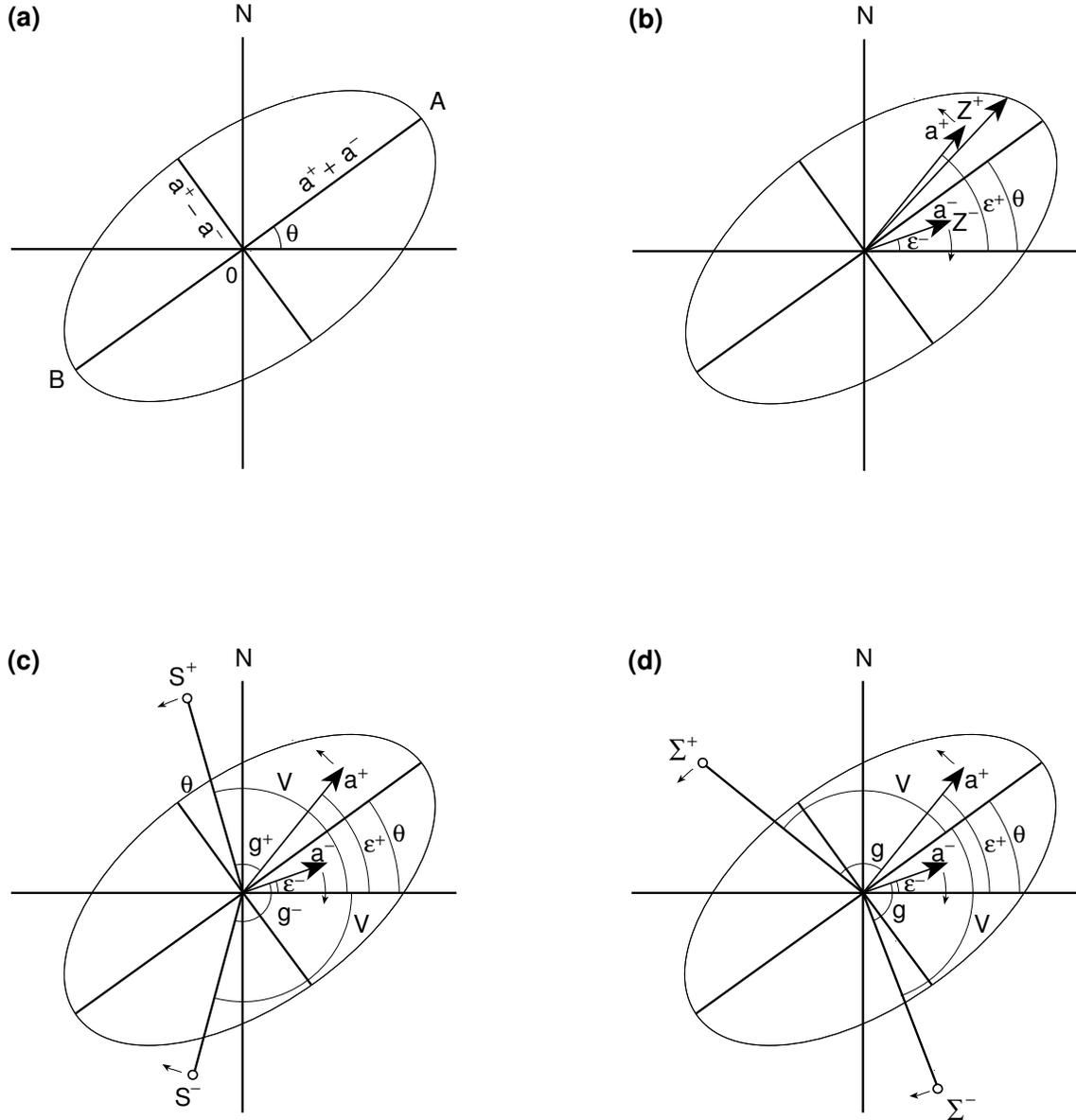
Figure 1 Delineation of current ellipse notation. (a) Dimensions of a constituent ellipse. (b) Configuration at $t = 0$. (c) Fictitious stars related to the east/west axis. (d) Fictitious stars related to the major semi-axis. (Redrawn from C. Wallace)

As was previously mentioned, provided that the complex variable condition is satisfied, the choice of a rectangular coordinate system for the original current measurements is arbitrary. Since all angles thus far have been specified with respect to the east/west axis, there is a corresponding arbitrariness in the phases of Z^+ and Z^-. One aim of Godin's analysis is to obtain invariant phases for these vectors by referring angular measurements to a major semi-axis of the constituent ellipse. In order to do this, he employs the construction shown in Figure 1d in which the major semi-axis OA of the constituent ellipse is used as the reference axis.

In particular, two different fictitious stars, $\sum^+$ and $\sum^-$, are now visualized, similar to S^+ and S^- respectively, except that their angular positions at $t = 0$ are $V(t_0)$ radians from OA in the appropriate directions. This approach has the advantage that the phase of both rotating vectors relative to their respective stars can now be expressed as a single Greenwich phase angle, g, where

$$g = V(t_0) - \left(\frac{\varepsilon^+ - \varepsilon^-}{2} \right).$$

Since, from the definitions of the fictitious stars, S^+, S^-, $\sum^+$ and $\sum^-$, the astronomical argument, $V(t_0)$, is identical in all the Greenwich phase expressions, g can be calculated terms of g^+ and g

g

14

$$\varepsilon^+ + \varepsilon^- < 360°, \quad \theta = \frac{\varepsilon^+ + \varepsilon^-}{2} \qquad\qquad \varepsilon^+ + \varepsilon^- \geq 360°, \quad \theta = \frac{\varepsilon^+ + \varepsilon^-}{2} - 180°$$
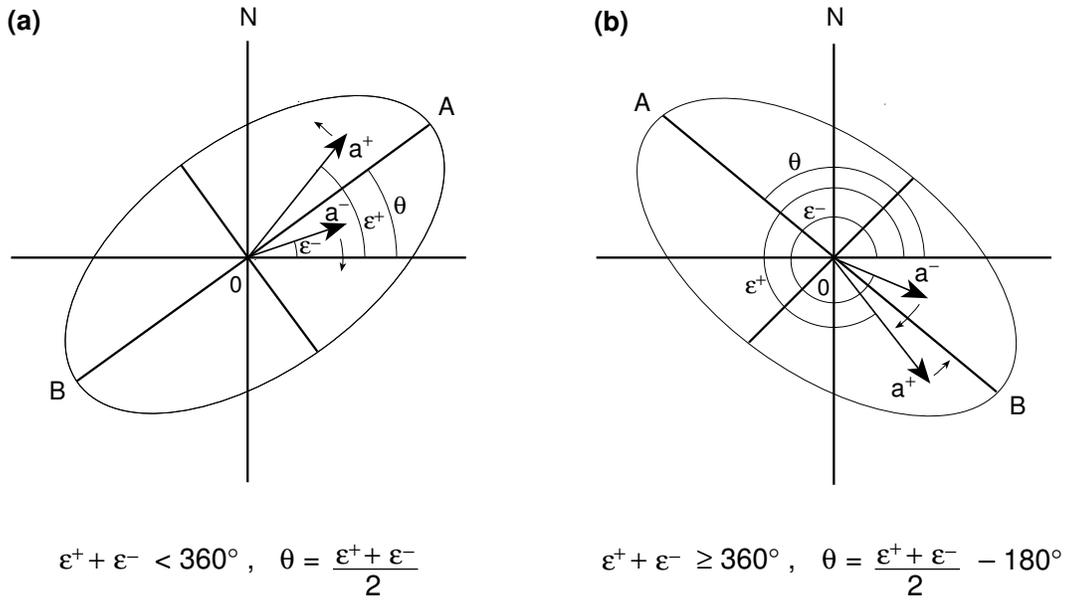
Figure 2 Definition of semi-axis used as reference axis. (Redrawn from C. Wallace)

the major semi-axis is only in the representation of the constituent ellipse. The ellipse itself is not affected.

From Figures 3 and 4, it can be seen that the maximum current (in the sense that Z^+ and Z^- coincide on OA), occurs at times

$$t = \frac{g - V(t_0) + n \cdot 360°}{\sigma}, \qquad n = \ldots, -1, 0, 1, \ldots$$

relative to $t = t_0$.

2.2 The Analysis Solution

Many of the techniques used in the analysis of tidal currents are the same as those for tidal heights. Rather than repeating here a discussion on topics such as the standard constituent data package (listed in Appendix 7.1), the formation and solution of the least squares matrices, and the calculations of astronomical and nodal modulation variables, we refer you to the *Manual for Tidal Heights Analysis and Prediction* (Foreman, 1977) for details. Instead, a brief description will be given of the steps followed by this analysis program and references to where method or calculation details can be found. In order of operation, these steps are as follows:

1. Reading all the input parameters, the tidal constituent data package, and the north/south and east/west current components for the proposed analysis period.

2. Calculation of the middle hour, t_m, of the analysis period.

3. Calculation at time, t_m, of the nodal modulation correction factors, f and u, and the astronomical arguments, V, for all the constituents in the standard data package. Both the data package and the subroutine that calculates these values are identical to those used in the tidal heights analysis program.

$$g = g^+ + \theta$$

$$g = g^- - \theta$$
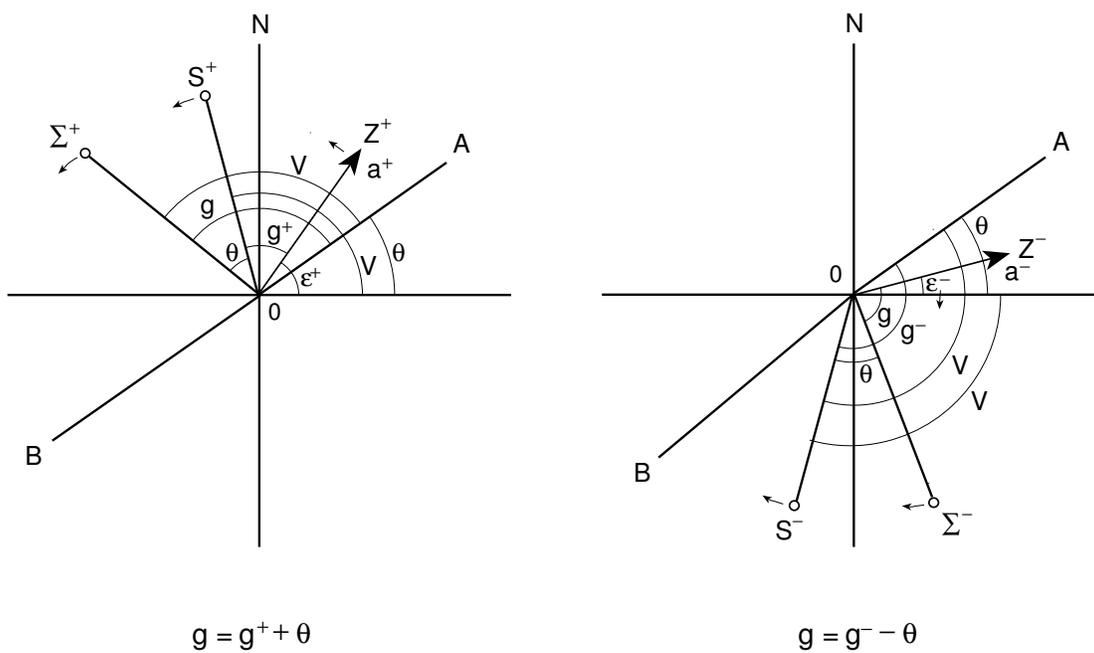
Figure 3 Angular relationships when $\varepsilon^+ + \varepsilon^- < 360°$. (Redrawn from C. Wallace)

$$g = g^+ + \theta$$

$$g = g^- + (360° - \theta)$$
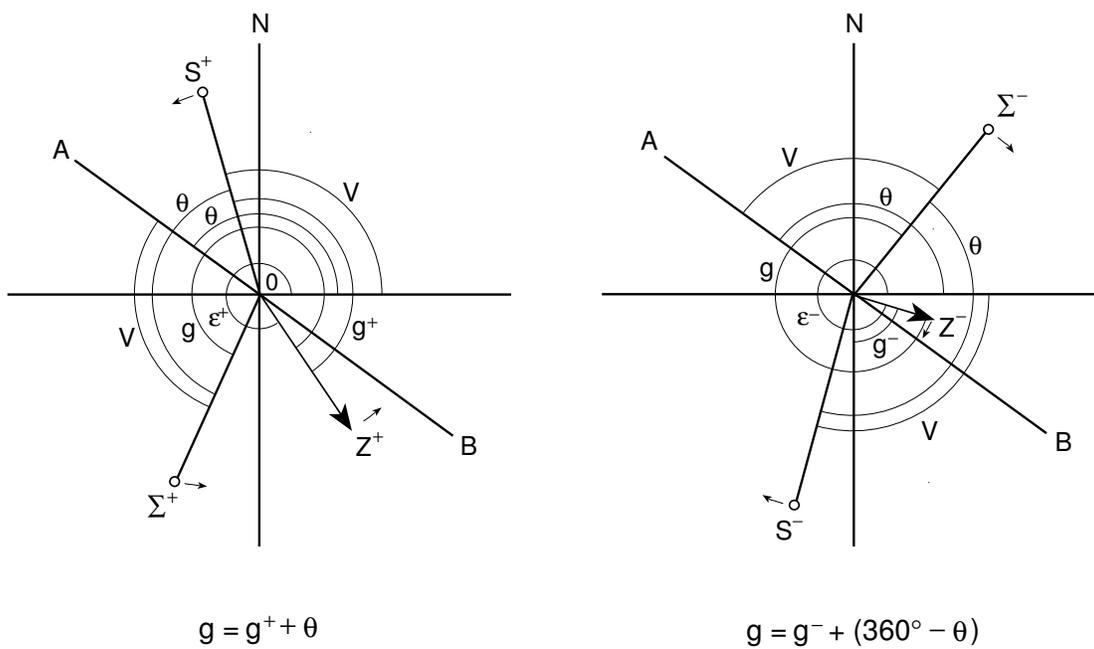
Figure 4 Angular relationships when $\varepsilon^+ + \varepsilon^- \geq 360°$. (Redrawn from C. Wallace)

4. Determination via the Rayleigh criterion, of the constituents to be used in the least squares fits. This criterion and the list of prospective candidates and their comparison constituents are again identical to those of the tidal heights method. Tables showing the order of constituent selection, as a function of analysis period length, and in accordance with the Rayleigh criterion, are given in Foreman (1977, pp. 10–13).

5. Construction and solution relative to time, t_m, of the least squares matrices for each of the X (east/west) and Y (north/south) current components. Except for the additional feature of being able to calculate hourly predictions based on the results of the foregoing analysis and to recalculate the rms residual error, the subroutine employed here is identical to the one for tidal heights. Hence those output variables which give details of the fit, such as error estimates, average, standard deviation, matrix condition number and rms residual error, will have been calculated in the same manner. The primary outputs however, are the arrays CX,SX,CY and SY, which are described in Section 2.1 and, if there is to be no inference, the predicted hourly component currents upon request.

6. Writing the preceding preliminary results on the line printer.

7. If so requested, scaling the CX,SX,CY and SY values to compensate for the application of moving average filters to the current observations prior to submission for analysis. Section 2.3 has details of this calculation.

8. Conversion of the preliminary results into polar coordinates, i.e. calculation of the parameters a^+, a^-, ε^+ and ε^- as described in Section 2.1.

9. Inference of the a^+, a^-, ε^+ and ε^- values for those designated constituents not included in the least squares fit and the adjustment of these values for those constituents used for the inference(s). Section 2.4 has details of this operation.

10. Calculation, in accordance with the formulae of Section 2.1 and including nodal modulation correction factors and astronomical arguments, of the following ellipse and Greenwich phase parameters: major and minor semi-axis lengths, angle of inclination, g^+, g^- and g. Note that when the nodal modulation amplitude and phase corrections are included in these formulae, a^+, a^- and $V(t_0)$ become $a^+/f(t_0)$, $a^-/f(t_0)$ and $V(t_0) + u(t_0)$ respectively.

11. If there has been inference, calculation, upon request, of the hourly predicted component currents based on least squares and inference results. Any scaling that may have been done to compensate for pre-filtering must initially be reversed though, so that the predicted values will have the same scaling as the original input data.

12. Writing all final results without (and with) inference on the line printer and permanent storage file and the hourly component predictions, if so requested, on their files.

2.3 Scaling Compensations for Pre-Filtering

If the sampling interval obtained from a current meter record is other than one hour, Godin (1972, p. 149) recommends that the data be filtered and the hourly values extracted before submission to the tidal currents analysis program. Such an operation will eliminate short-period fluctuations that are related to turbulence and of no relevance to tidal analysis. In particular, he suggests that if the original data were sampled at n-minute intervals, and $60/n$ is integer-valued, say n_0, then the sequence $(A_{n_0})^2 A_{n_0+1}$ moving average be applied if n_0 is an even number, and the sequence $A_{n_0}(A_{n_0+1})^2$, if n_0 is odd.

The definition of the moving average filter, A_n, is as follows. Suppose that the original time series of observations is $\{z_k\}$, $k = 1, \ldots, m$, where all the observations are equally spaced in time and $m \geq n$. Then the applications of A_n results in replacing the former sequence with $\{z_k'\}$ for $k = 1, \ldots, m - n + 1$ where

$$z_k' = \frac{1}{n} \sum_{i=k}^{k+n-1} z_i.$$

Assuming that the kth element of the original sequence was recorded at time $(k-1)\Delta t$, then in the new sequence it will be at time $[k - 1 + (n-1)/2]\Delta t$. Hence not only has there been a loss of $n - 1$ members from the sequence, but a shift of $(n-1)\Delta t/2$ for the times of corresponding elements. This latter point implies that if n is an even number and the original record included observations on the hour, the filtered record would not have hourly values. Thus, a second A_n filter applied to the results of the first is needed to bring the observation times back into correspondence with those of the original record and so enable the extraction of hourly values. For example, if the original record has $\Delta t = 15$ minutes and the first observation is at 1:00 a.m., then after one pass with an A_4 filter,

its spectrum, $F_n(\sigma)$, is calculated as

$$F_n(\sigma) = \sum_{k=-(n-1)/2}^{(n-1)/2} \frac{1}{n} \exp(-2\pi i k \Delta t \sigma)$$
$$= \frac{\sin(n\pi\Delta t\sigma)}{n\sin(\pi\Delta t\sigma)}.$$

Hence one pass of the moving average filter A_n will have the effect of multiplying the response at frequency, σ, in the original record by $F_n(\sigma)$. Since it follows that the application of three successive moving average filters, $A_n \cdot A_n \cdot A_{n+1}$, results in a net factor of $F_n(\sigma) \cdot F_n(\sigma) \cdot F_{n+1}(\sigma)$, the scaling compensation required to obtain the amplitude response of the original data at frequency σ is $1/[F_n(\sigma) \cdot F_n(\sigma) \cdot F_{n+1}(\sigma)]$.

2.4 Inference

If the length of a specific tidal record is such that certain important constituents will not be included directly in the analysis, provision is made via the input on file reference number 4 to include these constituents indirectly by inferring their major and minor semi-axis lengths and Greenwich phase lags from neighbouring constituents that are included. If suitable amplitude ratios and phase differences can be specified, inference has the effect of significantly reducing any periodic behaviour in the ellipse parameters and phases of the constituent used for the inference. This is due to the removal of interaction from the neighbouring inferred constituent. If it so happens that a constituent specified for inference is included directly in the analysis, the program will ignore the inference calculations.

The amplitude ratios and phase differences required for inference calculations should be obtained empirically from the results of longer analyses of data at the same or surrounding stations. Tidal current values are preferable but tidal heights results may be used as input by setting each of the two amplitude ratios and the two phase differences equal to the respective values obtained from the tidal heights analysis. However, Godin (1972, p. 212) warns that the latter technique may fail in the vicinity of an amphidromic point.

If the results of a previous tidal currents analysis are used for calculating the inference variables, and it is decided that the two phase differences should be set equal, namely to the difference in the g values, care should be taken to ensure that the angles of inclination of the two constituent ellipses are reasonably close. If their difference is about 180°, then one value and its corresponding Greenwich phase, g, should be altered by 180° before calculating the inference phase difference. If this is not done, the subsequent inference adjustments will not have the proper relationship between the constituents, and it may well happen that the rms residual error after inference is higher than before, i.e. inference has not improved the fit.

The actual adjustments are as follows. Assume that the constituent with frequency, σ_2, is to be inferred from the constituent with frequency, σ_1, and that the latter's contribution, after conversion of the least squares fit results into polar coordinates (and before nodal modulation), was found to be

$$a_0^+ \exp(\varepsilon_0^+ + 2\pi\sigma_1 t) + a_0^- \exp\left[i(\varepsilon_0^- - 2\pi\sigma_1)\right].$$

Defining the following variables for the constituents with frequencies, σ_1 and σ_2, respectively:

$$
\begin{aligned}
VU_1, VU_2 &= \text{the astronomical argument plus nodal modulation phase correction;} \\
g_1^+, g_1^-, g_2^+, g_2^- &= \text{Greenwich phase lags for the counterclockwise and clockwise rotating} \\
&\quad \text{component vectors;} \\
a_1^+, a_1^-, a_2^+, a_2^- &= \text{amplitudes of the counterclockwise and clockwise rotating component} \\
&\quad \text{vectors after inference, but before nodal modulation;} \\
f_1, f_2 &= \text{nodal modulation amplitude correction factors;} \\
A_1^+, A_1^-, A_2^+, A_2^- &= \text{amplitudes of the counterclockwise and clockwise rotating component} \\
&\quad \text{vectors after both inference and nodal modulation;} \\
\varepsilon_1^+, \varepsilon_1^-, \varepsilon_2^+, \varepsilon_2^- &= \text{initial phases of the counterclockwise and clockwise rotating} \\
&\quad \text{component vectors.}
\end{aligned}
$$

Then upon setting r^+, r^-, ζ^+ and ζ^- to be the respective variables RPL, RMIN, ZETAP and ZETAM that are read from file reference number 4, the following relationships can be seen:

$$
r^+ = \frac{A_2^+}{A_1^+} = \frac{a_2^+ f_1}{a_1^+ f_2},
$$

$$
r^- = \frac{A_2^-}{A_1^-} = \frac{a_2^- f_1}{a_1^- f_2},
$$

$$
\zeta^+ = g_1^+ - g_2^+ = VU_1 - \varepsilon_1^+ - VU_2 + \varepsilon_2^+,
$$

$$
\zeta^- = g_1^- - g_2^- = VU_1 + \varepsilon_1^- - VU_2 + \varepsilon_2^-.
$$

Letting $\Delta = \sigma_2 - \sigma_1$, the objective of inference can be stated as decomposing the signal found at frequency, σ_1, into

$a_1^+ \exp(i\varepsilon_1^+ + 2\pi i \sigma$ $\qquad\qquad\qquad$)00( )4 ()43156   56363   6363

Setting

$$T^+ = 1 + \frac{r^+(f_2/f_1)\exp\left[i(VU_2 - VU_1 + \zeta^+)\right]\sin(\pi\Delta N)}{\pi\Delta N}$$

and

$$T^- = 1 + \frac{r^-(f_2/f_1)\exp[i(VU_1 - VU_2 - \zeta^-)]\sin(\pi\Delta N)}{\pi\Delta N},$$

the equation relating the tidal signals before and after inference is then

$$a_0^+ \exp(i\varepsilon_0^+ + 2\pi i\sigma_1 t) + a_0^- \exp(i\varepsilon_0^- - 2\pi i\sigma_1 t)$$
$$= a_1^+ \exp(i\varepsilon_1^+ + 2\pi i\sigma_1 t)T^+ + a_1^- \exp(i\varepsilon_1^- - 2\pi i\sigma_1 t)T^-.$$

Regrouping similar terms in $\sigma_1 t$, this becomes

$$\exp(2\pi i\sigma_1 t)\left[a_0^+ \exp(i\varepsilon_0^+) - a_1^+ \exp(i\varepsilon_1^+)T^+\right]$$
$$+ \exp(-2\pi i\sigma_1 t)\left[a_0^- \exp(i\varepsilon_0^-) - a_1^- \exp(i\varepsilon_1^-)T^-\right] = 0.$$

Now in order to draw some conclusions from this last equation, let us re-express it in the simpler form

$$\exp(it)(w + ix) + \exp(-it)(y + iz) = 0.$$

Expanding and collecting real and imaginary parts here yields

$$(w + y)\cos(t) + (z - x)\sin(t) = 0$$

and

$$(x + z)\cos(t) + (w - y)\sin(t) = 0.$$

Since these equations must hold for all t, it follows that

$$w + y = z - x = x + z = w - y = 0.$$

Hence

$$w = x = y = z = 0.$$

Therefore, setting

$$a_0^+ \exp(i\varepsilon_0^+) = w_0 + ix_0,$$
$$a_1^+ \exp(i\varepsilon_1^+) = w_1 + ix_1,$$
$$a_0^- \exp(i\varepsilon_0^-) = y_0 + iz_0,$$
$$a_1^- \exp(i\varepsilon_1^-) = y_1 + iz_1,$$
$$T^+ = c + id,$$
$$T^- = g + ih$$

and applying the result of the simplified equation to the last inference equation, gives

$$w_0 - w_1 c + x_1 d = 0,$$
$$w_0 - w_1 d - x_1 c = 0,$$
$$y_0 - y_1 g + z_1 h = 0,$$
$$z_0 - y_1 h - z_1 g = 0.$$

Solving these simultaneous equations for w_1, x_1, y_1 and z_1 yields

$$w_1 = (w_0 c + x_0 d)/(c^2 + d^2),$$
$$x_1 = (x_0 c - w_0 d)/(c^2 + d^2),$$
$$y_1 = (y_0 g + z_0 h)/(g^2 + h^2),$$
$$z_1 = (z_0 g - y_0 h)/(g^2 + h^2).$$

Reconstructing these results into polar coordinate form then gives the following adjusted values for the constituent used for inference:

$$a_1^+ = \sqrt{w_1^2 + x_1^2},$$
$$\varepsilon_1^+ = \arctan(x_1/w_1),$$
$$a_1^- = \sqrt{y_1^2 + z_1^2}$$

and

$$\varepsilon_1^- = \arctan(z_1/y_1).$$

And finally, making use of the inference assumptions yields the following values for the inferred constituent:

$$a_2^+ = r^+ a_1^+ (f_2/f_1),$$
$$a_2^- = r^- a_1^- (f_2/f_1),$$
$$\varepsilon_2^+ = \zeta^+ + \varepsilon_1^+ + VU_2 - VU_1$$

and

$$\varepsilon_2^- = -\zeta^- + \varepsilon_1^- - VU_2 + VU_1.$$

3 USE OF THE TIDAL CURRENTS PREDICTION COMPUTER PROGRAM

3.1 General Description

This program produces tidal current values at a given location for a specified period of time. For each of the tidal constituents to be used in the prediction, the Greenwich phase lag, and the current ellipse major and minor semi-axis lengths and angle of inclination, are required as input. Output can either be the times, magnitudes and directions of all maximum and minimum currents respectively, or equally spaced values expressed in the form of north/south and east/west components, or vector magnitudes and directions.

3.2 Routines Required

(1) **MAIN** ...... reads in tidal station and time period information, ellipse parameters and Greenwich phases of constituents to be used in the prediction and calculates the desired tidal currents.

(2) **SLOPE** ...... calculates for a specific time, the current vector north/south and east/west components, and the derivative of the magnitude squared.

(3) **ASTRO** ...... reads the standard constituent data package and calculates the frequencies, astronomical arguments, and nodal corrections for all constituents.

(4) **PUT** ...... controls the output for maximum–minimum predictions.

(5) **CPUT** ...... controls the output for equally spaced predictions.

(6) **GDAY** ...... returns the consecutive day number from a specific origin for any given date and vice versa.

(11) **ASTR** ...... calculates ephermides for the sun and moon.

3.3 Data Input

All input data required by the tidal currents prediction program are read from file reference number 8. A sample set is given in Appendix 7.4. Although data types (i), (ii) and (iii) are identical to types (ii), (iii) and (iv) expected on file reference number 8 by the analysis program, for completeness they are repeated here.

(i) Two cards specifying values for the astronomical arguments SO,HO,PO,ENPO,PPO,DS,DH,DP, DNP,DPP in the format (5F13.10).

SO = mean longitude of the moon (cycles) at the reference time origin;
HO = mean longitude of the sun (cycles) at the reference time origin;

PO = mean longitude of the lunar perigee (cycles) at the reference time origin;

ENPO = negative of the mean longitude of the ascending node (cycles) at the reference time origin;

PPO = mean longitude of the solar perigee (perihelion) at the reference time origin.

DS,DH,DP,DNP,DPP are their respective rates of change over a 365-day period at the reference time origin.

Although these argument values are not used by the program that was revised in October 1992, in order to maintain consistency with earlier programs, they are still required as input. Polynomial approximations are now employed to more accurately evaluate the astronomical arguments and their rates of change.

(ii) At least one card for all the main tidal constituents specifying their Doodson numbers and phase shift along with as many cards as are necessary for the satellite constituents. The first card for each such constituent is in the format (6X,A5,1X,6I3,F5.2,I4) and contains the following information:

(iv) One card with the tidal station information `ISTN,(NA(J),J=1,4),ITZONE,LAD,LAM,LOD,`
`LOM` in the format (`5X,I4,1X,3A6,A4,A3,1X,I2,1X,I2,2X,I3,1X,I2`).

```
          ISTN
```

predictions. All information on files 10, 11 and 12 is written on the line printer in the same format. However, the line printer also records the station name and location, along with the ellipse parameters and phase lags of the constituents used in the prediction. Appendix 7.5 lists the output on files 10, 11 and 12 resulting from the input of Appendix 7.4.

When maximum and minimum current values are desired, the station number, date and a series of up to four current magnitudes along with their directions and occurrence times, are listed on each record. Two and sometimes three records are required per day and the format of these variables on file reference number 12 is (`1X,I4,I3,2I2,4(I5,F6.2,F6.1)`).

When equally spaced currents are requested in component form, file 10 receives the north/ south values and 11 the east/west. If the currents are requested in vector form, the magnitudes are on 10 and the directions on 11. In all cases, eight values are listed per record preceded by the station number, the time, day, month and year of the first value and followed by the time increment between values. On both devices, the format for these variables is (`1X,I4,F6.2,I3,2I2,8F7.2,F6.2`). On the line printer, the component (or vector) values are not listed separately, i.e. one record of north/south components (or current magnitudes) is followed directly by the corresponding east/west values (or current directions).

3.5 Program Conversion, Storage and Dimension Guidelines

The source program and constituent data package described in this manual have been tested on various mainframe, PC and workstation computers at the Institute of Ocean Sciences, Patricia Bay. Although as much of the program as possible was written in basic FORTRAN, some changes may be required before the program and data package can be used on other installations. Please write or call the author if any problems are encountered.

The program in its present form requires approximately 37,000 bytes for the storage of its instructions and arrays. As with the analysis program, changing the number or type of constituents in the standard data package may require alteration to the dimensions of some arrays. Restrictions on the minimum dimension of all arrays are now given.

Let

MTAB be the total number of constituents contained in the data package (at present 146);

M be the number of constituents to be included in the prediction;

MCON be the number of main constituents in the standard data package (at present 45);

MSAT be the sum of the total number of satellites for these main constituents and, the number of main constituents with no satellites (at present 162 plus 8 for the constituent data package containing no third-order satellites for both N_2 and L_2);

MSHAL be the sum for all shallow water constituents of the number of main constituents from which each is derived (at present 251);

NITER be the number of iterations required to reduce the time interval within which it is known that a high or low tide exists, to a desired length (with the largest initial interval size of 3 h and a 6-min final interval, NITER is 5).

Then in the main program, array KONTAB should have minimum dimension MTAB+1; arrays SIGTAB,V,U and F should have minimum dimension MTAB; arrays KON,EMAJ,EMIN,EINC and G should have minimum dimension M+1; arrays SIG,INDX,ANGO,CMAJ,CMIN,SMAJ,SMIN,CHA,CHB, CHM,SHA,SHB,SHM,C,S,COSE and SINE should have minimum dimension M and the two-dimensional array BTWOC should have a minimum dimension M by NITER. Array COSINE which stores

pre-calculated cosine function values over the range of 0° to 450° and is used as a look-up table, at present has 2501 elements.

In subroutine **SLOPE**, arrays `F,CMAJ,CMIN,SMAJ,SMIN,SIG` and `INDX` are in `COMMON` and should have the same dimensions as in the main program; and arrays `COSE` and `SINE` are passed in the argument list from the main program and so need only be dimensioned 2.

In subroutine **ASTRO**, arrays `KON` and `NJ` should have minimum dimension `MTAB+1`; arrays `FREQ,U,V` and `F` should have minimum dimension `MTAB`; arrays `II,JJ,KK,LL,MM,NN` and `SEMI` should have minimum dimension `MCON+1`; arrays `EE,LDEL,MDEL,NDEL,IR` and `PH` should have minimum dimension `MSAT` and arrays `KONCO` and `COEF` should have minimum dimension `MSHAL+4`.

In subroutine **PUT**, the dimensions of arrays `RK,DIRK` and `ITIME` should be at least as large as the maximum number of extreme current values per day (i.e. at present assumed to be 18).

In subroutine **CPUT**, the dimension of arrays `X` and `Y` should be at least equal to the number of equally spaced tidal current values per output record (at present, this is 8).

In subroutine **GDAY**, both arrays `NDM` and `NDP` should have dimension 12.

4 TIDAL CURRENTS PREDICTION PROGRAM DETAILS

4.2 The Maximum and Minimum Current Prediction Method

Letting X and Y be the east/west and north/south current components respectively, it is easily seen that the times for which the current magnitude, namely $\sqrt{X^2 + Y^2}$, will attain a maximum or minimum value, will be the same as those for the magnitude squared, namely $X^2 + Y^2$. Therefore, we can find all maximum and minimum currents by solving the equation that results from setting the derivative of the magnitude squared with respect to time, equal to zero.

Expanding equation (1) of Section 4.1 to include the contributions from m constituents, this result may be written as

$$\left(\sum X_j\right) \frac{\partial}{\partial t} \left(\sum X_j\right) + \left(\sum Y_j\right) \frac{\partial}{\partial t} \left(\sum Y_j\right) = 0,$$

where for each constituent

$$X(t, t_0) = f(t_0) \left[(a^+ + a^-) \cos\theta \cos\phi(t, t_0) - (a^+ - a^-) \sin\theta \sin\phi(t, t_0)\right],$$

$$\frac{d}{dt} X(t, t_0) = -2\pi\sigma f(t_0) \left[(a^+ + a^-) \cos\theta \sin\phi(t, t_0) + (a^+ - a^-) \sin\theta \cos\phi(t, t_0)\right],$$

$$Y(t, t_0) = f(t_0) \left[(a^+ + a^-) \sin\theta \cos\phi(t, t_0) + (a^+ - a^-) \cos\theta \sin\phi(t, t_0)\right]$$

and

$$\frac{d}{dt} Y(t, t_0) = 2\pi\sigma f(t_0) \left[-(a^+ + a^-) \sin\theta \sin\phi(t, t_0) + (a^+ - a^-) \cos\theta \cos\phi(t, t_0)\right].$$

The method employed to solve this equation is similar to the one used in the prediction of high and low tidal heights (Foreman, 1977, p. 34). We first bracket all extrema by moving forward in time with steps of size Δt and comparing signs of the interval endpoints. Once an interval whose endpoints differ in sign has been found, the zero value is located via the method of bisection coupled with linear interpolation.

Because each tidal constituent has two maximum and two minimum values per cycle, as opposed to one of each in the case of tidal heights, the recommended step size values, Δt, are on half those listed in the tidal heights manual (Foreman, 1977, p. 35), namely:

(i) $\Delta t = 1.5$ h for semidiurnal tide,

(ii) $\Delta t = 0.25$ h for mixed tide,

(iii) $\Delta t = 3$ h for diurnal tide.

Determination of the tidal nature at a particular station may be obtained by calculating the diurnal to semidiurnal ratio of tidal height amplitudes for the major constituents M_2, S_2, K_1 and O_1. This value is called the form number (Dietrich, 1963) and is defined precisely as

$$F = \frac{K_1 + O_1}{M_2 + S_2}.$$

The tide is then said to be

(i) semidiurnal if $0 \leq F \leq 0.25$,

(ii) mixed   if $0.25 < F \leq 3.00$,

(iii) diurnal   if $F > 3.00$.

If tidal heights analysis results are not available, F may be approximated using either the X or Y component amplitudes (e.g. using the notation of Section 2.1, the X component amplitude is $\sqrt{(CX)^2 + (SX)^2}$). For Race Rocks, the example used in Appendix 7.4, the east/west and north/south components both yield F values of 0.7.

In more detail, the search algorithm for an extremum is then as follows:

(i) Move forward in time from the origin, or the last extrema, in steps of Δt until either a change in sign exists between the derivative values at the endpoints of the interval, (t_a, t_b), or t_b extends beyond the desired prediction period. Each constituent contribution in the summation, $D(t)$ is evaluated by equations (2) and (3) of Section 4.1. When an interval containing an extremum is located, set $k = 1$ and proceed to (ii).

(ii) Calculate $t_k = t_a + \Delta t / 2^k$ and for each constituent in the sum, evaluate $D(t_k)$ by using the formulae:

$$\sin(t_k) = \frac{\sin(t_a) + \sin(t_b)}{2 \cos \Delta t / 2^k},$$

$$\cos(t_k) = \frac{\cos(t_a) + \cos(t_b)}{2 \cos \Delta t / 2^k}.$$

If $|D(t_k)| \leq 10^{-16}$, set $D(t_k) = 10^{-16}$.

(iii) Re-assign whichever of t_a or t_b has the same derivative sign as $D(t_k)$, by t_k. If the new interval length, $t_b - t_a$, is less than 0.1 h, proceed to (iv). Otherwise set $k = k + 1$ and return to (ii).

(iv) Use the following linear interpolation formula to find the extremum t_E,

$$t_E = t_a + \frac{D(t_a)(t_b - t_a)}{D(t_a) - D(t_b)},$$

and evaluate the X (real) and Y (imaginary) components of the current at this time via summing the respective constituent contributions given in equation (1) of Section 4.1. For each one, obtain the required sine and cosine values by using a pre-calculated stored table of 2501 cosine values with arguments in the range of $0°$ to $450°$. The current magnitude is then $\sqrt{X^2 + Y^2}$ and its direction measured counterclockwise from east is $\arctan(Y/X)$. Return to (i).

5 CONSISTENCY OF THE ANALYSIS AND PREDICTION PROGRAMS AND ACCURACY OF THEIR RESULTS IN RELATION TO THE METHODS EMPLOYED

As in the case of the tidal heights analysis and prediction programs, there is one noteworthy inconsistency between the tidal currents analysis and prediction programs. In particular, if a pseudo-tidal record were synthesized by the prediction program and analysed using the same constituents, the ellipse parameter and phase results given by the analysis program would not be identical to those used as input for the prediction program.

In a small part, this discrepancy is due to round-off accumulated during the calculations and truncation of the synthesized values to conform to input and output formats. However, a test performed on the UNIVAC 1106 at Patricia Bay with a six-month period of synthesized hourly currents indicates that such errors occur no sooner than the fourth digit. The remainder of the difference (which is, at worst, in the third digit) can be attributed to different approximating assumptions for the calculation of f and u, the nodal and modulation amplitude and phase correction factors. Whereas the prediction program calculates these values at the sixteenth day of each month in the desired time period and keeps them constant throughout the entire month, the analysis program assumes them to be constant over the entire analysis period and equal to their true values at the central hour of that period. However, if so desired, synthesized values in which the calculation of the nodal modulation factors is consistent with that of the analysis method can be obtained from the analysis program by setting input variable `INDPR` to 1.

As would be expected, the inaccuracy in the nodal modulation calculation for periods longer than two months is worse in the case of the analysis method and becomes more significant as the analysis period increases. In fact, there exists an optimal period length, which Godin estimates to be approximately one year, beyond which the expected accuracy improvement through better resolution of the constituents is overshadowed by this and other nodal modulation assumptions. In particular, once the record length is close to nine years, nodal modulation in its present form breaks down because some constituents, normally considered as satellite, should be resolved directly.

It is also important to note that significantly different results can be expected in a synthesis/analysis test if there is at least one more constituent used in the synthesis than the analysis. This is because the least squares fit technique will adjust the ellipse parameters and phases of constituents included in the analysis to partially account for contributions due to constituents included in the synthesis but not the analysis. In fact, even after the extra constituents have been inferred (e.g. P_1 is included in the synthesis and in the analysis via inference from K_1) there will still be some discrepancies in the results not only for the inferred and inferee constituents due to small inaccuracies in the approximating inference assumptions, but also for neighbouring constituents whose least squares fit results were affected by the presence of the inferred constituent and whose final results were not adjusted, as were those of the inferee, during inference (e.g. the presence of P_1 affects not only K_1 but to a lesser extent, neighbouring constituents such as NO_1 and J_1). However, except for round-off and truncation errors, and the slightly different f and u values, having more constituents in the analysis than the synthesis will not affect the results.

6 REFERENCES

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Appendix 7.1 Standard Constituent Input Data for the Tidal Currents Computer Program.
This Data is Read by File Reference Number 8.

```
Z0          0.0              M2
SA          0.0001140741     SSA
SSA         0.0002281591     Z0
MSM         0.0013097808     MM
MM          0.0015121518     MSF
MSF         0.0028219327     Z0
MF          0.0030500918     MSF
ALP1        0.0343965699     2Q1
2Q1         0.0357063507     Q1
SIG1        0.0359087218     2Q1
Q1          0.0372185026     O1
RHO1        0.0374208736     Q1
O1          0.0387306544     K1
TAU1        0.0389588136     O1
BET1        0.0400404353     NO1
NO1         0.0402685944     K1
CHI1        0.0404709654     NO1
PI1         0.0414385130     P1
P1          0.0415525871     K1
S1          0.0416666721     K1
K1          0.0417807462     Z0
PSI1        0.0418948203     K1
PHI1        0.0420089053     K1
THE1        0.0430905270     J1
J1          0.0432928981     K1
2PO1        0.0443745198
SO1         0.0446026789     OO1
OO1         0.0448308380     J1
UPS1        0.0463429898     OO1
ST36        0.0733553835
2NS2        0.0746651643
ST37        0.0748675353
ST1         0.0748933234
OQ2         0.0759749451     EPS2
EPS2        0.0761773161     2N2
ST2         0.0764054753
ST3         0.0772331498
O2          0.0774613089
2N2         0.0774870970     MU2
MU2         0.0776894680     N2
SNK2        0.0787710897
N2          0.0789992488     M2
NU2         0.0792016198     N2
ST4         0.0794555670
OP2         0.0802832416
GAM2        0.0803090296     H1
H1          0.0803973266     M2
M2          0.0805114007     Z0
H2          0.0806254748     M2
MKS2        0.0807395598     M2
ST5         0.0809677189
ST6         0.0815930224
LDA2        0.0818211815     L2
```

L2	0.0820235525	S2
2SK2	0.0831051742	
T2	0.0832192592	S2
S2	0.0833333333	M2
R2	0.0834474074	S2
K2	0.0835614924	S2
MSN2	0.0848454852	ETA2
ETA2	0.0850736443	K2
ST7	0.0853018034	
2SM2	0.0861552660	
ST38	0.0863576370	
SKM2	0.0863834251	
2SN2	0.0876674179	
NO3	0.1177299033	
MO3	0.1192420551	M3
M3	0.1207671010	M2
NK3	0.1207799950	
SO3	0.1220639878	MK3
MK3	0.1222921469	M3
SP3	0.1248859204	
SK3	0.1251140796	MK3
ST8	0.1566887168	
N4	0.1579984976	
3MS4	0.1582008687	
ST39	0.1592824904	
MN4	0.1595106495	M4
ST9	0.1597388086	
ST40	0.1607946422	
M4	0.1610228013	M3
ST10	0.1612509604	
SN4	0.1623325821	M4
KN4	0.1625607413	
MS4	0.1638447340	M4
MK4	0.1640728931	MS4
SL4	0.1653568858	
S4	0.1666666667	MS4
SK4	0.1668948258	S4
MNO5	0.1982413039	
2MO5	0.1997534558	
3MP5	0.1999816149	
MNK5	0.2012913957	
2MP5	0.2025753884	
2MK5	0.2028035475	M4
MSK5	0.2056254802	
3KM5	0.2058536393	
2SK5	0.2084474129	2MK5
ST11	0.2372259056	
2NM6	0.2385098983	
ST12	0.2387380574	
2MN6	0.2400220501	M6
ST13	0.2402502093	
ST41	0.2413060429	
M6	0.2415342020	2MK5
MSN6	0.2428439828	
MKN6	0.2430721419	
ST42	0.2441279756	
2MS6	0.2443561347	M6
2MK6	0.2445842938	2MS6

```
NSK6      0.2458940746
2SM6      0.2471780673    2MS6
MSK6      0.2474062264    2SM6
S6        0.2500000000
ST14      0.2787527046
ST15      0.2802906445
M7        0.2817899023
ST16      0.2830867891
3MK7      0.2833149482    M6
ST17      0.2861368809
ST18      0.3190212990
3MN8      0.3205334508
ST19      0.3207616099
M8        0.3220456027    3MK7
ST20      0.3233553835
ST21      0.3235835426
3MS8      0.3248675353
3MK8      0.3250956944
ST22      0.3264054753
ST23      0.3276894680
ST24      0.3279176271
ST25      0.3608020452
ST26      0.3623141970
4MK9      0.3638263489
ST27      0.3666482815
ST28      0.4010448515
M10       0.4025570033
ST29      0.4038667841
ST30      0.4053789360
ST31      0.4069168759
ST32      0.4082008687
ST33      0.4471596822
M12       0.4830684040
ST34      0.4858903367
ST35      0.4874282766


  .7428797055  .7771900329  .51870513089  .3631582592  .7847990160  000GMT 1/1/76
13.3594019864  .9993368945  .1129517942  .0536893056  .0000477414  INCR./365DAYS
        Z0        0  0  0   0  0  0 0.0      0
        SA        0  0  1   0  0 -1 0.0      0
        SSA       0  0  2   0  0  0 0.0      0
        MSM       0  1 -2   1  0  0  .00     0
        MM        0  1  0  -1  0  0 0.0      0
        MSF       0  2 -2   0  0  0 0.0      0
        MF        0  2  0   0  0  0 0.0      0
        ALP1      1 -4  2   1  0  0 -.25     2
        ALP1     -1  0  0 .75 0.0360R1    0 -1  0 .00 0.1906
        2Q1       1 -3  0   2  0  0-0.25    5
        2Q1      -2 -2  0 .50 0.0063     -1 -1  0 .75 0.0241R1  -1  0  0 .75 0.0607R1
        2Q1       0 -2  0 .50 0.0063      0 -1  0 .0  0.1885
        SIG1      1 -3  2   0  0  0-0.25    4
        SIG1     -1  0  0 .75 0.0095R1    0 -2  0 .50 0.0061     0 -1  0 .0  0.1884
        SIG1      2  0  0 .50 0.0087
        Q1        1 -2  0   1  0  0-0.25   10
        Q1       -2 -3  0 .50 0.0007     -2 -2  0 .50 0.0039    -1 -2  0 .75 0.0010R1
        Q1       -1 -1  0 .75 0.0115R1   -1  0  0 .75 0.0292R1   0 -2  0 .50 0.0057
        Q1       -1  0  1 .0  0.0008      0 -1  0 .0  0.1884     1  0  0 .75 0.0018R1
        Q1        2  0  0 .50 0.0028
```

```
RHO1    1 -2  2 -1  0  0-0.25    5
RHO1   0 -2  0 .50 0.0058      0 -1  0 .0  0.1882     1  0  0 .75 0.0131R1
RHO1   2  0  0 .50 0.0576      2  1  0 .0  0.0175
O1      1 -1  0  0  0  0-0.25    8
O1     -1  0  0 .25 0.0003R1    0 -2  0 .50 0.0058     0 -1  0 .0  0.1885
O1      1 -1  0 .25 0.0004R1    1  0  0 .75 0.0029R1   1  1  0 .25 0.0004R1
O1      2  0  0 .50 0.0064      2  1  0 .50 0.0010
TAU1    1 -1  2  0  0  0-0.75    5
TAU1   -2  0  0 .0  0.0446     -1  0  0 .25 0.0426R1   0 -1  0 .50 0.0284
TAU1    0  1  0 .50 0.2170      0  2  0 .50 0.0142
BET1    1  0 -2  1  0  0 -.75    1
BET1    0 -1  0 .00 0.2266
NO1     1  0  0  1  0  0-0.75    9
NO1    -2 -2  0 .50 0.0057     -2 -1  0 .0  0.0665    -2  0  0 .0  0.3596
NO1    -1 -1  0 .75 0.0331R1   -1  0  0 .25 0.2227R1  -1  1  0 .75 0.0290R1
NO1     0 -1  0 .50 0.0290      0  1  0 .0  0.2004     0  2  0 .50 0.0054
CHI1    1  0  2 -1  0  0-0.75    2
CHI1    0 -1  0 .50 0.0282      0  1  0 .0  0.2187
PI1     1  1 -3  0  0  1-0.25    1
PI1     0 -1  0 .50 0.0078
P1      1  1 -2  0  0  0-0.25    6
P1      0 -2  0 .0  0.0008      0 -1  0 .50 0.0112     0  0  2 .50 0.0004
P1      1  0  0 .75 0.0004R1    2  0  0 .50 0.0015     2  1  0 .50 0.0003
S1      1  1 -1  0  0  1-0.75    2
S1      0  0 -2 .0  0.3534      0  1  0 .50 0.0264
K1      1  1  0  0  0  0-0.75   10
K1     -2 -1  0 .0  0.0002     -1 -1  0 .75 0.0001R1  -1  0  0 .25 0.0007R1
K1     -1  1  0 .75 0.0001R1    0 -2  0 .0  0.0001     0 -1  0 .50 0.0198
K1      0  1  0 .0  0.1356      0  2  0 .50 0.0029     1  0  0 .25 0.0002R1
K1      1  1  0 .25 0.0001R1
PSI1    1  1  1  0  0 -1-0.75    1
PSI1    0  1  0 .0  0.0190
PHI1    1  1  2  0  0  0-0.75    5
PHI1   -2  0  0 .0  0.0344     -2  1  0 .0  0.0106     0  0 -2 .0  0.0132
PHI1    0  1  0 .50 0.0384      0  2  0 .50 0.0185
THE1    1  2 -2  1  0  0 -.75    4
THE1   -2 -1  0 .00  .0300     -1  0  0 .25 0.0141R1   0 -1  0 .50  .0317
THE1    0  1  0 .00  .1993
J1      1  2  0 -1  0  0-0.75   10
J1      0 -1  0 .50 0.0294      0  1  0 .0  0.1980     0  2  0 .50 0.0047
J1      1 -1  0 .75 0.0027R1    1  0  0 .25 0.0816R1   1  1  0 .25 0.0331R1
J1      1  2  0 .25 0.0027R1    2  0  0 .50 0.0152     2  1  0 .50 0.0098
J1      2  2  0 .50 0.0057
OO1     1  3  0  0  0  0-0.75    8
OO1    -2 -1  0 .50 0.0037     -2  0  0 .0  0.1496    -2  1  0 .0  0.0296
OO1    -1  0  0 .25 0.0240R1   -1  1  0 .25 0.0099R1   0  1  0 .0  0.6398
OO1     0  2  0 .0  0.1342      0  3  0 .0  0.0086
UPS1    1  4  0 -1  0  0 -.75    5
UPS1   -2  0  0 .00 0.0611      0  1  0 .00 0.6399     0  2  0 .00 0.1318
UPS1    1  0  0 .25 0.0289R1    1  1  0 .25 0.0257R1
OQ2     2 -3  0  3  0  0 0.0     2
OQ2    -1  0  0 .25 0.1042R2    0 -1  0 .50 0.0386
EPS2    2 -3  2  1  0  0 0.0     3
EPS2   -1 -1  0 .25 0.0075R2   -1  0  0 .25 0.0402R2   0 -1  0 .50 0.0373
2N2     2 -2  0  2  0  0 0.0     4
2N2    -2 -2  0 .50 0.0061     -1 -1  0 .25 0.0117R2  -1  0  0 .25 0.0678R2
2N2     0 -1  0 .50 0.0374
```

```
MU2     2 -2  2  0  0  0 0.0     3
MU2    -1 -1  0 .25 0.0018R2  -1  0  0 .25 0.0104R2   0 -1  0 .50 0.0375
N2      2 -1  0  1  0  0 0.0     4
N2     -2 -2  0 .50 0.0039    -1  0  1 .00 0.0008     0 -2  0 .00 0.0005
N2      0 -1  0 .50 0.0373
NU2     2 -1  2 -1  0  0 0.0     4
NU2     0 -1  0 .50 0.0373     1  0  0 .75 0.0042R2   2  0  0 .0  0.0042
NU2     2  1  0 .50 0.0036
GAM2    2  0 -2  2  0  0 -.50    3
GAM2   -2 -2  0 .00 0.1429    -1  0  0 .25 0.0293R2   0 -1  0 .50 0.0330
H1      2  0 -1  0  0  1 -0.50   2
H1      0 -1  0 .50 0.0224     1  0 -1 .50 0.0447
M2      2  0  0  0  0  0 0.0     9
M2     -1 -1  0 .75 0.0001R2  -1  0  0 .75 0.0004R2   0 -2  0 .0  0.0005
M2      0 -1  0 .50 0.0373     1 -1  0 .25 0.0001R2   1  0  0 .75 0.0009R2
M2      1  1  0 .75 0.0002R2   2  0  0 .0  0.0006     2  1  0 .0  0.0002
H2      2  0  1  0  0 -1 0.0     1
H2      0 -1  0 .50 0.0217
LDA2    2  1 -2  1  0  0 -0.50   1
LDA2    0 -1  0 .50 0.0448
L2      2  1  0 -1  0  0 -0.50   5
L2      0 -1  0 .50 0.0366     2 -1  0 .00 0.0047     2  0  0 .50 0.2505
L2      2  1  0 .50 0.1102     2  2  0 .50 0.0156
T2      2  2 -3  0  0  1 0.0     0
S2      2  2 -2  0  0  0 0.0     3
S2      0 -1  0 .0  0.0022     1  0  0 .75 0.0001R2   2  0  0 .0  0.0001
R2      2  2 -1  0  0 -1 -0.50   2
R2      0  0  2 .50 0.2535     0  1  2 .0  0.0141
K2      2  2  0  0  0  0 0.0     5
K2     -1  0  0 .75 0.0024R2  -1  1  0 .75 0.0004R2   0 -1  0 .50 0.0128
K2      0  1  0 .0  0.2980     0  2  0 .0  0.0324
ETA2    2  3  0 -1  0  0 0.0     7
ETA2    0 -1  0 .50 0.0187     0  1  0 .0  0.4355     0  2  0 .0  0.0467
ETA2    1  0  0 .75 0.0747R2   1  1  0 .75 0.0482R2   1  2  0 .75 0.0093R2
ETA2    2  0  0 .50 0.0078
M3      3  0  0  0  0  0 -.50    1
M3      0 -1  0 .50  .0564

2PO1 2   2.0 P1         -1.0 O1
SO1  2   1.0 S2         -1.0 O1
ST36 3   2.0 M2          1.0 N2       -2.0 S2
2NS2 2   2.0 N2         -1.0 S2
ST37 2   3.0 M2         -2.0 S2
ST1  3   2.0 N2          1.0 K2       -2.0 S2
ST2  4   1.0 M2          1.0 N2        1.0 K2        -2.0 S2
ST3  3   2.0 M2          1.0 S2       -2.0 K2
O2   1   2.0 O1
ST4  3   2.0 K2          1.0 N2       -2.0 S2
SNK2 3   1.0 S2          1.0 N2       -1.0 K2
OP2  2   1.0 O1          1.0 P1
MKS2 3   1.0 M2          1.0 K2       -1.0 S2
ST5  3   1.0 M2          2.0 K2       -2.0 S2
ST6  4   2.0 S2          1.0 N2       -1.0 M2       -1.0 K2
2SK2 2   2.0 S2         -1.0 K2
MSN2 3   1.0 M2          1.0 S2       -1.0 N2
ST7  4   2.0 K2          1.0 M2       -1.0 S2       -1.0 N2
2SM2 2   2.0 S2         -1.0 M2
```

```
ST38  3   2.0 M2        1.0 S2        -2.0 N2
SKM2  3   1.0 S2        1.0 K2        -1.0 M2
2SN2  2   2.0 S2       -1.0 N2
NO3   2   1.0 N2        1.0 O1
MO3   2   1.0 M2        1.0 O1
NK3   2   1.0 N2        1.0 K1
SO3   2   1.0 S2        1.0 O1
MK3   2   1.0 M2        1.0 K1
SP3   2   1.0 S2        1.0 P1
SK3   2   1.0 S2        1.0 K1
ST8   3   2.0 M2        1.0 N2        -1.0 S2
N4    1   2.0 N2
3MS4  2   3.0 M2       -1.0 S2
ST39  4   1.0 M2        1.0 S2         1.0 N2       -1.0 K2
MN4   2   1.0 M2        1.0 N2
ST40  3   2.0 M2        1.0 S2        -1.0 K2
ST9   4   1.0 M2        1.0 N2         1.0 K2       -1.0 S2
M4    1   2.0 M2
ST10  3   2.0 M2        1.0 K2        -1.0 S2
SN4   2   1.0 S2        1.0 N2
KN4   2   1.0 K2        1.0 N2
MS4   2   1.0 M2        1.0 S2
MK4   2   1.0 M2        1.0 K2
SL4   2   1.0 S2        1.0 L2
S4    1   2.0 S2
SK4   2   1.0 S2        1.0 K2
MNO5  3   1.0 M2        1.0 N2         1.0 O1
2MO5  2   2.0 M2        1.0 O1
3MP5  2   3.0 M2       -1.0 P1
MNK5  3   1.0 M2        1.0 N2         1.0 K1
2MP5  2   2.0 M2        1.0 P1
2MK5  2   2.0 M2        1.0 K1
MSK5  3   1.0 M2        1.0 S2         1.0 K1
3KM5  3   1.0 K2        1.0 K1         1.0 M2
2SK5  2   2.0 S2        1.0 K1
ST11  3   3.0 N2        1.0 K2        -1.0 S2
2NM6  2   2.0 N2        1.0 M2
ST12  4   2.0 N2        1.0 M2         1.0 K2       -1.0 S2
ST41  3   3.0 M2        1.0 S2        -1.0 K2
2MN6  2   2.0 M2        1.0 N2
ST13  4   2.0 M2        1.0 N2         1.0 K2       -1.0 S2
M6    1   3.0 M2
MSN6  3   1.0 M2        1.0 S2         1.0 N2
MKN6  3   1.0 M2        1.0 K2         1.0 N2
2MS6  2   2.0 M2        1.0 S2
2MK6  2   2.0 M2        1.0 K2
NSK6  3   1.0 N2        1.0 S2         1.0 K2
2SM6  2   2.0 S2        1.0 M2
MSK6  3   1.0 M2        1.0 S2         1.0 K2
ST42  3   2.0 M2        2.0 S2        -1.0 K2
S6    1   3.0 S2
ST14  3   2.0 M2        1.0 N2         1.0 O1
ST15  3   2.0 N2        1.0 M2         1.0 K1
M7    1   3.5 M2
ST16  3   2.0 M2        1.0 S2         1.0 O1
3MK7  2   3.0 M2        1.0 K1
ST17  4   1.0 M2        1.0 S2         1.0 K2        1.0 O1
ST18  2   2.0 M2        2.0 N2
```

```
3MN8 2   3.0 M2        1.0 N2
ST19 4   3.0 M2        1.0 N2        1.0 K2        -1.0 S2
M8   1   4.0 M2
ST20 3   2.0 M2        1.0 S2        1.0 N2
ST21 3   2.0 M2        1.0 N2        1.0 K2
3MS8 2   3.0 M2        1.0 S2
3MK8 2   3.0 M2        1.0 K2
ST22 4   1.0 M2        1.0 S2        1.0 N2        1.0 K2
ST23 2   2.0 M2        2.0 S2
ST24 3   2.0 M2        1.0 S2        1.0 K2
ST25 3   2.0 M2        2.0 N2        1.0 K1
ST26 3   3.0 M2        1.0 N2        1.0 K1
4MK9 2   4.0 M2        1.0 K1
ST27 3   3.0 M2        1.0 S2        1.0 K1
ST28 2   4.0 M2        1.0 N2
M10  1   5.0 M2
ST29 3   3.0 M2        1.0 N2        1.0 S2
ST30 2   4.0 M2        1.0 S2
ST31 4   2.0 M2        1.0 N2        1.0 S2        1.0 K2
ST32 2   3.0 M2        2.0 S2
ST33 3   4.0 M2        1.0 S2        1.0 K1
M12  1   6.0 M2
ST34 2   5.0 M2        1.0 S2
ST35 4   3.0 M2        1.0 N2        1.0 K2        1.0 S2
```

Appendix 7.2 Sample Tidal Station Input Data for the Analysis Program.

The following sample input for file reference numbers 4, 10 and 11 will produce an analysis of Race Rocks, British Columbia current data for the period 1400 PST February 8, 1972 to 2400 PST March 3, 1972 inclusive. Constituents P_1 and K_2 will be inferred, shallow water constituent M_{10} is specifically designated for analysis inclusion, a scaling compensation will be made for the application of moving average filters to the original 10-min data and hourly   n

(ii) File reference number 10 input data (hourly north/south current components):

```
1   7077         8 272999999999999999999999999999999999999999999999999999999999999999
2   7077         8 27299999   166   262   141   -20  -176   -26    28   128   288   133  -144
1   7077         9 272  -108   -14    60    38   -95   -84    41    83    91    84    30    14
2   7077         9 272    23   110   165    95    25  -107  -143    14   -39    -1   -21  -141
1   7077        10 272  -188  -148    50   124    69   -82  -196  -187   -85   -24    19    17
2   7077        10 272   -84   -95     0    72    48   -56  -115   -74   -45  -159   -73  -116
1   7077        11 272  -134   -27  -125  -114   -12   -18  -127  -131  -169  -154   -49  -110
2   7077        11 272  -230  -345  -223    26   166   133    83    24    92    70   -49   -58
1   7077        12 272  -151  -214  -341  -246   -12    67  -116  -258  -367  -368  -226   -68
2   7077        12 272   -49  -100  -125  -273  -140    82    66    59   -99   -48    88    66
1   7077        13 272  -124  -294  -303  -358  -206     1  -168  -316  -360  -417  -309  -138
2   7077        13 272    57    69   149   -41  -277  -101   178   272   177   -18    62   118
1   7077        14 272    63  -109  -424  -514  -373  -174   -72  -380  -206    76   -78  -230
2   7077        14 272  -187   135   270   328   122  -285    11   146   104   116   -30    48
1   7077        15 272   139   145    30  -226  -405  -237    47    48    -1    52   -42    17
2   7077        15 272   -25   -84   136   265   339   254    -8    -3    15   124    76    67
1   7077        16 272   258   135  -102  -242  -138   181   305   188    84   103   195   193
2   7077        16 272   100    38   202   288    97   164   228   106   250   310   231   266
1   7077        17 272   144    98   133    38   -45    24   300   132     3    59   168   154
2   7077        17 272    85   114   164   131   -18  -116    -5    95   -20   -88   -36    41
1   7077        18 272   126   117    69    37  -156  -350  -285   -50   100   -32    54   116
2   7077        18 272   112    87   131   153    15    55    19     3    -7   -52  -282  -345
1   7077        19 272  -171   162   159    13  -138  -212  -104    -4    87     9    64   114
2   7077        19 272   211    92     0   107   102    60   -15  -265  -179   -68   -45   -47
1   7077        20 272   -22    63   124    81   -69  -136  -128   -84    39    16    70    68
2   7077        20 272    35   184   119    65   156   207    21  -363  -317   -44    43   -58
1   7077        21 272   -91   -48    -4    70   -41  -151  -133   -22     2    16   -26    18
2   7077        21 272   -15     6   125    86    72    55    61   -16  -265  -258     1    36
1   7077        22 272    47    94    89    24    98   126    60    -7    30    91   100    38
2   7077        22 272   -36    57   121   119    31    24    33    92    93  -183   -94   228
1   7077        23 272   327   253   231   150   129   185   180    70   -33   -30    14    80
2   7077        23 272    20   -38   -20   -11   -35    10    52    60   108   112  -131  -320
1   7077        24 272  -151    32    69   156    24  -122  -149  -187   -70    41    45   -31
2   7077        24 272   -74  -150  -120   -54     6   -55   -77   109    73    13   194    32
1   7077        25 272  -195  -253  -168    17   120   -25  -124  -377  -459  -246  -115   -58
2   7077        25 272   -81  -144  -216  -153   -90    18   -30   -78    18     4    32   182
1   7077        26 272    -2  -322  -272   135   255   110  -198  -353  -295  -370  -607  -532
2   7077        26 272  -422  -399  -282  -207  -135  -101   -32     7  -179  -107    40    18
1   7077        27 272   -32  -171  -371  -509  -343   -68  -139  -450  -332  -107   -96  -129
2   7077        27 272  -369  -474  -470  -332  -244  -136   -57    99   184    54   102   147
1   7077        28 272    22  -130  -254  -367  -260   -79    11  -189  -289  -112   -32    35
2   7077        28 272    93   180   233   157    17   -63  -207  -105    66   163    91    76
1   7077        29 272    15  -161  -226  -275  -186    47   -39  -183  -212  -131   -22   -34
2   7077        29 272    18    68    48    66    -4   140    75    42    94   146   173    74
1   7077         1 372   -11    22  -125  -292   -25   236   126    46   104   223   255   202
2   7077         1 372   145   146  -103  -269  -245    81   178   -27  -233   -36   167    78
1   7077         2 372   -11    45    46  -142  -215  -168    30    39   -63   -12    24    29
2   7077         2 372    76   187   114    32    20   -51    68   104    37   -51   -95    26
1   7077         3 372   167   191   190    67   -39   -29    68    96   -69    14   157   113
2   7077         3 372    46   174    46    52    92    27    -6    -5    29    40   -34   -40
1   7077         4 372    36    90   145    -4  -154  -137   -19    27   -50   -96    37   199
2   7077         4 372   203   219   209    71    74    20  -149  -194  -113    62    88   -11
```

```
1  7077         5 372   -24   -16   -91  -187  -182  -128   -42    44    96    59    37   143
2  7077         5 372   150    33     3   129    15    25   -69  -187  -198    -2   142   -17
1  7077         6 372  -253  -204  -149  -154  -154  -115   -40    92   147    28  -132   -62
2  7077         6 37299999999999999999999999999    10    92    10   -58    -1    62    64
1  7077         7 372    -1  -133  -213  -151   -86   -47    -1   -22    -7    -3    -8    32
2  7077         7 372   128   103    14    -4    25   -89    14    90   -18   -53   -14   125
1  7077         8 372   206    50     7   -57   -73   -25    -1    38    73    65   -27   -74
2  7077         8 372   -38    65   -37  -143  -126  -100  -115   -47   -36    12    38     8
1  7077         9 372   -30    46     0  -110   -63   -44    -2    43    17    39    32   -18
2  7077         9 372   -87  -118   108   134   -40   -45   -16   -56    26    34    13    10
1  7077        10 372   -89  -102   -37    61   -80  -265  -213  -127   -86   -36   -10  -121
2  7077        10 372  -182  -171   -67    71    27  -160  -138   -47   -46    28    23  -129
1  7077        11 372  -334  -330  -163  -107  -232  -357  -306  -329  -449  -515  -513  -443
2  7077        11 372  -307  -239  -282  -155    59   -42  -245  -242  -146  -125    34    47
1  7077        12 372   -53  -240  -246  -118   -60  -139  -227  -326  -428  -509  -627  -516
2  7077        12 372  -310  -178  -325  -519  -259   -21   -29   -29   -89   -57   -28   128
1  7077        13 372   148  -131  -320  -235  -121  -160  -287  -358  -479  -283  -197  -172
2  7077        13 372    31   159   142   167   -57  -248   -51   100    23  -111   -46    82
1  7077        14 372   180    39  -105   -76    13    -5  -208  -407  -255  -237   -76   104
2  7077        14 372   176   192    96    45     7   -54  -196  -170   -25   -55   -48    52
1  7077        15 372    76   139   159    62   -77   -68  -211  -519  -308   -75    -7   145
2  7077        15 372    77   140   253   240    -1    34    67    74   105   174   221   240
```

(iii) File reference number 10 input data (hourly north/south current components):

```
1   7077        8 272999999999999999999999999999999999999999999999999999999999
2   7077        8 27299999  -755  -802  -687  -688  -551  -221    41   301   557   684   633
1   7077        9 272   534   363   203   163    46   -90   -66   -30   -25   -20  -119  -326
2   7077        9 272  -553  -716  -771  -739  -503  -343  -354  -124   135   375   672   813
1   7077       10 272   713   586   379   187   109     4   -81  -178  -234  -278  -350  -519
2   7077       10 272  -693  -767  -738  -863  -961  -882  -705  -422   -39   290   620   845
1   7077       11 272   882   839   518   199    12  -109  -281  -590  -572  -485  -449  -437
2   7077       11 272  -626  -802  -851  -885 -1140 -1202 -1059  -800  -355    88   471   856
1   7077       12 272  1044   887   471    40  -208  -228  -345  -578  -609  -523  -343  -176
2   7077       12 272  -220  -553  -814  -955 -1162 -1447 -1545 -1210  -640  -162   354  1092
1   7077       13 272  1454  1338  1020   413  -114  -316  -462  -725  -803  -608  -443  -429
2   7077       13 272  -378  -401  -535  -721  -866 -1214 -1455 -1363 -1080  -514    97   579
1   7077       14 272  1122  1542  1248   795   232  -216  -458  -773  -699  -328   -61   -82
2   7077       14 272   -45    41    71  -112  -525  -893 -1315 -1494 -1378  -845  -263   282
1   7077       15 272   820  1282  1525  1294   658   -89  -530  -574  -550  -411  -143   131
2   7077       15 272   452   215    41   -73  -347  -879 -1108 -1322 -1434 -1115  -487   180
1   7077       16 272   706  1093  1372  1222   865   376   -48  -401  -583  -600  -465  -101
2   7077       16 272   511   639   617   554   400     9  -320  -732 -1120 -1230  -919  -228
1   7077       17 272   652  1076  1321  1581  1329   861   317  -156  -517  -636  -638  -397
2   7077       17 272    -7   484   565   658   679   369   -27  -407  -719  -915  -902  -752
1   7077       18 272  -318   319   851  1159  1072   743   370  -158  -653 -1108 -1294 -1121
2   7077       18 272  -861  -460    29   413   710   706   447    97  -202  -518  -766  -737
1   7077       19 272  -539  -124   401   826   859   686   312  -129  -621 -1043 -1300 -1328
2   7077       19 272 -1178  -771  -264   196   508   728   721   578   206  -161  -393  -478
1   7077       20 272  -429  -203   184   616   804   725   434    59  -307  -714 -1203 -1625
2   7077       20 272 -1623 -1211  -687  -132   220   486   845   897   589   522   428   270
1   7077       21 272   152   132   208   403   592   619   489   320   126  -319  -847 -1225
2   7077       21 272 -1425 -1361 -1082  -616    32   471   537   825   950   693   631   597
1   7077       22 272   323    53   -45   -12   111   236   360   336   163   -36  -299  -829
2   7077       22 272 -1223 -1371 -1299  -885  -385   268   465   466   838   990   735   671
1   7077       23 272   564   364    80    -2   -44   -23   110   249   283   161   -88  -404
2   7077       23 272  -636  -812 -1102 -1227 -1073  -528   155   274   589   992  1142  1067
1   7077       24 272   837   605   367    85   -79  -219  -310  -195    38   101   -29  -156
2   7077       24 272  -347  -730 -1031 -1213 -1328 -1166  -744   -24   223   440   880  1249
1   7077       25 272  1232   895   409   115   -68  -194  -371  -448  -279   199   430   314
2   7077       25 272     9  -333  -792 -1095 -1264 -1341 -1162  -638   -82   271   568   965
1   7077       26 272  1334  1129   699   453   104  -267  -591  -564  -484  -248   -13   306
2   7077       26 272   357    66  -310  -741 -1098 -1260 -1301 -1120  -725  -183   271   627
1   7077       27 272  1130  1355   960   273  -214  -468  -625  -830  -619  -236   -11    66
2   7077       27 272   254   249    50  -307  -745 -1066 -1346 -1446 -1188  -770  -148   311
1   7077       28 272   796  1182  1135   731   173  -243  -542  -792  -823  -578  -344   -60
2   7077       28 272     0   135   166   -24  -198  -561 -1004 -1235 -1143  -672   -23   463
1   7077       29 272   699   986  1150  1065   567   247   -79  -385  -547  -515  -233   172
2   7077       29 272   296   404   370   235    31   -39  -300  -853  -950  -623   -43   641
1   7077        1 372   965  1128  1293  1219   905   533   173  -243  -504  -388  -136   309
2   7077        1 372   628   744   912   794   362   -62  -309  -601  -881  -891  -502   115
1   7077        2 372   394   542   904   890   536   141  -281  -550  -922 -1170 -1063  -831
2   7077        2 372  -302   217   341   564   535   293   -72  -336  -582  -782  -728  -444
1   7077        3 372   -64   257   541   698   550   217  -138  -495  -873 -1131 -1241 -1048
2   7077        3 372  -537   140   363   525   699   597   381   140   -59  -313  -586  -572
1   7077        4 372  -271    13   373   719   658   432   140  -201  -583 -1008 -1195 -1060
2   7077        4 372  -705  -194   233   331   610   738   637   357    80  -113  -188  -203
```

```
1  7077       5 372   -52   191   454   605   505   317    49  -302  -653  -896-1140-1286
2  7077       5 372-1049  -660  -228   103   206   458   554   497   261     8   -56    -4
1  7077       6 372   -25   -70    11   197   267   144  -107  -424  -717-1068-1226-1311
2  7077       6 372999999999999999999999999999   178   426   474   308   200   237   134
1  7077       7 372    76    70   138   160   273   385   314    89  -170  -419  -679  -891
2  7077       7 372-1022  -965  -700  -335    -3   180   373   628   758   674   369   151
1  7077       8 372    77    37    23    61    33   -24   -86  -156  -336  -615  -736  -755
2  7077       8 372  -830  -955  -905  -662  -424  -134   108   316   473   506   494   405
1  7077       9 372   226    -5   -95  -185  -253  -298  -342  -357  -348  -403  -479  -621
2  7077       9 372  -748  -757  -794  -875  -740  -484  -157     8   187   400   524   537
1  7077      10 372   418   156  -129  -270  -385  -528  -485  -430  -374  -298  -346  -487
2  7077      10 372  -608  -703  -725  -810  -937  -828  -539  -181    87   405   740   824
1  7077      11 372   657   426   173   -79  -263  -512  -622  -495  -456  -467  -442  -368
2  7077      11 372  -401  -493  -621  -775-1021-1184  -941  -477  -126   164   511   754
1  7077      12 372   896   713   203  -107  -301  -474  -577  -664  -577  -394  -405  -405
2  7077      12 372  -282  -184  -376  -708  -981-1276-1235  -927  -443   -68   242   578
1  7077      13 372   949  1116   789   140  -233  -463  -769  -899  -939  -706  -403  -214
2  7077      13 372   -98   -47   -59  -325  -885-1185-1437-1371  -866  -396   -50   327
1  7077      14 372   767  1107   932   469    30  -357  -775  -979  -974  -629  -310    69
2  7077      14 372   276   416   455   308   -69  -702-1305-1310-1170  -748   -94   223
1  7077      15 372   510   738   890   871   399  -109  -635-1101-1205-1163  -715  -172
2  7077      15 372   132   300   375   347   179  -212  -588  -881-1119  -972  -551     5
```

Appendix 7.4   Sample Input for the Tidal Currents Prediction Program.

The following sample input for file reference number 8 will synthesize three sets of currents at Race Rocks, British Columbia:

 (i) the times, magnitudes and directions of all maximum and minimum values for the period 0100 PST July 1, 1976 to 2400 PST July 31, 1976,

 (ii) the magnitudes and directions of hourly currents for the period 0100 PST July 1, 1976 to 2400 PST July 5, 1976,

(iii) the north/south and east/west hourly current components for the period 0100 PST July 1, 1976 to 2400 PST July 31, 1976.

Note that the ellipse parameter and phase input values of the constituents to be used in the prediction were selected from the results listed in Appendix 7.3. The number of the constituent, its frequency and its g^+ and g^- values are not required.

The output results for file reference numbers 10, 11 and 12 are listed in Appendix 7.5.

```
 .7428797055   .7771900329   .5187051308   .3631582592   .7847990160   000GMT 1/1/76
13.3594019864   .9993368945   .1129517942   .0536893056   .0000477414   INCR./365DAYS
        Z0       0   0   0   0   0   0 0.0      0
        SA       0   0   1   0   0  -1 0.0      0
        SSA      0   0   2   0   0   0 0.0      0
        MSM      0   1  -2   1   0   0  .00     0
        MM       0   1   0  -1   0   0 0.0      0
        MSF      0   2  -2   0   0   0 0.0      0
        MF       0   2   0   0   0   0 0.0      0
        ALP1     1  -4   2   1   0   0 -.25     2
        ALP1    -1   0   0 .75 0.0360R1    0  -1  0 .00 0.1906
        2Q1      1  -3   0   2   0   0-0.25     5
        2Q1     -2  -2   0 .50 0.0063     -1  -1  0 .75 0.0241R1   -1   0   0 .75 0.0607R1
        2Q1      0  -2   0 .50 0.0063      0  -1  0 .0  0.1885
        SIG1     1  -3   2   0   0   0-0.25     4
        SIG1    -1   0   0 .75 0.0095R1    0  -2  0 .50 0.0061      0  -1  0 .0  0.1884
        SIG1     2   0   0 .50 0.0087
        Q1       1  -2   0   1   0   0-0.25    10
        Q1      -2  -3   0 .50 0.0007     -2  -2  0 .50 0.0039     -1  -2  0 .75 0.0010R1
        Q1      -1  -1   0 .75 0.0115R1   -1   0  0 .75 0.0292R1    0  -2  0 .50 0.0057
        Q1      -1   0   1 .0  0.0008      0  -1  0 .0  0.1884      1   0  0 .75 0.0018R1
        Q1       2   0   0 .50 0.0028
        RHO1     1  -2   2  -1   0   0-0.25     5
        RHO1     0  -2   0 .50 0.0058      0  -1  0 .0  0.1882      1   0  0 .75 0.0131R1
        RHO1     2   0   0 .50 0.0576      2   1  0 .0  0.0175
        O1       1  -1   0   0   0   0-0.25     8
        O1      -1   0   0 .25 0.0003R1    0  -2  0 .50 0.0058      0  -1  0 .0  0.1885
        O1       1  -1   0 .25 0.0004R1    1   0  0 .75 0.0029R1    1   1  0 .25 0.0004R1
        O1       2   0   0 .50 0.0064      2   1  0 .50 0.0010
        TAU1     1  -1   2   0   0   0-0.75     5
        TAU1    -2   0   0 .0  0.0446     -1   0  0 .25 0.0426R1    0  -1  0 .50 0.0284
        TAU1     0   1   0 .50 0.2170      0   2  0 .50 0.0142
```

```
BET1    1  0 -2  1  0  0 -.75   1
BET1    0 -1  0 .00 0.2266
NO1     1  0  0  1  0  0-0.75   9
NO1    -2 -2  0 .50 0.0057     -2 -1  0 .0  0.0665     -2  0  0 .0  0.3596
NO1    -1 -1  0 .75 0.0331R1   -1  0  0 .25 0.2227R1   -1  1  0 .75 0.0290R1
NO1     0 -1  0 .50 0.0290      0  1  0 .0  0.2004      0  2  0 .50 0.0054
CHI1    1  0  2 -1  0  0-0.75   2
CHI1    0 -1  0 .50 0.0282      0  1  0 .0  0.2187
PI1     1  1 -3  0  0  1-0.25   1
PI1     0 -1  0 .50 0.0078
P1      1  1 -2  0  0  0-0.25   6
P1      0 -2  0 .0  0.0008      0 -1  0 .50 0.0112      0  0  2 .50 0.0004
P1      1  0  0 .75 0.0004R1    2  0  0 .50 0.0015      2  1  0 .50 0.0003
S1      1  1 -1  0  0  1-0.75   2
S1      0  0 -2 .0  0.3534      0  1  0 .50 0.0264
K1      1  1  0  0  0  0-0.75  10
K1     -2 -1  0 .0  0.0002     -1 -1  0 .75 0.0001R1   -1  0  0 .25 0.0007R1
K1     -1  1  0 .75 0.0001R1    0 -2  0 .0  0.0001      0 -1  0 .50 0.0198
K1      0  1  0 .0  0.1356      0  2  0 .50 0.0029      1  0  0 .25 0.0002R1
K1      1  1  0 .25 0.0001R1
PSI1    1  1  1  0  0 -1-0.75   1
PSI1    0  1  0 .0  0.0190
PHI1    1  1  2  0  0  0-0.75   5
PHI1   -2  0  0 .0  0.0344     -2  1  0 .0  0.0106      0  0 -2 .0  0.0132
PHI1    0  1  0 .50 0.0384      0  2  0 .50 0.0185
THE1    1  2 -2  1  0  0 -.75   4
THE1   -2 -1  0 .00  .0300     -1  0  0 .25 0.0141R1    0 -1  0 .50  .0317
THE1    0  1  0 .00  .1993
J1      1  2  0 -1  0  0-0.75  10
J1      0 -1  0 .50 0.0294      0  1  0 .0  0.1980      0  2  0 .50 0.0047
J1      1 -1  0 .75 0.0027R1    1  0  0 .25 0.0816R1    1  1  0 .25 0.0331R1
J1      1  2  0 .25 0.0027R1    2  0  0 .50 0.0152      2  1  0 .50 0.0098
J1      2  2  0 .50 0.0057
OO1     1  3  0  0  0  0-0.75   8
OO1    -2 -1  0 .50 0.0037     -2  0  0 .0  0.1496     -2  1  0 .0  0.0296
OO1    -1  0  0 .25 0.0240R1   -1  1  0 .25 0.0099R1    0  1  0 .0  0.6398
OO1     0  2  0 .0  0.1342      0  3  0 .0  0.0086
UPS1    1  4  0 -1  0  0 -.75   5
UPS1   -2  0  0 .00 0.0611      0  1  0 .00 0.6399      0  2  0 .00 0.1318
UPS1    1  0  0 .25 0.0289R1    1  1  0 .25 0.0257R1
OQ2     2 -3  0  3  0  0 0.0    2
OQ2    -1  0  0 .25 0.1042R2    0 -1  0 .50 0.0386
EPS2    2 -3  2  1  0  0 0.0    3
EPS2   -1 -1  0 .25 0.0075R2   -1  0  0 .25 0.0402R2    0 -1  0 .50 0.0373
2N2     2 -2  0  2  0  0 0.0    4
2N2    -2 -2  0 .50 0.0061     -1 -1  0 .25 0.0117R2   -1  0  0 .25 0.0678R2
2N2     0 -1  0 .50 0.0374
MU2     2 -2  2  0  0  0 0.0    3
MU2    -1 -1  0 .25 0.0018R2   -1  0  0 .25 0.0104R2    0 -1  0 .50 0.0375
N2      2 -1  0  1  0  0 0.0    4
N2     -2 -2  0 .50 0.0039     -1  0  1 .00 0.0008      0 -2  0 .00 0.0005
N2      0 -1  0 .50 0.0373
NU2     2 -1  2 -1  0  0 0.0    4
NU2     0 -1  0 .50 0.0373      1  0  0 .75 0.0042R2    2  0  0 .0  0.0042
NU2     2  1  0 .50 0.0036
GAM2    2  0 -2  2  0  0 -.50   3
GAM2   -2 -2  0 .00 0.1429     -1  0  0 .25 0.0293R2    0 -1  0 .50 0.0330
```

```
H1      2  0 -1  0  0  1-0.50    2
H1      0 -1  0 .50 0.0224    1  0 -1 .50 0.0447
M2      2  0  0  0  0  0 0.0     9
M2     -1 -1  0 .75 0.0001R2  -1  0  0 .75 0.0004R2   0 -2  0 .0  0.0005
M2      0 -1  0 .50 0.0373    1 -1  0 .25 0.0001R2   1  0  0 .75 0.0009R2
M2      1  1  0 .75 0.0002R2   2  0  0 .0  0.0006    2  1  0 .0  0.0002
H2      2  0  1  0  0 -1 0.0     1
H2      0 -1  0 .50 0.0217
LDA2    2  1 -2  1  0  0-0.50    1
LDA2    0 -1  0 .50 0.0448
L2      2  1  0 -1  0  0-0.50    5
L2      0 -1  0 .50 0.0366    2 -1  0 .00 0.0047    2  0  0 .50 0.2505
L2      2  1  0 .50 0.1102    2  2  0 .50 0.0156
T2      2  2 -3  0  0  1 0.0     0
S2      2  2 -2  0  0  0 0.0     3
S2      0 -1  0 .0  0.0022    1  0  0 .75 0.0001R2   2  0  0 .0  0.0001
R2      2  2 -1  0  0 -1-0.50    2
R2      0  0  2 .50 0.2535    0  1  2 .0  0.0141
K2      2  2  0  0  0  0 0.0     5
K2     -1  0  0 .75 0.0024R2  -1  1  0 .75 0.0004R2   0 -1  0 .50 0.0128
K2      0  1  0 .0  0.2980    0  2  0 .0  0.0324
ETA2    2  3  0 -1  0  0 0.0     7
ETA2    0 -1  0 .50 0.0187    0  1  0 .0  0.4355    0  2  0 .0  0.0467
ETA2    1  0  0 .75 0.0747R2   1  1  0 .75 0.0482R2   1  2  0 .75 0.0093R2
ETA2    2  0  0 .50 0.0078
M3      3  0  0  0  0  0 -.50    1
M3      0 -1  0 .50  .0564

2PO1 2   2.0 P1        -1.0 O1
SO1  2   1.0 S2        -1.0 O1
ST36 3   2.0 M2         1.0 N2        -2.0 S2
2NS2 2   2.0 N2        -1.0 S2
ST37 2   3.0 M2        -2.0 S2
ST1  3   2.0 N2         1.0 K2        -2.0 S2
ST2  4   1.0 M2         1.0 N2         1.0 K2        -2.0 S2
ST3  3   2.0 M2         1.0 S2        -2.0 K2
O2   1   2.0 O1
ST4  3   2.0 K2         1.0 N2        -2.0 S2
SNK2 3   1.0 S2         1.0 N2        -1.0 K2
OP2  2   1.0 O1         1.0 P1
MKS2 3   1.0 M2         1.0 K2        -1.0 S2
ST5  3   1.0 M2         2.0 K2        -2.0 S2
ST6  4   2.0 S2         1.0 N2        -1.0 M2        -1.0 K2
2SK2 2   2.0 S2        -1.0 K2
MSN2 3   1.0 M2         1.0 S2        -1.0 N2
ST7  4   2.0 K2         1.0 M2        -1.0 S2        -1.0 N2
2SM2 2   2.0 S2        -1.0 M2
ST38 3   2.0 M2         1.0 S2        -2.0 N2
SKM2 3   1.0 S2         1.0 K2        -1.0 M2
2SN2 2   2.0 S2        -1.0 N2
NO3  2   1.0 N2         1.0 O1
MO3  2   1.0 M2         1.0 O1
NK3  2   1.0 N2         1.0 K1
SO3  2   1.0 S2         1.0 O1
MK3  2   1.0 M2         1.0 K1
SP3  2   1.0 S2         1.0 P1
SK3  2   1.0 S2         1.0 K1
```

```
ST8  3   2.0 M2        1.0 N2        -1.0 S2
N4   1   2.0 N2
3MS4 2   3.0 M2       -1.0 S2
ST39 4   1.0 M2        1.0 S2         1.0 N2        -1.0 K2
MN4  2   1.0 M2        1.0 N2
ST40 3   2.0 M2        1.0 S2        -1.0 K2
ST9  4   1.0 M2        1.0 N2         1.0 K2        -1.0 S2
M4   1   2.0 M2
ST10 3   2.0 M2        1.0 K2        -1.0 S2
SN4  2   1.0 S2        1.0 N2
KN4  2   1.0 K2        1.0 N2
MS4  2   1.0 M2        1.0 S2
MK4  2   1.0 M2        1.0 K2
SL4  2   1.0 S2        1.0 L2
S4   1   2.0 S2
SK4  2   1.0 S2        1.0 K2
MNO5 3   1.0 M2        1.0 N2         1.0 O1
2MO5 2   2.0 M2        1.0 O1
3MP5 2   3.0 M2       -1.0 P1
MNK5 3   1.0 M2        1.0 N2         1.0 K1
2MP5 2   2.0 M2        1.0 P1
2MK5 2   2.0 M2        1.0 K1
MSK5 3   1.0 M2        1.0 S2         1.0 K1
3KM5 3   1.0 K2        1.0 K1         1.0 M2
2SK5 2   2.0 S2        1.0 K1
ST11 3   3.0 N2        1.0 K2        -1.0 S2
2NM6 2   2.0 N2        1.0 M2
ST12 4   2.0 N2        1.0 M2         1.0 K2        -1.0 S2
ST41 3   3.0 M2        1.0 S2        -1.0 K2
2MN6 2   2.0 M2        1.0 N2
ST13 4   2.0 M2        1.0 N2         1.0 K2        -1.0 S2
M6   1   3.0 M2
MSN6 3   1.0 M2        1.0 S2         1.0 N2
MKN6 3   1.0 M2        1.0 K2         1.0 N2
2MS6 2   2.0 M2        1.0 S2
2MK6 2   2.0 M2        1.0 K2
NSK6 3   1.0 N2        1.0 S2         1.0 K2
2SM6 2   2.0 S2        1.0 M2
MSK6 3   1.0 M2        1.0 S2         1.0 K2
ST42 3   2.0 M2        2.0 S2        -1.0 K2
S6   1   3.0 S2
ST14 3   2.0 M2        1.0 N2         1.0 O1
ST15 3   2.0 N2        1.0 M2         1.0 K1
M7   1   3.5 M2
ST16 3   2.0 M2        1.0 S2         1.0 O1
3MK7 2   3.0 M2        1.0 K1
ST17 4   1.0 M2        1.0 S2         1.0 K2         1.0 O1
ST18 2   2.0 M2        2.0 N2
3MN8 2   3.0 M2        1.0 N2
ST19 4   3.0 M2        1.0 N2         1.0 K2        -1.0 S2
M8   1   4.0 M2
ST20 3   2.0 M2        1.0 S2         1.0 N2
ST21 3   2.0 M2        1.0 N2         1.0 K2
3MS8 2   3.0 M2        1.0 S2
3MK8 2   3.0 M2        1.0 K2
ST22 4   1.0 M2        1.0 S2         1.0 N2         1.0 K2
ST23 2   2.0 M2        2.0 S2
```

```
ST24 3   2.0 M2           1.0 S2           1.0 K2
ST25 3   2.0 M2           2.0 N2           1.0 K1
ST26 3   3.0 M2           1.0 N2           1.0 K1
4MK9 2   4.0 M2           1.0 K1
ST27 3   3.0 M2           1.0 S2           1.0 K1
ST28 2   4.0 M2           1.0 N2
M10  1   5.0 M2
ST29 3   3.0 M2           1.0 N2           1.0 S2
ST30 2   4.0 M2           1.0 S2
ST31 4   2.0 M2           1.0 N2           1.0 S2        1.0 K2
ST32 2   3.0 M2           2.0 S2
ST33 3   4.0 M2           1.0 S2           1.0 K1
M12  1   6.0 M2
ST34 2   5.0 M2           1.0 S2
ST35 4   3.0 M2           1.0 N2           1.0 K2        1.0 S2
```

```
     7120 RACE ROCKS BC          PST 48 14  139 12
 1 Z0    .00000000    .945    .000   13.5  180.0  166.5  193.5
 5 2Q1   .03570635    .442   -.052    5.1  121.5  116.5  126.6
 6 Q1    .03721850    .461   -.065  175.1  236.8   61.8   51.9
 7 O1    .03873065   2.410   -.253  177.5  250.2   72.8   67.7
 8 NO1   .04026859    .494   -.112    6.8   92.2   85.5   99.0
 9 P1    .04155259   1.272    .232  178.7  270.5   91.8   89.3 INF FR K1
10 K1    .04178075   5.043   -.221     .9   88.2   87.3   89.1
11 J1    .04329290    .142    .103   22.9  123.9  101.0  146.8
12 OO1   .04483084    .455    .125  125.7  334.4  208.8  100.1
13 UPS1  .04634299    .180    .070  159.3   27.1  227.8  186.4
16 N2    .07899925   1.369   -.035  173.8  225.2   51.4   39.0
17 M2    .08051140   6.980   -.295  178.3  249.2   70.9   67.6
19 S2    .08333333   2.278   -.148    5.9   90.6   84.7   96.4
20 K2    .08356149    .462   -.054  164.9  264.4   99.5   69.2 INF FR S2
21 ETA2  .08507364    .157   -.024   76.9   62.8  345.9  139.7
```

```
001007076 031007076 EXTR       0.25
001007076 005007076 EQUI       1.0
001007076 031007076 EQUI  COMP 1.0
```

Appendix 7.5 Tidal Currents Prediction Results Arising from the Input Data of Appendix 7.4.

(i) File reference number 10 output: the hourly current magnitudes for the period 0100 PST July 1, 1976 to 2400 PST July 5, 1976, followed by the north/south hourly current components for the period 0100 PST July 1, 1976 to 2400 PST July 31, 1976.

```
STN 1ST HR   DATE     1      2      3      4      5      6      7      8   DT HRS

7120  1.00  1 776    4.79   1.99   0.70   2.21   2.09   0.77   3.41   7.22  1.00
7120  9.00  1 776   10.55  12.39  12.08   9.46   4.94   1.02   6.27  10.55  1.00
7120 17.00  1 776   12.74  12.44   9.83   5.61   1.05   3.79   6.73   7.76  1.00
7120  1.00  2 776    6.86   4.52   1.57   1.04   2.45   2.23   0.78   3.04  1.00
7120  9.00  2 776    6.46   9.28  10.62   9.95   7.23   2.94   2.21   6.87  1.00
7120 17.00  2 776   10.22  11.51  10.51   7.48   3.19   1.77   5.61   8.06  1.00
7120  1.00  3 776    8.61   7.33   4.74   1.65   1.03   2.56   2.56   1.18  1.00
7120  9.00  3 776    1.91   4.73   7.05   8.06   7.33   4.87   1.15   3.12  1.00
7120 17.00  3 776    6.89   9.34   9.88   8.36   5.10   1.01   3.81   7.44  1.00
7120  1.00  4 776    9.57   9.84   8.32   5.52   2.21   0.79   2.75   3.29  1.00
7120  9.00  4 776    2.43   0.89   2.22   4.14   5.09   4.63   2.74   0.21  1.00
7120 17.00  4 776    3.53   6.41   8.11   8.10   6.27   2.91   1.54   5.79  1.00
7120  1.00  5 776    9.28  11.27  11.39   9.70   6.63   2.92   0.64   3.28  1.00
7120  9.00  5 776    4.58   4.42   3.07   1.19   1.15   2.29   2.39   1.27  1.00
7120 17.00  5 776    0.82   3.32   5.52   6.72   6.41   4.45   1.10   3.25  1.00


STN 1ST HR   DATE     1      2      3      4      5      6      7      8   DT HRS

7120  1.00  1 776   -0.15  -0.17  -0.30  -0.48  -0.66  -0.77  -0.76  -0.62  1.00
7120  9.00  1 776   -0.35   0.00   0.34   0.61   0.75   0.71   0.50   0.17  1.00
7120 17.00  1 776   -0.20  -0.55  -0.80  -0.89  -0.83  -0.64  -0.38  -0.14  1.00
7120  1.00  2 776    0.03   0.07  -0.02  -0.21  -0.44  -0.65  -0.76  -0.74  1.00
7120  9.00  2 776   -0.56  -0.28   0.06   0.36   0.55   0.59   0.45   0.17  1.00
7120 17.00  2 776   -0.20  -0.56  -0.84  -0.96  -0.91  -0.70  -0.38  -0.04  1.00
7120  1.00  3 776    0.24   0.39   0.37   0.20  -0.08  -0.39  -0.64  -0.78  1.00
7120  9.00  3 776   -0.75  -0.58  -0.31  -0.01   0.23   0.35   0.31   0.10  1.00
7120 17.00  3 776   -0.21  -0.56  -0.85  -1.00  -0.97  -0.75  -0.40   0.01  1.00
7120  1.00  4 776    0.39   0.65   0.73   0.61   0.33  -0.05  -0.43  -0.73  1.00
7120  9.00  4 776   -0.88  -0.85  -0.68  -0.41  -0.14   0.06   0.12   0.03  1.00
7120 17.00  4 776   -0.19  -0.49  -0.76  -0.94  -0.95  -0.78  -0.44  -0.01  1.00
7120  1.00  5 776    0.42   0.76   0.93   0.89   0.65   0.25  -0.20  -0.61  1.00
7120  9.00  5 776   -0.91  -1.03  -0.97  -0.76  -0.49  -0.23  -0.06  -0.03  1.00
7120 17.00  5 776   -0.13  -0.34  -0.57  -0.76  -0.83  -0.73  -0.48  -0.10  1.00
7120  1.00  6 776    0.32   0.68   0.91   0.95   0.77   0.43  -0.02  -0.48  1.00
7120  9.00  6 776   -0.85  -1.07  -1.11  -0.98  -0.74  -0.45  -0.21  -0.06  1.00
7120 17.00  6 776   -0.04  -0.15  -0.32  -0.50  -0.61  -0.60  -0.46  -0.20  1.00
7120  1.00  7 776    0.12   0.44   0.67   0.76   0.67   0.42   0.05  -0.35  1.00
7120  9.00  7 776   -0.71  -0.97  -1.07  -1.01  -0.82  -0.56  -0.29  -0.09  1.00
7120 17.00  7 776    0.02   0.01  -0.08  -0.22  -0.35  -0.42  -0.39  -0.28  1.00
7120  1.00  8 776   -0.09   0.11   0.29   0.39   0.37   0.24   0.01  -0.26  1.00
7120  9.00  8 776   -0.52  -0.72  -0.83  -0.82  -0.70  -0.52  -0.31  -0.12  1.00
7120 17.00  8 776    0.01   0.06   0.04  -0.04  -0.14  -0.24  -0.30  -0.31  1.00
7120  1.00  9 776   -0.27  -0.20  -0.13  -0.07  -0.04  -0.06  -0.13  -0.22  1.00
7120  9.00  9 776   -0.31  -0.39  -0.43  -0.43  -0.39  -0.32  -0.23  -0.14  1.00
7120 17.00  9 776   -0.07  -0.02  -0.01  -0.03  -0.07  -0.14  -0.21  -0.29  1.00
```

```
7120  1.00 29 776  -0.13  -0.12  -0.19  -0.28  -0.36  -0.37  -0.30  -0.13  1.00
7120  9.00 29 776   0.10   0.34   0.52   0.59   0.52   0.31  -0.02  -0.39  1.00
7120 17.00 29 776  -0.74  -1.00  -1.11  -1.05  -0.85  -0.55  -0.22   0.05  1.00
7120  1.00 30 776   0.21   0.23   0.13  -0.06  -0.26  -0.42  -0.48  -0.41  1.00
7120  9.00 30 776  -0.23   0.00   0.23   0.38   0.40   0.25  -0.03  -0.40  1.00
7120 17.00 30 776  -0.76  -1.05  -1.17  -1.11  -0.86  -0.49  -0.06   0.32  1.00
7120  1.00 31 776   0.57   0.65   0.53   0.28  -0.06  -0.38  -0.60  -0.68  1.00
7120  9.00 31 776  -0.60  -0.39  -0.14   0.09   0.20   0.16  -0.04  -0.36  1.00
7120 17.00 31 776  -0.72  -1.03  -1.19  -1.15  -0.90  -0.49   0.01   0.49  1.00
```

(ii) File reference number 11 output: the hourly current directions for the period 0100 PST
July 1, 1976 to 2400 PST July 5, 1976 followed by the east/west hourly current components
for the period 0100 PST July 1, 1976 to 2400 PST July 31, 1976.

```
STN 1ST HR   DATE     1       2       3       4       5       6       7       8  DT HRS

7120  1.00  1 776 181.74 184.94 334.95 347.49 341.67 271.30 192.92 184.90  1.00
7120  9.00  1 776 181.89 180.02 178.38 176.29 171.31  43.97   4.58   0.94  1.00
7120 17.00  1 776 359.08 357.45 355.36 350.86 308.22 189.68 183.27 181.02  1.00
7120  1.00  2 776 179.76 179.08 180.56 348.58 349.62 343.05 283.40 193.98  1.00
7120  9.00  2 776 185.00 181.71 179.69 177.93 175.60 168.44  11.75   1.38  1.00
7120 17.00  2 776 358.87 357.19 355.42 352.60 343.41 203.20 183.87 180.27  1.00
7120  1.00  3 776 178.40 176.98 175.52 173.10 355.62 351.34 345.49 318.93  1.00
7120  9.00  3 776 203.23 187.09 182.52 180.07 178.17 175.86 164.58   1.87  1.00
7120 17.00  3 776 358.24 356.57 355.09 353.14 349.06 311.61 186.04 179.90  1.00
7120  1.00  4 776 177.65 176.20 174.98 173.66 171.47 356.39 350.99 347.23  1.00
7120  9.00  4 776 338.86 287.63 197.81 185.75 181.60 179.32 177.50   7.89  1.00
7120 17.00  4 776 356.85 355.65 354.60 353.34 351.25 344.47 196.80 180.12  1.00
7120  1.00  5 776 177.39 176.11 175.30 174.73 174.41 175.02 341.82 349.21  1.00
7120  9.00  5 776 348.56 346.55 341.67 320.00 205.39 185.82 181.48 181.19  1.00
7120 17.00  5 776 350.89 354.19 354.03 353.48 352.56 350.51 334.47 181.73  1.00


STN 1ST HR   DATE     1       2       3       4       5       6       7       8  DT HRS

7120  1.00  1 776  -4.78  -1.99   0.63   2.16   1.98   0.02  -3.32  -7.19  1.00
7120  9.00  1 776 -10.55 -12.39 -12.08  -9.44  -4.88   0.73   6.25  10.54  1.00
7120 17.00  1 776  12.73  12.43   9.80   5.54   0.65  -3.74  -6.72  -7.76  1.00
7120  1.00  2 776  -6.86  -4.52  -1.57   1.02   2.41   2.13   0.18  -2.95  1.00
7120  9.00  2 776  -6.43  -9.28 -10.62  -9.94  -7.21  -2.88   2.17   6.87  1.00
7120 17.00  2 776  10.21  11.50  10.47   7.42   3.05  -1.62  -5.60  -8.06  1.00
7120  1.00  3 776  -8.61  -7.32  -4.73  -1.64   1.03   2.53   2.48   0.89  1.00
7120  9.00  3 776  -1.76  -4.69  -7.04  -8.06  -7.33  -4.86  -1.11   3.12  1.00
7120 17.00  3 776   6.89   9.32   9.84   8.30   5.01   0.67  -3.79  -7.44  1.00
7120  1.00  4 776  -9.56  -9.81  -8.29  -5.49  -2.18   0.78   2.71   3.21  1.00
7120  9.00  4 776   2.26   0.27  -2.11  -4.12  -5.09  -4.63  -2.74   0.21  1.00
7120 17.00  4 776   3.52   6.40   8.07   8.05   6.19   2.81  -1.47  -5.79  1.00
7120  1.00  5 776  -9.27 -11.25 -11.35  -9.66  -6.60  -2.91   0.61   3.23  1.00
7120  9.00  5 776   4.49   4.30   2.92   0.91  -1.03  -2.28  -2.39  -1.27  1.00
7120 17.00  5 776   0.81   3.31   5.49   6.67   6.36   4.39   1.00  -3.25  1.00
7120  1.00  6 776  -7.53 -11.01 -12.96 -12.99 -11.09  -7.66  -3.39   0.85  1.00
7120  9.00  6 776   4.28   6.33   6.77   5.76   3.80   1.57  -0.23  -1.09  1.00
7120 17.00  6 776  -0.77   0.59   2.51   4.33   5.34   4.99   3.06  -0.31  1.00
7120  1.00  7 776  -4.58  -8.94 -12.49 -14.47 -14.39 -12.18  -8.24  -3.28  1.00
7120  9.00  7 776   1.75   5.92   8.55   9.30   8.28   5.98   3.15   0.61  1.00
7120 17.00  7 776  -0.98  -1.29  -0.36   1.37   3.18   4.31   4.11   2.27  1.00
7120  1.00  8 776  -1.11  -5.48  -9.98 -13.65 -15.60 -15.30 -12.65  -8.07  1.00
7120  9.00  8 776  -2.41   3.29   7.97  10.81  11.45  10.00   7.04   3.45  1.00
7120 17.00  8 776   0.19  -1.95  -2.55  -1.65   0.24   2.34   3.75   3.73  1.00
7120  1.00  9 776   1.92  -1.56  -6.11 -10.78 -14.49 -16.28 -15.58 -12.36  1.00
7120  9.00  9 776  -7.11  -0.83   5.30  10.11  12.75  12.86  10.66   6.89  1.00
7120 17.00  9 776   2.58  -1.18  -3.53  -4.04  -2.83  -0.51   1.98   3.65  1.00
7120  1.00 10 776   3.70   1.77  -1.94  -6.73 -11.50 -15.09 -16.51 -15.24  1.00
7120  9.00 10 776 -11.33  -5.46   1.26   7.49  12.04  14.07  13.36  10.29  1.00
7120 17.00 10 776   5.75   0.94  -2.98  -5.15  -5.24  -3.50  -0.70   2.10  1.00
7120  1.00 11 776   3.84   3.72   1.48  -2.55  -7.52 -12.23 -15.46 -16.28  1.00
7120  9.00 11 776 -14.27  -9.66  -3.30   3.56   9.54  13.45  14.60  12.94  1.00
7120 17.00 11 776   9.04   3.97  -0.99  -4.69  -6.36  -5.83  -3.53  -0.37  1.00
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7120  1.00 12 776   2.50   4.02   3.50   0.83  -3.49  -8.48 -12.87 -15.48  1.00
7120  9.00 12 776 -15.49 -12.67  -7.46  -0.86   5.79  11.14  14.13  14.25  1.00
7120 17.00 12 776  11.67   7.17   1.90  -2.84  -5.99  -6.96  -5.77  -3.03  1.00
7120  1.00 13 776   0.24   2.89   3.95   2.91  -0.17  -4.61  -9.34 -13.12  1.00
7120  9.00 13 776 -14.88 -13.99 -10.46  -4.90   1.58   7.64  12.02  13.90  1.00
7120 17.00 13 776  12.99   9.67   4.86  -0.24  -4.42  -6.80  -7.00  -5.25  1.00
7120  1.00 14 776  -2.29   0.84   3.06   3.56   2.04  -1.25  -5.53  -9.69  1.00
7120  9.00 14 776 -12.62 -13.43 -11.74  -7.75  -2.22   3.71   8.79  11.98  1.00
7120 17.00 14 776  12.68  10.86   7.07   2.30  -2.30  -5.71  -7.23  -6.72  1.00
7120  1.00 15 776  -4.57  -1.59   1.22   2.94   2.97   1.18  -2.02  -5.81  1.00
7120  9.00 15 776  -9.18 -11.16 -11.12  -8.88  -4.82   0.23   5.21   9.05  1.00
7120 17.00 15 776  10.95  10.56   8.07   4.13  -0.30  -4.20  -6.72  -7.43  1.00
7120  1.00 16 776  -6.36  -3.99  -1.13   1.32   2.64   2.40   0.64  -2.15  1.00
7120  9.00 16 776  -5.23  -7.70  -8.82  -8.17  -5.77  -2.08   2.11   5.89  1.00
7120 17.00 16 776   8.39   9.09   7.85   4.98   1.17  -2.71  -5.81  -7.51  1.00
7120  1.00 17 776  -7.55  -6.10  -3.67  -0.99   1.19   2.30   2.08   0.65  1.00
7120  9.00 17 776  -1.53  -3.80  -5.46  -5.96  -5.07  -2.91   0.08   3.20  1.00
7120 17.00 17 776   5.72   7.02   6.77   4.99   2.04  -1.44  -4.70  -7.07  1.00
7120  1.00 18 776  -8.12  -7.70  -6.05  -3.63  -1.09   0.97   2.12   2.16  1.00
7120  9.00 18 776   1.24  -0.26  -1.83  -2.91  -3.14  -2.36  -0.72   1.41  1.00
7120 17.00 18 776   3.47   4.92   5.32   4.47   2.46  -0.36  -3.43  -6.15  1.00
7120  1.00 19 776  -7.99  -8.61  -7.95  -6.21  -3.81  -1.28   0.87   2.25  1.00
7120  9.00 19 776   2.71   2.33   1.38   0.27  -0.59  -0.88  -0.48   0.52  1.00
7120 17.00 19 776   1.84   3.07   3.79   3.68   2.58   0.58  -2.02  -4.76  1.00
7120  1.00 20 776  -7.14  -8.68  -9.10  -8.31  -6.49  -4.00  -1.30   1.12  1.00
7120  9.00 20 776   2.87   3.74   3.74   3.07   2.06   1.08   0.45   0.35  1.00
7120 17.00 20 776   0.76   1.51   2.26   2.66   2.38   1.28  -0.61  -3.05  1.00
7120  1.00 21 776  -5.63  -7.87  -9.31  -9.63  -8.71  -6.68  -3.90  -0.83  1.00
7120  9.00 21 776   1.98   4.09   5.22   5.30   4.52   3.22   1.81   0.69  1.00
7120 17.00 21 776   0.12   0.15   0.66   1.31   1.73   1.55   0.55  -1.28  1.00
7120  1.00 22 776  -3.72  -6.34  -8.61 -10.02 -10.19  -8.98  -6.51  -3.21  1.00
7120  9.00 22 776   0.37   3.59   5.91   6.99   6.78   5.49   3.56   1.54  1.00
7120 17.00 22 776  -0.08  -0.96  -1.01  -0.40   0.48   1.15   1.14   0.19  1.00
7120  1.00 23 776  -1.74  -4.37  -7.18  -9.54 -10.85 -10.68  -8.91  -5.75  1.00
7120  9.00 23 776  -1.75   2.38   5.88   8.13   8.79   7.88   5.76   3.02  1.00
7120 17.00 23 776   0.35  -1.62  -2.53  -2.34  -1.32  -0.01   0.96   1.06  1.00
7120  1.00 24 776  -0.03  -2.25  -5.23  -8.29 -10.68 -11.70 -10.93  -8.35  1.00
7120  9.00 24 776  -4.32   0.44   5.01   8.54  10.38  10.25   8.34   5.21  1.00
7120 17.00 24 776   1.66  -1.47  -3.51  -4.12  -3.38  -1.77   0.01   1.19  1.00
7120  1.00 25 776   1.19  -0.25  -2.97  -6.39  -9.68 -11.93 -12.43 -10.83  1.00
7120  9.00 25 776  -7.26  -2.31   3.09   7.86  11.08  12.16  10.98   7.94  1.00
7120 17.00 25 776   3.85  -0.30  -3.57  -5.30  -5.28  -3.81  -1.54   0.61  1.00
7120  1.00 26 776   1.80   1.45  -0.58  -3.91  -7.77 -11.15 -13.07 -12.84  1.00
7120  9.00 26 776 -10.27  -5.70   0.03   5.80  10.42  12.99  13.05  10.71  1.00
7120 17.00 26 776   6.63   1.83  -2.55  -5.54  -6.61  -5.74  -3.45  -0.63  1.00
7120  1.00 27 776   1.69   2.63   1.71  -1.02  -4.96  -9.14 -12.42 -13.82  1.00
7120  9.00 27 776 -12.75  -9.22  -3.81   2.41   8.17  12.27  13.90  12.82  1.00
7120 17.00 27 776   9.39   4.52  -0.61  -4.79  -7.14  -7.30  -5.48  -2.44  1.00
7120  1.00 28 776   0.75   3.00   3.49   1.90  -1.51  -5.92 -10.19 -13.15  1.00
7120  9.00 28 776 -13.87 -11.96  -7.63  -1.71   4.58   9.90  13.15  13.67  1.00
7120 17.00 28 776  11.47   7.16   1.84  -3.20  -6.83  -8.29  -7.44  -4.75  1.00
7120  1.00 29 776  -1.15   2.19   4.19   4.16   1.97  -1.90  -6.48 -10.55  1.00
7120  9.00 29 776 -12.98 -12.98 -10.35  -5.55   0.45   6.35  10.86  13.00  1.00
7120 17.00 29 776  12.37   9.20   4.31  -1.10  -5.75  -8.59  -9.10  -7.34  1.00
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7120   1.00 30 776  -3.96  -0.03   3.28   4.98   4.55   2.02  -1.95  -6.34  1.00
7120   9.00 30 776  -9.93 -11.70 -11.06  -8.01  -3.14   2.47   7.56  10.97  1.00
7120  17.00 30 776  11.92  10.23   6.34   1.18  -4.02  -8.08 -10.11  -9.76  1.00
7120   1.00 31 776  -7.30  -3.49   0.59   3.81   5.33   4.75   2.27  -1.42  1.00
7120   9.00 31 776  -5.28  -8.22  -9.38  -8.34  -5.24  -0.76   4.06   8.06  1.00
7120  17.00 31 776  10.26  10.11   7.60   3.30  -1.84  -6.64 -10.06 -11.38  1.00
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(iii) File reference number 12 output: the times, magnitudes and directions of all maximum or minimum current values for the period 0100 PST July 1, 1976 to 2400 PST July 31, 1976.

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 STN  DATE  TIME  MAG    DIR  TIME  MAG    DIR  TIME  MAG    DIR  TIME  MAG    DIR

7120  1 776   243  0.25 268.7   426  2.38 346.3   600  0.77 269.0 1022 12.56 179.4
7120  1 776  1353  0.72  85.6  1723 12.92 358.4  2109  0.81 265.0
7120  2 776     1  7.75 181.0   334  0.12 278.7   522  2.57 348.2   704  0.76 269.0
7120  2 776  1111 10.65 179.4  1435  0.53  83.0  1804 11.52 357.1  2139  0.79 264.6
7120  3 776    47  8.66 178.7   435  0.05  59.9   630  2.75 349.0   822  0.79 267.9
7120  3 776  1206  8.06 179.9  1516  0.27  79.9  1846  9.93 355.4  2209  0.71 263.0
7120  4 776   138  9.96 176.7   543  0.07  64.8   752  3.30 347.8  1008  0.84 266.0
7120  4 776  1312  5.11 181.1  1556  0.05  46.1  1930  8.33 354.0  2241  0.57 262.3
7120  5 776   234 11.58 175.6   649  0.12 275.2   923  4.68 348.0  1229  0.64 259.9
7120  5 776  1435  2.50 182.7  1639  0.08 278.1  2019  6.79 353.2  2315  0.39 260.5
7120  6 776   331 13.26 175.9   747  0.39 268.5  1046  6.91 350.7  1452  0.24 258.4
7120  6 776  1613  1.12 182.3  1738  0.10 276.0  2117  5.43 353.4  2355  0.23 258.1
7120  7 776   428 14.72 177.1   838  0.59 269.2  1153  9.36 353.7  1618  0.05 248.6
7120  7 776  1743  1.34 179.0  1914  0.11 270.5  2223  4.43 354.6
7120  8 776    43  0.15 255.8   522 15.77 178.8   924  0.62 272.8  1247 11.53 356.3
7120  8 776  1704  0.03 151.3  1853  2.55 179.0  2053  0.13 273.0  2330  3.96 355.5
7120  9 776   136  0.23 262.2   614 16.35 180.3  1008  0.40 277.2  1332 13.13 358.4
7120  9 776  1739  0.05 227.0  1946  4.09 180.3  2212  0.15 270.3
7120 10 776    32  3.93 355.1   232  0.46 267.9   702 16.51 181.2  1049  0.06  21.7
7120 10 776  1414 14.15 360.0  1813  0.22 261.8  2032  5.45 181.8  2314  0.18 274.9
7120 11 776   128  4.07 353.8   324  0.74 269.1   748 16.35 181.4  1129  0.52  84.8
7120 11 776  1454 14.61   0.9  1847  0.50 266.1  2115  6.44 182.9
7120 12 776     7  0.17 276.6   217  4.13 352.7   412  0.96 271.1   830 15.84 181.2
7120 12 776  1207  0.94  87.5  1532 14.55   1.0  1922  0.79 266.6  2155  6.98 183.3
7120 13 776    55  0.08 286.0   303  3.99 352.1   457  1.08 271.7   911 14.91 180.9
7120 13 776  1245  1.15  88.0  1610 13.94   0.4  1957  1.00 267.3  2235  7.20 182.6
7120 14 776   143  0.10  80.6   347  3.65 352.0   539  1.12 272.4   950 13.47 180.7
7120 14 776  1322  1.12  87.7  1646 12.76 359.3  2029  1.07 266.1  2314  7.29 180.7
7120 15 776   233  0.29  80.6   433  3.22 352.0   623  1.10 273.0  1029 11.42 180.8
7120 15 776  1357  0.88  86.5  1720 11.09 357.8  2057  1.01 264.2  2353  7.45 178.4
7120 16 776   327  0.41  80.1   524  2.77 351.0   714  1.05 272.3  1109  8.85 181.3
7120 16 776  1430  0.52  84.2  1752  9.13 355.9  2119  0.89 263.6
7120 17 776    32  7.75 176.3   426  0.37  76.0   624  2.43 348.2   818  0.98 271.6
7120 17 776  1152  5.98 182.5  1459  0.14  78.0  1822  7.16 353.7  2137  0.74 263.8
7120 18 776   113  8.17 175.1   530  0.19  70.2   736  2.35 345.1   952  0.83 266.2
7120 18 776  1243  3.19 185.6  1521  0.18 269.4  1851  5.40 351.2  2154  0.57 261.0
7120 19 776   159  8.65 175.0   634  0.04 300.2   902  2.79 346.7  1220  0.53 262.8
7120 19 776  1354  0.95 203.6  1531  0.40 268.2  1923  3.93 348.9  2215  0.37 259.8
7120 20 776   251  9.13 175.8   730  0.18 268.7  1030  3.89 351.5  1533  0.63 301.2
7120 20 776  2007  2.74 347.3  2243  0.15 256.7
7120 21 776   345  9.68 177.2   817  0.24 271.7  1135  5.42 354.6  1727  0.67 275.4
7120 21 776  2113  1.79 349.2  2321  0.06  94.6
7120 22 776   437 10.29 178.6   854  0.23 273.8  1220  7.07 356.2  1656  0.71 269.2
7120 22 776  1830  1.27 211.0  2032  0.41 280.4  2230  1.25 357.1
7120 23 776     7  0.17  88.4   524 10.97 179.5   925  0.17 279.5  1254  8.81 357.3
7120 23 776  1709  0.75 268.2  1917  2.66 193.7  2202  0.20 280.3  2336  1.16   1.6
7120 24 776    59  0.15  92.2   605 11.71 179.8   955  0.04 339.3  1326 10.57 358.2
7120 24 776  1730  0.79 267.7  1954  4.17 188.9  2300  0.20 281.4
7120 25 776    30  1.36 358.3   153  0.02 141.1   645 12.50 179.7  1026  0.21  74.6
7120 25 776  1358 12.15 358.9  1755  0.83 267.5  2029  5.54 187.3  2342  0.30 276.7
7120 26 776   118  1.88 354.2   247  0.16 262.3   725 13.26 179.3  1100  0.43  82.3
7120 26 776  1431 13.34 359.3  1823  0.89 267.8  2101  6.66 186.6
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7120 27 776   14 0.38 273.5  201  2.65 353.3  341 0.29 265.2  805 13.83 179.0
7120 27 776 1137 0.60  85.5 1506 13.92 359.3 1852 0.97 268.9 2133  7.54 185.6
7120 28 776   45 0.34 272.8  245  3.58 354.8  436 0.35 263.6  847 13.93 178.8
7120 28 776 1216 0.64  85.1 1541 13.82 358.8 1921 1.03 267.6 2207  8.32 184.1
7120 29 776  119 0.12 289.0  329  4.45 357.0  533 0.38 267.5  930 13.32 179.0
7120 29 776 1256 0.54  83.5 1617 13.12 357.8 1948 1.08 265.9 2242  9.20 182.0
7120 30 776  201 0.23  81.9  418  5.09 358.6  632 0.47 267.5 1015 11.78 179.7
7120 30 776 1334 0.34  79.5 1652 11.97 356.6 2014 1.07 265.0 2321 10.25 179.5
7120 31 776  251 0.56  84.0  514  5.38 358.5  738 0.67 267.5 1102  9.39 180.8
7120 31 776 1409 0.14  71.2 1727 10.54 355.3 2039 1.01 265.5
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