ASF Chartlets: A Picture Is Worth a 1000 Numbers

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Abstract

After five years of producing chartlets that show the Additional Secondary Factor (ASF) only where it was actually observed in the field, the Canadian Hydrographic Service (CHS) is in the final preparation stages of publishing the ASF corrections in a contoured map format throughout most Canadian Loran-C waters. The method of calculating the theoretical ASF (based on certain electrical properties) and then the incorporation of 100,000 data points of observed ASF data will be discussed as well as the visual presentation in map form. The impact and usefulness of such a product will also be discussed.

Background

During 1980 and 1981, the Radio Technical Commission for Marine Services' (RTCM) Special Committee No. 75 met to discuss the minimum performance standards for Loran-C coordinate converters. One of the most significant realizations of those meetings was the need for information about the Additional Secondary Factor (ASF) of each Loran-C rate. The Defense Mapping Agency (DMA) undertook to prepare booklets of ASF predictions throughout the coastal waters of the United States. Although Canada was not bound by any recommendation of the RTCM, the Canadian Hydrographic Service felt that providing similar information to Canadian mariners was necessary. However, after discussions within CHS and with several ship's captains, we considered that a map presentation was more useful than a digital one. Our reasoning was based on such points as:

- our publishing of Decca Fixed Errors (which are roughly akin to Loran-C ASF) in the form of correction tables was poorly received by the maritime public to the extent that they were not used,
- the Decca Company's publication of the same Decca Fixed Errors in map form was far more readable,

- condensation of information (particularly since we intended to go 200 miles off-shore),
- better portrayal of areas of rapid change versus areas of no change, and
- mariners probably have a better idea of where they are on a map than in a matrix of tabulated values.

One consideration was that we did not have a sophisticated ASF prediction package such as our colleagues at DMA had, but to more than offset that disadvantage, we had extensive data collection of observed ASF. By that time, the Loran-C public was well aware of the pitfalls of using only ASF predictions as was demonstrated by the early large scale charts near Los Angeles. We now know that phase recovery is underestimated off a rocky, low conductivity coastline and that the models also assume geometrical straight line propagation rather than wave propagation. This is particularly serious in the case of a transmission path grazing a coastline.

We had already begun making chartlets showing the actual observed ASF in the areas that we had surveyed, for internal inventory purposes; therefore, it was a relatively easy matter to improve the cartographic quality of these diagrams for publication. Over the past five years we have continued to add the new survey data to these chartlets and to publish them in a relatively timely manner.

Nevertheless, we felt that observed ASF chartlets were only an interim measure until we could provide a contoured format for the ASF correction. Now is the time to get away from interim measures and do the job properly!

Great Lakes

In the Great Lakes, we have extensive ASF observations throughout Lake Ontario, Erie, Huron and Georgian Bay, including the North Channel, and adequate information in Lake Superior. We also have National Ocean Survey and/or US Coast Guard data provided by DMA in Lake Ontario, Erie, St. Clair, Huron, Michigan and some very sparse data in Lake Superior. We were able to fit mathematical polynomials to this relatively dense data and present them in a contoured format on the chartlets. The preparation of the chartlets brought forth a problem that had been identified earlier in the 9960-Z ASF in Lake Huron near Point Clark where the American and Canadian data sets differed by about 1 microsec. That prompted a resurvey of the area in 1988 which has not completely resolved the problem.

Atlantic Coast & Gulf of St. Lawrence

Our data base of observed ASF in Atlantic Canada is probably our most extensive since this is a vast area; we have surveyed a great deal over a nine year period, including detailed observations in some test areas for special studies. Our surveys include the whole coast of Nova Scotia (including Sable I.), New Brunswick, Prince Edward Island, the Gaspé Peninsula, St. Lawrence River estuary, the Magdalen Islands, the Strait of Belle Isle, and selected areas of the coasts of Newfoundland. Along with this data, we also have GPS positioned data on Georges Bank and Doppler satellite positioned data scattered throughout the Scotia Shelf and Gulf of St. Lawrence. We have also received US Coast Guard data from New York City to Grand Manan.

In support of our off-shore multi-discipline surveys by using rho-rho Loran-C/Doppler Satellite/Doppler Sonar Log fixing, we developed an on-line Millington's Method ASF computation using the CIA digital coastline. We brought this ASF computation program into the office and improved it. We realize that there are perhaps more sophisticated ASF prediction techniques, however by using this method we have found that there is usually a systematic residual difference, around 0.5 microsec., between the computed and observed ASF that is almost a constant over a large area. We are exploiting the fact that the shape of the ASF surface is roughly correct but that the surface must be tacked down with groups of real ASF data. Because of this relationship between computed and observed ASF, we have developed a routine for applying this residual difference to the computed ASF values and to use these adjusted values as input to a lattice drawing routine or for contouring the ASF chartlets. Subjective judgment and experience are necessary in the application of the expected differences in areas where there are no observed data. The geographical variation of conductivity, the varying amount of land, and the wrong estimate of the conductivity cause only slowly varying residual differences which can be easily handled. What causes us more trouble is; 1) the fact that our prediction model underestimates phase recovery within a few wavelengths of a rocky coast, and 2) the fact that the model treats propagation in a straight line rather than wave motion which bends around corners.

Pacific Coast

Our data includes detailed surveys in Georgia, Juan de Fuca and Hecate Straits and the approaches to Prince Rupert as well as off-shore data based on Doppler satellite fixing. We also received from DMA detailed surveys in Juan de Fuca Strait and off-shore data presumably based on Doppler satellite fixing. During the off-shore surveys, using the same rho-rho Loran-C/Doppler satellite positioning system, it was found that the Millington's Method ASF computation routine sometimes gave unreliable answers because of the many fiords and islands. Also the topography contributed to significant delays that were not accounted for in the ASF computations. By using only the observed ASF data, we have been able to use the same methodology as in the Great Lakes; namely, the use of polymonials to express the ASF. For satisfactory results, the data upon which the polynomial is based must be adequately distributed over the region of interest and may not be adequate for prediction in areas with no surveys and is definitely not valid close in-shore where the ASF changes rapidly due to phase recovery. There is also the inability of the chartlets to show all this detail close to shore. Therefore, some areas have been identified with the note,"Insufficient data" and have also been ear-marked for surveys.

Publication

The observed ASF diagrams have been published in a Canadian Coast Guard publication "Radio Aids to Marine Navigation" which is required on board ships under the Charts and Publications Regulations promulagated under the Canada Shipping Act. The following contoured style ASF chartlets will supercede the observed ASF diagrams in Radio Aids to Marine Navigation:

Loran-C Rates:	Area:
5930 X & Y	West end of Nova Scotia,
5930 X & Y	South of Sable Island,
5930 X, Y & Z	Halifax to SW Newfoundland and to PEI,
5930 X, Y & Z	West part of Gulf of St. Lawrence,
5930 X, Y & Z	East part of Gulf of St. Lawrence,
5930 X, Y & Z	Southeast of Newfoundland,
5930 X, Y & Z	East of Newfoundland,
5990 X, Y & Z	Juan de Fuca and Georgia Straits,
5990 X, Y & Z	West of Vancouver Island,
5990 X, Y & Z	Queen Charlotte Sound,
5990 X, Y & Z	Hecate Strait & Dixon Entrance,
7930 W	Halifax to SW Newfoundland and to PEI,
7930 W	West part of Gulf of St. Lawrence,
7930 W	East part of Gulf of St. Lawrence,
7930 W & X	Southeast of Newfoundland,
7930 W & X	East of Newfoundland,
7930 W & X	Northeast of Newfoundland,
8970 X & Y	Lake Superior,
8970 X & Y	Lakes Huron & Erie and Georgian Bay,

9960 W & X	West end of Nova Scotia,
9960 W & X	West part of Gulf of St. Lawrence,
9960 W, X, Y & Z	Lake Huron, Erie & Ontario and Georgian Bay.

At present, only a few of the chartlets have been prepared and are available for constructive criticism, which we would be glad to receive. We have learned that it is best to have prototypes available for such a purpose since we do not necessarily think of all aspects on the first drafting.

Technical Concerns

We, the authors, are very concerned with the derivation of ASF and the use of it. We are looking at Loran-C as providing a positioning capability that will complement GPS - which we believe it is capable of doing in many areas. We also foresee that at least some of the future user public will have Electronic Chart Displays and that there will be a Loran-C coordinate converter as part of the positioning system. It therefore follows that ASF data is necessary to calculate the correct position. Consequently, accurate ASF is needed to produce a position without systematic biases that can be used in conjunction with GPS data. Therefore, such matters as the knowledge of the horizontal datum of the survey , error-free survey data, the integrity of the receivers used, the Loran-C transmitters and controlling TD's being correct have to be confirmed.

We are also concerned that the prediction techniques used by CHS and by others are not sufficiently realistic. The conductivities are selected very subjectively, topography is neglected, and dispersion, because there is a faster propagation path than the geodesic line, is never considered. Yet they all degrade the accuracy unless they are thoroughly mapped and appreciated. Even after an accurate position is determined, that position may be very wrong when applied to certain charts - at least in Canada and possibly elsewhere too. This is because a number of CHS charts are based on very old surveys and the geographic grid on those charts is not consistent with any geographic grid used today - be it North American Datum of 1927 or 1983 or World Geodetic System of 1972 or 1984. In fact, we are so concerned with the possibility that a user will use Loran-C correctly, apply the ASF correction correctly and determine an accurate position but will apply that position on one of these old charts and come to grief because of the inaccuracy of the horizontal grid of the chart that we plan to warn him that the ASF is INACCURATE so that he is duly cautioned. Of course, the mariner using GPS will have to be similarly cautioned.

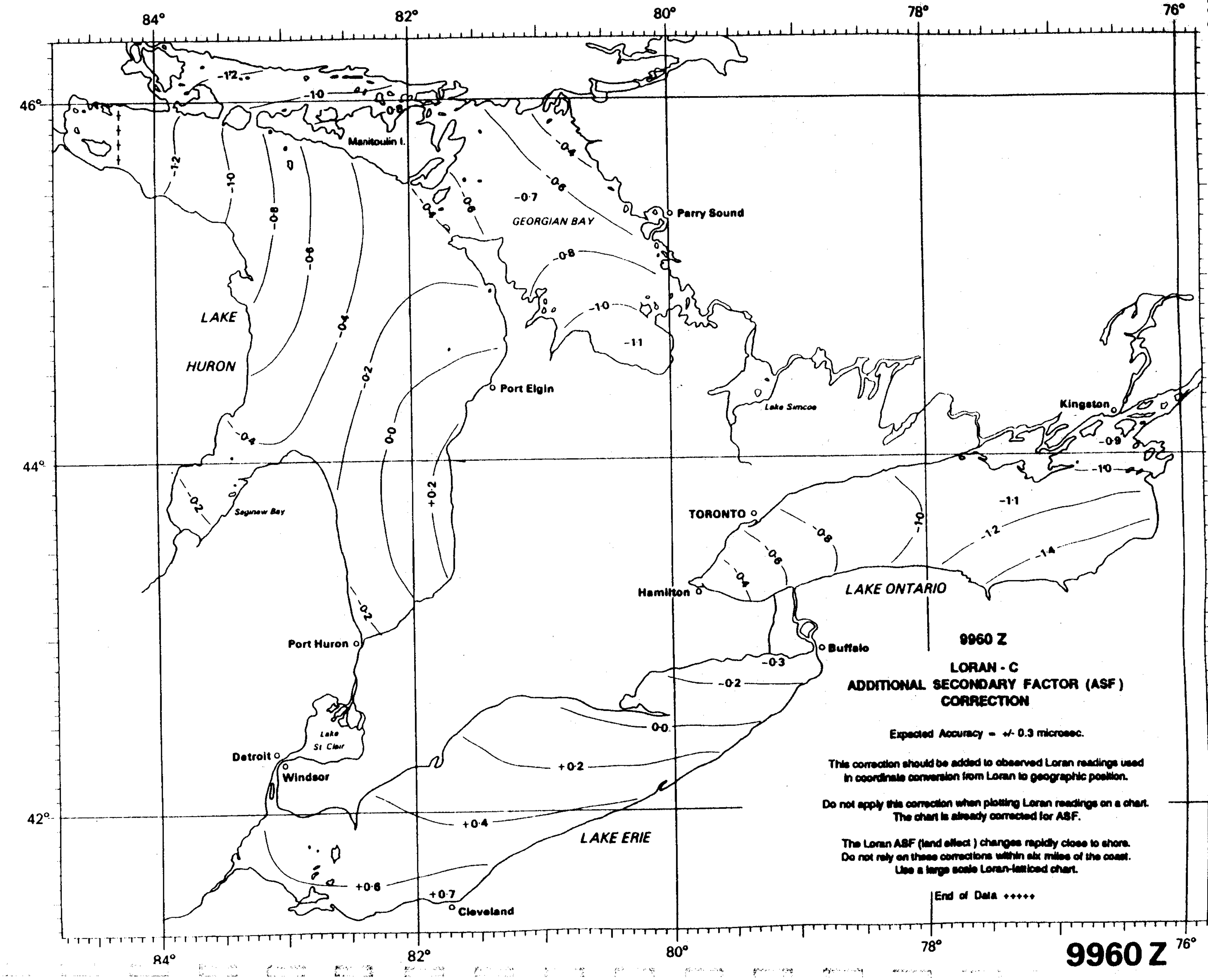
We also realize that we are preparing these chartlets at a scale of about 1:2,500,000 and at that scale we cannot display the intricacies along the coast line because detail is suppressed and some resolution is lost. Our tests have undeniably shown that there can be a rapid phase recovery near the coast of up to a full microsecond exceeding that predicted by Millington's Method. Hence we are planning a caution note to go on each ASF chartlet for the near-shore effects. We suggest that the large scale latticed charts should be used instead because the rapid change in the ASF has been included closer to the shore in the lattices than in the ASF chartlets. Also, the mariner might be induced to use his radar or make visual fixes.

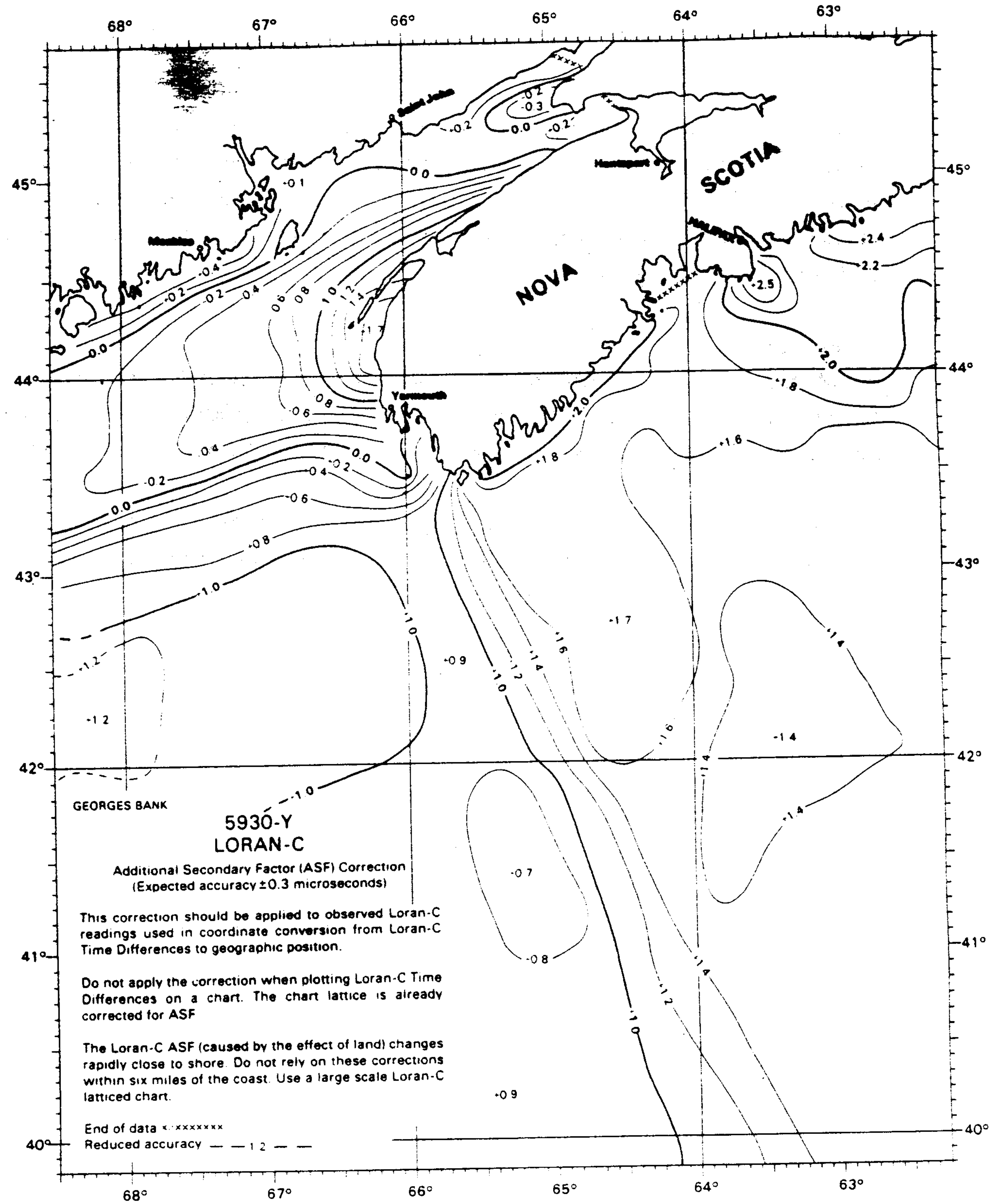
There is a concern that is independent of chartlet scale. It is accepted mathematical practice that the accuracy of a contoured map is plus/minus half of the contour interval 95% of the time. Therefore, by the properties of a Gaussian distribution, the standard deviation is a quarter of the contour interval; or in the case of the area from Cape Sable to LaHave River (southwest of Halifax, N.S.), the 5930-Y ASF is 2.0 microsec ± 0.05 microsec. That accuracy is equivalent to 10 metres! Or, in other terms, the equivalent of a lattice line on a chart of 1:5,000 scale. This scares us because we would not think of latticing a chart at that scale! Therefore, an expected accuracy of ± 0.3 microsec is stated in the title block of each diagram. That value roughly accounts for the seasonal stability of the pattern, prediction techniques, and calibration survey accuracy. We are concerned that the mariner will select the wrong Time Difference pairs, but we also acknowledge that some manufacturers are writing sufficient software into their converters that the converter will know which Time Differences to use.

We invite you to make your comments known to CHS on our presentation of the ASF data and to express your suggestions on other forms of presentation of this data that might be useful to you. To those of the audience that are thinking of improving the Loran-C system by getting rid of the controlling monitors, we ask that you consider the fact that we have eleven years of TD calibration data at stake. Any change to the method of controlling the timing would change the location of the line of position which, in turn, changes its location on large scale charts. Also, because a timing change would allow users to select whatever station pairs he chooses, there would be an additional work-load of providing the ASF chartlets for the extra station pairs.

Conclusion

The Canadian Hydrographic Service will be publishing a whole new series of chartlets in the Radio Aids to Marine Navigation that will show Loran-C ASF in a contoured format. We believe that the data is accurate since it is based on surveyed ASF values and that it is provided in a meaningful yet compact manner for the user.


9960 Z
LORAN - C
ADDITIONAL SECONDARY FACTOR (ASF) CORRECTION
Expected Accuracy = +/- 0.3 microsec.
This correction should be added to observed Loran readings used in coordinate conversion from Loran to geographic position.
Do not apply this correction when plotting Loran readings on a chart. The chart is already corrected for ASF.
The Loran ASF (land effect) changes rapidly close to shore. Do not rely on these corrections within six miles of the coast. Use a large scale Loran-latticed chart.
End of Data +++++
LAKE HURON
LAKE ONTARIO
LAKE ERIE
GEORGIAN BAY
Manitoulin I.
Parry Sound
Port Elgin
Lake Simcoe
Kingston
TORONTO
Hamilton
Buffalo
Port Huron
Saginaw Bay
Lake St Clair
Detroit
Windsor
Cleveland
-1.2
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
+0.2
-0.7
-1.1
-0.9
-1.4
-0.3
+0.4
+0.6
+0.7
84°
82°
80°
78°
76°
46°
44°
42°
9960 Z


NOVA
SCOTIA
Yarmouth
GEORGES BANK
5930-Y
LORAN-C
Additional Secondary Factor (ASF) Correction
(Expected accuracy ±0.3 microseconds)
This correction should be applied to observed Loran-C readings used in coordinate conversion from Loran-C Time Differences to geographic position.
Do not apply the correction when plotting Loran-C Time Differences on a chart. The chart lattice is already corrected for ASF
The Loran-C ASF (caused by the effect of land) changes rapidly close to shore. Do not rely on these corrections within six miles of the coast. Use a large scale Loran-C latticed chart.
End of data ×××××××
Reduced accuracy — — 1.2 — —

5930-Y

Biographies

Speaker:

David H. Gray, M.A.Sc., Professional Engineer, Canada Lands Surveyor, has been with the Canadian Hydrographic Service since 1971 where he is a geodesy and radio positioning specialist. He has been responsible for Loran-C data analysis and has been officer in charge of several Loran-C surveys. He is also involved with conversion of charts to NAD83 and maritime boundary delimitations.

Co-author:

R. Michael (Mike) Eaton has been involved in Loran-C since 1971, first for offshore surveying and then in planning Loran expansion and in producing lattices to 2 mm accuracy for CHS charts of the Atlantic Region. He was awarded the WGA medal of merit in 1983.

Mike was educated in the UK, and has a physics degree from Dalhousie University, Halifax, Nova Scotia. He recently retired from the CHS, but continues to work on Loran ASF, and on the joint introduction of Navstar GPS and the Electronic Chart.