1 Introduction

Background

The NAVEFF model reported in Maynord (1996b) is an analytical/empirical model for estimating the maximum return velocity and drawdown that occurs across a river section during passage of shallow draft navigation. The analytical part of the model makes use of the one dimensional energy equation along with mass conservation to define the average return velocity and drawdown during vessel passage. By basing the NAVEFF model on conservation laws, the model can be applied to a wide range of cross-section sizes without having to collect verification data for all channel sizes as would be required for a purely regression based approach. The empirical part of the model proportions the average return velocity and drawdown on each side of the vessel depending upon the vessels position in the cross section. An exponential decay function is used to define the return velocity and drawdown distribution between the vessel and the shoreline.

While most of the prototype return velocity and drawdown data taken on the Upper Mississippi River System (UMRS) by the Illinois State Water Survey (ISWS) and WES have been taken in the region near the shore, the NAVEFF model was based on data from a physical model which was first verified against prototype data in the near shore region and then used to collect data in the physical model from the shoreline to the center of the tow.

The empirical data used to develop the NAVEFF model resulted in the following limitations:

1) Blockage ratio N = Channel cross-sectional area/vessel cross-sectional area < 85. This limitation poses no significant problem for evaluating tow effects on the UMRS because magnitude of drawdown and return velocity for N>85 is negligible for even high speed tows.

2) Total barge length > 0.4 times the channel width. Comparisons of return velocity for various tow lengths (Maynord and Martin, 1998) show that, over the majority of the cross-section, return velocity decreases as the tow length/channel width falls below 0.4. Stated otherwise, NAVEFF will give a conservative estimate for tows that are short relative to the channel width.

3) Centerline of tow must be greater than 10 percent of channel width away from shoreline.

4) Predictions valid from shoreline to one vessel width away from vessel centerline.

5) River reaches where cross section is not changing rapidly.

In addition to the above limitations, the NAVEFF model has not been evaluated in bends because of lack of data in these reaches. In mild bends where tows can travel through without flanking/maneuvering resulting in a skewed tow, the method presented herein should be valid. When the tow is skewed with respect to the centerline, the effective width of the tow increases to an amount that is not known and the model is not valid. However, when the tow is skewed because of flanking/maneuvering through the bend, the speed of the tow relative to the water is generally low which results in low, many times insignificant, values of return velocity and drawdown.

The empirical part of the NAVEFF model was developed based on physical model investigations of the Illinois River near Kampsville (Maynord and Martin, 1997) and the Mississippi River near Clark's Ferry (Maynord and Martin, 1998). Both physical models were adjusted and verified against field data collected by the Illinois State Water Survey (ISWS). The NAVEFF model compared favorably to physical model and field data from Kampsville and Clark's Ferry (Maynord, 1996b) since this was the data used to develop the model. The physical model return velocity from the Kampsville model (Maynord and Martin, 1997) used to develop the NAVEFF model ranged up to 1.0 m/sec and drawdown from the Kampsville model ranged up to 0.35 m. Prototype return velocity data compared to NAVEFF in Maynord (1996b) ranged up to 0.4 m/sec while prototype drawdown ranged up to 0.1 m.

Independent data were also used in Maynord (1996b) to test NAVEFF. Return velocity data from field tests on the Illinois River and the Mississippi River were used from Environmental Science and Engineering (1981) and were found to provide fair agreement with the NAVEFF model (Maynord, 1996b). Return velocity and drawdown data were collected at four sites on the Ohio River by the US Army Engineer District, Louisville. The NAVEFF model provided a reasonable prediction of both return velocity and drawdown (Maynord, 1996b) on the four Ohio River sites.

Some investigators prefer to look at a variety of methods for estimating parameters such as return velocity and drawdown. Other methods that are available for estimating return velocity and drawdown include Hochstein and Adams (1989), an earlier version of the approach used in NAVEFF and provided in Maynord and Siemsen (1991), Mazumder et al (1993), Bhowmik et al (1995), and Bhowmik et al (1998).

Objective

The objective of this study is to compare the NAVEFF model to additional return velocity and drawdown field data from the UMRS and the Gulf Intracoastal Waterway that were not used in development of the model. Of particular interest is the use of field data in which enough velocity meters were used to test the shape of the exponential distribution used in the NAVEFF model to define the return velocity distribution across the channel. In addition to return velocity and drawdown, the maximum water-level drawdown from NAVEFF model was compared to observed squat from deep draft ships on the St Lawrence Seaway.

Approach

The NAVEFF model was tested against the following data:

(1) ISWS data on the Illinois River near McEvers Island (Bhowmik et al, 1994a), the Mississippi River near Apple River Island (Bhowmik et al, 1994b), and the Mississippi River near Goose Island (Bhowmik et al, 1994c)

(2) Waterways Experiment Station data on the Mississippi River at Pool 8 and the Illinois Waterway at Lagrange, (Pratt and Fagerburg, draft).

(3) Gulf Intracoastal data reported in Zhang et al (1993)

(4) Ship squat data on the St Lawrence Seaway reported in Tothill (1966)

To evaluate the goodness of fit of the NAVEFF model to the observed data, two error measures are used from Maynord (1996a). The mean relative error (MRE) is a measure of the dispersion of the predictions and is defined as

$$MRE = \frac{\Sigma \left| \frac{CALCULATED - OBSERVED}{OBSERVED} \right|}{n} \qquad \textbf{(1)}$$

Where n = number of observations. The second error measure, mean trend error (MTE), is defined as

$$MTE = \frac{\Sigma \frac{CALCULATED - OBSERVED}{OBSERVED}}{n}$$

MRE and MTE become percentages when multiplied by 100. MRE is similar to Willmott's (1982) mean absolute error (MAE) but is divided by the individual observed value to provide a relative error. MTE is similar to Willmott's mean bias error (MBE) but is also divided by the individual observed value to provide a relative error measure. Willmott points out that these relative error measures (MRE and MTE) have problems because they are unbounded and are strongly affected by small observed values. An alternative to MRE and MTE that is not as affected by individual low observed values is to divide the difference between observed and computed by the average observed value rather than the individual observed value as used herein. Evaluation of MRE and MTE is as follows:

1) If MRE is low, MTE will also be low, and the model is accurately predicting observed results and dispersion is low.

2) If MRE is not low, MTE is used to determine if the model follows a trend of high or low prediction. Positive MTE indicates over prediction, negative MTE, under prediction. If MTE is low but MRE is high, the average trend of the model is correct but the dispersion is large.

The difference measures of MRE and MTE are used in lieu of the frequently used correlation coefficient r or r^2. The author has observed cases where correlation coefficients and difference measures such as MRE give opposite findings regarding how well a model fits observed data. Willmott (1982) also questions whether Ar@ or Ar^2A should be used at all. Willmott states AThe main problem is that the magnitudes of r and r^2 are not consistently related to the accuracy of the prediction, i.e., where accuracy is defined as the degree to which model-predicted observations approach the magnitudes of their observed counterparts.@ Willmott states that they should not be part of an array of model performance measures and recommends difference measures such as MBE and MAE. If this study had been to compare different models to a selected data set, absolute difference measures MBE and/or MAE would have been used in the evaluation. In this study, a single model (NAVEFF) was compared to several different data sets. Because the magnitude of return velocity and drawdown differed in the data sets, relative difference measures MRE and MTE were chosen for this evaluation.