4 Model Applications

Additional numerical experiments were conducted to evaluate the ability of the 2-D model to simulate the currents and waves generated in the field by a vessel navigating along a waterway. Two sites were selected for comparison. The Kampsville and Clark's Ferry sites were chosen because both prototype and physical model data are available for comparison. The field data sets used for the model evaluation were obtained by the Illinois State Water Survey (Bhowmik, Soong, and Xia 1993, 1994). The laboratory data are a product of the physical forces study conducted at the U.S. Army Engineer Waterways Experiment Station. These two studies provided excellent data sets with which the numerical model could be evaluated.

Kampsville Site (*W. C. Norman*)

The first site investigated was the Kampsville site, located on the Illinois Waterway System at river mile 35.2. Details of the field observations are reported in Bhowmik, Soong, and Xia (1993). The effects of barges navigating through the Kampsville site were further documented in a laboratory environment by Maynord and Martin (1997). This investigation employed a 1:25-scale model of the Kampsville site with various tow arrangements and navigation conditions.

The Kampsville site data set used for this report is for a 3-wide by 4-long downbound barge train towed by the M.V. *William C. Norman*. This vessel, which traveled at 2.9 m/sec, was 237.7 m long by 32.0 m wide, and drafted at 2.74 m. The river flow rate was 628 m^3/sec with a 4.67-m depth at the thalweg. A sketch of the river cross section at Kampsville is illustrated in Plate 3 in which the sailing line is referenced to the thalweg. The cross-section sketch also shows the location of Bhowmik's gauges. Model parameters used in the simulations are listed in the following tabulation.

The numerical model computational mesh of the laboratory test facility is shown in Plate 4. The mesh consisted of 2069 nodes and 2434 elements. Both triangular and quadrilateral elements were used. The increased longitudinal resolution on the side slopes was in the vicinity of the physical model test section where the data acquisition gauges were located.

Model Parameter	Value Used for Simulations	
	Physical Model	Prototype
g, m/sec^2	9.81	9.81
n	0.010	0.025
C	0.1	0.1
A, m/sec^2	0.036082	0.0047134
T_s, sec	16.13	615.26
β	0.25	0.25
α	1.5	1.5
Δt, sec	1.025	5.14

The selection of appropriate parameters for the model was made from hydraulic experience and not as an adjustment to match the flume results. The numerical model was run independently from the flume testing, in a "blind" test. The vessel speed was 0.582 m/sec. A Manning's *n* value of 0.010 was assumed for the smooth concrete and the epoxy-painted plywood. This value is in agreement with *n* values presented in Brater and King (1976).

Velocities are compared in the x-direction (parallel to path of tow) and in the y-direction (perpendicular to tow motion). Tow motion is from right to left in Plate 4. Positive velocities in the x-direction are in the same direction as the tow motion. That is, return currents are taken as negative x-direction velocities. The y-direction velocities are positive in the direction away from the vessel. The timing scale is such that zero is the time when the bow reaches the station where the probe is located.

Time-histories of computed velocities are compared with those measured in the flume in Plates 5-10. The flume data are a 1.0-sec moving average of the raw data. Generally, the x velocity compares well, though the maximum values are somewhat low. The y velocity compares quite well as the bow passes and the currents are away from the vessel (in the positive direction). Near the stern, where the currents are toward the vessel (in the negative direction), the y-component currents are consistently high in the numerical model. The results suggest that the level of turbulence chosen in the numerical model may be too low. The turbulence level could be increased by selecting a value of C larger than 0.1.

The computed and measured velocities at probe 6V (Plate 10), which is located near the top of the right side slope, did not compare as well. Differences between models could be attributed to instrument placement or bathymetry variations near the bank in the physical model. Numerical results may differ due to several possibilities including insufficient resolution near the side boundaries, an inadequate turbulence model for the low Reynolds numbers found in the physical model, or an inappropriate 2-D assumption in an area where there is a potential for vertical motion.

Wave heights relative to the still water level are shown in Plates 11 and 12. The computed values are in reasonable agreement with those measured in the flume, with the exception of the latter portion of the time-history when the vessel has passed the test section. The numerical model did not simulate a tow deceleration, whereas the flume tow was decelerated. Perhaps this explains the difference in the wave rebound after the vessel passes the test section. Attention is focused on the drawdown at wave rod 1W (Plate 11), approximately 0.5 vessel width from the vessel. The maximum value on the drawdown portion of the curve is captured by the numerical model.

Evaluation of the hydrodynamic model was continued by comparison with field data (Bhowmik, Soong, and Xia 1993). The model parameters for these runs are shown in the earlier tabulation. Details of the numerical model computational mesh in the vicinity of the data gauges are illustrated in Plate 13.

Model comparisons with flume and field data are shown in the time-histories of longitudinal and lateral velocities at a particular point within the river (Plates 14-19). Plate 20 illustrates the drawdown generated by the barge train. In Plates 14-20, zero time corresponds to the bow of the vessel crossing the river section. Plate 21 illustrates the distribution of maximum return currents across the channel. The numerical model accurately reproduces the maximum return current at distances greater than about two vessel widths from the sailing line. Discrepancies in the immediate vicinity of the vessel result from the hydrostatic pressure assumption of the model. Vessel movement generates significant vertical accelerations in and adjacent to the vessel path. However, horizontal momentum is conserved, and the model accurately simulates the far field where the pressure distribution is hydrostatic.

Clark's Ferry Trip 2 (*Kevin Michael*)

The data set used in this report from the Clark's Ferry site, Trip 2, is of conditions resulting from a 3-wide by 4-long downbound barge train towed by the M.V. *Kevin Michael*. This particular site was selected for model examination because of the presence of numerous dikes and because field data (Bhowmik, Soong, and Xia 1994) and physical model data (Maynord and Martin 1998) are available for comparison. Plate 22 shows the river cross section of this site. A typical reach of river containing a dike field was simulated (Plate 23). The barge train was 237.7 m long by 32.0 m wide and drafted at 2.74 m. The vessel was traveling downstream at 2.31 m/sec. The river discharge was 673 m^3/sec. Model parameters are listed in the following tabulation. Plate 24 shows a representative portion of the computational mesh in the vicinity of the dike field.

Time-histories of velocities are provided in Plates 25-28. The flow in the vicinity of the dike field is considerably different from that observed at the prismatic channel of the Kampsville site. Generally, the model-computed maximum change in velocity from the ambient current is in agreement with the field measurements. However, the model-computed ambient currents do not agree as well with the

Model Parameter	Value
g, m/sec^2	9.81
N	0.025
C	0.1
a, m/sec^2	0.00292, 0
t_s, sec	791.6364
β	0.25
α	1.5
Δt, sec	2.0

ambient currents measured in the field. Maximum return currents as distributed across the channel are shown in Plate 29. Although the physical model and field data are somewhat limited, the numerical model seems to reasonably predict the return currents at a distance of about 2.5 vessel widths from the sailing line.