2 Prototype Kampsville

Prototype Data Collection

ISWS collected physical data on the hydrodynamic changes associated with tow and barge traffic movement on the UMR-IWWS. These data were collected from the Illinois and Mississippi Rivers. A detailed report on the Kampsville prototype investigation is found in Bhowmik, Soong, and Xia (1993).

The Kampsville site is located on the IWWS at river mile (RM) 35.2 in a relatively straight reach (Figure 1). A reconnaissance trip, before the actual field data collection, gathered information on site characteristics, bathymetry, cross-sectional profiles, discharge, suspended sediment, and bed materials. The actual field data collection trip included collecting data on ambient conditions and during an event. Data were taken for three periods relative to each tow event: (a) pre-passage, (b) actual passage, and (c) post-passage. Trip 1 field data were collected for seven consecutive days (October 11-17, 1990), and trip 2 for three consecutive days (August 13-15, 1991). Trip 2 collected wave and velocity data especially during evening hours when water surface was calm. Figures 2 and 3 show cross sections for trips 1 and 2, respectively.

Instrumentation

Data were collected with (a) two Interocean current meters (model S4's), (b) two Marsh McBirney (MMB) 527 velocity meters, (c) four MMB511's, and (d) one wave gauge. The instruments were placed in the experiment reach for data collection. Velocity data in both the x- and y-directions were sampled at one sample per second. Positive x-velocities were downstream and positive y-velocities were toward the left bank. Wave data were sampled at 10 samples per second.

For trip 1, velocity meters were deployed as shown in Figure 2. The three MMB511's at 33.5 m from the right bank were mounted at vertical heights of 0.31, 1.22, and 2.44 m above the riverbed. These MMB511 meters were utilized to measure the variations of horizontal velocity components at various heights above the bed. The trip 1 wave gauge was 11.3 m from the right bank.

For trip 2 the velocity was measured at locations shown in Figure 3. Three MMB511's were mounted at vertical heights of 0.46, 1.31, and 2.13 m above the riverbed 22.9 m from the right bank. The trip 2 wave gauge was 9.1 m from the right bank.

Discharges and stages were measured at different times during trip 1 and trip 2. Table 1 shows discharges, average channel velocities, average flow depths, and water-surface elevations.

The average water-surface slope on this reach was 0.196 m/km (0.096 ft/mile) during trip 1 and 0.051 m/km (0.025 ft/mile) during trip 2. These slopes are determined by the daily stages at Hardin, IL, RM 21.6 and Pearl, IL, RM 43.1.

Events

Trip 1 monitored 25 barge trips and trip 2 monitored 22 barge events. Tables 2 and 3 (trips 1 and 2, respectively) give the name, date, draft, barge configuration, tow speed relative to earth, distance from the center line of the tow to the bank, and the tow direction.

Analysis of Data

Prototype and physical model data contained velocity and water level changes not caused by the tow. These changes included the normal fluctuations found in turbulent flow, eddies shedding from upstream bends, and changes from upstream structures or tributaries. Comparisons between the model and prototype must be based on tow-induced motion and not on extraneous components found in both prototype and physical model. Filtering out unwanted information, if a limiting frequency can be identified, is one alternative. Since prototype tows are generally 300 m long and travel at about 3 m/sec, the time the tow is adjacent to the measuring point is about 100 sec, which roughly defines the period of the event and leads to a frequency of 0.01-Hz interest. To make certain that tow information is not filtered, a limiting frequency of 0.02 Hz was selected for filtering the data. Filtering out fluctuations above a certain frequency was needed because model velocity, prototype velocity, and wave meters had different frequency responses. For example, the prototype electromagnetic velocity meters sampled at 1 Hz, but the acoustic Doppler velocity meters used in the physical model sampled at 25 Hz, equivalent to 5 Hz in the prototype. A fast Fourier transform (FFT) filtered out components of velocity or drawdown occurring at frequencies greater than 0.02 Hz in both the prototype and the physical model. The physical model was filtered after scaling values to their prototype equivalent. Plots are presented in Figures 4 to 12 of unfiltered and filtered data from the *William C. Norman* prototype tow. These plots suggest that under the trip 1 flow and pool elevation, ambient conditions in the Illinois River vary significantly due to long period variations that have frequencies similar to the tow event.

Tows Selected for Comparison with Physical Model

Six prototype tows were selected for comparison with the physical model. Selection was based on the following:

a. *Number of meters functioning during experiments*. Some tows were not used because one or more meters malfunctioned.

b. *Tow configuration and draft*. To simulate tow events producing the maximum deviation from ambient conditions, only 3-wide by 4- or 5-long, loaded barges were used in the adjustment/calibration of the physical model. Events producing the maximum deviation from ambient were desired so the model would correctly reproduce the worst river conditions. Also note that the 3-wide by 5-long, loaded tow is a standard configuration.

The six tows selected were *William C. Norman, Rambler, Charles Lehman,* and *Mr. Lawrence* from trip 1 and *Jack D. Wofford* and *Olmstead* from trip 2.

Definitions

Experiment result terms are defined as follows:

a. The terms "left bank" or "right of the thalweg" refer to positions in the cross section when looking at the cross section in a downstream direction.

b. Ambient velocity is the velocity measured without tow traffic effects but close enough to the tow passage to eliminate variations due to flow and/or stage changes. In the Illinois Waterway at Kampsville, the prototype data presented for the *William C. Norman* suggest that ambient velocity should be measured over at least 5 minutes to obtain a representation of the mean.

c. Impact velocity is the maximum velocity or minimum velocity that occurs during the tow event for a given mechanism. For example, the impact velocity from return currents would be the maximum velocity (for upbound tows) or minimum velocity (for downbound tows) that occurs adjacent to the vessel. The return velocity is the difference between the impact velocity and the ambient velocity.

Variation in Prototype Data

It is important to recognize that the prototype data in the verification process are subject to variation caused by measurement inaccuracy in tow speed, tow draft, tow position, tow alignment, water velocity, water level variation, and ambient discharge. Also of concern is the following: lack of knowledge about the propeller speed, applied horsepower, shape of the barge bow, and whether the physical model had a straight constant cross section whereas that of the prototype varied longitudi- nally. All barges in the prototype verification experiments were reported to have a 2.74-m draft. The writers' experience suggests that the draft of the loaded barges could have been ± 0.15 m (6 in.). Tow alignment relative to the river axis could be skewed by several degrees resulting in an effective tow width greater than the sum of the widths of the barges. To screen the prototype data for possible inconsisten- cies, the Schijf (1949) equation was used to compute the average return velocity and drawdown (Table 4). Therefore, consider that the Schijf equation provides a cross- sectional average return velocity and the prototype data are near-bottom velocity data from which a maximum value was extracted. The prototype data for each tow event were examined for a similar ratio of maximum observed return velocity/Schijf average return velocity. The filtered data from each prototype velocity meter were analyzed for the maximum return current/Schijf average return current (Table 5). For the Kampsville site, meters not close to the channel boundary were expected to have similar values for a given tow event. Meters 332, 642, 1000, 999, 040, and 071 were not close to the boundary. Meters 999 and 1000 were also expected to give similar results because they were at the same lateral position and are away from the channel perimeter. The only data that are clearly suspect are *Olmstead* meter 1000 and *Mr. Lawrence* meter 1000 because they differ significantly from the other meters for that tow event. The other meters gave similar values as expected.

It is not possible to define the variability of the prototype data by comparing the same event run numerous times as will be done in the physical model experiments. However, two tow events, the *Jack D. Wofford* and the *Olmstead*, were nearly identical in speed, direction, distance from right bank, draft, configuration, channel cross-sectional area, and flow rate. As shown in Table 5, these two tows produced similar values at all meters.

The variation of the ambient velocity about the mean from the filtered data could establish the significance of tow-induced changes. For example, if natural stream velocity variations over periods about 100 sec (100 sec based on period of tow event) are ± 5 cm/sec, one might conclude that tow-induced changes less than 5 cm/sec are no different from the natural variations. The filtered prototype data were analyzed for the maximum and minimum values prior to any tow effects. The relative ambient velocity variation was found by dividing the difference between maximum and minimum values by two and then dividing by the mean ambient velocity (Table 6). Using an average value from Table 6 as a guide, natural velocity fluctuations (with periods similar to a tow event period) fluctuate about the mean ambient current an average of ±12 percent.