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AIS Data Case Study: River Level and Vessel Approach Variation at Melvin Price Locks and Dam in St. Louis District

US Army Corps of Engineers®

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PURPOSE: The US Army Corps of Engineers (USACE), St. Louis District (MVS), manages multiple lock and dam structures on the Mississippi River. One of these, Melvin Price Locks and Dam (MPLD), was the subject of at least 12 allision events from downbound (southbound) vessels between January and November 2018 according to US Coast Guard (USCG) records, an unusually high number for this location. In an effort to understand how vessel operations change under varying river conditions, historical river gauge data and historical vessel position data for both upbound (northbound) and downbound (southbound) traffic were examined together to describe general approach paths for vessels at different water levels. Historic tracks for vessels involved in allision events are not included in this work because of ongoing investigations at the time of publication.

INTRODUCTION: Waterways within the USACE MVS handle an average of over 100 million tons of commodities a year (USACE-WCSC 2019). The MVS area of responsibility includes parts of the Upper Mississippi River, the Illinois River, and the Missouri River. The MPLD sits on Upper Mississippi River at River Mile 201 north of downtown St. Louis, Missouri. In 2018, the MPLD handled over 38,000 loaded barges and almost 18,000 empty barges as part of over 6,200 lockages, which placed it within the top five busiest locks in terms of barges handled across the inland waterway system (USACE-NDC 2019). In this area, the Mississippi River water levels are highly variable and in a single year can fluctuate dramatically (Figure 1). Towing vessel operators must adjust their navigation practices in response to these dynamic environmental conditions. The Automatic Identification System (AIS) transceiver units aboard ships broadcast time-stamped and georeferenced vessel position reports along with other pieces of information. The primary purpose of these broadcasts from vessels is real-time situational awareness and collision avoidance. These broadcasts are collected by shoreside receivers and ultimately archived by the

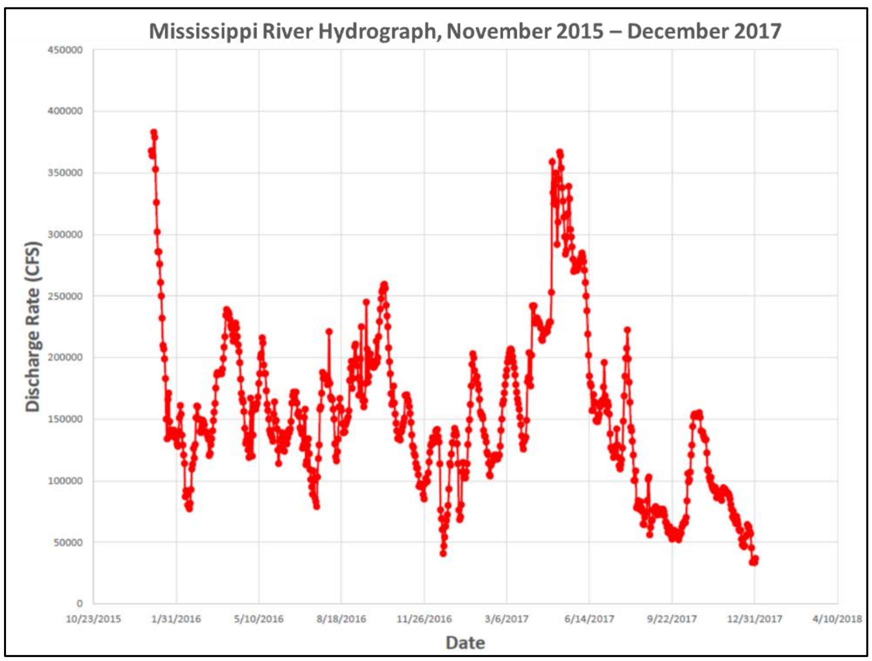

Figure 1. Mississippi River Hydrograph, November 2015 through December 2017. River flows, measured in cubic feet per second, can vary from just under 50,000 cubic feet per second (cfs) to almost 400,000 cfs within a single year.

USCG as part of the Nationwide Automatic Identification System (NAIS) program (USCG 2018). Archived AIS data have been used for different aspects of waterway performance monitoring in multiple locations around the United States (DiJoseph et al. 2019; Mitchell and Scully 2014; Scully and Mitchell 2015). However, this was the first application of historical AIS data analysis within MVS for the purpose of investigating an unusually high number of allision events at a single location as well as regular (non-allision) approaches to the MPLD under different river conditions.

METHOD: AIS data for the section of the Upper Mississippi River spanning River Miles 197 to 204 in the year 2018 were acquired from the USCG NAIS archive, via the AIS Analysis Package (AISAP) software (USACE-ERDC 2019). These georeferenced and time-stamped data were provided in comma-separated-value format, which is accessible to most spreadsheet software packages. In addition to the vessel position, AIS records include heading (direction of travel) information, allowing for separation of tows moving either upriver or downriver. At MPLD, the river flows approximately from west to east, therefore direction of travel was sorted as follows: upbound tows had headings of between 181–360 degrees (deg) (westerly direction of travel), and downbound tows had headings from 1–180 deg (easterly direction of travel). An example of AIS vessel position reports overlain on satellite imagery for downbound vessels preparing to enter the lock are shown as blue points in Figure 2; the data for upbound vessels departing the lock are shown as red points in Figure 3.

After assigning a direction of travel within the geospatial software program ArcMap 10.4.1 (ESRI 2019), a clustering analysis process was performed to consolidate the many overlapping points within a 5 ft radius and within a single day, into a single representative point. This allowed for a cleaner visualization of the most heavily utilized areas of the

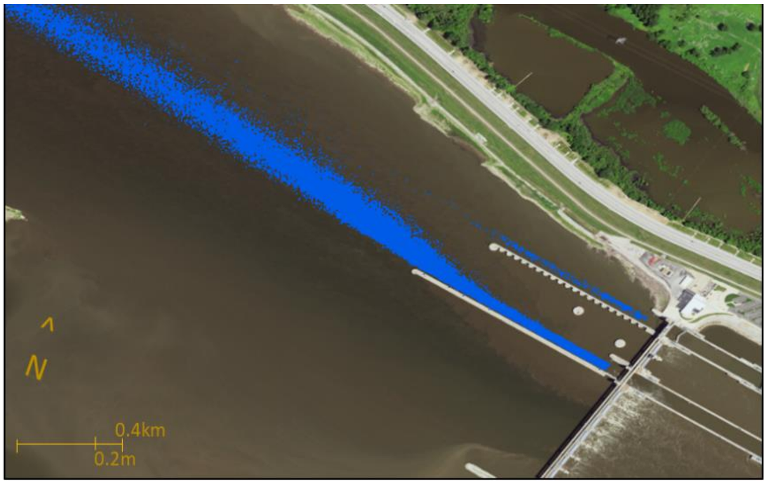

Figure 2. AIS position reports (blue points) for downbound vessel traffic preparing to enter MPLD.

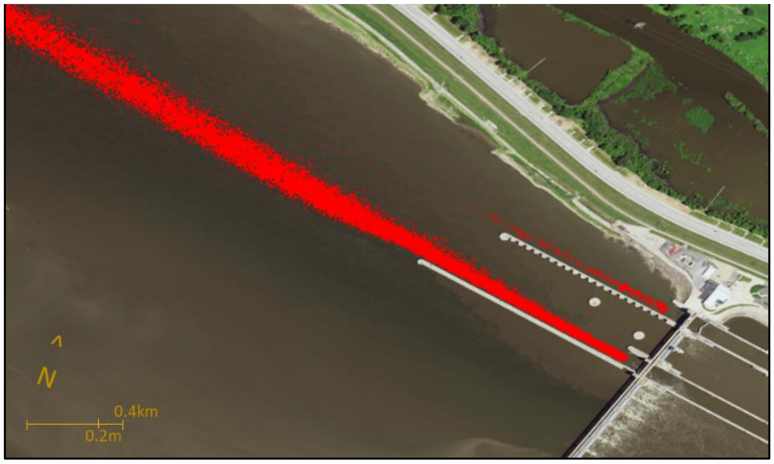

Figure 3. AIS position reports (red points) for upbound vessel traffic leaving MPLD.

Figure 4. Generalized upbound (red) and downbound (blue) tow vessel movements upriver from MPLD.

waterway. Then, the clustered points were connected with a line to make a representative track line. It is known that vessels do not follow the same path when exiting and entering the upriver side of the lock. An example of this general difference in waterway utilization based solely on travel direction is shown in Figure 4.

After the vessel position reports were sorted by travel direction and clustered to condense the points, they were sorted temporally so they could be binned into relation to corresponding river level data. In response to changes in river levels, the operators at MPLD can open different gates to control water level and flow over the dam. As the river level increases, more dam gates are opened. After 250 linear feet (ft) of gates along the dam are opened, it is essentially a free-flowing open river. The number and duration of open gates, and the occurrence of 12 vessel downbound allision events with the MPLD structure, are shown in Figure 5.

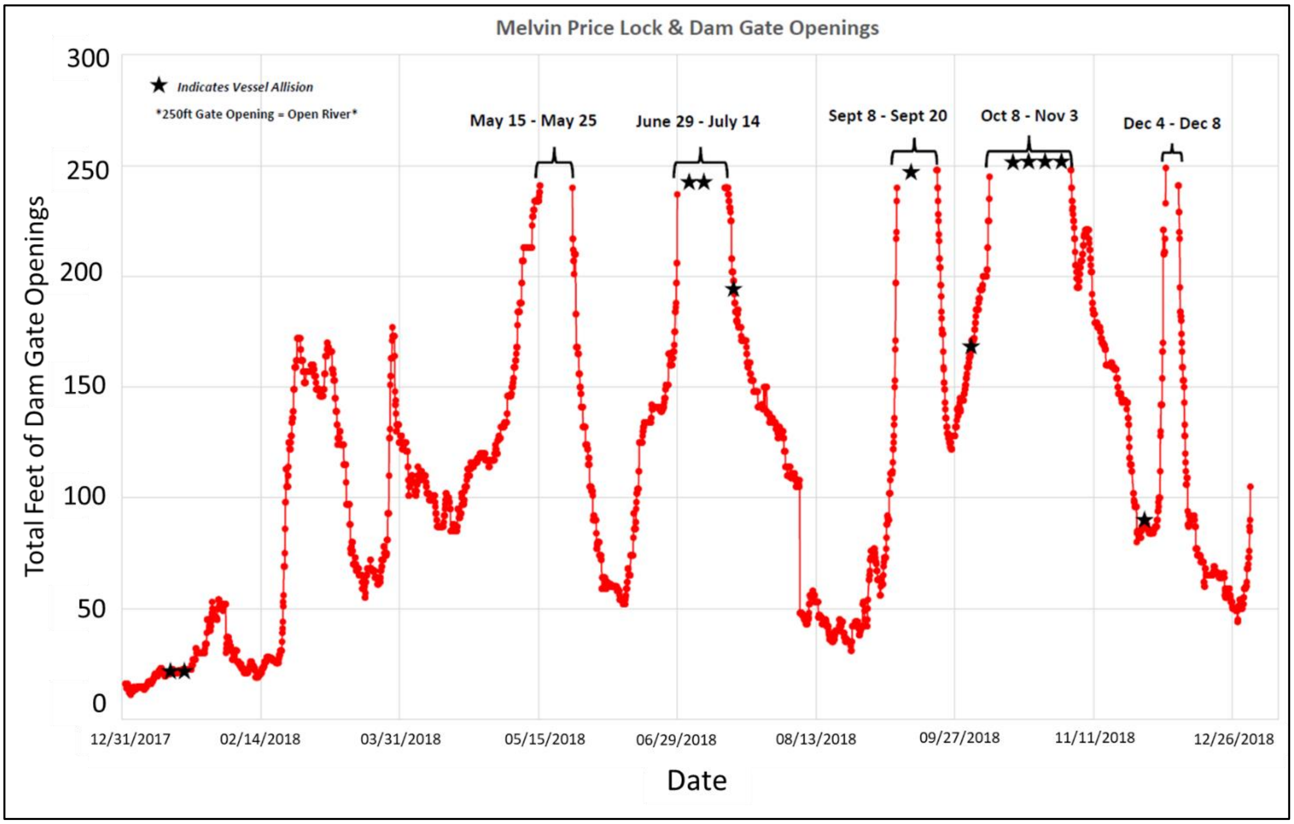

Figure 5. Linear footage and duration of dam gate openings at MLPD, 2018, and occurrence of 12 vessel allision events. Black stars represent unique allision events. Curly brackets indicate date ranges when 250+ ft of dam gates were open.

RESULTS: As shown in Figure 5, there were five times when 250 ft or more of dam gates were open (15–25 May; 29 June–14 July; 8–20 September; 8 October–3 November; 4–8 December). In some cases, the footage opened jumped from below 250 ft to over 250 ft in a single day, so there is no associated point on the graph that falls exactly on the 250 ft line. There were seven allision events in 2018 when the water was high enough so that 250 ft (or more) of dam gates had been opened at the Melvin Price Dam. There were two allision events in January 2018 under very low-flow conditions (less than 50 ft of dam gates open) and two events when there were between 150 ft and 200 ft of dam gates open. Allision events may occur for multiple reasons; however, this project was specifically investigating possible connections to river flow conditions. Separating the vessel track lines (produced from the cluster analysis process) and grouping them based on river flow levels resulted in four distinct representative tracklines for vessels preparing to enter the lock at MPLD under different flow conditions. These tracklines are shown in Figure 6. The purple line represents vessels that were entering the dam under the lowest flow conditions, from 25,000 cfs to 75,000 cfs of river flow. This is also the approach path most in line with the lock opening. The green line represents vessels entering the dam under flow conditions ranging from 175,000 cfs to 225,000 cfs and shows an approach that – as compared to the purple trackline – is slightly shifted towards the left descending bank (LDB). The orange line represents vessels approaching during flow conditions ranging from 225,000 cfs to 275,000 cfs and is shifted more towards the LDB than either the purple or green line. The red line represents vessels approaching during flow conditions of 275,000 cfs to 325,000 cfs, and is the trackline most shifted towards the LDB. The tracklines for vessels that experienced allision events are not shown in this technical note due to an ongoing investigation at the time of publication.

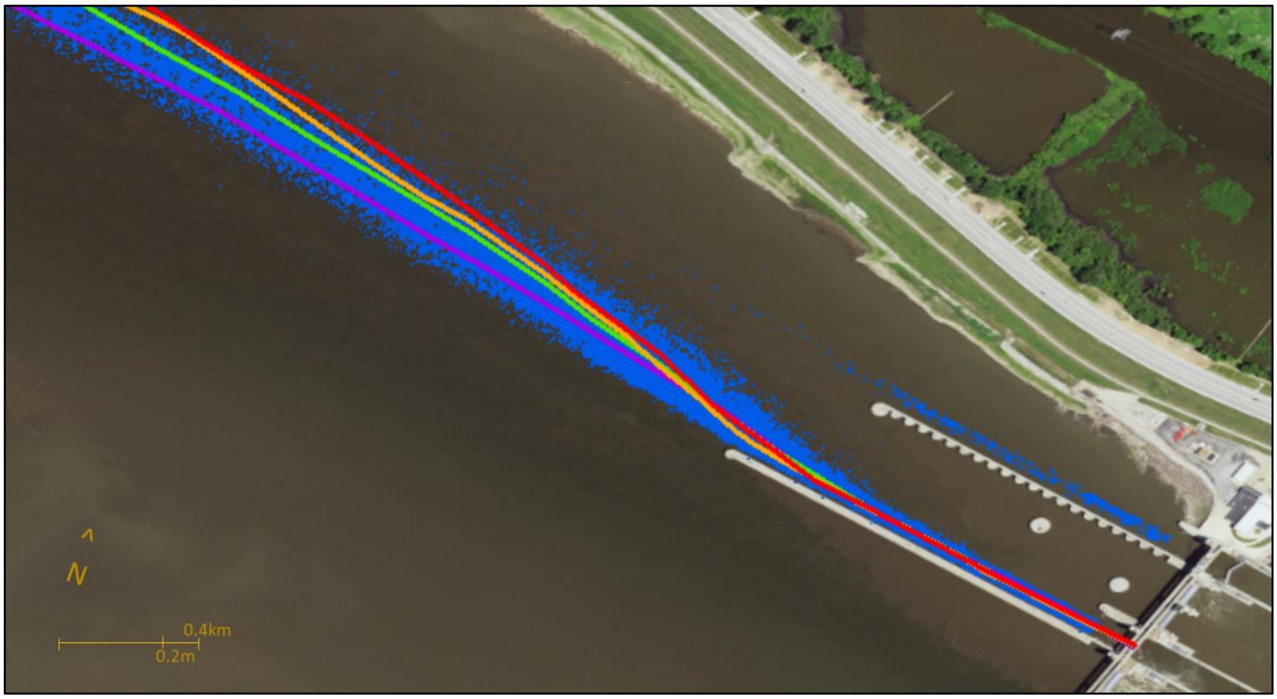

Figure 6. The following colors depict the clustered path of tow vessels entering the MPLD under different river discharge rate bands: purple: 25,000 cfs – 75,000 cfs; green: 175,000 cfs – 225,000 cfs; orange: 225,000 cfs – 275,000 cfs; red: 275,000 cfs – 325,000 cfs. Blue points show all position reports (not clustered) for downbound vessels during the study period.

The representative vessel tracklines shown in Figure 6 demonstrate that as flow conditions increase, the vessel pilots are generally compensating for the increased crosscurrent or *outdraft* in the approach area immediately upstream of the lock. This outdraft is caused by the high flow over the dam that pulls water laterally from the bank towards the gates of the dam (USACE-MVS 1964). This increased outdraft river condition is associated with wider approach paths as vessels move towards the guide wall and line up with the lock chamber. These results have served to inform MVS staff about the relationship between the high number of downbound (southbound) vessel allision events at MPLD in 2018 and river flow conditions. This information has been used to explore the possibility of broadcasting information about river level conditions near MPLD to vessels as they approach the structure so that mariners can prepare their approach towards the lock and possibly prevent allision events from occurring. Although the vessel heading information was extracted from AIS messages to identify upbound and downbound vessels, the difference between course and heading at different water levels was not examined in this work and remains a potential area of future research.

ADDITIONAL INFORMATION: This Coastal and Hydraulics Engineering Technical Note (CHETN) was prepared by Marin Kress, *Marin.M.Kress@usace.army.mil*, US Army Engineer Research and Development Center. Portions of this work were previously described in a 2019 whitepaper released by the MVS Applied River Engineering Center, for which Cory Tabbert (*Cory.R.Tabbert@usace.army.mil*) served as team lead. An online visual summary of this work is also available at *https://arcg.is/48Pzb*. The publication of this CHETN is funded by the USACE Navigation Systems Research Program and should be cited as follows:

> Tabbert, C., J. Vest, A. Rhoads, D. Myers, T. Lauth, E. Brauer, J. Wallace, D. Gordon, and M. Kress. 2020. *AIS Data Case Study: River Level and Vessel Approach Variation at Melvin Price Locks and Dam in St. Louis District*. ERDC/CHL CHETN-IX-51. Vicksburg, MS: US Army Engineer Research and Development Center. *http://dx.doi.org/10.21079/11681/35957*

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