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Reception of Automatic Identification System (AIS) Message 21 from US Army Corps of Engineer AIS Sites along the Upper Mississippi River, Mile 0 to 301

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PURPOSE: The purpose of this study was to map the on-vessel receipt of message 21 broadcasts from shoreside Automatic Identification System (AIS) sites. Message 21 is one of 27 different AIS messages, and it is used to provide information about real and virtual aids to navigation (AtoNs). Virtual AtoNs are broadcast to warn mariners of hazards like temporary construction zones or submerged debris that may not be marked with a physical buoy. In this study, message 21 was broadcast from different shore-based AIS transceiver sites along the river. Equipment onboard the patrol vessel *Pathfinder* was monitored for receipt of message 21 during patrols on the Mississippi River that ranged from Lock and Dam (L&D) 22 to Cairo, Illinois, with the confluence of the Ohio River. The *Pathfinder* is owned by the US Army Corps of Engineers (USACE) and is based out of the St. Louis District (MVS). Understanding where vessels receive, or do not receive, message 21 has important implications for maritime safety in this heavily traveled portion of the inland waterway system.

INTRODUCTION: The Upper Mississippi River (UMR) experiences heavy traffic. For example, the portion of the UMR from river mile 0 to 195 (i.e., from the confluence with the Ohio River to the confluence of the Missouri River) handled 120,693 commercial vessel trips and over 110 million tons of cargo in CY2020 (USACE-WCSC 2022). Table 1 shows the total commodity tonnage and the tonnage for the top five commodities in this stretch of waterway during CY2016 through CY2020. This 195-mile stretch falls within the study area and shows the high level of traffic moving through MVS's area of responsibility. Navigation safety is a high priority on this busy waterway and was the primary motivation for this study of where AIS message 21 broadcasts were being received.

Table 1. Total tonnage on the section of the Mississippi River between the mouth of the Missouri River and the mouth of the Ohio River, CY2016–CY2020.

	CY2020	CY2019	CY2018	CY2017	CY2016
All commodities combined	**110,307,664**	**97,921,493**	**115,014,483**	**113,538,601**	**111,041,863**
Top five commodities by tonnage					
Corn	22,164,709	14,276,818	27,164,137	25,021,791	25,903,684
Soybeans	21,840,053	16,658,748	15,290,749	17,530,277	20,350,253
Sand and gravel	10,055,689	8,979,785	8,628,901	5,692,494	4,520,632
Cement and concrete	6,880,302	6,275,376	6,328,303	6,320,319	5,683,488
Coal and lignite	6,530,209	6,639,577	8,976,384	10,201,607	8,435,276

Source: Data adapted from USACE-WCSC (2020).

"AIS is an autonomous and continuous broadcast system that exchanges maritime safety information between participating vessels and shore stations. . . . AIS can be a means to transmit information to ships in port or underway that contributes to safety-of-navigation and protection of the environment. This includes meteorological and hydrographic data, carriage of dangerous cargos, safety and security zones, status of locks and Aids to Navigation (AtoNs), and other port/waterway safety information" (Johnson et al. 2014, 14). "AIS operates using the very high frequency (VHF) radio spectrum, operating on 161.975 MHz and 162.025 MHz. VHF transmissions are generally line-of-sight (i.e., the antenna of the transmitting site must have an unobstructed path to the receiving site's antenna). The transmission may be attenuated or blocked by the earth (radio horizon based on antenna heights or terrain) or man-made structures" (DiJoseph et al. 2021, 1–2).* To maximize transmission and reception capabilities, AIS equipment, like other shipboard sensors, is usually installed near the vessel bridge or high on the vessel's superstructure. Figure 1 shows the *Pathfinder* with equipment, including a satellite communication antenna (i.e., the large white dome) and an AIS antenna (i.e., the thin, white, whip-like feature barely visible against the sky), mounted atop the pilot house.

Figure 1. The US Army Corps of Engineers (USACE) vessel *Pathfinder*. (Photograph by J. Vest, USACE St. Louis District.)

The distance at which AIS signals can be successfully transmitted and received may be reduced by multiple factors, "such as transmission power, equipment condition, and quality of installation. Therefore, not all AIS signals transmitted by vessels are received by shore AIS sites" (DiJoseph et al. 2021, 2), and vice versa. AIS broadcasts have 27 different parts (i.e., 27 messages or message types), with each message containing a specific type of information. Message types 6, 7, 8, 21, 25, and 26 are binary messages that can be used to transfer information to vessels, and message 21 is reserved

* For a full list of the spelled-out forms of the units of measure used in this document, please refer to US Government Publishing Office Style Manual, 31st ed. (Washington, DC: US Government Publishing Office, 2016), 248–252, *https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf*.

for AtoN reports on position and status (Johnson et al. 2014). Details on AIS message structure and the development of transmission protocols to use it as a communication method from shore stations to vessels are available in technical reports (Johnson et al. 2014; Johnson and Gonin 2014). A study published in 2014 documented the method for transmitting AIS messages from a USCG shoreside site in Louisville, Kentucky, to vessels in the area and the resulting improvement in navigational safety perceived by participating mariners (Johnson and Gonin 2014). In 2016, new AIS carriage requirements went into effect for the majority of commercial self-propelled vessels on US navigable waterways. This included any vessel over 65 ft in length, towing vessels over 26 ft in length with a greater than 600 hp engine, vessels certified to carry 150 or more passengers, dredges in or near a commercial channel, and vessels moving certain dangerous cargo (USCG, n.d.; US Code of Regulations 2019). Other AIS technical details, including information on message types, are available from multiple standard-setting organizations (IALA 2008; IEC 2001; ITU-R 2014; PIANC 2019).

The USACE Lock Operations Management Application (LOMA) program links a network of AIS stations on the inland waterway system with multiple stations in MVS (Figure 2). The AIS stations consist of an off-the-shelf AIS AtoN station that meets the IEC-62320-2 test standard (IEC 2006). The current stations transmit at 12.5 W and are mounted at various heights above the ground.

Recent studies examined the spatial extent of historical AIS data received from vessels by stationary AIS sites on the Ohio River in 2018 (DiJoseph et al. 2021) and on the Missouri River in select months of 2020 (Tetreault et al. 2022). Sites in the LOMA network are regularly used to transmit geographically focused notifications via AIS message 21. However, no studies have examined the reception of AIS messages from different AIS sites by vessels. This study is the first to examine if and where message 21 broadcasts from specific base stations are received by vessels on the portion of the UMR between L&D 22 (located at UMR mile 301.2 near Saverton, Missouri) and the confluence with the Ohio River (at UMR mile 0).

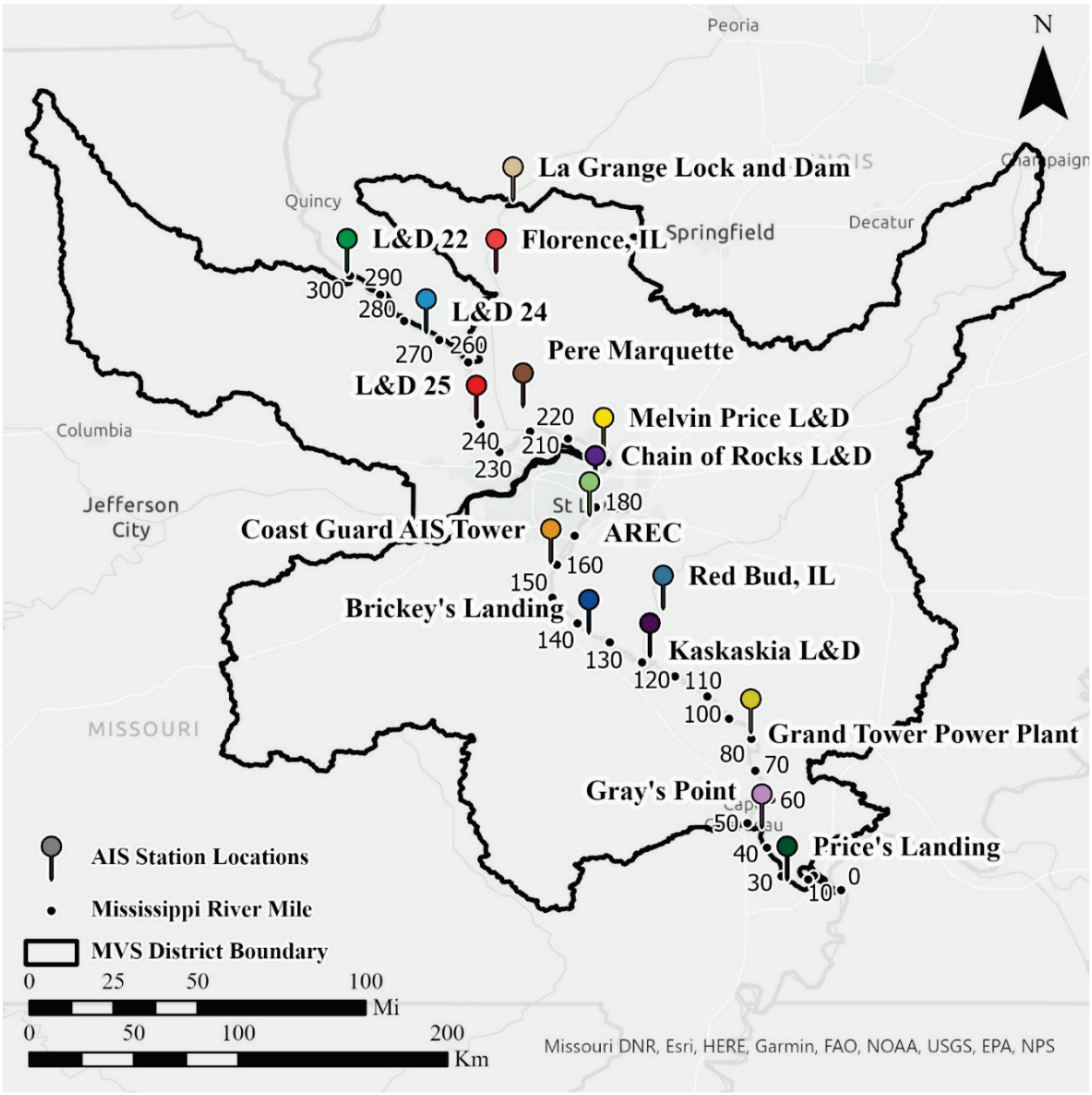

Figure 2. Automatic Identification System (AIS) station sites in the USACE St. Louis District (MVS) located along parts of the Upper Mississippi River (UMR), Illinois River, and Kaskaskia River. Mile markers are shown for the Mississippi River.

METHOD: AIS message 21 data were collected onboard the *Pathfinder* during six different patrol cruises spanning 24 days between October 2021 and March 2022. Three patrol cruises started in St. Louis, at the USACE Applied River Engineering Center (AREC), and went upriver to L&D 22 at river mile 301.2, and three cruises started at AREC and went downriver to Cairo, Illinois. Table 2 provides the dates for all six cruises. During each cruise, different portions of the river received five or six passes based on the movements of the *Pathfinder* while on patrol.

Table 2. *Pathfinder* patrol cruise and data collection dates.

***Pathfinder* patrol cruise**	**Start date**	**End date**
St. Louis AREC to L&D 22	4 October 2021	7 October 2021
St. Louis AREC to Cairo, IL	8 October 2021	9 October 2021
St. Louis AREC to L&D 22	3 November 2021	4 November 2021
St. Louis AREC to Cairo, IL	3 January 2022	6 January 2022
St. Louis AREC to Cairo, IL	19 January 2022	21 January 2022
St. Louis AREC to Cairo, IL	31 January 2022	3 February 2022
St. Louis AREC to L&D 22	7 March 2022	10 March 2022

Note: AREC refers to Applied River Engineering Center; L&D refers to Lock and Dam.

Each message 21 broadcast included the unique Maritime Mobile Service Identity (MMSI) number of the AIS transceiver from which it was broadcast. For example, the MMSI for the AIS station at Pere Marquette is 993661108, so all messages from this station included this number. The time stamps of all received AIS message 21 records were compared to the time stamped GPS position reports of the *Pathfinder*. A 30 sec time window was allowed for a match between the two types of records. Records were matched in Microsoft Excel using the index and match functions. The resulting joined files were imported into ArcPRO (ESRI 2022), and the spatial extent of messages received by the *Pathfinder* was mapped for each AIS base station. Figure 3 shows an example of individually matched records plotted on the UMR inside of a broadcast area for both the Pere Marquette site and the L&D 25 site. In Figure 3, the points at which messages were received from the Pere Marquette site are shown in brown, while the points at which messages were received from the L&D 25 site are shown in red. Although the Pere Marquette site is not located on the UMR, it has better broadcast range than the L&D 25 site, which is located on the UMR.

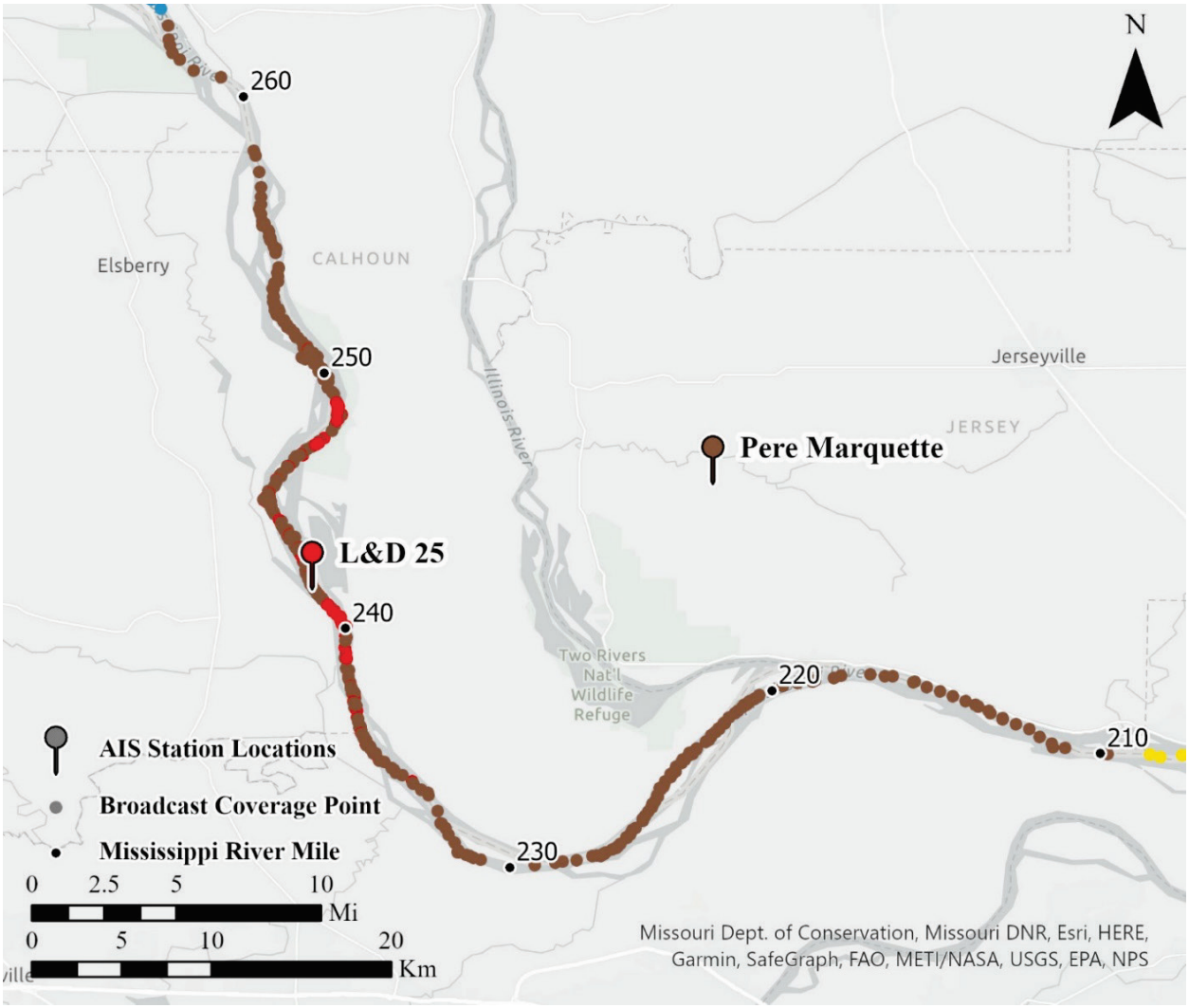

Figure 3. Map showing reception of AIS message 21 from the Lock and Dam (L&D) 25 site (*red dots*), Pere Marquette site (*brown dots*), and Mel Price site (*yellow dots*) during the *Pathfinder* patrol voyages.

RESULTS: Figure 4 through Figure 6 show the results of the transceiver coverage mapping process. Six distinct no-reception zones were identified; the *Pathfinder* did not receive AIS message 21 as broadcast from USACE-owned AIS sites in these zones. These no-reception zones were located, approximately, at river mile 293 to 282 (although some messages were received near 289), 165 to 143, 107 to 91, 74 to 61, 41 to 34, and 14 to 0. The no-reception zone from river mile 165 to 143 is within the likely reception zone of an AIS shoreside tower owned by USCG, but USACE LOMA staff members do not have the technical permissions to initiate AIS message 21 broadcasts from this tower.

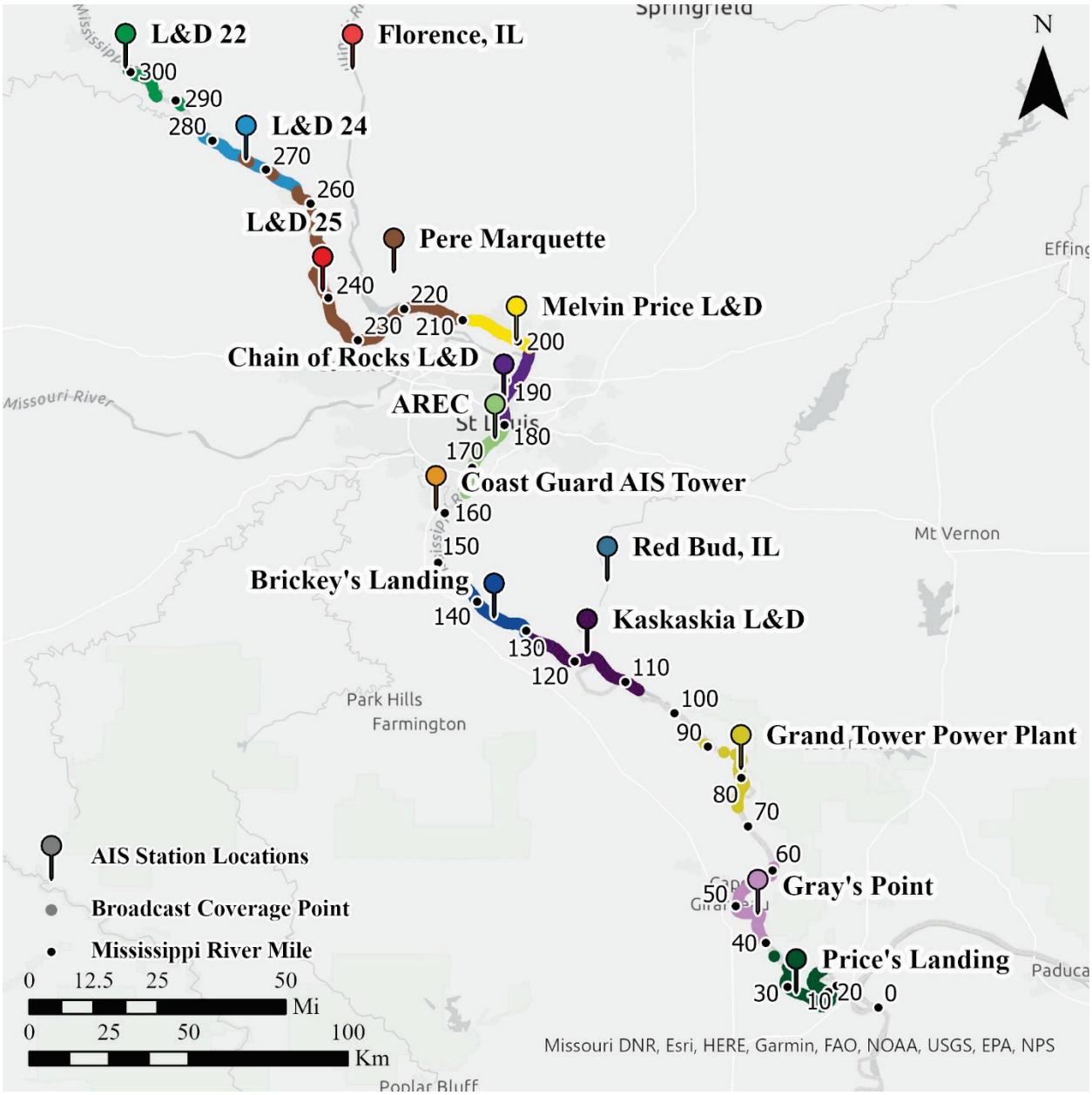

Figure 4. AIS message 21 reception, color coded by AIS broadcast sites, as recorded by the *Pathfinder* while on patrol cruises on the UMR, river mile 0 to 301.2.

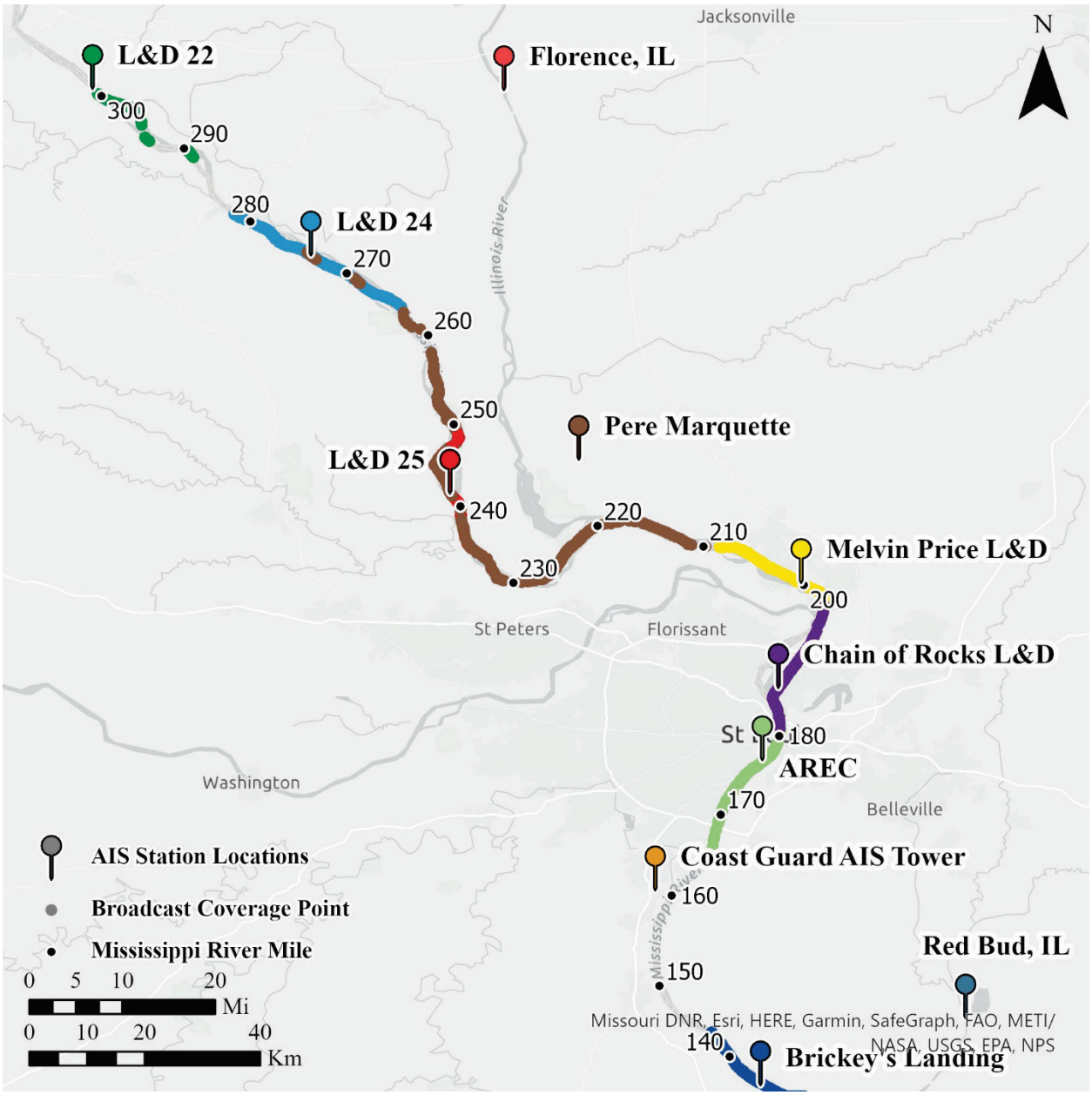

Figure 5. AIS message 21 reception, color coded by AIS broadcast site, as recorded by the *Pathfinder* while on patrol cruises. Detail of the area from L&D 22 at UMR river mile 301.2 to UMR river mile 140.

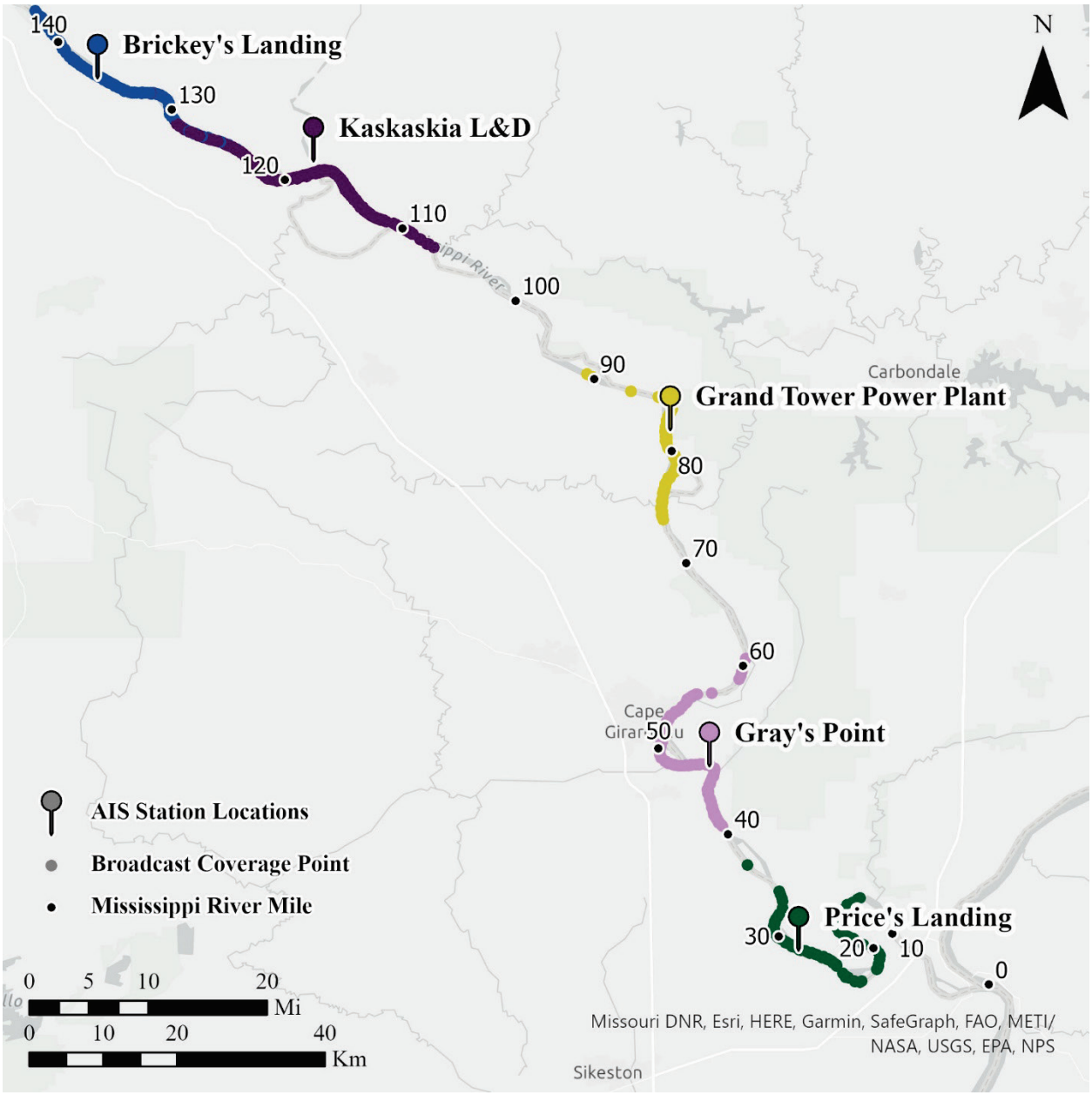

Figure 6. AIS message 21 reception, color coded by AIS broadcast site, as recorded by the *Pathfinder* while on patrol cruises. Detail of the area from UMR river mile 140 to river mile 0.

SUMMARY: This study represents an important step in identifying AIS message 21 gaps on the UMR. Future work on this topic is planned, including automating (i.e., scripting) the records-matching process, mapping the receiving range of AIS shoreside units to identify no-reception zones, and expanding this type of vessel-based AIS message 21 reception analysis to additional USACE-owned vessels that transit other parts of the inland waterway system. Additional information about this study is available from the authors upon request.

ADDITIONAL INFORMATION: This Coastal and Hydraulics engineering technical note (CHETN) was prepared by Jacob Zlotopolski (Jacob.P.Zlotopolski@usace.army.mil), John C. Vest (John.C.Vest@usace.army.mil), and Cory R. Tabbert (Cory.R.Tabbert@usace.army.mil) of USACE–

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