Issued: December 18, 2023 Pipeline Investigation Report: PIR-23-02

Marathon Pipe Line LLC Pipeline Rupture and Crude Oil Release

Edwardsville, Illinois
March 11, 2022

1 Factual Information

1.1 Accident Description

On March 11, 2022, at 8:15:21 a.m. local time, a 22-inch diameter crude oil pipeline operated by Marathon Pipe Line, LLC (Marathon) ruptured at a girth weld in Edwardsville, Illinois, resulting in the release of about 3,500 barrels of crude oil, some of which entered Cahokia Creek.[1] (See figure 1.) The rupture occurred at milepost 6.2 on the Woodpat pipeline, the northernmost of three parallel pipelines sharing one right-of-way and the closest to the creek.[2] Figure 2 shows the alignment of Cahokia Creek, a tributary of the Mississippi River. No injuries or fatalities

Figure 1. Ruptured pipeline and Cahokia Creek. (Source: Marathon.)

[1] (a) Visit www.ntsb.gov to find additional information in the public docket for this NTSB accident investigation (case number PLD22FR002). Use the CAROL Query to search safety recommendations and investigations. (b) All times in this report are local time unless otherwise noted. (c) A *girth weld* joins two pipes along their circumference.

[2] A *milepost* is a unit of measure used to define the location on a pipeline relative to a chosen starting point in miles and fractions of miles.

occurred as a result of the rupture. Marathon estimated the cost of property damage and emergency response to be $21,807,059.

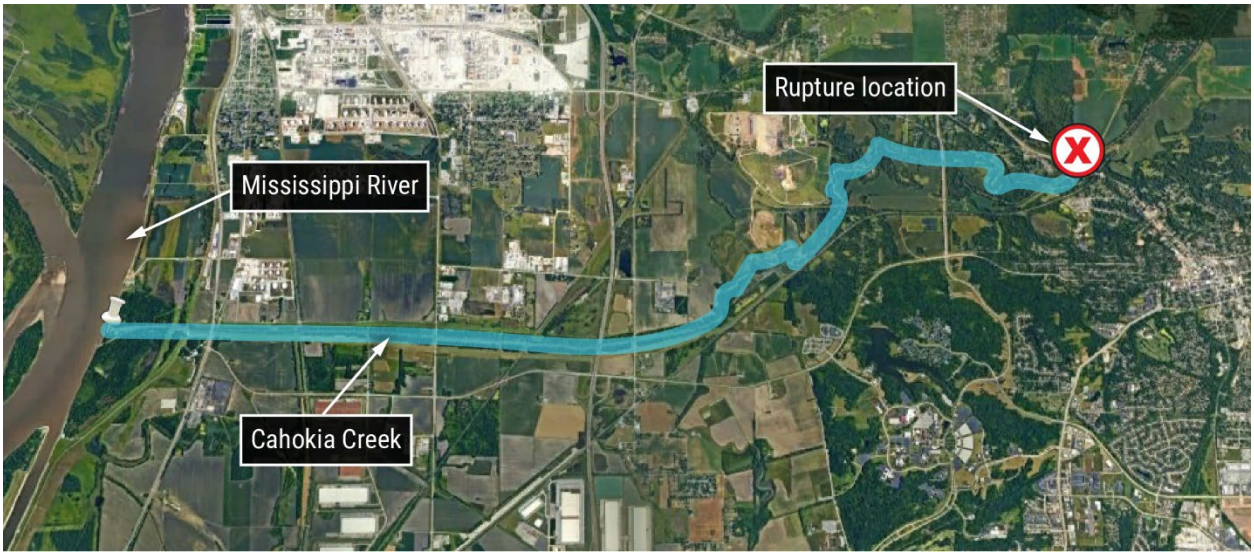

Figure 2. Cahokia Creek and Mississippi River.

The Woodpat pipeline is operated from Marathon's Pipeline Operations Center (POC) in Findlay, Ohio, and is monitored and controlled by a supervisory control and data acquisition system.[3] The pipeline's operating pressure at the time of failure was 467 pounds per square inch, gauge.[4] Additional pipeline specifications are presented in table 1.

[3] (a) Marathon's POC monitors and controls the Marathon pipeline network 24 hours a day, 7 days a week. (b) *Supervisory control and data acquisition* is a computer system used by operations centers to gather and analyze real-time data.

[4] The maximum operating pressure of the pipeline was 881 pounds per square inch, gauge.

Table 1. Woodpat pipeline specifications.

Pipeline Specification	Value
Material	Steel
Grade[1]	API-5L-X46
Longitudinal Seam Weld	Low-frequency electric resistance welded
Wall Thickness	0.344 inch
Manufacturer	Youngstown Sheet & Tube
Year Installed	1949
Flow Direction	West to east
External Coating Type	Coal tar enamel
Cathodic Protection Method	Impressed current

[1] American Petroleum Institute 5LX defines specific grades of carbon steel pipeline, each with a minimum yield strength. The higher the grade of the pipeline, the higher the strength of the steel used to manufacture that pipeline.

About 8:15 a.m. on March 11, a rate-of-change alarm at Marathon's POC showed low suction pressure at the Roxana pump station, about 6 miles upstream of the rupture site.[5] A 55-mile segment of the Woodpat pipeline was isolated at 8:23:18 a.m.[6] Field personnel identified the origin of the rupture at the girth weld about 9:51 a.m., and the mainline block valves nearest the rupture location were closed about 10:07 a.m. to reduce the length of the isolated pipeline segment to about 27 miles.[7]

1.2 Emergency Response

Marathon deployed both internal and contracted oil spill removal organizations (OSROs), which brought oil containment and recovery equipment to control the release of oil and prevent it from traveling further downstream.[8] The OSROs arrived at the rupture location by 10:50 a.m. on March 11.

By the evening of March 12, Marathon had established 10 oil spill containment sites along Cahokia Creek. Each of these sites were equipped with containment booms

[5] *Pump stations* are positioned at various points to move product along the pipeline. The suction side of a pump station is the lower-pressure input side.

[6] When a segment of pipeline is *isolated*, valves are closed to halt the flow of product.

[7] *Mainline block valves* are closed to isolate a pipeline segment.

[8] US Environmental Protection Agency. 2022. *Polrep #1: Initial Marathon Pipeline Release Wood River to Patoka System*.

and vacuum trucks.[9] No impacts on downstream potable water sources on the Mississippi River were documented. In the area of the rupture, the OSROs dug an interceptor trench, contained the oil-contaminated soil, and removed pooled oil.[10] Recovered oil and contaminated water were temporarily stored in the vacuum trucks and in portable frac tanks stationed near the accident site.[11] The OSROs took recovered liquids to Marathon's Wood River Station to separate the oil from the creek water and to measure the recovery amounts.[12]

By April 1, 2022, the most severely contaminated soil had been removed from the excavated area around the pipeline. In coordination with the Illinois Environmental Protection Agency, Marathon conducted soil sample testing to determine the extent of the soil contamination.[13] After testing and removal of contaminated soil, the pipeline was backfilled with clean soil from an off-site source.

1.3 Integrity Management

In the years leading up to the accident, Marathon assessed the threat of external loads on the Woodpat pipeline and took the below actions to address slope stability issues near the accident location.[14]

[9] (a) A *containment boom* is a temporary floating barrier used to contain an oil spill. (b) *Vacuum trucks* are used during a crude oil spill response to suction oil from surfaces.

[10] An *interceptor trench* acts as a catchment area to prevent contaminants from spreading.

[11] A *frac tank* is a large portable container used for temporary storage and separation of liquids such as oil/water mixtures.

[12] Marathon reported that the total recovered amount of oil (free oil plus oil recovered from solid waste) was 3,362 barrels.

[13] According to Marathon's pipeline corridor soil sampling plan, soil sample testing was to be conducted until the oil was not detectable by sight or smell and photoionization detector readings were less than 50 parts per million. See Antea Group, 2022, *Marathon Pipe Line LLC (MPL) Edwardsville Response: Pipeline Corridor Soil Sampling Plan*.

[14] *External loads* are loads transmitted to a pipeline from an external source; for example, those imposed by land movement.

- **August 21, 2012:** A caliper/inertial measurement unit (IMU) assessment for mechanical damage and geometric anomalies was conducted.[15]
- **2014:** Concrete revetment mats were installed along the Cahokia Creek bank to protect the pipeline from erosion found in 2012.[16]
- **2017:** The revetment mats installed in 2014 were repaired, and additional mats and riprap were installed.[17]
- **January 5, 2018:** A caliper/IMU assessment and bending strain analysis found 18 areas with total bending strains of more than 0.125 percent—the highest of which (0.34 percent) was near the rupture location.[18] Recommended mitigation efforts included in-situ strain monitoring, finite element assessments, stress relief, further IMU assessments, pipeline movement assessments, and pipeline replacement.[19]
- **July 7, 2021:** An investigation, completed in response to the 2018 IMU assessment, indicated the left bank of Cahokia Creek was eroded, with evidence of slope instability including recent failures, scarps, and cracking.[20] This investigation recommended increased monitoring of bank instability, repeat depth-of-cover surveys, and additional reinforcement of the bank. Based on this investigation, Marathon planned on conducting a bending strain and pipeline movement analysis in 2022, but that was not completed before the rupture occurred.

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[15] An *IMU assessment* provides mapping information that is aligned with in-line inspection tools to locate pipeline anomalies, features, and fittings. Data from an IMU assessment can be used to calculate curvature along a pipeline. See General Electric, 2012, *Excerpt from circumferential magnetic flux leakage final report*.

[16] *Concrete revetment mats* consist of flexible concrete connected by fiber rope and are used for erosion control.

[17] *Riprap* is piled or stacked rocks used for erosion control.

[18] *Bending strain*, the change in pipeline length over original length caused by bending deformation, is a common indicator of surrounding ground movement. See Rosen, 2019, *Bending Strain Report: Marathon Petroleum, 22" Crude Oil Pipeline Roxanna to Patoka Woodpat, January 2018*.

[19] A *finite element assessment* is the use of calculations, models, and simulations to predict and understand the behavior of an object or structure under various physical conditions.

[20] A *scarp* is a long, steep slope or cliff at the edge of a plateau or ridge, usually formed by erosion. See GeoMorphic Solutions, 2021, *Strain Investigation Feature No. 25 WPAT 22-inch ROW 15 Strain Investigation Study*.

- **August 31, 2021:** Another caliper/IMU assessment was completed. As of the date of the accident, Marathon had not requested the strain report from this assessment.

1.4 Postaccident Assessment and Testing

1.4.1 Geotechnical Assessment

After the accident, a hydrotechnical analysis and slope stability assessment determined the earth movement at the rupture location was due to scouring in the creek that was localized on the bank near the rupture location because of large, woody debris.[21] The assessment determined that the slope instability had continued after the revetment mats and riprap were installed in 2014 and 2017.

1.4.2 Metallurgical Testing

While on scene, the National Transportation Safety Board (NTSB) observed complete circumferential separation at a girth weld at the rupture origin. The NTSB retained three sections of the Woodpat pipeline for metallurgical testing, which was completed by a third-party contractor directed by the NTSB.[22] Inspections of the fractured girth weld revealed weld defects. Scanning electron microscopy was performed on the fracture features of the girth weld, and those features exhibited characteristics consistent with overstress fracture.[23]

1.4.3 GPS Survey

The day after the rupture, Marathon performed GPS surveys of the Woodpat pipeline after the rupture. Figure 3 displays the results from the 2022 GPS surveys (green dotted line) with data from the IMUs conducted in 2018 (blue line) and 2021 (yellow line).

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[21] *Scouring* is the removal of sediment from streambeds and streambanks by moving water. See Geosyntec, 2022, *Memorandum Addressing Cause of Ground Movement Edwardsville, Illinois*.

[22] One section came from the upstream side of the ruptured girth weld, including the upstream fracture face; one came from the downstream side, including the downstream fracture face; and one encompassed the next upstream girth weld, as an exemplar sample.

[23] *Scanning electron microscopy* is used to obtain high-resolution images of pipe surfaces, particularly of fracture surfaces, cracks, and other defects. See the NTSB Materials Laboratory Factual Report contained in the docket for this investigation for further details.

Figure 3. IMU data for Woodpat pipeline from 2018 and 2021 and 2022 postaccident GPS survey.

1.4.4 Failure Analysis

Marathon performed a failure analysis on the ruptured girth weld using the 2012, 2018, and 2021 IMU assessments. As part of the failure analysis, Marathon completed a numerical analysis using calibrated models established by the 2018 and 2021 IMU data and postaccident data to conduct a strain analysis and collect deviation-from-straight values.[24] (See table 2.) The failure analysis indicated increased strain approximately 10

[24] Marathon did not calculate deviation-from-straight values at the time of the 2018 and 2021 IMU assessments.

feet from the rupture location, with maximum total strain near the ruptured girth weld between 0.61 and 0.83 percent, and a deviation-from-straight value of just over 8 feet.[25]

Table 2. Analysis of 2018 and 2021 IMU data and 2022 postaccident data.

Date	Maximum Combined Bending Strain (%)	Bending Strain near Girth Weld (%)	Horizontal Deviation from Straight[1]
2018	0.34	0.02	5.7 feet
2021	0.41	0.25	8 feet
2022 (time of rupture)	–	0.42 (estimated)	8.2 feet

[1] *These values were calculated in the postaccident numerical analysis.*

1.5 Postaccident Actions

1.5.1 Marathon Pipeline LLC

Following the rupture, Marathon conducted repairs and remediation activities. All girth welds that had not been removed were examined using ultrasonic phased array testing.[26] Marathon also reevaluated its integrity management program and standardized its method of geohazard threat identification, increased the use of in-line inspection to locate pipeline segments at risk from geohazards, expanded training for controllers, introduced technologies to assist employees with identifying geohazards, and contributed to research projects related to geohazards.

On March 14, 2022, Marathon sent the Pipeline and Hazardous Materials Safety Administration (PHMSA) a commitment letter that included specific actions the company would take in response to the rupture. This included performing fitness-for-service calculations on the unearthed girth welds in the area of the rupture, reinforcing repairs to girth welds that were exposed during postaccident response, conducting a geotechnical analysis of the Cahokia Creek bank, completing site evaluations at locations on the Woodpat pipeline at which increased strain had been identified, summarizing events that would trigger mitigative action, and completing a strain analysis from the 2021

[25] Maximum total strain is the maximum membrane strain within 10 feet of the girth weld plus the maximum bending strain. Tensile strain capacity in this area was calculated to be 0.29 percent. See ADV Integrity, Inc., 2023, *Edwardsville Failure Analysis: Final Report*.

[26] *Ultrasonic phased array testing* is often conducted in the field to determine if there are any defects in the weld.

in-line inspection.[27] Marathon also updated its geohazard susceptibility criteria and applied the criteria to all its pipelines.[28]

On March 15, 2022, Marathon installed about 60 feet of new pipe to replace the sections that had been removed and restarted the pipeline at 7:31 a.m.

On April 5, 2022, Marathon led an operator-to-operator information sharing webinar, supported by the NTSB and PHMSA, for approximately 900 attendees, that addressed details of the incident, response, and initial lessons learned.

1.5.2 Pipeline and Hazardous Materials Safety Administration

PHMSA oversaw the implementation of the activities outlined by Marathon in its commitment letter. In June 2022, PHMSA published an advisory bulletin reminding the pipeline industry of the threat of earth movement and for pipeline operators to monitor and mitigate threats to pipeline integrity.[29] In December 2022, PHMSA held a public meeting reviewing recent geohazard failures including the Edwardsville rupture.

2 Analysis

In this accident, a 22-inch diameter crude oil pipeline operated by Marathon ruptured at a girth weld in Edwardsville, Illinois, resulting in the release of about 3,500 barrels of crude oil, some of which entered Cahokia Creek. The NTSB's postaccident laboratory testing of the ruptured sections of pipe showed that the girth weld had experienced an overstress fracture. A review of records showed that Marathon had documented multiple indications of slope instability near the rupture location dating back to 2012, when an integrity assessment identified erosion along the Cahokia Creek bank. In 2014, Marathon installed concrete revetment mats to stabilize the bank.

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[27] *Fitness-for-service calculations* are quantitative engineering evaluations, based on guidance contained in American Petroleum Institute Recommended Practice 579, that assess the structural integrity of in-service components that may contain a flaw or damage or that may be operating under a specific condition that might cause a failure.

[28] Marathon's revised geohazard assessment frequency is once a year for pipeline segments with observed geohazard issues, every 3 years for segments determined to be susceptible to geohazards, and every 5 years for segments designated for monitoring only.

[29] For more information, see PHMSA Advisory Bulletin: Potential for Damage to Pipeline Facilities Caused by Earth Movement and Other Geological Hazards. Also cited in the advisory bulletin was a 2020 pipeline rupture in Hillsboro, Kentucky. See NTSB, 2022, *Enbridge Inc. Natural Gas Pipeline Rupture, Hillsboro, Kentucky, May 4, 2020*, NTSB/PIR-22-01.

In the years that followed, caliper/IMU assessments, strain analyses, and risk assessments indicated that the site of the rupture continued to experience slope instability and that further reinforcement of the creek bank was necessary. In 2017, Marathon repaired previously installed revetment mats and added more mats and riprap. However, postaccident analyses reviewed and conducted by the NTSB showed that these actions, as well as Marathon's actions in 2014, were ineffective in completely protecting the pipeline from external loads that were due to slope instability. Marathon did not take further action to stabilize the creek bank after 2017.

Although Marathon conducted IMU assessments in 2018 and 2021, it did not deploy the strain monitoring recommended by the 2018 IMU assessment and bending strain analysis, nor did it pursue finite element assessments, stress relief, pipeline movement assessments, or pipeline replacement before the accident. Finite element assessments would have facilitated a more-accurate assessment of the strain on the pipeline and would have allowed Marathon to better foresee the pending safety issues related to slope instability and deploy better strain mitigations that could have prevented the rupture.

Further, a 2021 strain investigation, also based on the 2018 IMU data, indicated that slope instability was still present and recommended monitoring and bank reinforcement, but Marathon did not do this by the time of the accident. Marathon had planned to conduct a bending strain and pipeline movement analysis in 2022, but the rupture preceded such action.

As a result of this accident, Marathon revised its total bending strain action limits to be more stringent, facilitating additional site investigations and remediation projects for locations that could be at risk of geohazard-related damage. The company also amended its geohazard assessment frequency, began collecting deviation-from-straight values to analyze bending strain features, expanded methods to proactively identify geohazard threats, and formalized the protocol to calculate total strain demand on pipelines from strain features.

After the accident, PHMSA issued an advisory bulletin on damage to pipeline facilities from earth movement and conducted a public meeting to discuss the prevention of geohazard accidents. Marathon conducted a widely attended information-sharing event on lessons learned from the rupture, supported by the NTSB and PHMSA.

3 Probable Cause

The National Transportation Safety Board determines that the probable cause of the Edwardsville, Illinois, crude oil pipeline rupture was an overstress fracture of a girth weld from external loads caused by slope instability that had not been completely mitigated by Marathon before the accident.

The NTSB is an independent federal agency charged by Congress with investigating every civil aviation accident in the United States and significant events in the other modes of transportation—railroad, transit, highway, marine, pipeline, and commercial space. We determine the probable causes of the accidents and events we investigate and issue safety recommendations aimed at preventing future occurrences. In addition, we conduct transportation safety research studies and offer information and other assistance to family members and survivors for each accident or event we investigate. We also serve as the appellate authority for enforcement actions involving aviation and mariner certificates issued by the Federal Aviation Administration (FAA) and US Coast Guard, and we adjudicate appeals of civil penalty actions taken by the FAA.

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For more detailed background information on this report, visit the NTSB Case Analysis and Reporting Online (CAROL) website and search for NTSB accident ID PLD22FR002. Recent publications are available in their entirety on the NTSB website. Other information about available publications also may be obtained from the website or by contacting –

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