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Hazardous Liquid Pipeline Strike and Subsequent Explosion and Fire aboard Dredging Vessel *Waymon Boyd*

EPIC Marine Terminal, Corpus Christi Ship Channel, Corpus Christi, Texas

August 21, 2020

Abstract: This report discusses the hazardous liquid pipeline breach and subsequent explosion and fire aboard dredging vessel *Waymon Boyd*. Safety issues identified in this report include inadequate project planning and risk assessment, pipeline damage prevention, and pipeline hazard training. As a result of this investigation, the National Transportation Safety Board makes three new safety recommendations to the Pipeline and Hazardous Materials Safety Administration, one new safety recommendation to the Coastal and Marine Operators, two new safety recommendations to the Coastal and Marine Operators and the Council for Dredging and Marine Construction Safety, three new safety recommendations to Orion Group Holdings, and one new safety recommendation to Enterprise Products.

Contents

Figures

Tables

Acronyms and Abbreviations

AIS	automatic identification system
APWA	American Public Works Association
CAMO	Coastal and Marine Operators
CDMCS	Council for Dredging and Marine Construction Safety
CFR	*Code of Federal Regulations*
DMPA	dredged material placement area
DOT	Department of Transportation
EDS	energy dispersive spectroscopy
hp	horsepower
HSE	health, safety, and environmental
ILI	in-line inspection
JHA	job hazard analysis
JSA	job safety analysis
MLLW	mean lower low water
PC	personal computer
PHMSA	Pipeline and Hazardous Materials Safety Administration
psi	pounds per square inch
psig	pounds per square inch gauge
PVC	polyvinyl chloride
RSPA	Research and Special Programs Administration
SCADA	supervisory control and data acquisition
SSSP	site-specific safety plan
TAC	Texas Administrative Code

Executive Summary

What Happened

On August 21, 2020, about 0802 central daylight time, the US-flagged dredge *Waymon Boyd* struck a submerged 16-inch liquid propane pipeline during dredging operations in Corpus Christi, Texas. A geyser of propane gas and water erupted adjacent to the vessel. Shortly thereafter, propane gas engulfed the vessel, and an explosion occurred. Fire damaged the vessel and surrounding shoreline. A total of 18 personnel employed by Orion Marine Group were working or resting on the dredge and assist boats (tender boats, anchor barges, booster barges, and a supply barge) on the day of the accident. Three crewmembers aboard the *Waymon Boyd* and one on an adjacent anchor barge died in the explosion and fire. Six crewmembers aboard the dredge were injured, one of whom later died from his injuries. The *Waymon Boyd*, valued at $9.48 million, was a total loss. The cost of pipeline damage was $2.09 million. The cost of physical damage to the EPIC facility was $120,000.

What We Found

The accident occurred because the *Waymon Boyd*'s rotating cutterhead struck Enterprise Products' pipeline TX219, breaching the pipeline, which allowed propane gas to escape, surround the dredge, and ignite within the engine room, causing the explosion. Inadequate planning and risk management by the dredging company, Orion Marine Group, meant that not enough controls were in place to mitigate the risk of the cutterhead breaching pipeline TX219.

We also found that the engineering drawings for the dredging project were deficient, which led to the Orion Marine Group project engineer misinterpreting information within the drawings and communicating incomplete and inaccurate information during the "one-call" ("Call Before You Dig") process, which dissuaded Enterprise Products from protecting pipeline TX219 in accordance with the company's damage prevention program.

Pipeline protection measures specific to dredging, such as greater collaboration between pipeline operators and dredging companies, sharing GPS coordinates of pipelines, improved marking requirements, and tolerance zones for dredging, could have prevented this accident.

We determined that the probable cause of this accident was Orion Marine Group's inadequate planning and risk management processes, which failed to identify the proximity of their dredging operation to Enterprise Products' pipeline TX219 and resulted in the absence of effective controls to prevent the dredge's cutterhead from striking the pipeline. Contributing to the accident were deficient dredging plans provided by Schneider Engineering and Consulting, which resulted in incomplete and inaccurate information communicated to Enterprise Products by Orion Marine Group during the one-call process, which resulted in insufficient measures to protect the pipeline from excavation damage.

What We Recommended

As a result of this investigation, we made recommendations to the companies involved in the accident to implement or update policies and procedures for dredging near pipelines. We also made recommendations to a federal regulator and industry organizations about developing additional guidance and training specific to pipeline protection for marine dredging projects and establishing tolerance zone guidance for marine construction and dredging projects near pipelines.

1. Factual Information

1.1 Accident Narrative

On August 21, 2020, about 0802 central daylight time, the US-flagged, nonpropelled, 152-foot-long cutter suction dredge *Waymon Boyd* (see figure 1) struck a submerged 16-inch liquid propane pipeline during dredging operations adjacent to the EPIC Marine Terminal, located on the Corpus Christi Ship Channel in Corpus Christi, Texas (see figure 2).[1]

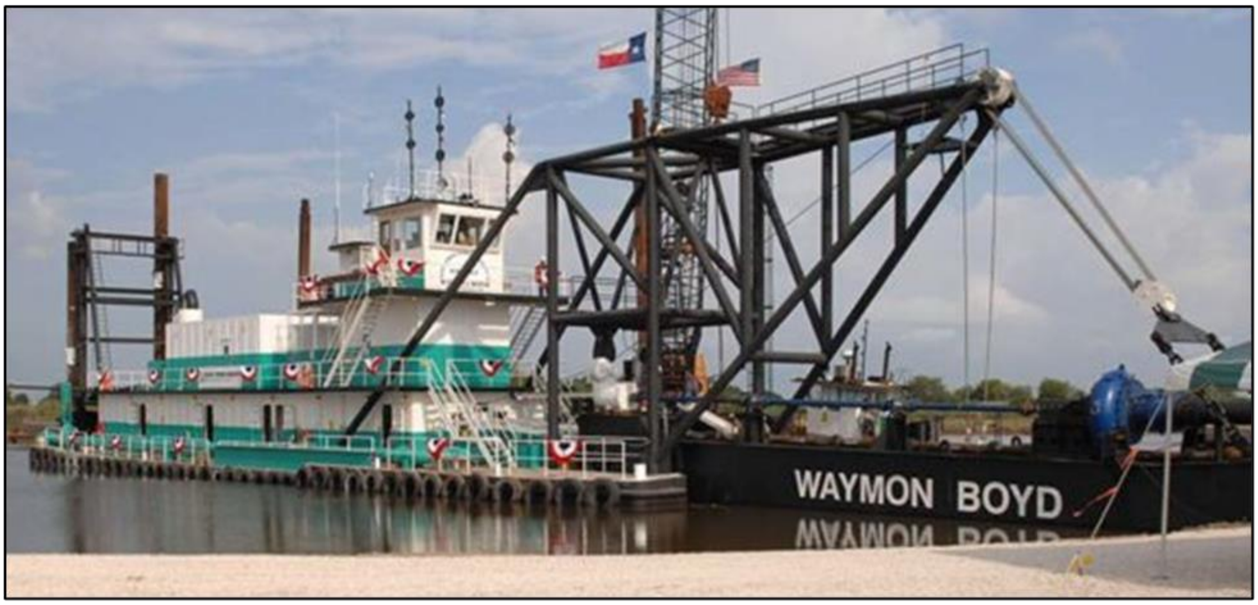

Figure 1. Dredge *Waymon Boyd* before the accident. (Source: Orion Marine Group)

A geyser of propane gas and water erupted adjacent to the vessel. Shortly thereafter, propane gas engulfed the vessel and ignited, and an explosion occurred. Fire damaged the vessel and surrounding shoreline. A total of 18 personnel employed by Orion Marine Group were working or resting on the dredge and assist boats (tender boats, anchor barges, booster barges, and a supply barge) on the day of the accident. Three crewmembers aboard the *Waymon Boyd* and one on an adjacent anchor barge died in the explosion and fire. Six crewmembers aboard the dredge were injured. The remaining eight personnel were uninjured. First responders located the injured and transported them to local hospitals. They were eventually transferred to burn units in San Antonio, Texas, where one of the

[1] Visit ntsb.gov to find additional information in the public docket for this NTSB accident investigation (case number DCA20FM026). Use the CAROL Query to search safety recommendations and investigations.

crewmembers later died from his injuries. The *Waymon Boyd*, valued at $9.48 million, was a total loss. The cost of pipeline damage was $2.09 million. The cost of physical damage to the EPIC facility was $120,000.

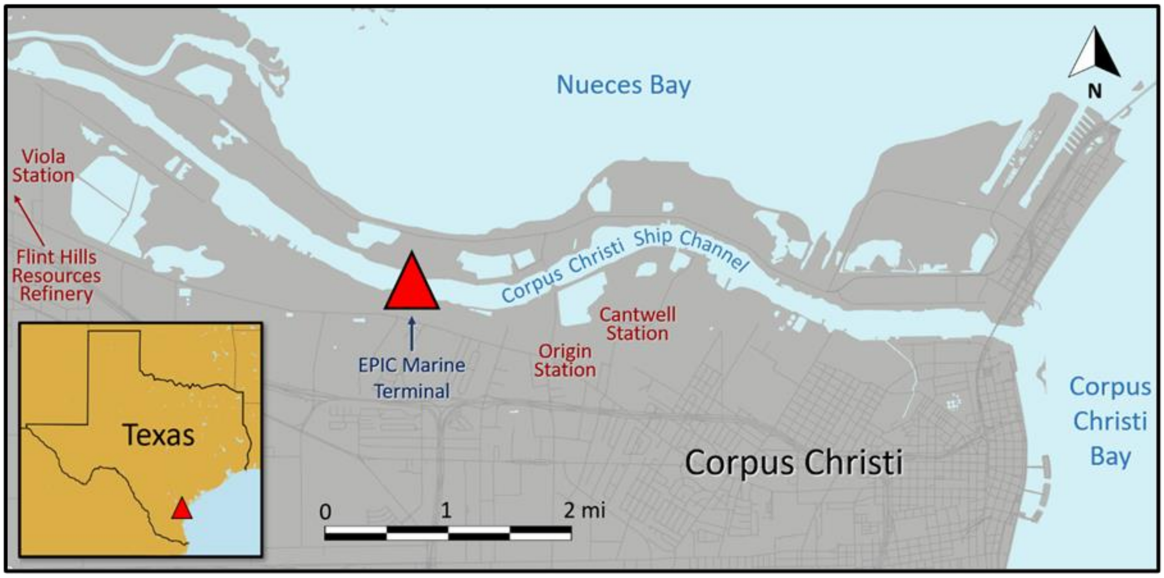

Figure 2. The accident site. (Background source: Google Maps)

1.1.1 Preaccident Events

1.1.1.1 The EPIC Dock Project

In 2019, EPIC Crude Terminal Company LP, a subsidiary of pipeline operator EPIC, began repurposing the dock at the former Interstate Grain Terminal, located on the Corpus Christi Ship Channel in Corpus Christi, Texas, to onload crude oil to tank ships for export. The facility, which is now known as the EPIC Marine Terminal, loaded its first tanker from the converted pier, designated the West Dock, in December 2019 (see figure 3). The West Dock is capable of loading Aframax-sized tankers.[2]

[2] An *Aframax* tanker is a medium-sized tank vessel capable of carrying 80,000–120,000 deadweight tons of crude oil (about 750,000 barrels). *Deadweight* refers to the carrying capacity of a vessel (weight of cargo, fuel, water, food, parts, and other consumables) but excluding the weight of the ship itself.

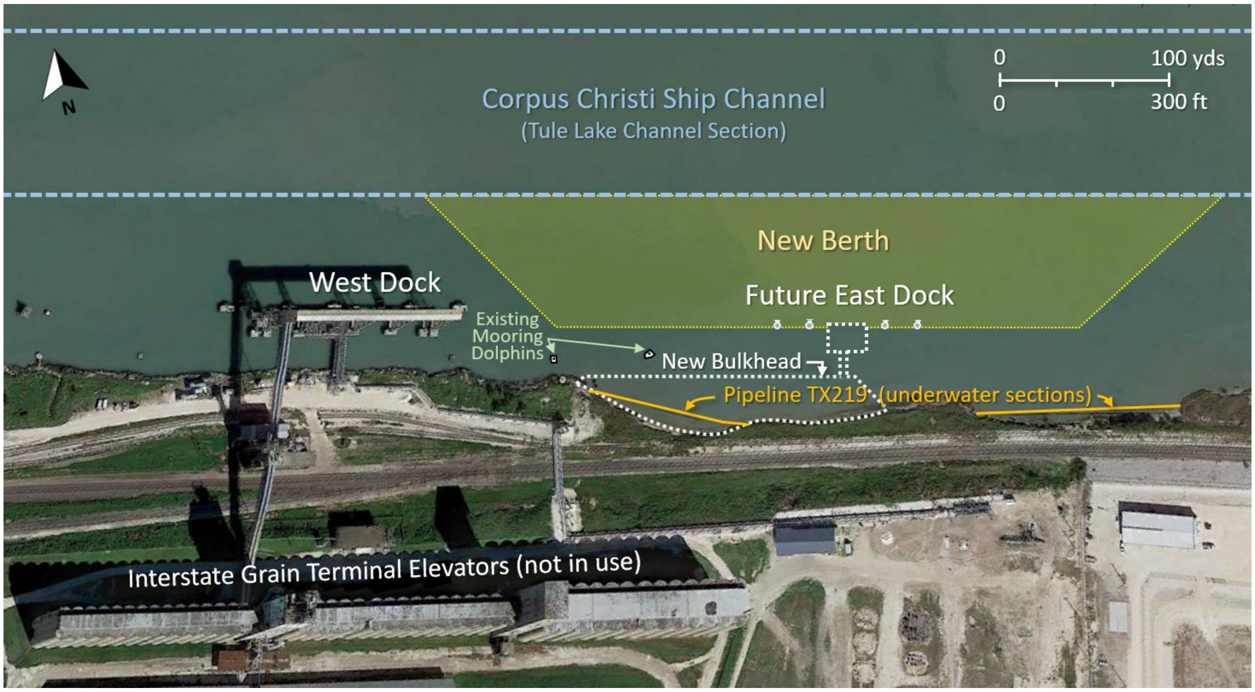

Figure 3. EPIC Marine Terminal, Corpus Christi, Texas. (Background source: Google Earth)

As the West Dock was being modified, EPIC Crude Terminal Company began planning for a second crude oil loading pier capable of supporting larger Suezmax-sized tankers.[3] The new pier, designated the East Dock, was to be located on the same property, about 300 yards to the east of the West Dock. In addition to construction of the pier, the East Dock project required the construction of a bulkhead along the shoreline and the dredging of a ship berth between the dock and the main shipping channel.

1.1.1.2 Dredging Project Start and Phase 1 Dredging Operations

The Orion Marine Group (Orion), a marine heavy-construction firm, was selected by EPIC Crude Terminal Company to construct the East Dock and dredge the associated berth. The marine construction and dredging operations were contracted separately and undertaken by different divisions within Orion, with dredging operations scheduled to be accomplished first. Due to the availability of equipment and access to the dredged material placement area (DMPA, the designated area where the dredged material was discharged), dredging for the East

[3] A *Suezmax* tanker is a large-sized tank vessel constructed to the maximum dimensions capable of transiting through the Suez Canal. These vessels typically have a capacity between 120,000–200,000 deadweight tons, which equates to between 800,000–1,000,000 barrels of crude oil.

Dock was conducted in two phases. Phase 1 occurred from May to June 2019, and phase 2 was planned to occur from July to October 2020.

The plans for the EPIC East Dock and berth were originally developed by Jacobs, an engineering and construction services firm. The Jacobs dredging plans called for the berth to be excavated to a depth of 46.5 feet mean lower low water (MLLW) to conform to the depth of the main shipping channel.[4] To achieve and maintain this depth, the area shoreside of the boundary of the berth was to be dredged on a slope with a grade of 2.5 feet of run for every 1 foot of rise (2.5:1; see figure 4).

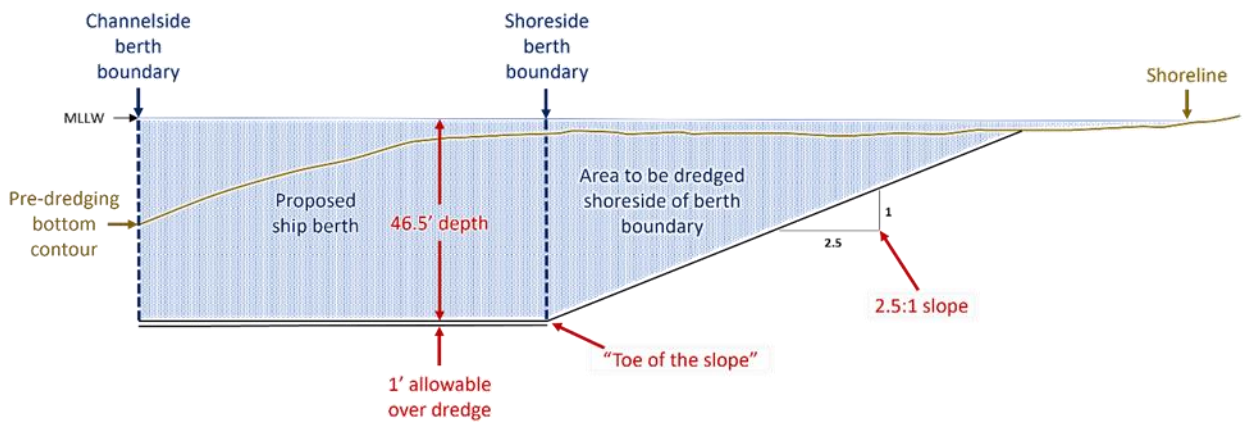

Figure 4. Cross-sectional view of EPIC East Dock berth as viewed looking east.

Before the conversion of the West Dock, EPIC Crude Terminal Company had commissioned a survey to identify all utilities running through the terminal property, including electrical lines, fiber-optic lines, and pipelines. The survey was conducted by TMI Solutions LLC and was dated December 28, 2018. Among other utilities, the TMI surveyors located three pipelines that ran parallel to the shoreline along the entire length of the terminal area. Two of the pipelines were in active use, and the third, a 10-inch diameter pipeline that ran between the two active pipelines, was abandoned. Due to the undulating shoreline, the pipelines ran partly on land and partly in the water. The lines were buried onshore but partially exposed in the water, lying in the bottom sediment of the waterway. The active pipelines were owned and operated by subsidiaries of Enterprise Products Partners LP (Enterprise). The most northerly of the pipelines, a 16-inch-diameter pipe designated TX219, carried

[4] (a) *MLLW* is the average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch. Typically, depths on charts and in marine construction plans are measured from the height of tide at MLLW. (b) Jacobs' final phase 1 construction plans were titled "New EPIC Dock Slip Dredging."

non-odorized liquefied propane. The other active pipeline, designated Line 124, carried natural gas and was also 16 inches in diameter.

On or about May 3, 2019, before the start of phase 1 dredging operations, a preconstruction meeting was held with Orion and EPIC Crude Terminal representatives. Orion representatives present at the meeting included the project manager, the survey superintendent, and two dredge superintendents who shared supervisory responsibilities for the dredge captains. One of the dredge superintendents recalled that during the preconstruction meeting, he was told that pipeline TX219 was "between 5 and 10 feet from the top of the [dredging area] slope."

On May 7, 2019, Orion made a notification of its intent to conduct excavation work via the Texas811 "Call Before You Dig," also known as "one-call," system. Enterprise received notification tickets for their pipelines, and, a day later, two Enterprise pipeline technicians visited the EPIC East Dock worksite. According to the technicians, they met with the "EPIC lead inspector" who told them that the dredging work would be north of the Enterprise pipelines. Although there was supposed to be no conflict with the pipelines, the EPIC representative stated that "cane poles"—bamboo poles about 18 feet in length—would be placed to mark the location of pipeline TX219. Each pole was placed in the bottom sediment, with most of the pole exposed above the waterline. The Enterprise technicians returned to the site a few days later to confirm the poles were in place, and the one-call tickets were closed.

On May 8, 2019, the Orion dredge *Leonard M. Fisher* was towed to the site, and dredging operations began the next day. Operations continued until June 27, and there were no issues reported during this phase.

1.1.1.3 Phase 2 Dredging Operations

In October 2019, EPIC Crude Terminal Company applied for and was granted a permit from the US Army Corps of Engineers to enlarge the East Dock berth by extending it another 167 feet to the west. Consequently, Orion assigned Schneider Engineering and Consulting (Schneider), a wholly owned subsidiary of Orion Marine Group's parent company, to update the phase 1 dredging plans to reflect the revised berth dimensions (see figure 5).

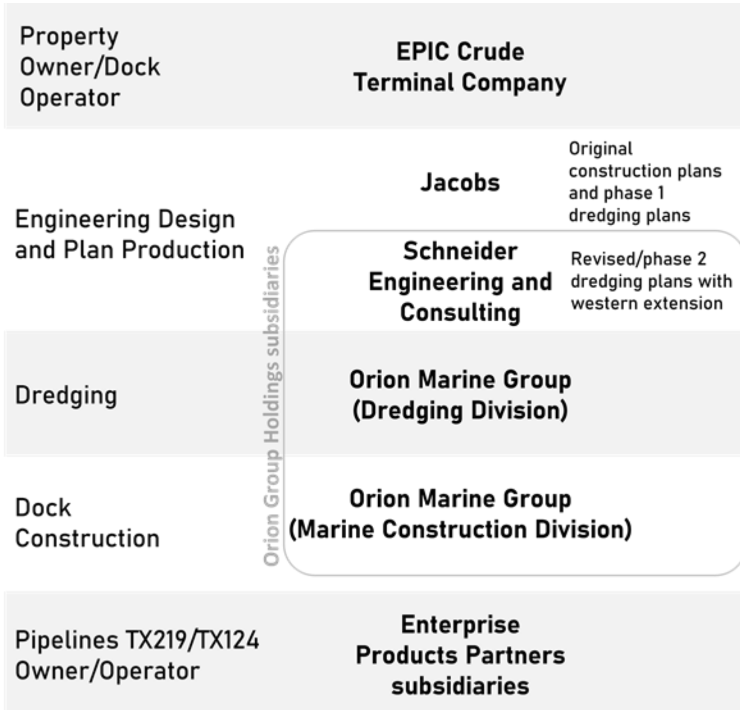

Figure 5. Companies involved in the EPIC dock project.

EPIC Crude Terminal Company's facilities engineering manager stated that he requested that the pipelines identified in the 2018 TMI utilities survey be included in the dredging plans. The survey data was provided to Orion, and the information was subsequently forwarded to the Schneider design engineer tasked with developing the phase 2 plans. The design engineer said that the survey data was imported into the computer-aided design (AutoCAD) software that he was using to develop the drawings. In a set of drawings entitled "EPIC Marine Terminal Dredging Construction Plans," dated June 23, 2020, the pipelines were shown in the "Existing Site Plan" drawing—an overhead view of the berth overlaid on a satellite image of the area—but did not appear in any other drawings, including the "Dredge Site Plan" and cross-sectional drawings of the site (see section 1.8.1.2 for more information about the phase 2 engineering drawings).

Due to the east-southeast/west-northwest orientation of TX219 in the underwater section of the pipeline, the 167-foot extension of the EPIC Dock berth brought the pipeline closer to the dredge template than it had been in the original Jacobs plans. However, the Schneider design engineer told investigators that during the development of the revised plans, he determined that the pipelines were outside of the dredge template. He said that, using the drawings, he measured the distance between the edge of the template (the top of the slope) and the pipelines and determined that it was "in the neighborhood of…8–10 feet" at the closest point. The engineer told investigators that during weekly "design phase" meetings, the presence of the pipelines was discussed among Schneider, EPIC, and Orion representatives.

Once the revised engineering plans for the East Dock berth were completed, they were passed to the Orion survey superintendent, who used the plans to build a dredge plan, or "dredge template" in DREDGEPACK, a module in the hydrographic data collection and processing software HYPACK. Among other functions, DREDGEPACK was used by the operator on the dredge, called the leverman, to display where the digging tool that he was controlling (the cutterhead) was in relation to the dredge template. Using the software display, the leverman could determine in real time what areas required dredging and whether the cutterhead was operating within the dredge template (see section 1.8.1.3.1 for more information on HYPACK/DREDGEPACK). Once the dredge template for phase 2 operations was completed by the survey superintendent, he loaded it onto the computer on board the *Waymon Boyd*, the dredge scheduled to conduct the phase 2 work.

On June 23, 2020, an Orion project engineer, who had not been involved with phase 1 operations, made a one-call notification for the phase 2 dredging operations. In response to the notification, tickets were once again generated for the active natural gas and propane Enterprise pipelines. A pipeline company technician—one of the same technicians that had responded to the 2019 one-call tickets—contacted the Orion project engineer to discuss the project and schedule a site visit. On June 29, the Orion project engineer sent the Schneider dredging plans to the Enterprise technician. In the accompanying email, the project engineer stated:

> It looks as though we will be about 60' off the shoreline, and the areas where the shoreline and pipelines are furthest in the water (closest to the new template), we have already completed dredging to grade [dredging the slope] …so there shouldn't be a need for concern.

A site visit with the Orion and Enterprise representatives was set for June 30; however, due to issues stemming from the COVID-19 pandemic, they did not meet as planned. The Enterprise pipeline technician said that he "looked at the EPIC's plans and saw the prism where [the Orion project engineer] said that we're going to be working, and it was well offshore. And with the knowledge that EPIC wanted to put in a bulkhead and fill in our lines with sand, we knew we were okay with clearing that ticket." According to the pipeline technician, he and the project engineer had a phone call during which they agreed that it was not necessary to physically mark the pipelines because they did not conflict with the dredging area. On the same day, another Enterprise technician closed the 2020 ticket for pipeline TX219 as "3-CLEAR," and included the following in the remarks: "EFQ pipeline TX219 will be clear from work area by 55ft. There will be no dredging near the channel shoreline." According to the Enterprise technician, this remark was based on the June 29 email from the Orion project engineer.

The Orion project engineer's supervisor, the project manager, also reviewed the Schneider dredging plans. During a subsequent discussion between the Orion project engineer and project manager, concern was raised regarding the placement of anchors used in dredging operations. Although the Orion project manager did not expect that the excavation would be near the pipelines, he suggested that the anchors could be placed near them. He discussed this concern with the dredge superintendent and also directed the project engineer to contact Enterprise again and inform the company about the anchors. The project engineer called the pipeline technicians, and they agreed to go out to the site and install cane poles to "courtesy" mark the pipeline.

On July 16, the Orion project engineer and the two Enterprise technicians met at the dredging site and noted that "about half" of the cane poles put in place the prior year were still in place. They boarded a skiff (small boat) and, after locating pipeline TX219 using a handheld device, the Enterprise technicians courtesy-marked the location using additional cane poles provided by Orion. The project engineer stated that the poles were placed on the channel side of the pipeline. The Enterprise technician estimated that the poles were spaced about 50 feet apart along the roughly 260-foot section of underwater pipe. He stated that he attempted to place a cane pole "about 10, 15 feet in the water [from the western shoreline], but it was too hard packed there. So, we followed the pipeline out a little further until it got soft enough for me to put one in." He told investigators that the first cane pole was between 30 and 40 feet from the shoreline where the pipeline entered the water.

The Enterprise technician stated that whereas a compulsory marking required markers every 20 feet, a courtesy marking only required markers every 200 feet. The Enterprise technician also explained that optional courtesy markings are only done if work is understood to be clear of a pipeline and "they [the excavator] want to feel better about the line being located so everybody knows what it is." The courtesy markings were not compliant with American Public Works Association (APWA) color-code guidelines. Although the pipeline technicians marked the on-land portion of the pipeline with yellow paint and flags, the cane poles marking the underwater portion of the pipeline were bare and did not display yellow flags that would have signified gas or hazardous liquid pipelines. Because the markings were courtesy markings, the pipeline was not required to be marked in accordance with Railroad Commission of Texas regulations and Enterprise mandatory locating and marking requirements. After the cane poles were installed, the project engineer took photographs of the poles and one of the pipelines that was visible from the skiff, under the water.

On July 20, the project engineer emailed the photos to the *Waymon Boyd* with the following message:

> There are 2 pipelines near the shoreline at Epic. They are marked with cane poles and we've been asked to stay 20' away from them. Please keep in mind when working in the area and placing swing anchors.

Both the dredge captain and the deck captain—the first- and second-in-command of the vessel, respectively—stated that they received and read the email. The leverman said in a postaccident interview that he was not told about the purpose of the cane poles. Further, he stated that there were no cane poles in the area he was dredging on the morning of the accident.

On July 25, category 1 Hurricane Hanna struck the Texas coast just south of Corpus Christi. The impact of the storm on the courtesy cane pole markings is unknown, but Texas law required the excavator to notify a utility owner if the status of markings changed (see section 1.10.1 for more information about federal and state statutes and regulations). There is no record of Orion contacting Enterprise regarding the cane poles after the hurricane passed. A photograph of the accident site taken some time after the storm, while phase 2 dredging operations were under way, shows the closest cane pole east of the accident pipeline breach was about halfway across the inlet in the channel that the pipeline crossed (see figure 6). A postaccident overhead image of the area shows the location of pipeline TX219 as well as the location of two cane poles and a downed pipeline marker, based on a postaccident survey conducted by SAM LLC.

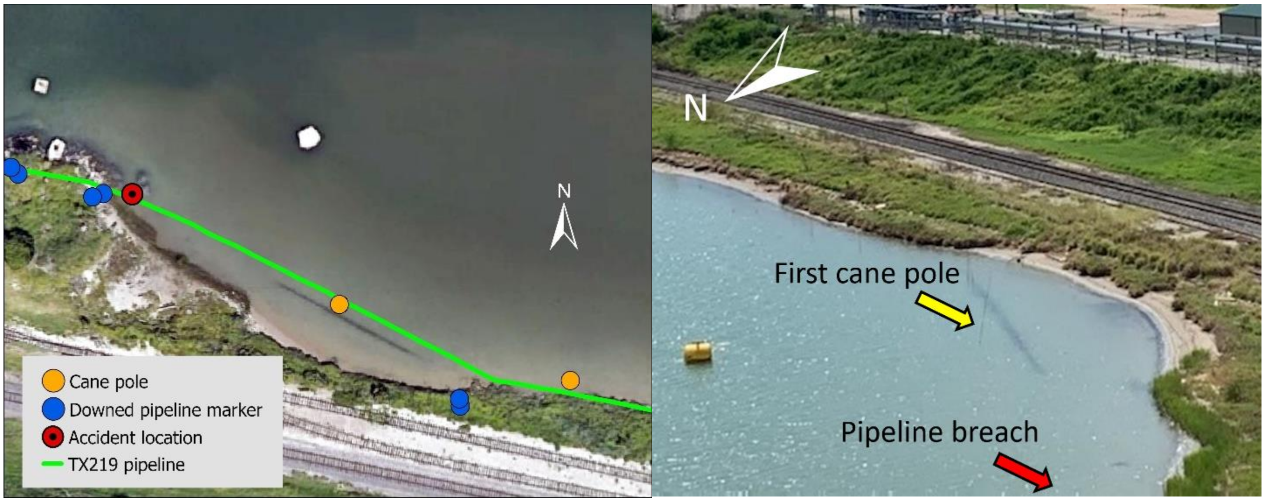

Figure 6. Postaccident temporary and permanent pipeline marker survey locations, accident location, and pipeline TX219 (*left*); preaccident photo of marking cane pole (*right*). (Sources: Enterprise Products [*left*]; EPIC Crude Terminal Company [*right*]; images annotated by NTSB)

The dredge captain recalled that he did not discuss the pipelines with the leverman, but he thought that the leverman knew where they were because of the leverman's experience and "because he can physically see it." The leverman said he was aware of a pipeline but believed there was only one—the single pipeline that he could visibly see under the water. (The abandoned 10-inch pipeline located between TX219 and another Enterprise-owned active natural gas pipeline was the only visibly uncovered pipeline near the accident site before the accident.) He recalled that the captain told him to keep the dredge anchors away from the pipeline but did not give him a specific standoff distance. Multiple other subordinate crewmembers stated that they were not made aware of the pipelines.

Figure 7. Waymon Boyd cutterhead postaccident. (Source: US Coast Guard)

The *Waymon Boyd* was a cutterhead-type dredge. A cutterhead is a rotating, toothed, digging tool (see figure 7) mounted at the end of framework, known as the ladder, at the bow of a dredge. The cutterhead can be lowered to the desired dredging depth by pivoting the ladder downward. When operating, the cutterhead breaks up the bottom sediment and other material to be dredged. The loosened material is then drawn away via a suction pipe that begins directly aft of the cutterhead. Suction at the pipehead is provided by pumps mounted on the ladder and/or in the dredge hull. The material is moved aft on the dredge via piping and then via a floating and/or submerged pipeline to a DMPA. Depending on the distance to the DMPA, barges with booster pumps may be placed along the dredge pipeline; two booster barges were used for the EPIC dock project.

On July 29, the *Waymon Boyd* was towed into position at the EPIC East Dock site in the early morning, and phase 2 dredging began later that day. From then on, the *Waymon Boyd* operated 24 hours a day in two 12-hour shifts. During a normal 12-hour shift, the dredge and its attendant barges and support vessels were crewed by 17–19 personnel. The dredge captain and deck captain worked an alternating rotation of 10 days on and 4 days off, with the deck captain assuming overall responsibility of the vessel when the dredge captain was off rotation. On the accident date, the deck captain was off rotation and not aboard the vessel. Although the captains' normal working hours were 0600 to 1800, they were on call 24 hours a day when on board and worked additional time as needed. The remainder of the crew worked a rotation of 14 days on and 7 days off, from 0530 to 1730 or 1730 to 0530. Most of the crew was berthed ashore when not on shift and were boated to and from the dredge each morning and evening.

Through the end of July and the first weeks of August, the *Waymon Boyd* operated at the dredge site (see figure 8), working generally east to west beginning on the channel side and moving progressively inshore, as observed in automatic identification system (AIS) data.

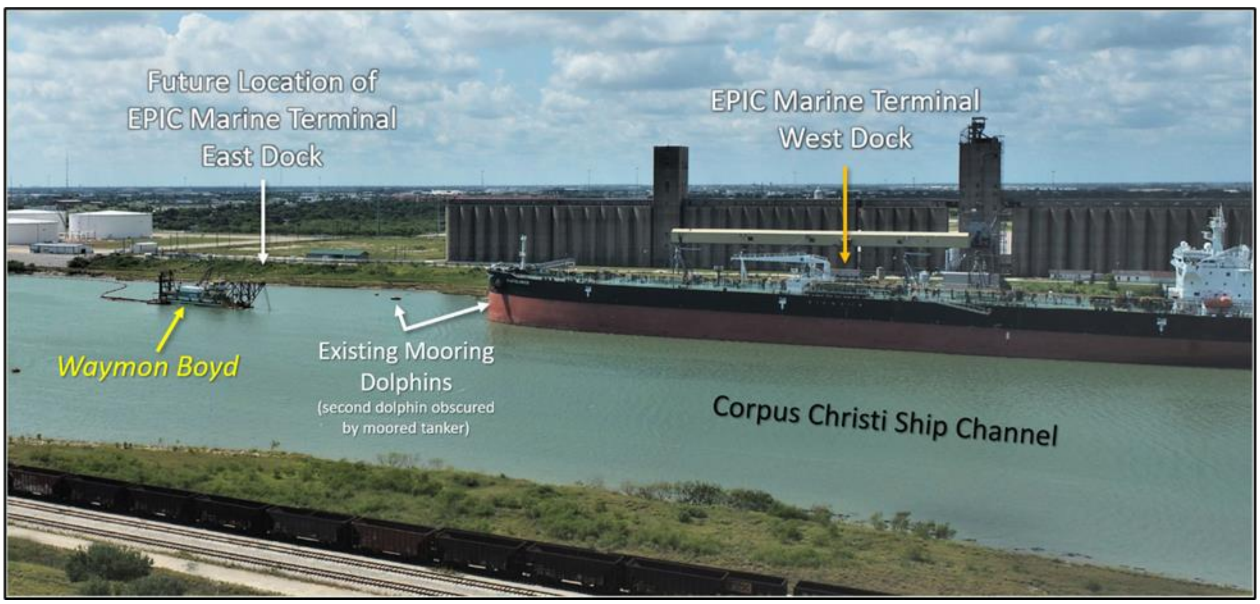

Figure 8. The *Waymon Boyd* at the EPIC Marine Terminal East Dock site, August 7, 2020. (Source: Orion Marine Group, annotated by NTSB)

In the early morning hours of August 21, the dredge was working in an area between two existing mooring dolphins located on the western side of the project area. About 0445, the dayshift leverman took the controls of the vessel after a 10- to 15-minute turnover discussion with the off-going leverman. The oncoming leverman stated that during the turnover, he was informed that the dredge was having “a lot of trouble with the rocks,” and that the rocks were preventing the dredge from reaching the top edge of the slope. After being relieved, the nightshift leverman went to the vessel’s berthing area.

The remainder of the crew conducted a shift change at 0530, and soon thereafter the oncoming crew gathered in and around the lever room, on the top level of the dredge, for a safety meeting.[5] Normally, the dredge captain or deck captain led the safety meeting; however, the captain was not present in the lever room on the morning of August 21 because he had been up the night before overseeing repairs to a coupling on the shaft that drove the cutterhead, which had sheared when the cutterhead “hit something hard.” When the dredge captain and deck captain were not present, the dredge captain expected the leverman to lead the meeting. All crewmembers on board the dredge that morning later told investigators that the safety meeting occurred, but the leverman said that he did not lead the meeting, nor could he recall who led the meeting. According to the crewmembers, the pipelines were not discussed during the meeting or any previous safety meeting conducted during the project. After the meeting, the crew began work and dredging operations continued.

1.1.2 Accident Events

The leverman stated that throughout the first hours of his shift, the cutterhead was continuously hitting rocks and cement debris. He said that when the cutterhead was near the surface, larger rocks and cement pieces were lifted up out of the water by the cutterhead and thrown through the air, while smaller pieces became lodged in the elbows of the dredge suction piping. Three to four times during the early morning, he had to stop the cutterhead and lift the ladder out of the water so that crewmembers could climb into the suction piping and clear out clogs. Each time, it took 30–40 minutes to unclog the system. The leverman stated that because of the downtime, the *Waymon Boyd* had dredged for only a short time on the morning of the accident. He also said that the excessive debris continued to hamper dredging near the top of the slope, limiting excavation to about 5 feet from the southern edge of the dredge template.

[5] The safety meeting occurred at the beginning of each shift and included a discussion of one or two safety topics, as well as the assignment of work tasks for the day.

The dredge captain told investigators that he awoke about 0700 that morning, checked on the leverman, and then proceeded to his office, located just aft of the lever room, to work on the dredge's daily report. About 0730, the leverman called him via the vessel's intercom to report that he was hitting debris. The captain returned to the lever room to assess the situation. When he arrived, he said that the leverman was working the dredge down the slope of the berth, with the cutterhead about 30–35 feet deep in the water at the time. After observing for a few moments, he told the leverman to avoid the debris and "just go around it."

About 0800, according to the captain, the leverman finished a series of side-to-side swings of the dredge and cutterhead at a particular location and then operated the controls to advance the dredge forward about 3 feet, a maneuver known as a "set" (see section 1.8.1.1 for a description of dredge operations and movement). While the dredge was moved forward, the cutterhead, still rotating, was raised to its highest operational position. The captain stated that in this position, the cutterhead was 9 feet below the water's surface.

The leverman explained that when excavating along a slope, he removed one layer of sediment at a time, beginning at the top and carefully stepping the cutterhead down the bank with each successive layer. After the leverman had completed the set, he swung the dredge slowly to port, toward the shoreline, making the first (top layer) cut of the bank in the new position. He said that the anchor winches that he was operating to swing the vessel were at the slowest speed ("idle") so that the cutterhead was not moving too fast as it struck debris.

AIS data from the *Waymon Boyd* shows the vessel's movement in the minutes preceding the accident (see figure 9). Beginning at 0757:25, the dredge swung in a rough arc in a southeasterly direction, toward the shoreline, with a speed over ground between 0.1 and 0.3 knots. The dredge's direction of movement did not reflect its orientation (heading information was not reported by the vessel's AIS), but the dredge captain and leverman told investigators that the vessel's heading was changing from a westerly to southwesterly direction as it moved. At 0802:45 (5 minutes 20 seconds elapsed), the swing to port stopped. At this point, the AIS position of the vessel was about 118.8 feet from pipeline TX219. (The AIS antenna was mounted on the top of the lever room, with a horizontal distance of 119.1 feet from the forward end of the cutterhead.[6])

[6] AIS antenna to cutterhead distance is based on measurements taken by the NTSB and Orion personnel, with the ladder depth assumed to be at the depression angle of 7° (10-foot depth).

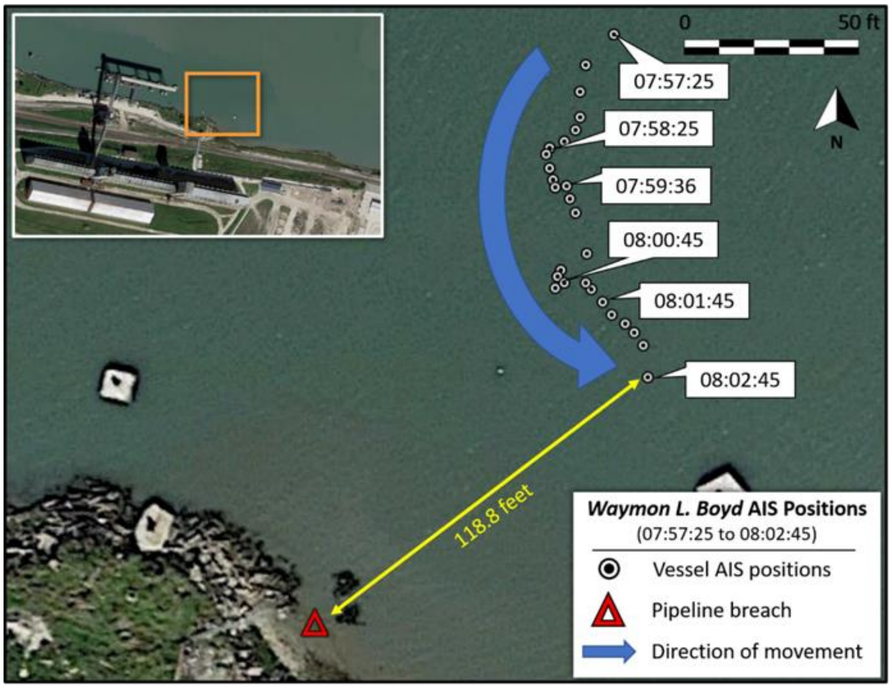

Figure 9. *Waymon Boyd* AIS data from 0757:25 to 0802:45 on the accident date. (Background source: Google Earth)

The leverman said that when the cutterhead was about 5 feet from the southern edge of the dredge template during his swing to port, water suddenly began shooting up off the surface of the waterway, about 2–3 feet landward of the cutterhead. He said the water spray reached as high as the top of the dredge. He did not see or smell any sign of gas. He told investigators that, not knowing what had occurred, he stopped the cutterhead, increased the speed of the motor driving the dredge's anchor winches, and operated the anchor winch control levers to swing the dredge to starboard, away from the spraying water, as quickly as possible. He then called the dredge captain.

The dredge captain said that when he answered the call, the leverman told him that he thought the cutterhead had hit a waterpipe. The captain walked out of his office and saw "some water shooting up" off the port side of the vessel. He said he could not see anything other than the water spray and did not smell anything, and so he believed, as the leverman did, that the dredge had hit a pipeline carrying water. The captain noted that at that time, the cutterhead was at the 9-foot-depth position about 50–60 feet from the eruption of water, and the dredge was swinging away from the eruption, toward the shipping channel. He returned to his office to call an EPIC contractor and inform him of the incident.

Pipeline TX219 ran about 5 miles from Enterprise's Viola Meter Station, located adjacent to the Flint Hills Resources Corpus Christi LLC refinery, to its Cantwell Station in Corpus Christi (see figure 2). TX219 was not a continuous transfer line; rather, propane was moved through the line in batches at scheduled intervals. The valves that controlled transfers through the line were remotely operated from a control center located in Houston, Texas.

A pipeline controller at the Enterprise control center told the NTSB that as a planned batch transfer (with operating pressure in the pipeline between 257 and 265 pounds per square inch gauge [psig]) was nearing completion at 0802, the pipeline supervisory control and data acquisition (SCADA) system alerted him of a low-pressure condition. The Viola Meter Station pipeline pressure at that moment was 156 psig. By 0805, the line pressure had decreased to 149 psig, triggering a subsequent low-pressure alarm in the SCADA system and the closing of an automatic control valve at the Viola Meter Station to isolate the pipeline.

A shoreside security camera at the Interstate Grain Terminal partially captured the geyser of water witnessed by the leverman and dredge captain (see figure 10; the dredge is not within the frame of the camera view). One minute six seconds after the water eruption began, an explosion occurred, shaking the security camera violently. Personnel contracted by EPIC who were several hundred yards away stated that they heard a large "boom" and that it shook the ground and buildings in the area. In the security video, flames spread from the right of the screen following the explosion, consuming much of the shoreline and the West Dock.

Figure 10. Screen captures from security camera footage showing, from top to bottom, the water and gas eruption before the explosion (as noted by red arrow), the initial explosion, and the ensuing fireball. The *Waymon Boyd* is outside of the frame of the camera. (Source: EPIC Crude Terminal Company)

The explosion occurred as the dredge captain was in his office calling the EPIC representative. He stated that "all the fire was in my face…and it was burning on the side and in front of me." He escaped from his office by climbing through a starboard-side window and went down a deck to warn those in the galley and berthing area. He couldn't reach the space because of the fire, so he jumped overboard from the starboard-side second level. The leverman said that when the explosion occurred, he fell on his back and had to stay on the floor because flames were coming in through the windows of the lever room. He eventually evacuated the space and jumped overboard from the starboard side on the third level. He and the dredge captain swam aft along the vessel, then to shore. They were eventually found and transported to a hospital, where they were treated for severe burns.

The chief engineer, nightshift leverman, and cook died on the dredge. The second engineer, who was standing on the deck of an anchor barge moored on the port side of the *Waymon Boyd*, was also killed in the accident. A mate and two deckhands escaped the vessel, were taken ashore, and were hospitalized for severe burns. One of the deckhands died 9 weeks after the accident as a result of injuries sustained in the explosion and fire. The remaining crewmembers, who had been working on the dredge's support vessels at the time of the fire, were uninjured.

1.2 Response

1.2.1 Firefighting and Search and Rescue

Minutes after the explosion, the Port of Corpus Christi's Security Command Center was notified of the explosion and fire. Refinery Terminal Fire Company in Corpus Christi was dispatched to the scene and began fighting fires along the shoreline near the terminal piping. A Port of Corpus Christi Police Department vessel also responded to the fire and assisted with evacuation of the *Waymon Boyd* crew, while landside police officers established on-scene command.

The US Coast Guard was notified of the explosion at 0810, dispatched a response boat from Coast Guard Station Port Aransas, located about 26 miles from the accident site, and launched an MH-65 helicopter from Air Station Corpus Christi. After arriving on scene, the helicopter airlifted two injured crewmembers to a hospital, then returned to conduct search and rescue operations. Throughout the day, additional Coast Guard surface and air units joined the response effort, searching for survivors and providing a security perimeter around the accident scene.

At 0934, the tugboats *Ted C Litton* and *Evelena* arrived on scene and began using their water monitors (cannons) to fight the fire on the dredge (see figure 11). About 20 minutes later, the tugboats *Signet Constellation*, *Signet Courageous*, and *Signet Stars & Stripes*, as well as the prevention and response tugboat *Signet Strength*, took over waterborne firefighting efforts.[7]

About 1100, the Coast Guard directed the establishment of a formal Unified Command to manage the roughly 50 agencies, facilities, and commercial entities that responded to the accident.

The *Signet* tugboats remained at the accident site until the fire on the *Waymon Boyd* was extinguished about 1300. Residual propane rising from the breached pipe continued to burn until 1610, when the pressure in pipeline TX219 equalized with the water pressure, the release of propane diminished, and the fire self-extinguished. The dredge, which continued to smolder, began to founder at 1400. Efforts to stabilize the vessel were unsuccessful, and it sank at 2151.

[7] A *prevention and response tugboat* is a towing vessel specially equipped for firefighting, emergency response, and oil spill recovery, in addition to the equipment normally found on a tugboat.

Figure 11. Tugboats *Ted C Litton* and *Evelena* fight the fire at the accident scene. (Source: Coast Guard)

1.2.2 Pipeline Isolation

At the direction of the pipeline controller in Houston, a local Enterprise pipeline technician drove to the Viola Meter Station and verified that the control valve had closed. Additionally, although flow had stopped in the pipeline, the Houston-based controller initiated commands at 0841 and 0843 to remotely close two motor-operated valves and further isolate pipeline TX219.

Enterprise later estimated that 6,024 barrels of propane were released from the pipeline. At ambient water and air temperature, the propane gas would have instantly flashed from the liquid phase to the gas phase once released from under pressure in the pipe, expanding in volume by a factor of 270:1. The release would have produced more than 9 million cubic feet of propane gas.

1.3 Injuries

Table 1. Injuries sustained in the *Waymon Boyd* accident.

Type of Injury	Crew	Passengers	Total
Fatal	4	0	4
Serious	6	0	6
Minor	0	0	0
None	8	0	8

1.4 Vessel and Pipeline Information

1.4.1 Vessel Particulars

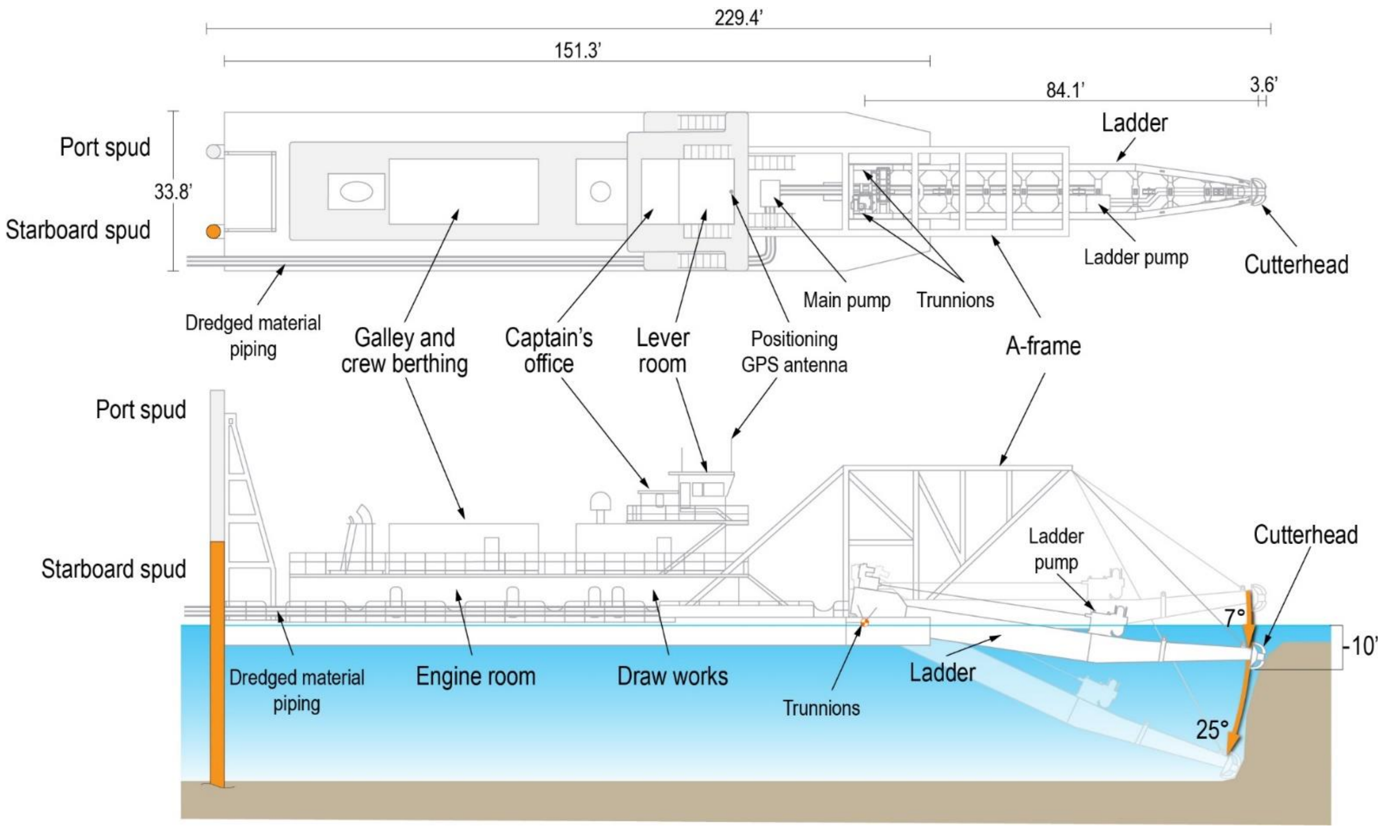

Figure 12. *Waymon Boyd* general arrangements.

The 290-gross-register-ton *Waymon Boyd* was built in 1950 in Rattlesnake, Florida, and originally named *Dredge No. 6*.[8] In 2005, Orion Marine Group acquired the vessel and began a major rebuild at its dredging operation headquarters in Port Lavaca, Texas, converting the dredge to diesel-electric power. It was renamed the *Waymon Boyd* when the rebuild was completed in 2006.

The hull of the dredge was a barge measuring 151.3 feet long by 33.8 feet wide, with a draft of 5.5 feet (see figure 12). The barge was designed with a slot at the bow in which the aft end of the 84.1-foot-long ladder (the framework on which the cutterhead and ladder pump were mounted) was fitted.[9] The ladder was supported on either side of the slot by trunnions that allowed the ladder to pivot downward during dredging operations. The forward end of the ladder with the cutterhead was raised and lowered via a derrick, called the A-frame, also mounted on the bow of the barge.

Table 2. Vessel particulars.

Vessel	***Waymon Boyd***
Type	Other (Dredge)
Flag	United States
Port of registry	Port Lavaca, Texas
Year built	1950
Official number (US)	N/A
IMO number	N/A
Classification society	N/A
Length (overall)	151.3 ft (46.1 m)
Beam	33.8 ft (10.3 m)
Draft (accident)	5.5 ft (1.7 m)
Tonnage	290 GRT
Engine power; manufacturer	N/A

[8] *Gross register tonnage*, or GRT, is a US national standard for the measurement of the volume of all enclosed spaces on a vessel.

[9] The *Waymon Boyd*'s ladder was cut into two pieces during salvage. The ladder length as presented here is the combined length of both sections, from the cutterhead's aft end to the center of the trunnions.

The cutterhead assembly was manufactured in the Netherlands by Vosta LMG. It was a model SC15 cutterhead containing five blades. Figure 19 shows a photograph of the front view of *Waymon Boyd*'s cutterhead assembly after underwater recovery. The blades were marked "A" through "E" by the manufacturer. Each blade contained a row of teeth. Blades "B," "D," and "E" each were manufactured with a row of six teeth, and blades "A" and "C" each were manufactured with a row of seven teeth. The distance between the teeth farthest from the center on blades C and E measured about 6.5 feet, representing the overall diameter of the cutterhead assembly. The axial length of the cutterhead assembly was 3.6 feet. During operation, the 2.9-ton (2.6-metric-ton) cutterhead assembly rotated clockwise when looking forward in the direction of dredging.

The cutterhead teeth could be changed out on site if damaged during operations. While the *Waymon Boyd* crew conducted repairs to the cutterhead shaft coupling the night before the accident, they inspected the cutterhead and found no damaged or missing teeth. The leverman stated that the crew reported no issues with the teeth when the ladder was raised to clean out suction piping clogs just before the accident.

Two large slurry pumps were installed on the *Waymond Boyd* to move the dredged material from the excavation point through the pipeline to the DMPA.[10] The ladder pump was mounted about midpoint on the ladder and provided the initial suction and system pressure to lift material from the digging depth. The main pump was located in the hull near the bow, just forward of the superstructure. This pump provided system pressure for the dredged material pipeline. Strainers were installed ahead of the inlets to prevent damage to the pump from rocks and large debris picked up during dredging. Crewmembers stated that before the accident, they had to clean the strainers frequently.

Two 70-foot-tall, 2.5-foot-diameter spuds—metal pilings that could be lowered to the bottom to provide anchor and pivot points for the dredge—were mounted on the stern of the barge.

The *Waymon Boyd* did not have main propulsion machinery, propellers, or rudders; it was towed to each project site and positioned by tugboats (see section 1.8.1.1 for more information about maneuvering the vessel during dredging operations). Electrical power aboard the dredge was provided by a 3,000-horsepower (hp) Alco 251 diesel generator. The generator was mounted about midship and centerline within the hull of the barge and extended up into the first

[10] *Slurry* is a mixture of solids suspended in a liquid, commonly used as a means of transporting the solids by using pumps to move the carrier liquid.

level of the superstructure. (For the remainder of this report, the entire space, including the area within the hull and within the superstructure above, will be referred to as the engine room.) The generator was oriented with its diesel engine aft and its alternator forward. A turbocharger was fitted on the aft end of the engine, and exhaust piping was routed aft and up to a stack mounted atop the aft end of the first level of the superstructure. In addition to basic services such as lighting, the main generator supplied electricity to several motors, ranging between 400 and 1,500 hp, which delivered dedicated motive power for each of the major mechanical components on the dredge: the ladder pump, main pump, cutterhead, and winches. A 450-hp backup generator was also located in the engine room aft of the main diesel generator.

Fuel from one of seven tanks supplied fuel for the generators via a manifold located on the engine room's port side. The fuel tanks were within the hull outboard of the engine room, three on the port side and four on the starboard side. Emergency fuel shutdown valves for the engines were located near the fuel manifold.

The control station for the main and backup generators was on the engine room's port side on the deck of the barge. In addition to the generator controls and monitoring gauges, the station was equipped with an "emergency voltage disconnect" switch that, when actuated, cut off all electrical loads from either generator.

Two fans mounted in the overhead supplied engine room ventilation, with the inlets on the top of the first level of the superstructure on either side of the stack. Ambient air in the engine room supplied combustion air for the diesel engine driving the generator.

Winches for the cable that raised and lowered the ladder and cables that heaved in or paid out anchor cables and raised and dropped the spuds—collectively known as the draw works—were located in a space forward of the engine room. The engine room and draw works were separated by a partial bulkhead and metal grating.

A berthing and galley space was on the second level of the *Waymon Boyd*'s superstructure, midship above the engine room. A transformer room, which converted the alternating current output of the generator to direct current power for the motors, was located forward on the second level above the draw works.

The lever room and dredge captain's office were on the third level above the transformer room. The lever room sat on a raised deck that was accessible via a short ladder. Windows on all sides of the lever room afforded the operator a 360° view of the worksite. During normal operations, the leverman operated the cutterhead, draw works, and pumps on the dredge from a single control station in the lever room. The winches were operated by five levers on the forward operating panel of the control station, organized from port to starboard as follows: port spud raise/drop, port anchor cable heave-in/payout, ladder raise/lower, starboard anchor cable heave-in/payout, and starboard spud raise/drop (see figure 13). On/off and speed controls for the anchor winch and cutterhead motors were located on the starboard side of the console. The display and keyboard for the DREDGEPACK computer was mounted in the starboard corner of the console. A display showing parameters for the dredge pumps and dredge material booster pumps was mounted in the port corner.

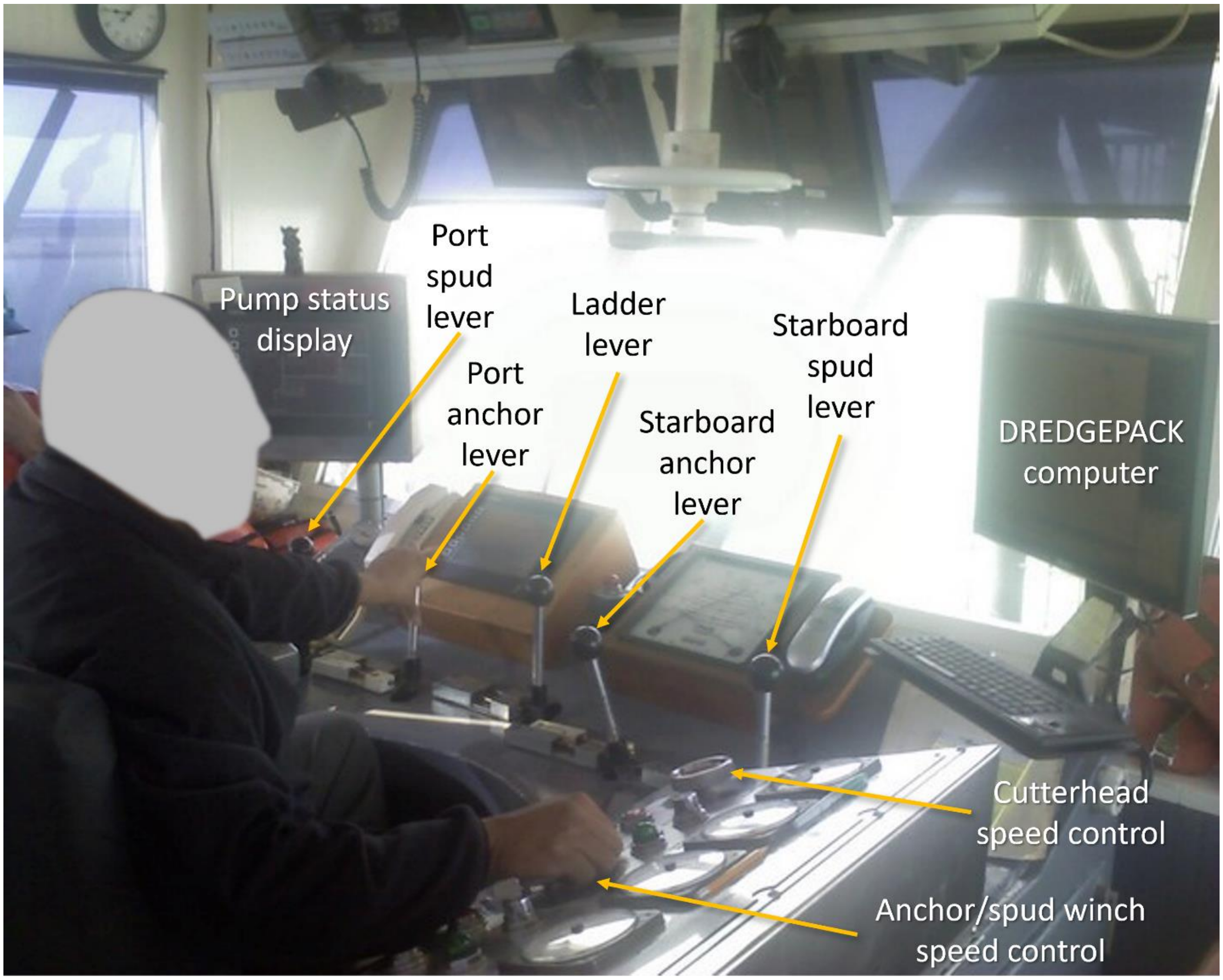

Figure 13. *Waymon Boyd* lever room preaccident. (Source: Orion Marine Group, annotated by NTSB)

The crew reported no major equipment casualties before or during the accident, other than the sheared shaft coupling that was repaired the night before.

The leverman stated that all equipment was operating correctly at the time the pipeline was breached.

1.4.2 Pipeline Overview

Hazardous liquid transmission pipeline TX219 was an intrastate pipeline owned by South Texas NGL Pipelines LLC and operated by Enterprise Products Operating LLC, both of which were subsidiaries of Enterprise Products Partners LP. The pipeline connected the Flint Hills Resources Corpus Christi LLC refinery to propane storage at the Enterprise Origin Station.

The breached pipe was part of a 9,151-foot pipeline segment that was made from 16-inch outside diameter, 0.219-inch wall thickness American Petroleum Institute Standard 5LX, Grade X-46 steel pipe with a specified minimum yield strength of 46,000 pounds per square inch (psi). The pipeline's maximum operating pressure was 787.5 psig, and the pipeline was generally operated between 250 and 300 psig. Near the accident site, the pipe was coated with coal tar and a 2-inch-thick exterior concrete coating.[11] The pipeline was constructed in 1968; however, the pipe manufacturer and the date the pipe was manufactured are unknown.

At the time of the accident, pipeline TX219 was used to transport grade HD-5 non-odorized propane, which is a highly volatile liquefied gas that forms a vapor cloud when released to the atmosphere.[12] Propane is an odorless, tasteless, and colorless gas at normal temperature and pressure. Transported under pressure, liquefied propane is 270 times more compact as a liquid than as a gas, thus making it economical to store and transport as a liquid. The vapor is 1.5 times as heavy as air, and it can collect in low areas without sufficient ventilation. Propane gas can collect in a confined space and create an explosive atmosphere, as well as threaten life by displacing breathable air. Propane has a narrow range of flammability when compared to other petroleum products. Flashback along a vapor trail is possible.

The Flint Hills Resources refinery produced and stored propane within its facility for injection into pipeline TX219 as needed. Propane entered Enterprise's pipeline facilities at the Viola Meter Station and flowed in an easterly direction 5.024 miles to a pipeline interconnect at Enterprise's Cantwell Station. At the Cantwell Station, pipeline TX219 was connected to a 6-inch-diameter, 0.47-mile pipeline that

[11] The extent of the concrete sleeving beyond the accident location is unknown.

[12] HD-5 propane is the most widely sold and distributed grade of propane in the US market. It may contain up to 5% propylene and a minimum of 90% propane. Other gases that constitute the remainder are isobutane, butane, and methane.

ran from the Cantwell Station to storage at the Enterprise Origin Station (see figure 14).

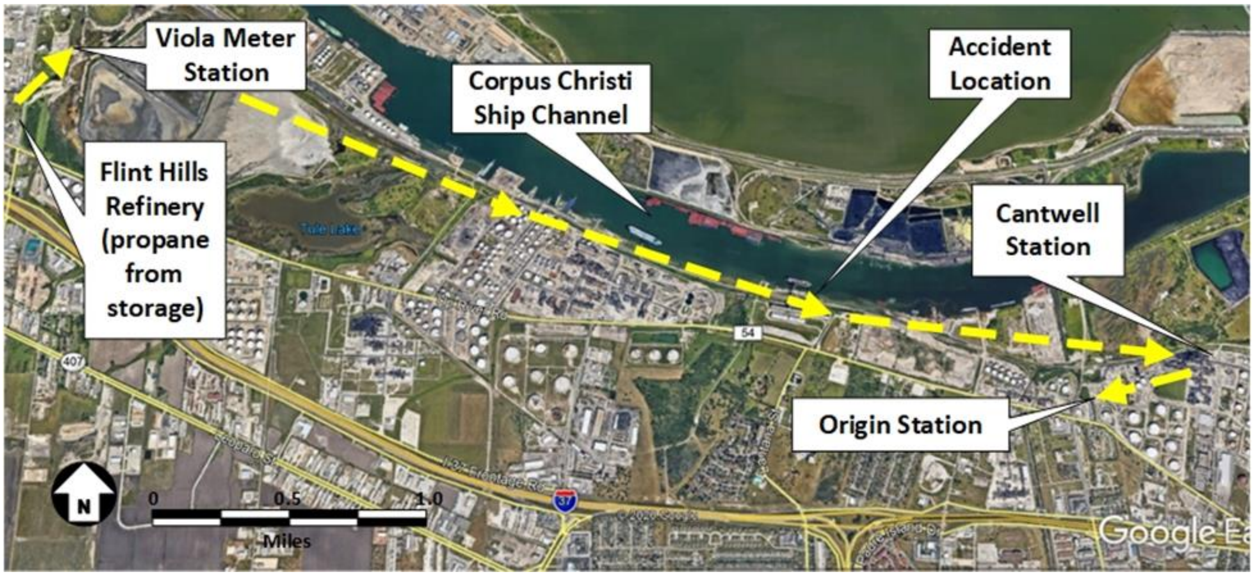

Figure 14. General flow path for Enterprise pipeline TX219. (Background source: Google Earth)

The Flint Hills Resources refinery supplied propane to pipeline TX219 in batch deliveries, meaning that the pipeline did not run continuously. Generally, two to three propane batches per day were transported on the pipeline. The pipeline remained full but only flowed when actively transporting product from the refinery. During the month before the accident, Enterprise received 75 batches of propane in volumes ranging from about 251 to 1,637 barrels.

Enterprise classified pipeline TX219 as an onshore pipeline, which generally ran parallel to the shoreline of the Corpus Christi Ship Channel near the accident.[13] Based upon Enterprise's records review for pipeline TX219, there was no known history of previous accidents, as defined by Title 49 *Code of Federal Regulations* (*CFR*) 195.50. Additionally, Enterprise pipeline integrity information analyses indicated that from 2011 until the date of the accident, pipeline TX219 had no history of unintentional in-service releases or near-miss incidents.

[13] While federal regulations do not define onshore pipelines, 49 *CFR* 195.2 defines offshore as "beyond the line of ordinary low water along that portion of the coast of the United States that is in direct contact with the open seas and beyond the line marking the seaward limit of inland waters." Among the applicable requirements for onshore pipelines are damage prevention programs and integrity assessments in high-consequence areas.

The breached segment of pipe was in the waterway from years of progressive land loss near the EPIC dock project area (see figure 15). The length of the pipeline TX219 segment traversing the waterway at the accident location was about 265 feet.[14]

Figure 15. EPIC dock project area, 1968 and 2016, showing the extent of land loss. The blue line indicates the TX219 location, and the red circle is the approximate accident location. (Sources: US Department of Agriculture [*left*]; US Geological Survey [*right*]; photos georeferenced and overlaid on a Maxar Technologies image)

In addition to the location of the pipelines, the December 28, 2018, TMI Solutions survey of existing utilities within the project area also included a depth of cover survey. The TMI survey found the pipeline had 0.4 feet of cover on the west end of the water exposure at the point where the pipeline transitioned back onto land nearest the accident location. The pipeline had 2.0 feet of cover at the east end of the underwater segment.

1.5 Damage

1.5.1 Vessel Damage

A photo of the *Waymon Boyd* taken after the fire had been extinguished and before the vessel sank shows the engine room bulkheads on the port side bowed outward (see figure 16). The draw works and engine room doors are missing, along with a bolted-on bulkhead patch panel. The main deck railing outboard of the opening created by the missing patch panel is bent outward. The aft deck above the first level of the superstructure, upon which the stack sits, is bent upward and forward. The galley and berthing compartment is displaced from its normal position on the

[14] Length determined by Google Earth measurement tools, January 31, 2020.

first level and sits at an angle on the deck. Fire and smoke damage is visible throughout the vessel.

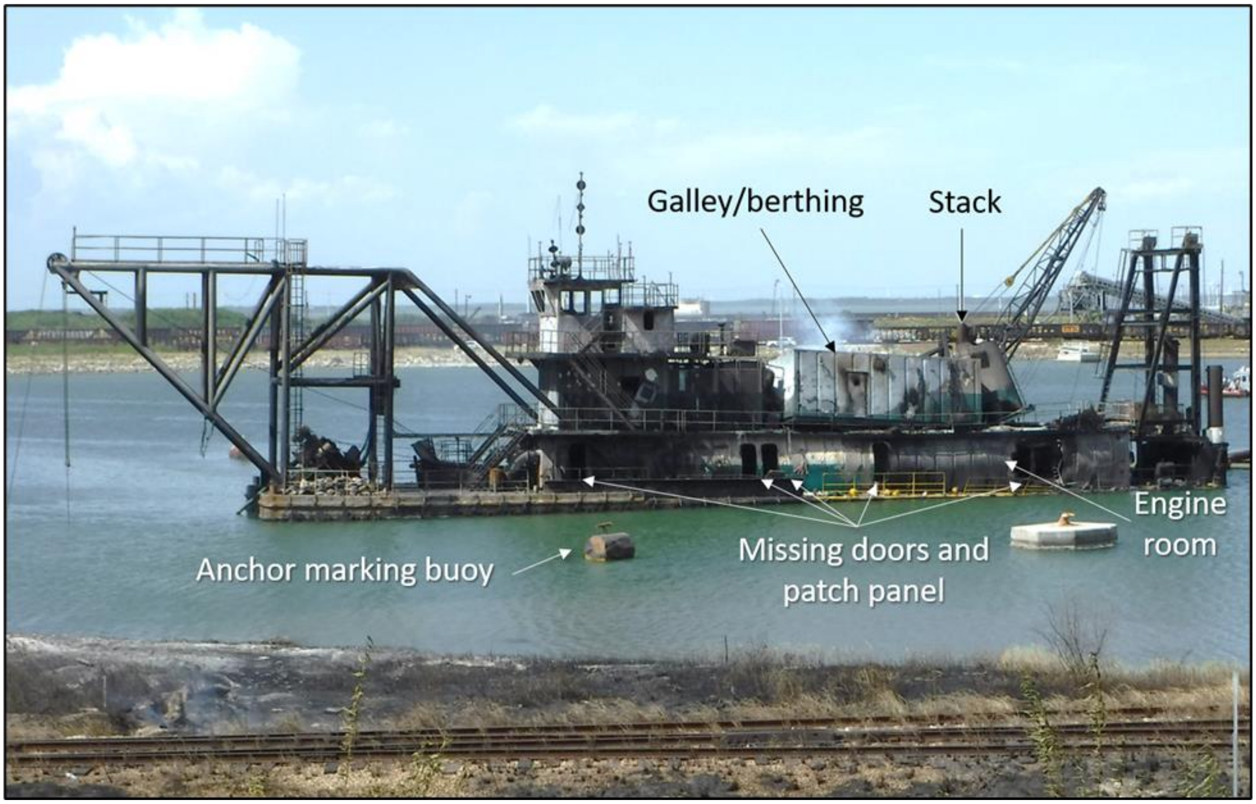

Figure 16. Post-fire photo of the *Waymon Boyd*, before sinking. (Source: Coast Guard)

During a post-salvage examination, investigators confirmed that the bulkheads on both the port and starboard sides of the engine room were bowed outward (see figure 17). A beam in the overhead of the space above the engine's turbocharger and exhaust system was bent upward. Investigators also found that a door to an electrical equipment box forward and above the main generator alternator was caved inward. The standby generator aft of the main generator engine had been displaced from its mounts. The fuel system had no visible breaches in either the piping system or the tanks.

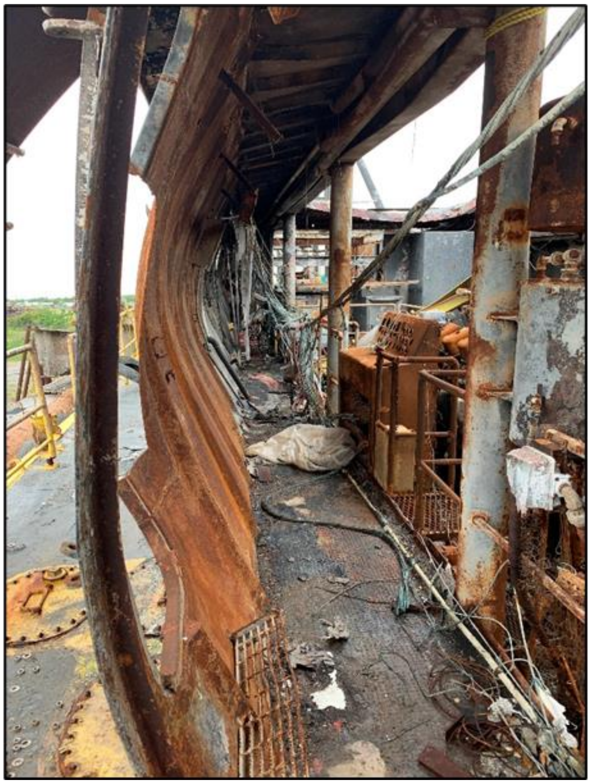

Figure 17. Post-salvage image of the *Waymon Boyd* engine room portside bulkhead, bowed outward.

On the top two levels of the *Waymon Boyd*'s superstructure, which had broken free of the dredge when it sank, all exterior paint had been burned away, and the aluminum door to the captain's office was almost completely melted (see figure 18).

Figure 18. The lever room and captain's office post-salvage. The arrow shows the remnants of the office door, which had melted in the fire.

An anchor barge moored to the *Waymon Boyd*'s starboard side aft sustained impact and fire damage. A second anchor barge moored on the dredge's port side sustained only minor damage, but the second engineer who was standing on the barge at the time of the explosion was fatally injured.

1.5.2 Cutterhead Damage

Preliminary on-site examination by the Coast Guard revealed that the second tooth from the center of the cutterhead on blade E was missing, and the third tooth from the center on blade B was fractured (see figure 19). The tooth nearest the center of the cutterhead on blade C appeared to have heavy contact damage and possible transfer of material at the tip portion (the material appeared different compared to the tooth). The tip of the third tooth from the center on blade E showed wear that was similar to the other blades, and possible metal buildup. The three affected teeth were submitted to the NTSB Materials Laboratory for detailed examination (see section 1.12).

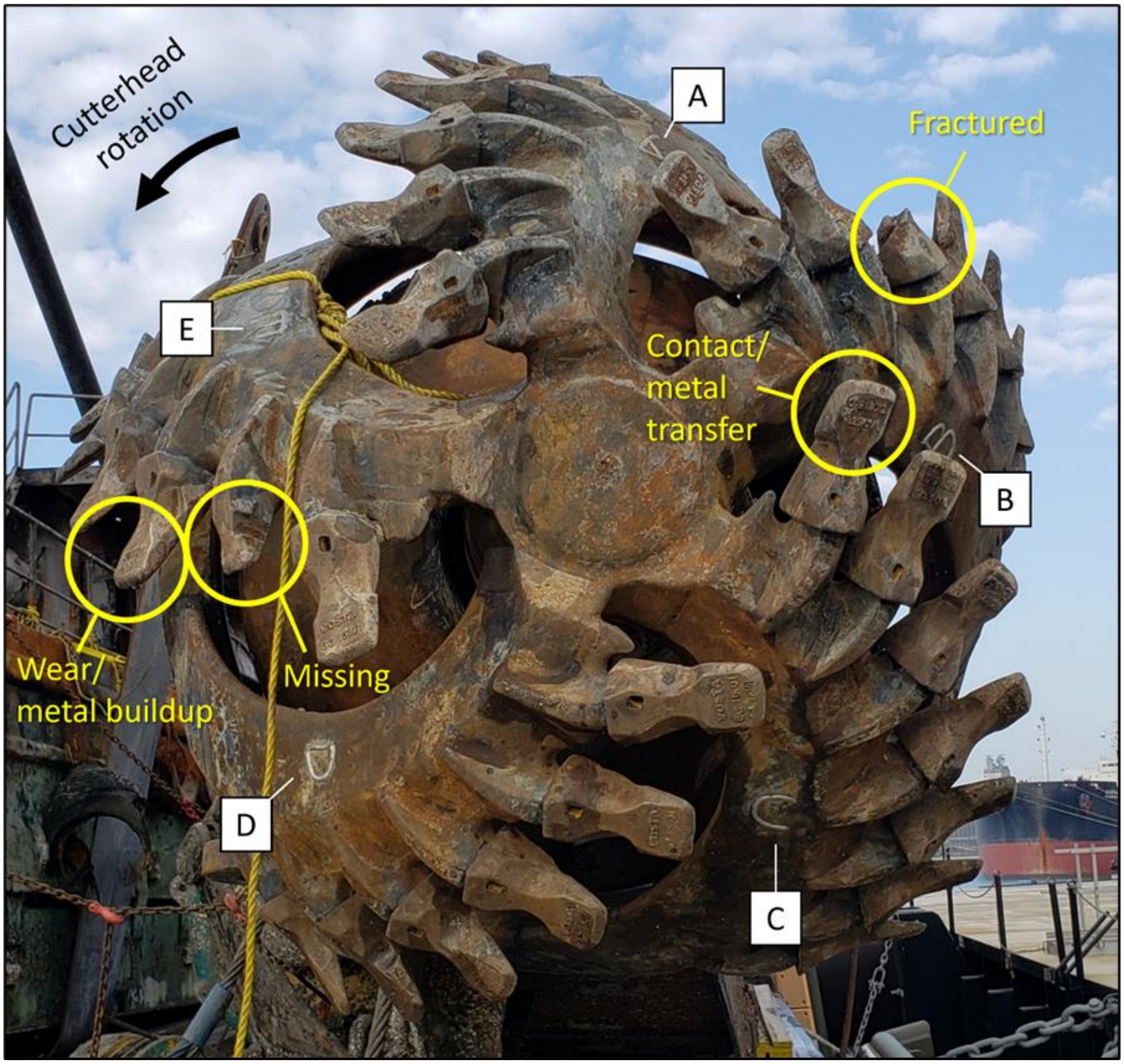

Figure 19. Front view of cutterhead assembly after underwater recovery (looking aft).

1.5.3 Pipeline Damage

On August 24, 2020, an Enterprise commercial diving contractor performed a video-recorded postaccident survey of pipeline TX219 (see figure 6 for pipeline breach location). A diver made the following observations and measurements (see figure 20):

- The pipeline was exposed such that there was about 1 foot of water under the damaged pipe segment.
- Two holes in the pipeline were found near the 6 o'clock position.
- The larger hole (east) was about 7 inches long and about 5 inches across.

- The smaller hole (west) was about 5 inches long and about 2.5 inches across.
- The girth weld was about 2 feet 8 inches west of the smaller hole.[15]
- Exterior concrete sleeving was missing from the pipeline around the breach. The concrete coating was intact 13 inches west of the girth weld.

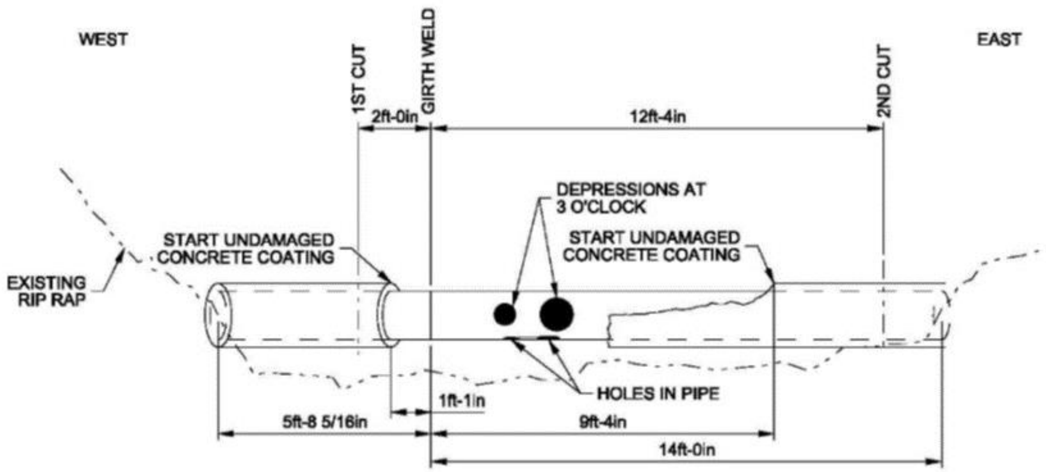

Figure 20. Drawing of the damaged pipeline segment and agreed-upon location for cuts. (Source: Enterprise Products)

A 14-foot 4-inch segment of the damaged pipe was sent to the NTSB Materials Laboratory for examination.

1.6 Waterway Information

The Port of Corpus Christi comprises the harbors surrounding Corpus Christi Bay, including facilities at La Quinta and Ingleside, Texas, the Rincon Industrial Area north of Corpus Christi, and the Corpus Christi Ship Channel (see figure 21). The port is the third largest in the United States, based on total revenue tonnage, and the second largest exporter of crude oil (Port of Corpus Christi, n.d.). In 2020, the port recorded 6,907 ship and barge movements and cargo operations totaling 160 million tons.

[15] A *girth weld* is a circumferential weld joining two sections of pipe together.

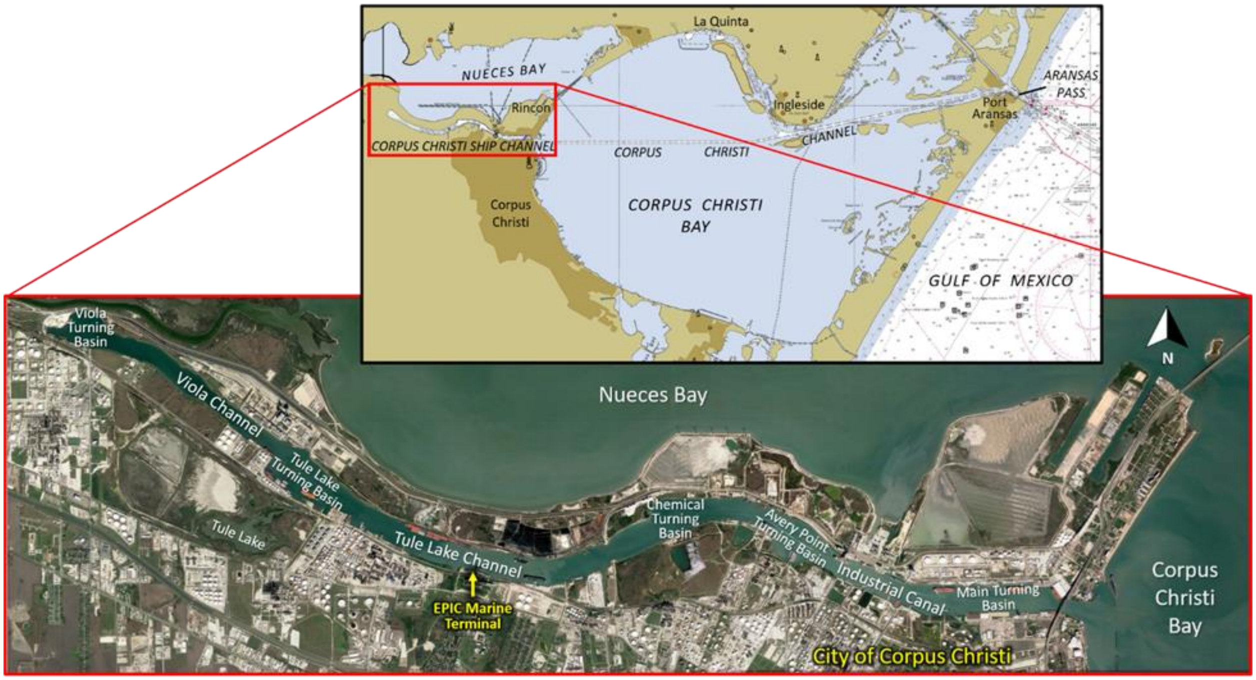

Figure 21. The Corpus Christi Ship Channel. (Sources: Google Earth [satellite imagery]; National Oceanic and Atmospheric Administration ENC Viewer [chart data])

The 9-mile-long, 47-foot-deep Corpus Christi Ship Channel, also known as the Inner Harbor, runs along the north side of the city of Corpus Christi from its entrance at Corpus Christi Bay west to its terminus at Viola. The channel is divided into three sections (Industrial Canal, Tule Lake Channel, and Viola Channel), with turning basins at the ends of each section. Liquid and bulk cargo loading terminals line both sides of the channel, which is restricted to commercial traffic only. The channel is connected to the Corpus Christi Channel, which crosses Corpus Christi Bay and provides access to the Gulf of Mexico via the Aransas Pass.

1.7 Environmental Conditions

At the time of the accident, the sky was clear, and visibility was unlimited. The air temperature was 83°F, and the water temperature was 88°F. Winds at the nearest weather station, located 1.6 miles from the accident site, were reported as from the southwest at 9 knots. However, large grain elevators on the EPIC property shielded the accident area, and based on video of a wind sock at the terminal, winds at the terminal at the time of the accident were light and variable. The water was calm in the Corpus Christi Ship Channel. The tidal range was 0.6 feet on the accident date, with low tide at 0400 and high tide at 1930, as measured at the closest tide gauge located at the *USS Lexington*, a display ship moored near the entrance to the ship channel.

1.8 Operations

1.8.1 Vessel Operations

1.8.1.1 Dredging Operations Overview

Excavating. During normal dredging operations on the *Waymon Boyd*, the starboard spud—known by the crew as the "digging spud"—was lowered to the bottom of the waterway to anchor the vessel's stern. Using barges equipped with lifting derricks, two stockless anchors were set out, one on either side of the dredge, with their flukes oriented in the direction of the dredge. Cables from each anchor ran through blocks on the port and starboard sides of the *Waymon Boyd*'s ladder and back to the winches in the draw works room. To begin dredging, the leverman lowered the ladder to set the cutterhead at the desired depth and engaged the pump and cutterhead motors.

Then, by paying out or heaving in the anchor cables, the leverman swung the dredge from one side to the other, pivoting the entire vessel around the starboard spud. This action moved the cutterhead and dredge suction in an arc, breaking up and carrying away material as the dredge swung. Figure 22 demonstrates typical dredging operations. Starting in position 1 with the starboard spud planted in the bottom sediment of the waterway, the leverman operates the levers to heave in the starboard anchor cable and pay out the port anchor cable. This action swings the vessel through points 2, 3, and 4, breaking up and suctioning away sediment in the path of the cutterhead. In position 4, the leverman lowers the cutterhead a designated amount and then repeats the procedure in the opposite direction, excavating the next layer. This process continues until the cutterhead reaches the planned depth of the excavation area.

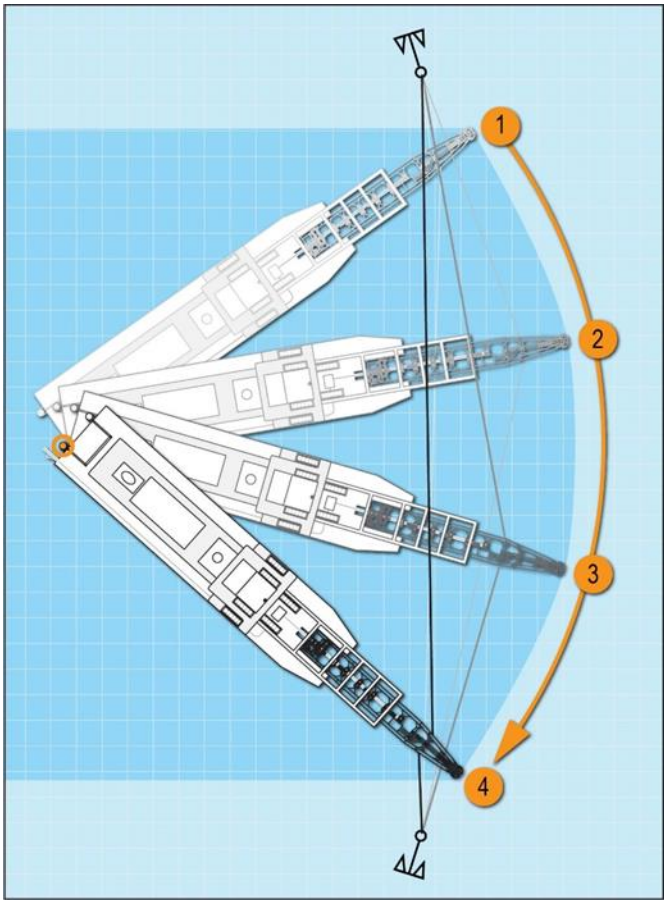

Figure 22. Typical dredging operations.

The dredge captain told investigators that when digging in an area that had not been previously dredged, known as making a "virgin cut," the cutterhead was lowered about 1 foot following each swing of the vessel. Once the desired dredge depth was reached, the leverman moved the dredge forward.

Forward Movement (Set). To move the dredge forward, a maneuver known as a "set," the leverman raised the ladder to the highest position such that it could continue to operate without the ladder pump taking in air. The dredge captain stated that at this position the cutterhead on the *Waymon Boyd* was about 9–10 feet below the water's surface (7° down angle on the ladder, per vessel drawings). The leverman then lowered the port spud—the "walking spud"—and raised the starboard spud. Using the anchors, he next swung the dredge about the port spud. He then lowered the starboard spud and raised the port spud. The combined actions advanced the dredge forward before beginning a new series of sweeps of the cutterhead. The dredge captain stated that during virgin cuts, the dredge moved 3–4 feet forward with each set. Figure 23 demonstrates a typical maneuver to move the dredge forward in which the leverman: (1) lowers the port spud and raises the starboard spud, allowing the vessel to pivot around the port spud; (2) operates the levers to heave in the port anchor cable and pay out the starboard anchor cable, which advances the starboard spud, as well as the entire dredge, forward; and (3) drops the starboard spud and raises the port spud, anchoring the vessel in the advanced position. The leverman then begins excavation in the new position.

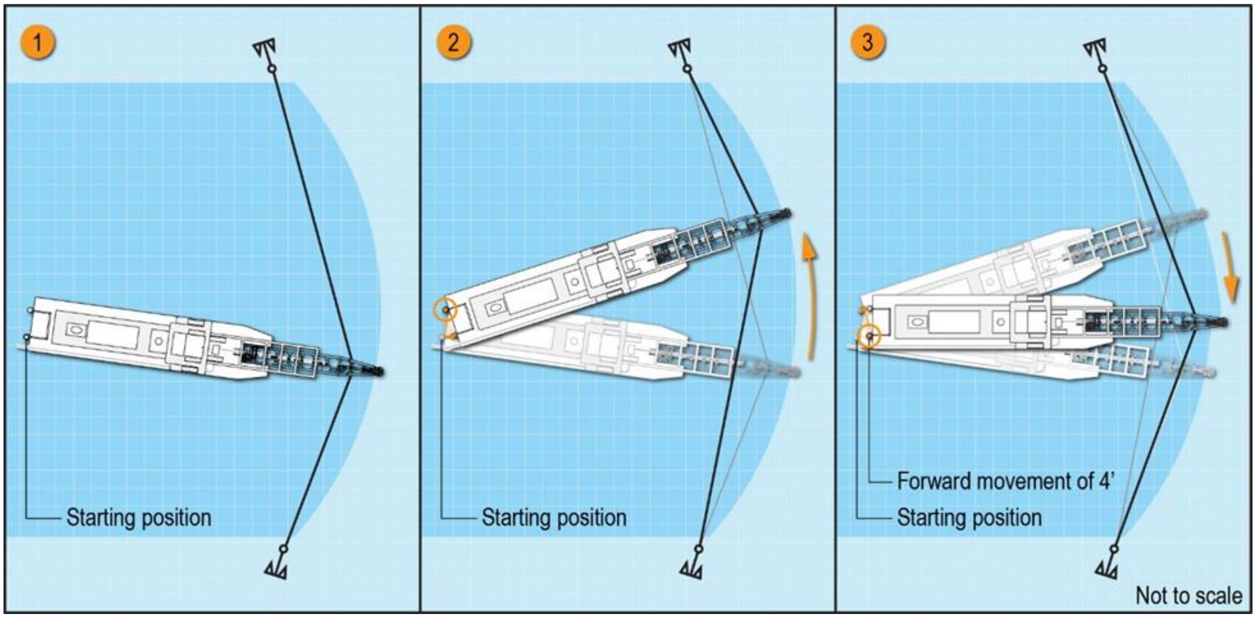

Figure 23. Typical maneuver to move the dredge forward.

1.8.1.2 Phase 2 Project Design Drawings

The Schneider design engineer developed the dredging plans for phase 2 of the EPIC dock project primarily using the 2019 version of AutoCAD. The dredging plans comprised four parts, with the first part containing the "Existing Site Plan," which was an overhead view of the project overlaid on a satellite image (see figure 24). The Existing Site Plan included boundary lines for the proposed ship berth, contour lines for the bottom topography at project start, and blue-colored lines depicting the locations of the pipelines in the area (blue lines were also used to depict other features along the shoreline). It did not include a depiction of the sloped area that was to be dredged outside the berth (the Jacobs plans for phase 1 of the project included a drawing similar to the Schneider Existing Site Plan but without the pipelines depicted).

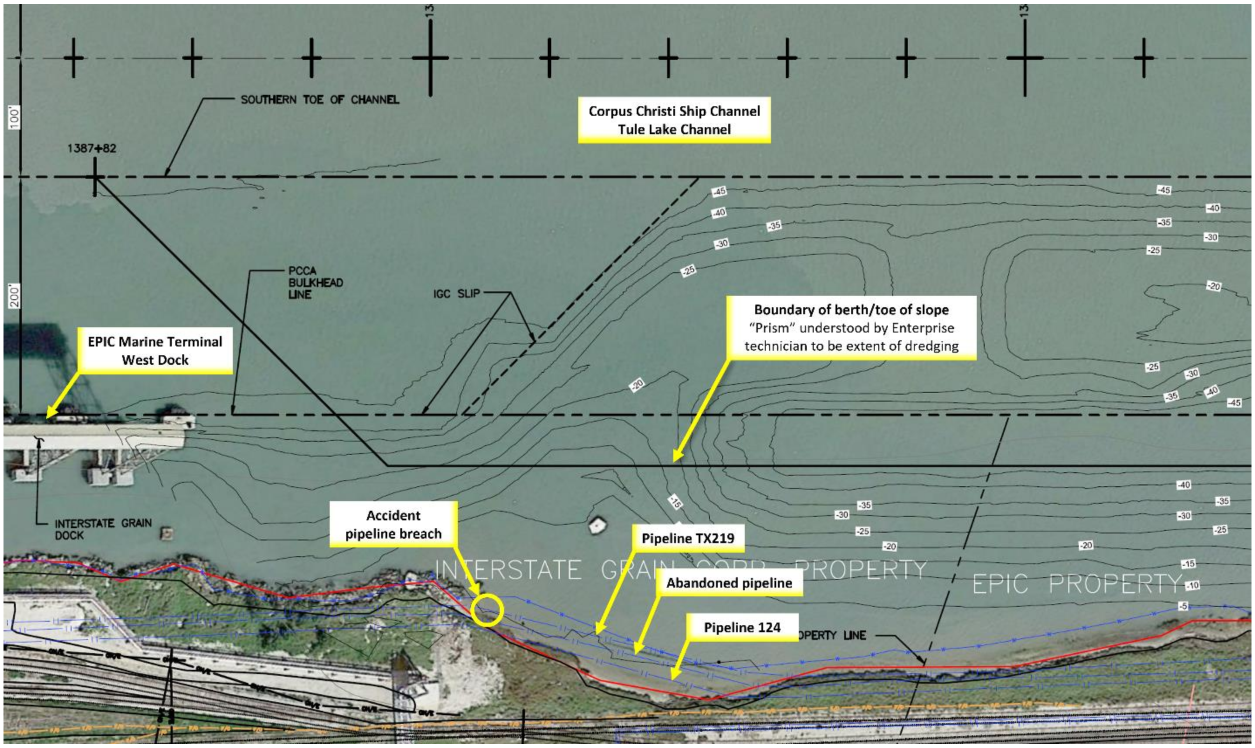

Figure 24. Annotated excerpt from the "Existing Site Plan," drawing no. G2.1, in the Schneider Engineering EPIC Marine Terminal dredging construction plan. (Source: Orion Marine Group, annotated by NTSB)

The second section of the dredging plans was the "Dredge Site Plan," an overhead drawing of the berth, along with the proposed dock, mooring dolphins, and the bulkhead that would extend out from the shoreline and be backfilled and covered (see figure 25). The area of the 46.5-foot-deep berth was shaded dark gray, and the legend for the drawing labeled the shaded area as the "dredge limits." A table in the plan labeled "Dredge Limit Coordinates" listed the coordinates of the boundary of the berth. The drawing included a partial depiction of the sloped areas to be dredged during phase 2 of the project, as indicated by contour lines decreasing in depth at 5-foot intervals (the sloped area dredged in phase 1 was not shown). The top of the slope was indicated by the 0-foot depth line, except in the area of the proposed bulkhead, where it terminated about 10-foot depth at the structure (the original Jacobs plans included a similar drawing with the slope fully depicted with the top of the slope identified as the project/slip baseline). When interviewed, the project engineer stated that the absence of the slope near the bulkhead was "clearly a gap in these plans" and that in cases where there were gaps in the plan, "we typically play it conservatively."

According to the Orion project engineer, there was no company policy providing a minimum distance between a pipeline and dredging area for which the pipeline was required to be included in the plan. The location of the pipelines on the EPIC property, as determined by the 2018 TMI Solutions survey data, was not included in the Schneider Engineering Dredge Site Plan. Therefore, the project engineer stated that to determine the distance between the top of the sloped area and the pipelines, she "repeatedly just looked at [Dredge Site Plan] and then the [Existing Site Plan] that actually shows the approximate location of the blue lines." When asked how close she thought the pipeline would be to the dredging template, she responded, "Far enough away."

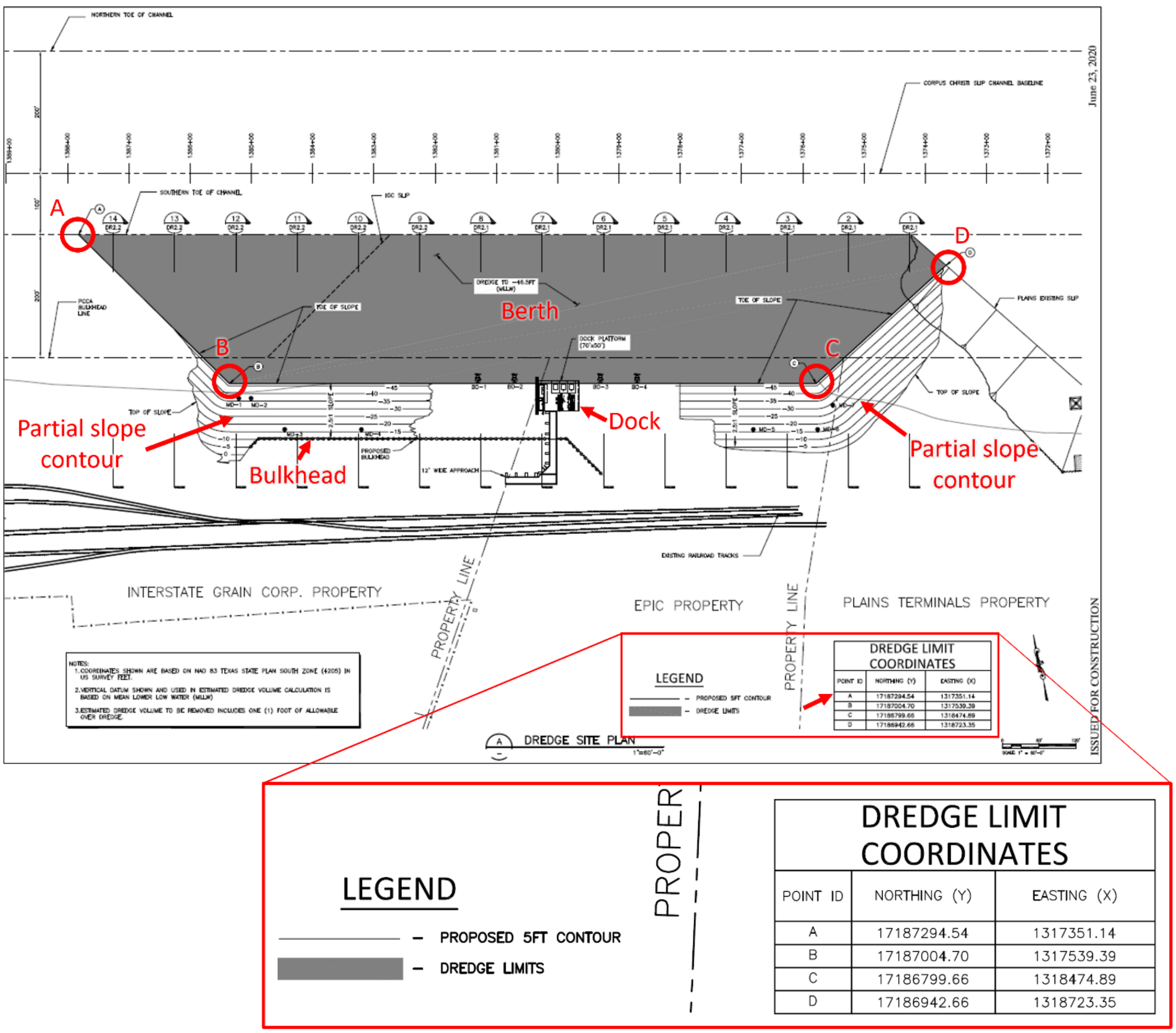

Figure 25. Annotated "Dredge Site Plan," drawing no. DR 1.1, with exploded view of legend and coordinates table, from EPIC Marine Terminal dredging construction plan. Pipelines are not shown in the drawing. (Source: Orion Marine Group, annotated by NTSB)

The third section of the dredging plans provided drawings of cross-sectional views of the dredging area at 100-foot increments (see figure 26). These drawings showed the proposed 46.5-foot depth of the berth and the sloped areas to be dredged outside the berth boundary. The cross-sectional drawings also included a depiction of the components of the proposed dock, where applicable, and the existing surface of the bottom that was to be removed by the dredging work. The drawings did not show the location of the pipelines in the TMI Solutions utilities survey. (The final section of the plans, which is not included in this report, provided a general layout of the pipeline that moved the dredged material from the work site to the DMPA.)

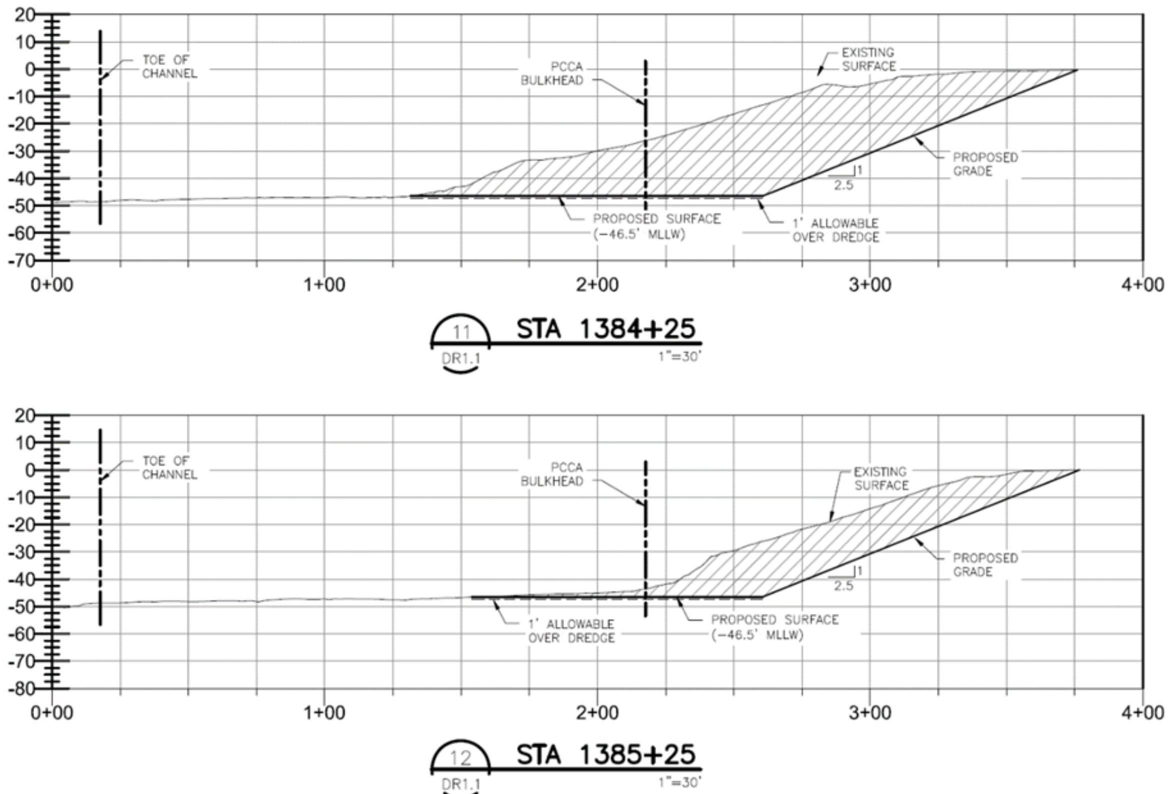

Figure 26. Excerpt from "EPIC Dock Cross Sections – 2," drawing no. DR2.2. Cross-sections 11 and 12, shown here, were on either side of the accident site. (Source: Orion Marine Group)

The Schneider design engineer told investigators that he did not think that his organization was responsible for providing a safe plan for working near pipeline TX219. He said that Schneider Engineering and Consulting has "quality control measures that we implement through our specifications," but he said that "safety protocols" largely are the responsibility of the contractor. He also said that "we can identify conflicts" but not provide "safety recommendations to those conflicts." The company did not have specifications, quality control measures, or best practices for standoff distances from pipelines or for establishing a safety corridor.

1.8.1.3 Hydrographic Survey and Dredging Software

1.8.1.3.1 HYPACK and DREDGEPACK Software Overview

Orion Marine Group used the hydrographic surveying and data processing software HYPACK, along with its dredging-industry-specific module DREDGEPACK, to plan, execute, and monitor its dredging projects. HYPACK allowed users to directly record data from hydrographic survey equipment (such as multibeam and sidescan sonars); process the data; and then present the data in various forms, including two-dimensional and three-dimensional models.

DREDGEPACK used HYPACK data to plan dredging projects, monitor their progress, and provide the leverman a tool to aid in the dredging work. Within DREDGEPACK, planners can develop a dredge template based on project engineering plans. A DREDGEPACK template is a set of planar surfaces that represent the bottom and sides of a planned dredge area (see figure 27). Each planar surface is defined by three or more nodes—points in space that are the corners of the plane. A template is constructed in DREDGEPACK by entering the coordinates for the nodes (easting, northing, and depth below MLLW).[16] The coordinates are usually taken from the project engineering, although the sloped sides of the template can also be constructed by entering the coordinates for the bottom of the dredge area and selecting a desired rise-to-run ratio for the slope. In this automated process, the coordinates for the top of the slope are generated by the software.

[16] *Eastings* and *northings* are the coordinates of a specific location expressed, respectively, as the distances eastward and northward of the reference point in a horizontal geodetic datum.

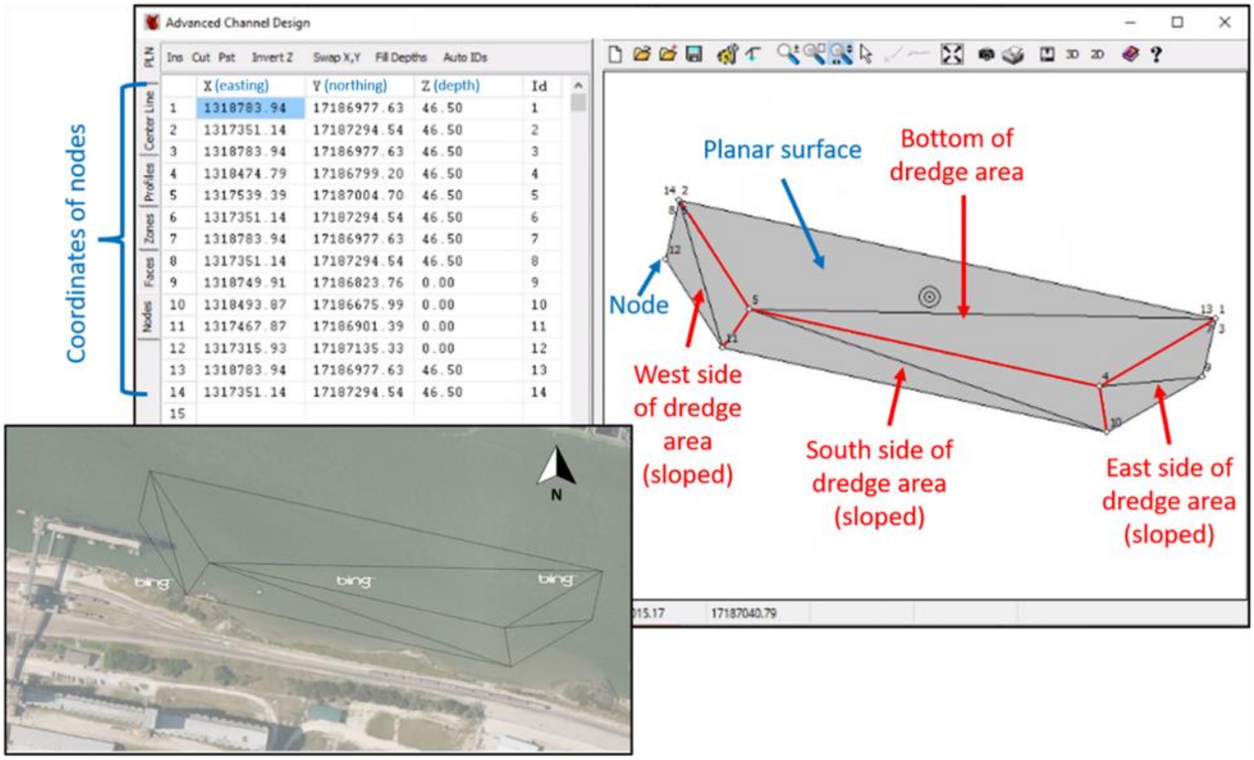

Figure 27. DREDGEPACK dredge template for the EPIC dock project. Inset is a dredge template overlaid onto a satellite image of the site. (Sources: Orion Marine Group, annotated in blue and red by NTSB [template data]; Microsoft Bing [satellite imagery])

Once the dredge template has been created, the planner uses the hydrographic data to create a "matrix" file in DREDGEPACK. A matrix is a color-coded representation of the bottom topography of the dredging area, divided into square cells. The cell height/width is selectable by the planner. The color scheme used in the matrix is configurable by the planner, and most use a single color with shade differences to indicate the depth within the dredge template boundaries, a distinctly different color to indicate the depth at the boundary of the template or within the allowable dredge, and another distinct color to indicate when the depth exceeds the template boundaries.[17]

Once the dredge template and matrix are created, they are loaded onto a DREDGEPACK-equipped personal computer (PC) at the leverman station on board the assigned dredge. The DREDGEPACK display on the PC is fully configurable by the user, but most presentations used aboard a dredge include an overhead or "Map" view of the dredge area, a cross-sectional or "CutterProfile" view of the area,

[17] *Allowable dredge* (or allowable overdepth dredging) is excavation that occurs outside the required authorized dimensions of a dredge plan to compensate for physical conditions and inaccuracies in the dredging process and allow for efficient dredging practices (Tavolaro, 2007).

and a listing of key dredge parameters, such as the cutterhead location, cutter depth, tidal correction, and vessel heading. The overhead view shows the matrix file, as well as a representation of the dredge and cutterhead. The cross-sectional view shows the location of the cutterhead in relation to the bottom topography and the dredge template. Figure 28 shows a sample DREDGEPACK display. As shown in the key parameters in the upper left, a significant tidal correction has been entered into the system. In the overhead view on the right of the display, the matrix cells range in color from red (shallowest) to purple (deepest). The cells are shown changing to purple as the cutterhead sweeps the channel. In the cross-sectional view on the lower left, the cutterhead is outside the template.

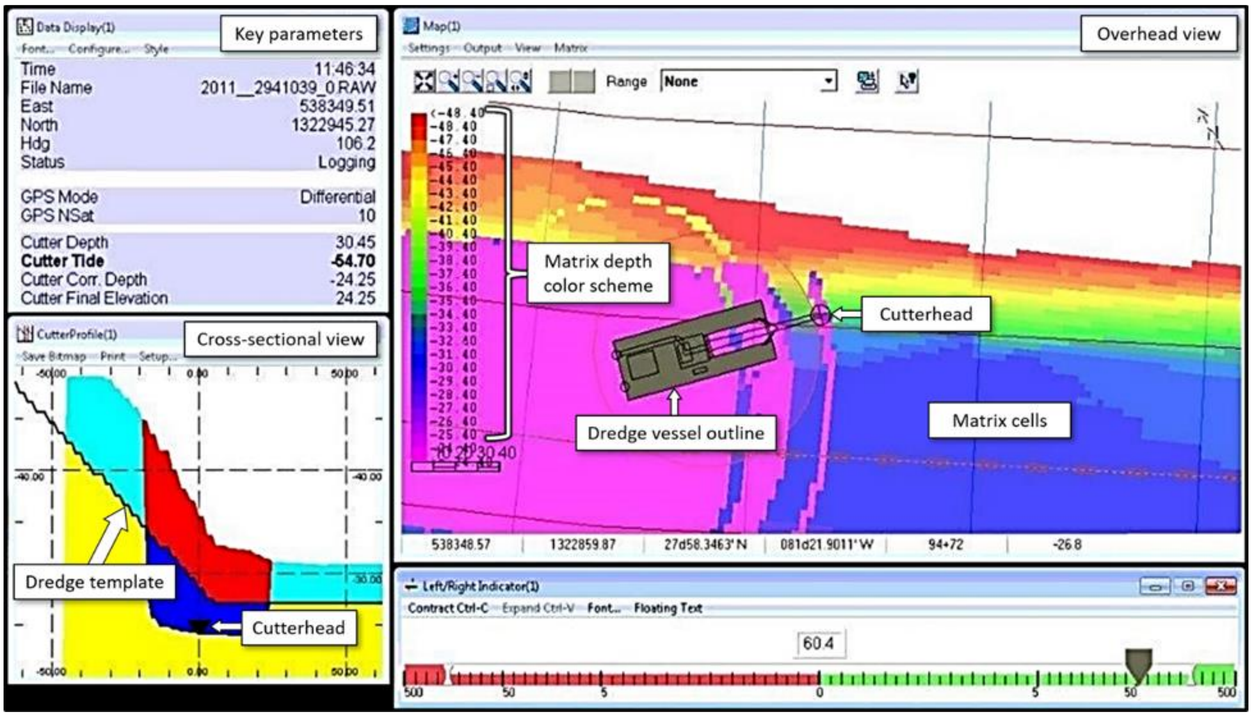

Figure 28. Sample DREDGEPACK display (does not reflect accident vessel or site). (Source: HYPACK)

During dredging operations, the leverman monitors DREDGEPACK while the dredge swings. As the cutterhead indicator on the overhead display moves through a matrix cell, the cell changes color to indicate a new bottom depth based on the cutterhead depth. In this manner, the leverman “repaints” the matrix to reflect the area being dredged. Thus, the leverman can use the matrix color coding, in conjunction with the cross-sectional view, to determine when he has reached the planned boundaries of the dredging area. Changes in matrix cell colors during dredging operations are based on the cutterhead depth and not actual hydrographic data, and therefore periodic surveys are required to validate the dredging work and to update the matrix file.

To ensure that the dredging work is accurately reflected in DREDGEPACK, the software requires accurate horizontal and vertical location data for the cutterhead, both geographically and relative to the dredge template. Inputs for horizontal position are normally provided by GPS for heading and location, and DREDGEPACK automatically converts the GPS' WGS84-datum-based location data to the datum used in the template. Input for the vertical position is provided by an inclinometer mounted on the ladder, along with a correction for the height of tide that can be automatically or manually updated. DREDGEPACK calculates the location of the cutterhead based on these inputs, the dimensions of the ladder and cutterhead, and the location of the GPS positional antennas on the vessel. All distance and depth dimensions are measured in relation to a reference point on the dredge vessel. These dimensions are configured in DREDGEPACK manually by the project planner. When needed, the inclinometer must be recalibrated to ensure accurate depth information, and tidal information must be entered by the leverman at regular intervals.

HYPACK and DREDGEPACK files are organized into "projects," and HYPACK survey data and DREDGEPACK templates and matrix files are generally organized under the same project for a single worksite. Data from dredging operations are recorded by DREDGEPACK on the PC aboard the dredge. These data can be downloaded for later playback and reconstruction.

Interviews with company and industry representatives indicated that the precision and accuracy of dredging operations are as expected for a piece of heavy machinery operating underwater, out of sight of the operator. As the Orion project manager stated to the NTSB, "You know, it's not scalpel surgery under water." A nearly identical description was also used by a HYPACK representative.

1.8.1.3.2 DREDGEPACK Data

At the time of the accident, Orion was using HYPACK version 2018 to plan and execute the EPIC East Dock dredging operation. GPS horizontal position data for DREDGEPACK was provided by a Trimble SPS855 marine global navigation satellite system receiver and associated equipment, which was accurate to within 1 meter.

The Orion survey superintendent who was responsible for creating the DREDGEPACK dredge templates told the NTSB that he developed the template for phase 2 of the EPIC dock project (figure 25, above) from the June 23, 2020, Schneider drawings. Using the coordinates listed in the "Dredge Site Plan," he created the nodes for the boundary of the berth floor. After entering the given coordinates, the survey superintendent used DREDGEPACK's slope creator tool to determine the coordinates for the nodes at the top of the sloped sides, entering a slope ratio of 2.5:1 in accordance with the engineering drawings. The NTSB reviewed the DREDGEPACK dredge template developed by the survey superintendent; there were no significant differences between the coordinates of the berth in the template and in the engineering plans. The slope in the template was confirmed to be 2.5:1, consistent with the engineering plans.

The survey superintendent stated that if a pipeline was within a dredging project area, he included the pipeline in the DREDGEPACK dredge template, usually as a black line with a label. If required for the project, he would also include lines showing standoff distances on either side of the pipeline. The superintendent relied on the project manager and project engineer, using the one-call process, to identify any pipelines and, if required, provide him with the location data to include in the DREDGEPACK template. For the EPIC dock project, he did not receive any data for pipelines from the project engineer, so he did not include them in the DREDGEPACK dredge template. He told the NTSB that based on the engineering plans, he was aware of the pipelines near the project area but believed that they were "up on the bank in the rocks, kind of out of the way." When he developed the DREDGEPACK template, the pipelines "were not considered at all." All Orion personnel interviewed by the NTSB stated similarly: the pipelines were not a major concern because they believed the pipelines were outside the dredge template.

Following the June 12, 2020, survey (the initial hydrographic survey for EPIC East Dock phase 2 operations), the superintendent created a matrix file for the project area. When the *Waymon Boyd* was assigned to the project, he uploaded the template and matrix files to the vessel by remotely accessing the dredge's DREDGEPACK computer from his computer at his office. He later updated the matrix files based on August 10 and August 17 hydrographic surveys.

The leverman told investigators that on his DREDGEPACK display, the cutterhead was indicated by an "X" in the cross-sectional view. He stated that when excavating the slope, he put the middle of the X on the line marking the slope in the DREDGEPACK dredge template as he worked the cutterhead down the incline.

The leverman told the NTSB that before the availability of the DREDGEPACK computer on board the dredge, dredge levermen relied on pipeline company inspectors to come on board dredges to watch and protect pipelines. He said that because dredges were now equipped with DREDGEPACK computers, the computer was his only means of knowing the locations of underwater pipelines, if they were included in the template.

The computer running DREDGEPACK on the *Waymon Boyd* was destroyed during the accident, and all data from this PC was lost. Although dredge superintendents had a feed from the dredge and could view the DREDGEPACK display in their office in real-time, the information from this feed was not recorded ashore. Thus, investigators were unable to playback and reconstruct the *Waymon Boyd*'s information from the accident. Configuration information entered into DREDGEPACK, such as the ladder and cutterhead dimensions and GPS antenna locations, was also lost and thereby could not be verified.

1.8.2 Pipeline Operations

1.8.2.1 Pipeline Control

The Enterprise pipeline control center was located in Houston, Texas, where a pipeline controller monitored and controlled the movement of propane in pipeline TX219 over a SCADA system. The SCADA system allowed the pipeline controller to monitor pipe pressures and product flow rate from one point to another along the system. The system also provided the pipeline operator the ability to open and close certain remotely controlled pipeline valves.

The SCADA system monitored the flow rate from the Viola Meter Station to Origin Station, the incoming pressure and outlet pressure at the Viola Meter Station, the Viola Meter Station to Origin Station pressure, and the Viola Meter Station control valve position (see figure 29). The pipeline operator also had the ability to remotely control closure of motor-operated valve MOV-20 and emergency shutdown valve SDV-25, which were located at the Viola Meter Station. When either of these valves closed, the feed to TX219 from Viola Meter Station to Cantwell Station was isolated. In the event anomalous conditions required further investigation, the pipeline controller relied on field pipeline resources such as pipeline operators and pipeline technicians to conduct field checks and to operate manual pipeline valves when needed.

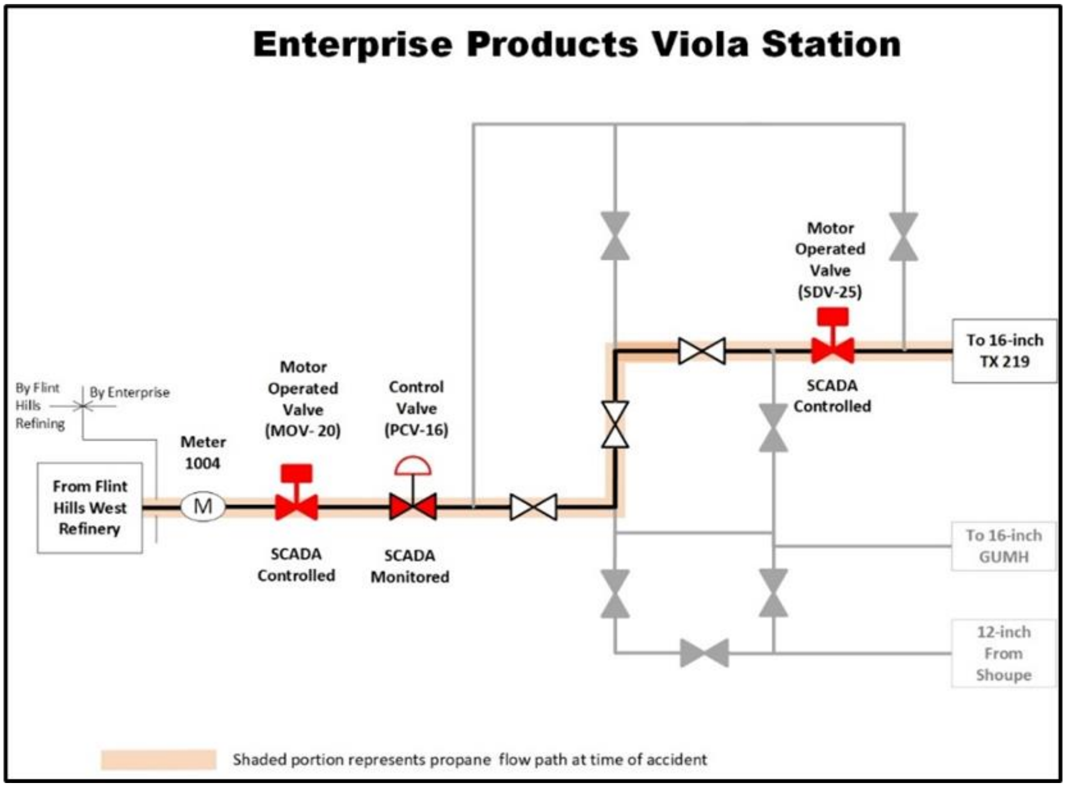

Figure 29. Viola Meter Station pipe and valve simplified diagram for pipeline TX219.

The pipeline controller's SCADA screen provided color-coded alarms coupled with audible alarms for circumstances such as overpressure or under-pressure conditions. In the case of pipeline TX219, the SCADA low-pressure alarm setpoint was 156 psig.

The control valve (PCV-16) was located downstream of the flow meter (Meter 1004) and had two setpoints relating to pressure and flow rate. If the meter detected pressure below 200 psig, the control valve would close completely. Additionally, the control valve would throttle the flow to ensure it did not exceed 420 barrels per hour for flow measurement accuracy purposes. The pump at Flint Hills Resources did not discharge at a pressure to Viola Meter Station that would have necessitated overpressure protection systems for pipeline TX219.

1.8.2.2 Emergency Shutdown Procedures

The Enterprise emergency response plan stated that the nearest upstream and downstream valves should be shut during an incident such as a line rupture, provided they can be safely accessed. The plan further stated that for large product releases and fires or explosion, emergency shutdown valves and remote closing valves should be activated as needed.

1.8.2.3 Pipeline Operations on the Day of the Accident

Enterprise pipeline flow recordings for pipeline TX219 indicated that at 0426 on the day of the accident, propane flow was initiated into the pipeline from Flint Hills Resources for batch number 75. The pipeline pressure increased from its no-flow state of about 200 psig and maintained a pressure of about 257–265 psig for the duration of the batch transport. The total batch volume to be transported in the pipeline was about 1,529 barrels. SCADA system pressure indications near the time of the accident showed that between 0630 and 0802, the pipeline pressure remained unchanged at 257 psig.

As the batch transfer was nearing completion, at 0802:49, the SCADA system alerted the pipeline controller with an annunciation of a low-pressure alarm indicating the Viola Meter Station pipeline pressure had dropped to 156 psig (see figure 29).[18] At the downstream end of the pipeline system, Origin Station meter 345 registered propane flow trending downward at 0803. The SCADA system annunciated an alarm at 0803:40 indicating no flow at meter 345.

At 0805:19, the SCADA system annunciated a subsequent low-pressure alarm indicating the line pressure at Viola Meter Station had dropped further to 149 psig. Also at 0805, the pipeline controller telephoned the Flint Hills Resources operator, who reported the refinery had finished transferring the propane batch to pipeline TX219. Flint Hills Resources shut down its propane delivery pump.

Also at 0805, the Flint Hills Refinery to Viola Meter Station control valve (PCV-16) automatically began to close (the low-pressure set point was 200 psig). At 0807, Viola Meter Station flow meter 1004 indicated propane entering the pipeline from the refinery had stopped. The pipeline controller did not know whether this control valve closure was prompted by completion of the batch transfer or by the low-pressure trend on the pipeline. Between the first indication of a pressure drop at 0802:49 and closure of the control valve, about 19 barrels of propane were injected into the pipeline along with the existing line pack of 6,015 barrels.

At 0809, the pipeline controller telephoned the Enterprise Corpus Christi facilities pipeline technician to request an investigation. The pipeline controller informed the pipeline technician that the SCADA screen indicated a sudden drop in pressure at flow meter 1004 and directed him to respond to the Viola Meter Station to determine if the pressure reading was accurate. The pipeline technician told the

[18] The Enterprise SCADA servers receive time validation from two Enterprise routers: a primary and a backup router. Both routers' primary timekeeping sources are National Institute of Standards and Technology Internet time servers.

pipeline controller that an explosion had occurred and that he observed fire on the Corpus Christi Ship Channel from his location at Origin Station.

At 0815, to eliminate the possibility of backflow in TX219, the pipeline controller telephoned the Origin Station pipeline operator and instructed him to close the manual valve at meter 345 to isolate TX219 from pipeline M4-6. The pipeline operator walked to the meter and completed shutting the valve about 0830, isolating pipeline TX219 from propane storage tanks at Origin Station.

At 0831, upon his arrival at the Viola Meter Station, the pipeline technician contacted the pipeline controller, and the two agreed that motor-operated valves should be closed to add redundant isolation to the control valve.

At 0841:25, the pipeline controller issued a command through the SCADA system to remotely close valve MOV-20. By 0842:19 the SCADA system reported the valve had successfully closed. At 0843:49, the pipeline controller issued a command to remotely close Viola Meter Station valve SDV-25. At 0845:19 the SCADA system reported the valve had successfully closed. The pipeline technician confirmed both valves had closed tightly. Also, about the same time, the pipeline technician advised the pipeline controller that the Flint Hills Resources valve site had been secured such that no additional propane could enter the Viola Meter Station.

At 0851, the pipeline technician traveled to the Cantwell Station downstream on the pipeline, where he assisted the pipeline operator to secure two additional valves for supplemental security of pipeline TX219, double-blocking pipeline M4-6 between the Cantwell Station and the Origin Station.

Between 0919 and 1003, the pipeline technician monitored continued pressure reduction on pipeline TX219 from the Cantwell Station and reported it to the Enterprise safety representative who was providing the data to emergency response officials at the scene of the pipeline accident.

1.8.3 Orion Marine Group Risk Management Processes

Orion’s risk management processes included site-specific safety plans (SSSPs), job hazard analyses (JHAs), and safety meetings. The company’s health, safety, and environmental (HSE) program policies manual required employees to use the “hierarchy of controls” to manage risk:

> The hierarchy of controls should be used to mitigate hazards. When a hazard is identified, first attempt to eliminate the hazard. If elimination is not practicable, use engineering controls. If engineering controls are not practicable, implement administrative controls. If the hazard cannot

> be adequately controlled using engineering and/or administrative controls, employees must use Personal Protective Equipment. A combination of engineering controls, administrative controls, and Personal Protective Equipment is usually best.

1.8.3.1 Site-specific Safety Plan

SSSPs were discussed in several locations in Orion's HSE program policies manual:

> The project manager in conjunction with the Regional HSE Managers are responsible for the implementation of the HSE Program contained herein. The project manager, in conjunction with the Site Superintendent will be responsible for ensuring that a pre-startup checklist and Site-Specific Safety Plan is completed [and] reviewed by the Regional team before commencing with any work.

SSSPs were also discussed within the context of Utility Location Services. Any safety measures required by the owner of the utility for a project were to be verified in the SSSP.

A risk matrix is used during risk assessment to define the level of risk by considering the likelihood against the severity. Risk matrices are useful for increasing the visibility of risks and aiding management decisions to select controls commensurate with risk. At the time of the accident, Orion Marine Group did not require risk matrices. The NTSB spoke with Orion's HSE director to better understand how the company manages risk. He said that safety department personnel develop SSSPs before work begins, and risk matrices were not developed nor included in the documents. The HSE director described his perspective on risk management as follows:

> [Risk management is] done as the project goes forward, when we're actually on site. You can't mitigate for hazards until you're actually on the project identifying what the hazards are. You can, you know, put a plan together in the office, but construction and dredging are in the field, and that's where we actually need to be boots on the ground before we can identify what the hazards are that we need to keep our crews safe from.

The "Epic Dock Site Specific Work Safety Plan" contained provisions pertaining to company policies, such as JHAs, equipment inspections, hazard hunts, behavior-based safety observation, stop-work reports, near-miss reports, the company's system to track hazard conditions, and preventive maintenance systems.

Further generalized content included training, water rescue procedures, personal protective equipment, emergency response, fire response, lighting, helicopter landing zones and safety, bio-hazardous waste, hazardous material spills, hazard labels, and storms. Site-specific content included emergency response information, such as local applicable phone numbers. Site-specific hazards were not addressed, nor were pipelines (including pipeline TX219).

The regional HSE manager, who developed the SSSP for the EPIC Marine Terminal project, said the SSSP was essentially an emergency response plan, which he completed by inputting applicable maps and phone numbers. He did not conduct a risk assessment, and the SSSP did not contain a risk assessment or a hazard control plan. The regional HSE manager indicated that he relied on the operational team for information about the project and did not collect any safety information himself. He said that he was unaware of the pipelines in the vicinity of the dredge template and acknowledged that incorporating a risk assessment into the SSSPs of future projects could enhance safety.

1.8.3.2 Job Hazard Analysis

According to Orion's HSE program policies manual, JHAs were required during safety meetings:

> A job hazard analysis (JHA) is one of the most important elements in any safety program. It is our policy to have a written JHA for all scopes of work in a project. We will not begin any operation without a thorough hazard analysis that has been reviewed and signed by the crew.

In addition, according to the document, the HSE department was required to participate in a "preplanning" JHA:

> When planning a project, the manager will consider any safety related items and discuss these items with the General and site superintendents. During this preplanning stage the project manager is responsible for authoring (along with HSE) the Job Hazard Analyses with assistance from the Site Superintendent and Crew.

Any JHAs produced during the morning safety meetings on the dredge were destroyed in the explosion and fire. There is no evidence that a "preplanning" JHA was completed. At the request of the NTSB, Orion provided several example JHAs. These largely covered the same topics, including personal protective equipment, pinch points, falls, etc. None of the example JHAs discussed the dredge plan or pipelines.

1.8.3.3 Safety Meeting

Orion's EPIC Dock Site Specific Work Safety Plan states that

> Daily meetings shall be held by Supervisors and Foreman to discuss scheduling and planning. Job Safety Analysis (JSA) will be a major component of these meetings ensuring that all employees are made aware of the hazards and trained when necessary, in the safe work procedures planned for specific tasks to which they may be assigned. No work or operations can take place before the completion of a JSA.[19]

According to the crew, topics of discussion during the safety meetings generally consisted of activities for the day, personal protective equipment, and the JHA. There is no evidence that the dredge plan and pipelines were discussed at any of the safety meetings for the EPIC dock project.

1.9 Key Personnel Information

1.9.1 General Information, Experience, and Qualifications

Eight crewmembers (seven on-shift and one off-shift), along with the dredge captain, were on board the *Waymon Boyd* or anchor barges moored alongside at the time of the accident. Nine other on-shift crewmembers were aboard the associated dredge tenders or booster-pump barges. Additionally, several shore-based Orion and Schneider personnel supported the overall dredging project and the day-to-day dredge operations. Three Enterprise pipeline personnel also had significant roles in the dredging project planning or emergency response to the pipeline breach. Below are summaries of the background and experience of key personnel on the dredge and ashore.

1.9.1.1 *Waymon Boyd* Crew

Dredge Captain. The dredge captain was overall in charge of the vessel. He was in his office, directly aft of the lever room, at the time of the explosion. He did not have, nor was he required to have, a Coast Guard merchant mariner credential or any other operator license or certification. The dredge captain began working on dredges in 2000, starting at the entry-level deckhand position, and throughout his career was promoted to positions of higher authority, including leverman. He had

[19] Orion Marine Group uses JHA and JSA interchangeably.

served as a deck captain on several company dredges, including the *Waymon Boyd*, from 2010 to March 2019, when he was promoted to dredge captain. During his time as dredge captain on the *Waymon Boyd*, the vessel worked seven projects in ports along the Texas Gulf Coast, including phase 2 of the EPIC East Dock project. The dredge captain's direct supervisors were the dredge superintendents.

Leverman. The leverman on duty at the time of the accident was in the lever room and at the controls of the vessel. He did not have, nor was he required to have, a Coast Guard merchant mariner credential or any other operator license or certification. According to employment records, he was hired as a deckhand in 1980 by King Fisher Marine Service. Except during periods of industry contraction when he had been laid off, he had worked for King Fisher Marine Service/Orion Marine Group (King Fisher Marine Service was acquired by Orion Marine Group in 1998) for his entire career and had been working as a leverman since the early 1990s. The leverman's direct supervisors were the dredge captain and deck captain.

Other Crew. Experience levels for other crewmembers ranged from 6 days for an entry-level booster-barge oiler to 16 years for a mate. Each crewmember stated that there were no formal classroom or onboard training requirements (other than basic requirements such as CPR), and all skills were passed down from senior to junior crewmembers while on the job.

1.9.1.2 Shore-based Personnel

Project Manager. The Orion Marine Group project manager reported to the dredging division director of operations and was responsible for business development, estimating project costs, reviewing project plans, providing project oversight, procuring materials and services, and supervising project engineers. He did not supervise the dredge crew; he exercised his project oversight duties by monitoring field reports and estimates for customer payments. The manager stated that he typically oversaw three projects at a time and had oversight of the EPIC East Dock project when the accident occurred. He held a bachelor's degree in agricultural systems management and had worked for Orion as a project leader and project manager since his university graduation in 2007.

Project Engineer. The Orion Marine Group project engineer reported to the project manager and was responsible for the day-to-day oversight of dredging projects, including reviewing lost time reports (downtime on the dredge for maintenance and repairs), leverman logs, and water quality control reports, and generating production recap reports, among other duties. The project engineer was also responsible for making one-call notifications, working with utility providers as necessary, and notifying Orion personnel of potential conflicts between utility lines and dredging projects. She conducted the one-call notifications and follow-up for phase 2 of the EPIC East Dock project. The project engineer held a bachelor's degree in offshore and coastal systems engineering and began working for Orion upon graduation from university in May 2019. At the time of the accident, she had been a project engineer for about 11 months. When asked by investigators, the project engineer stated that she had not received any training on pipeline safety since being hired by Orion. The EPIC dock project was the second project she worked on for which pipelines were marked.

Survey Superintendent. The Orion Marine Group survey superintendent reported to the dredging division director of operations and was responsible for overseeing hydrographic and inland surveys of marine dredging projects. He told investigators that the purpose of the surveys was to "check quality behind the dredges to make sure that they're digging correctly and they're removing the correct amount of dirt." As part of his responsibilities, he directly supervised Orion's survey crews, each consisting of a hydrographic survey boat operator and survey technician. The superintendent was also responsible for building the dredging template for each project in DREDGEPACK software and installing the template on the assigned dredge. He had created and loaded the DREDGEPACK template in use by the leverman on board the *Waymon Boyd* at the time of the accident. He held a high school diploma and had worked for King Fisher Marine Service/Orion Marine Group (King Fisher/Orion) since 2000, beginning as a boat operator and advancing to survey technician, before being promoted to superintendent.

Dredge Superintendents. Two Orion Marine Group dredge superintendents reported to the dredging division director of operations and shared responsibilities for the overall direction and coordination of the day-to-day activities on each of the company's dredges. According to the position description for the dredge superintendents, they were also responsible for working with the dredge captains, deck captains, and other dredge crewmembers to ensure that dredge work was progressing consistent with the projected time schedule and that all operations were being performed in a safe and efficient manner. They were the direct supervisors for all dredge captains and exercised their duties by monitoring dredging operations via a real-time display of DREDGEPAK data linked from the dredges to their office, through regular phone calls to the captains and levermen, and by making visits to the dredges.

Superintendent 1 had worked for King Fisher/Orion for his entire career, starting as a deckhand in 1981. He had held various deck and engineering positions on dredges, including leverman, deck captain, and dredge captain, before being promoted to superintendent in 1999. Superintendent 2 had also worked for King

Fisher/Orion for his entire career, starting as a deckhand in 1982. He had held various deck and engineering positions on dredges, including leverman, deck captain, and dredge captain, before being promoted to superintendent in 2010.

Regional Health, Safety, and Environmental Manager. The regional HSE manager was responsible for overseeing safety programs and training for Orion Marine Group's dredging fleet. He managed a team of five safety supervisors and a safety coordinator, who conducted safety training and responded to safety concerns or incidents. In consultation with the project manager, the regional HSE manager also drafted SSSPs for each dredging project. The regional HSE manager had worked for Orion since April 2019. His supervisor was Orion Marine Group's HSE director.

Design Engineer. The Schneider design engineer reported to the firm's principal engineer and was responsible for making calculations and using design software to develop plans for structures and other construction elements used in the marine environment. He worked with drafters to produce drawings based on the plans he generated, and the plans and drawings were then reviewed by the principal engineer. The design engineer developed the dredging and construction plans and drawings for the EPIC East Dock project. He held a bachelor's degree in civil engineering and worked for Orion Marine Construction, a part of the Orion Marine Group, for 2 years following his university graduation. He moved to Schneider when it was established in 2012 and had held the position of design engineer since 2015, when he obtained his Florida professional engineer's license. He was also licensed as a professional engineer in Texas, Louisiana, and South Carolina.

1.9.1.3 Pipeline Personnel

Pipeline Controller. The pipeline controller who was on duty at the time of the accident had been qualified by Enterprise as a controller for 5 years, during which he gained experience operating pipeline TX219. He was responsible for simultaneously controlling 5–10 pipelines during a 12-hour shift. His training included an initial 6-to-8-month in-service training period. He received annual recurrent training that covered new and existing company procedures in pipeline control. The pipeline controller had not been involved with any other pipeline in-service failures during his tenure with Enterprise.

Hazardous Liquids Pipeline Technician. The hazardous liquids pipeline technician who participated in the July 2020 one-call ticket review for pipeline TX219 before this accident had been employed by Enterprise for 4 years, 11 months. His educational background included attendance at Del Mar College for firefighting, fire science, and emergency medical services. Before his employment with Enterprise, he worked as a firefighter for 5 years and then as a safety consultant for local refineries in Corpus Christi for 2 years.

His daily duties included reviewing one-call tickets and overseeing pipeline integrity work such as anomaly repairs. In addition, he coordinated right-of-way mowing, facility maintenance, painting of above-ground piping, and valve inspections. In a typical workday, the hazardous liquids pipeline technician responded to about 10–12 one-call tickets. He said that he did not have experience reviewing dredge plans.

Gas Pipeline Technician. The gas pipeline technician who participated in the one-call ticket review for pipeline TX219 had been employed with Enterprise for 4 years in this capacity. His prior employment included working as a contractor specializing in pipeline damage prevention for Phillips 66 and Enterprise. He estimated that 90% of his job duties involved reviewing and responding to one-call tickets, with a workload of about 10–15 tickets each day. His duties also included damage prevention, pipeline maintenance, and pipeline equipment inspections. He said that he did not have experience reviewing dredge plans. His on-job training included the Enterprise Products Right-of Way College, which he initially completed in 2017, along with refresher training in 2019.

1.9.2 *Waymon Boyd* Crew Work/Rest

The leverman's normal working hours were from about 0445 to 1645 when working dayshifts. He stated that he occasionally worked overtime if the opposite shift was delayed in arrival. The leverman slept on the dredge, but he said he was never bothered or awoken during his off-shift time. He stated that he always slept well when on the dredge, except the first day of night shifts as he adjusted to the opposite schedule. He said he was well rested on the accident day. He said he drank no alcoholic beverages the night before or morning of the accident or at any time while on board the dredge. The leverman was not tested for alcohol or other drugs following the accident.

The remainder of the crew, including the dredge captain, reported getting between 7 and 9 hours of sleep each night, and most reported that they slept well the night before the accident.

1.9.3 *Waymon Boyd* Crew Cell Phone Usage

The NTSB reviewed records for cell phones assigned or belonging to the leverman and a company cell phone assigned to the vessel. Information for the leverman's personal phone included voice call, data usage, and text information. No calls were made before the accident, but a series of outgoing calls were made just after the accident. No pertinent data usage or texts occurred around the time of the accident. Information for the company phone only included voice call information; no pertinent calls were made surrounding the accident time.

1.9.4 Toxicological Testing

Injured crewmembers transported to the hospital, including the leverman and dredge captain, did not undergo toxicology testing. Tests were negative for the survivors who were not transported and who submitted to testing.

Ethanol was identified in each of the deceased crewmembers.[20] Typically, after use, ethanol is distributed rapidly and symmetrically throughout all body tissues. Ethanol may also be produced by microbial action in postmortem body tissues (Russell 2004). When ethanol is from postmortem production, the levels in various tissues tend to vary considerably. Among these individuals, the levels were widely variable.

In accordance with 49 *CFR* 199.105(b), on August 21, 2020, the pipeline controller underwent postaccident toxicology testing, including a breath test for ethanol, which was negative, and a urine test for drugs, which was also negative.[21]

[20] *Ethanol* is the specific form of alcohol found in beer, wine, and liquor.

[21] The urine testing can identify urinary metabolites of amphetamine, methamphetamine, cocaine, codeine, morphine, heroin, phencyclidine (PCP), methylenedioxymethamphetamine (MDMA), methylenedioxyamphetamine (MDA), methylenedioxyethylamphetamine (MDEA), tetrahydrocannabinol (THC), oxycodone, oxymorphone, hydrocodone, and hydromorphone.

1.10 Pipeline Damage Protection Regulations and Industry Practices

1.10.1 Federal and State Regulations

1.10.1.1 Federal Pipeline Damage Prevention Regulations

Federal damage prevention program regulations (49 *CFR* 195.442) mandate that an operator of a buried pipeline must establish a written program to prevent damage to the pipeline from mechanical excavation activities. An operator may comply with any of the damage prevention program requirements by participation in a one-call system.

The damage prevention program must identify persons who normally engage in excavation activities in the area where the pipeline is located. The program must also provide notification to the public in the vicinity of the pipeline and to identified excavators as often as needed to make them aware of the damage prevention program and how to obtain information about the location of underground pipelines before excavation activities begin.

The program must also provide a means for the operator to receive notification of planned excavation activities. If the operator has buried pipelines near excavation activity, the program must provide for notification to persons who give notice of their intent to excavate, including a description of the type of temporary marking to be provided and how to identify such markings. Temporary markings for buried pipelines should be placed in advance of the excavation activity.

If the pipeline operator has reason to believe an onshore pipeline could be damaged by excavation activities, they must provide for inspection during and after excavation activities to verify the integrity of the pipeline.

The Pipeline and Hazardous Materials Safety Administration (PHMSA) uses program evaluation guidelines to annually assess state agency overall pipeline safety program performance. A state agency's performance is the major factor considered each year in allocating grant-in-aid funds to support the cost of inspection and enforcement programs.

1.10.1.2 State of Texas Regulations

The State of Texas is one of 15 states certified as an interstate agent of the Secretary of Transportation, assuming inspection responsibility for interstate hazardous liquid pipeline facilities and reporting violations to PHMSA for compliance action. To participate as an interstate agent, states must first take full intrastate jurisdiction and focus resources on intrastate facilities, such as pipeline TX219.

State regulations pertaining to underground pipeline damage prevention are found in Title 16, Part 1, Chapter 18 of the Texas Administrative Code (TAC). In general, the Code requires the excavator to notify a notification center before beginning work and obligates the excavator to avoid damaging underground pipelines. Applicable provisions of the Code include the following:

Rule 18.3 Excavator Notice to Notification Center. An excavator must contact the notification center in accordance with Chapter 251 of the Texas Utilities Code. For large projects that cannot be fully described by online locate tickets, the operator and excavator must conduct a face-to-face meeting to discuss the scope of the excavation activities and establish protocols for protecting the pipeline.

Rule 18.4 Excavator Obligation to Avoid Damage to Underground Pipelines. An excavator shall plan an excavation in such a manner as to avoid damage to and minimize interference with all underground pipelines near the excavation and shall take all reasonable steps to protect underground pipelines from damage. Among these requirements, an excavator shall make a visual check for any unmarked underground pipelines. Furthermore, if the excavator has knowledge of the existence of a conflicting underground pipeline but has already received an “all clear” or a “no conflict” response from a pipeline operator, or the positive response is unclear or obviously erroneous, the excavator shall not begin excavating until a second notice is given to the one-call notification center.[22]

Rule 18.6 General Marking Requirements. All pipeline markings must conform to the requirements of APWA Uniform Color Code (ANSI Standard Z535.1, Safety Color Code). The code states that, to increase the visibility of temporary markings, color-coded vertical markers such as stakes or flags should supplement surface markings.

Rule 18.7 Excavator Marking Requirements. Rule 18.7(a) requires that before giving notice pursuant to Rule 18.3, an excavator shall mark, if applicable according to Rule 18.3(c), the specific excavation area using white paint flags, or stakes, whichever is most visible for the terrain (this practice is also known as white

[22] The TAC defines a *positive response* as notification to the excavator by markings left at an excavation site, or by written or verbal correspondence, that allows an excavator to know before the beginning of excavation that underground pipelines have been located and marked or no underground pipelines in the vicinity of the excavation exist.

lining). Furthermore, under Rule 18.7(b), the excavator shall mark the area of excavation using intervals that show the direction of the excavation.

Rule 18.9 Options for Managing an Excavation Site in the Vicinity of an Underground Pipeline. This regulation provides recommended voluntary protocols for operators and excavators to jointly establish for excavations near underground pipelines, depending on the scope of the excavation and the characteristics of each job. According to Section (a)(9), the protocol may designate the extent of a tolerance zone, provided that it shall not be less than half the nominal diameter of the underground pipeline plus a minimum of 18 inches on either side of the outside edge on a horizontal plane. The protocol may also include the type of excavation permitted within the tolerance zone and provide for any other agreement with respect to excavation activities and/or marking requirements to ensure safe excavation near an underground pipeline. If an excavator and an operator jointly establish protocols pursuant to this section, a record of such an agreement is required to be maintained by the excavator and the operator. The Railroad Commission of Texas enforces the terms of damage prevention protocols when there is a written agreement between the parties.

1.10.2 Recommended Practices and Guidance

1.10.2.1 Pipeline and Hazardous Materials Safety Administration

In 1999, the US Department of Transportation (DOT) sponsored a study of one-call systems and damage prevention best practices called the *Common Ground Study* (DOT 1999).[23] The *Common Ground Study* identified several best practices specific to excavation, which included the following:

- *White lining*. When the excavation site cannot be clearly and adequately identified on the locate ticket, the excavator designates the area to be excavated using pre-marking before the arrival of the locator. The excavation area is marked with white paint, flags, stakes, or a combination of these to outline the dig site before notifying the one-call system and before the line locator arrives on the job. PHMSA has compiled a summary of state damage prevention laws, which indicate that 37 states and Puerto

[23] In 1998, Congress passed the *Transportation Equity Act for the 21st Century*, in which the DOT was instructed to conduct a study of best practices in place nationwide for enhancing worker safety, protecting vital underground infrastructure, and ensuring public safety during excavation activities in the vicinity of underground facilities. The DOT charged the former Office of Pipeline Safety (now PHMSA) with conducting the study.

Rico, including Texas, have enacted various provisions for white lining (PHMSA n.d.).[24]

- *Pre-excavation meetings*. When practical, the excavator requests a meeting with the pipeline locator at the job site before actual marking of facility locations. The meeting is intended to facilitate communications, coordinate the marking with actual excavation, and assure identification of high priority facilities.
- *Locate verification*. Before excavation, the excavator verifies the dig site matches the one-call request and confirms that all facilities have been marked.
- *Information-sharing*. Work site review with excavator crews to share information about the location of underground facilities.
- *Facility avoidance*. The excavator uses reasonable care to avoid damaging underground facilities and plans the excavation to minimize interference with underground facilities in or near the work area.

PHMSA also provides pipeline safety information specifically related to marine damage prevention on its website (PHSMA 2021).

1.10.2.2 Coastal and Marine Operators' Pipeline Industry Initiative

Among other things, the Coastal and Marine Operators' (CAMO) Pipeline Industry Initiative was organized to address challenges in preventing damage to coastal and marine pipelines.[25] CAMO has published public safety announcements and other guidance documents that are available from its website (CAMO n.d.).

In 2019, CAMO published a guide of recommended best practices for working near underwater pipelines (CAMO 2019). Intended to promote safe dredging and marine construction operations near underwater pipelines, the guide provided

- General information about pipeline types, their markings, and signage;
- Overview of the one-call process;
- Procedures for avoiding pipelines by the establishment of tolerance zones;
- Procedures for obtaining and providing pre-project information about the project scope and surveying for existing pipelines;

[24] See Title 16, Part 1, Chapter 18.7 of the TAC.

[25] The CAMO Group is an industry consortium composed of pipeline operators and industry stakeholders. CAMO focuses mainly on Gulf states but includes 26 US national and Canadian corporations.

- Safety, environment, and emergency response planning;
- Overview of dredging operations for pipeline operators; and
- Suggested timeline and objectives for planning projects near underwater pipelines.

The guidance, which is intended for marine construction personnel for planning and avoidance of underwater pipelines, emphasized the importance of knowing the product in each pipeline because products may vary in volatility and have different characteristics when released, and it suggested that the product should be clearly stated in contingency plans to minimize safety risks if a release occurs. The guide further suggested that all project plans should have basic pipeline information stored in multiple, readily available locations.

The CAMO guidance cautioned construction personnel not to rely on maps and other third-party sources of pipeline location information.[26] Instead, location data and work-limit boundaries should always be provided by the pipeline company. The guidance stated that "it is essential that both the project manager and the pipeline company representative have direct and detailed discussions on the locations of all underwater pipelines that could be impacted" (CAMO 2019).[27]

The CAMO best practices guide suggested that marking pipelines in marine areas is very challenging because markers can be accidentally moved or removed by weather events, wave action, vessels, and erosion. Temporary pipeline markers may include such things as buoys, cane poles, or polyvinyl chloride (PVC) pipe. The guide further stated that the pipeline company may provide GPS coordinates to electronically mark the pipeline aboard the dredge and marine vessels.

The guide discussed that tolerance zones, as defined in state laws, are designed for on-land application and are too small for marine activities. Although tolerance zones vary among dredging companies, the guide indicated that 75 feet appears to be the "no-go working distance" for most. A "no-go working distance" is where work may be unsafe or require special pipeline avoidance procedures. The guide stated that before work begins, all parties should be in mutual agreement on tolerance zone distances. Texas regulations for excavation within the statutory tolerance zone state that the excavator shall exercise reasonable care to prevent damage to underground pipelines.

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[26] *Third-party* refers to organizations or stakeholders not related to the utility company or its contractors.

[27] See section 1.8 of the *Recommended Best Practices Guide*.

The CAMO best practices guide indicated that the main signs of a pipeline leak include continuous bubbling, blowing, or hissing sound from the water. The guide recommended having active gas detectors during operations because gases may be odorless. The guide also provided a list of recommended actions to take after a pipeline leak, such as shutting down ignition sources, drifting out of the area, and evacuating.

1.10.2.3 Council for Dredging and Marine Construction Safety

Orion Marine Group is a member of the Council for Dredging and Marine Construction Safety (CDMCS), an organization whose purpose is to "create an injury-free workplace and safety-first culture for the dredging and marine construction industry." The CDMCS states that its mission is to "share best practices, apply lessons learned, and actively partner with the US Army Corps of Engineers, and other federal, state and local government agencies and stakeholders" (CDMCS n.d.).

In response to an April 2018 accident in which the dredge *Jonathon King Boyd* struck a gas pipeline in Matagorda Bay, Texas, the CDMCS formed the Pipeline Task Force (see section 1.13.1 for more information about the accident).[28] The Pipeline Task Force is a joint interagency, public-private initiative focused on ensuring safe dredging operations in ports and waterways with submerged gas and hazardous liquid pipelines through enhanced communication, collaboration, and exchange of best practices among all stakeholders.

In January 2020, as a result of the Pipeline Task Force's work, the CDMCS published *Pipeline Incident Prevention*, a best practices guide to promote safe dredging and construction operations near underwater gas and hazardous liquid pipelines (CDMCS 2020).[29] The CDMCS guidance is similar to the best practices published by CAMO. *Pipeline Incident Prevention* explained that statutory tolerance zones around pipelines, ranging between 18 and 30 inches, were intended for land-based excavation and not suited for marine applications like dredging. In conjunction with the best practices guide, the CDMCS also published a "Checklist for Safe Dredging Near Underwater Gas & Hazardous Liquid Pipelines." Together, these

[28] *Jonathon King Boyd* and *Waymon Boyd* were originally owned and operated by King Fisher Marine Service (established 1940) in Port Lavaca, Texas. Orion Marine Group acquired King Fisher Marine and *Waymon Boyd* and *Jonathon King Boyd* in 1998. In 2010, RLB Contracting Inc. acquired *Jonathon King Boyd*.

[29] The recommended practices are applicable to operations conducted in US Army Corps of Engineers (the Corps of Engineers) federal navigation channels, including those channels the Corps of Engineers contracts with industry to dredge.

documents provided guidance for dredging companies for planning, identifying, and avoiding pipelines.[30]

Both *Pipeline Incident Prevention* and the accompanying checklist provided recommended actions for a dredge crew in the event of an emergency involving a pipeline breach. These actions included, but were not limited to, the following:

- Immediately stop all operations and keep yourself safe.
- Shut down or minimize the use of all possible ignition sources: motors, generators, lights, etc.
- Account for all crewmembers and communicate the hazards to them.
- Call 911 (required), Channel 16, or the Coast Guard and describe your location.
- If possible, drift out of the area before starting an ignition source.
- Evacuate the vessel if needed.
- Contact the pipeline company emergency number in your plan to shut down the line.

1.10.3 Company Policies for Pipeline Protection

1.10.3.1 Enterprise Damage Prevention Program

The most recent revision of the Enterprise damage prevention program became effective May 4, 2016, and contained protocols and procedures intended to address company policies and applicable federal, state, and local regulations. The program stated that Enterprise participates in a qualified one-call system in every state in which it operates.

Texas state law requires that a person who intends to excavate shall notify a state notification center (Texas811) no later than 48 hours before the time the excavation is to begin, during which a pipeline operator must contact the excavator, review project plans, and determine whether to locate and mark its pipelines.[31] There are two ways to contact Texas811 to request a ticket to have utilities marked: by phoning 811 or by using an online ticket-entry system. The notification must include a

[30] For more information on the CDMCS guidance, see the Nautical Operations, Human Performance, and System Safety Group Factual Report and Pipeline Operations Group Factual Report for this accident.

[31] *Texas Underground Facility Damage Prevention and Safety Act*, Utilities Code, Title 5, Chapter 251.

description of the planned excavation location and other details about the nature of the project and the organization performing the work. Within 2 hours of notification, Texas811must identify which utilities have lines near the proposed work area and notify the utility operators of the excavation plans. When a notification indicates potential impact to Enterprise facilities, Texas 811 forwards notifications to the Enterprise one-call center in Houston, Texas.

The Enterprise damage prevention program directed personnel assigned to locating pipelines (line locators) to, among other things, contact the one-call ticket originator to discuss the exact location of the excavation as defined on the ticket and the planned activities at the excavation site.[32] Line locators were also directed to determine if the area of excavation was properly identified in the one-call ticket, as well as the direction, distance, and start and stop locations of proposed excavation activity. The line locator was supposed to record notes of the conversations or meetings with the ticket originator in the one-call ticket.

According to the program, a site visit may not be required if contact with the ticket originator has determined that, "without question," the excavation activity falls outside of designated buffer zones or rights-of-way. However, the line locator must conduct a site visit if any questions exist. If the site meeting determined that the excavation posed no risk to Enterprise's pipelines, the line locator was to complete the one-call ticket with a status of "Cleared." If the meeting determined that a planned excavation would pose a risk to the pipeline, the program called for the pipelines to be located and marked, and the one-call ticket status to be identified as "Marked."

The program also provided for required marking areas and marking frequency. For excavations occurring within 50 feet of the centerline of Enterprise's pipelines, the pipeline must be located and marked at intervals of 20 feet. In surveying the pipeline to mark its location, the line locator was supposed to use an electronic line locator instrument in which an electronic signal is transmitted to the target pipeline and located with a handheld receiver. The program further provided that for any excavation within 12 feet of a pipeline, Enterprise field personnel must be on site to monitor excavation. Excavations and encroachment activities outside of 12 feet could be monitored by Enterprise representatives as needed, based on the judgment of company management. The program provided that if heavy equipment will be operating on or crossing company rights-of-way, line locators should consult

[32] A *one-call ticket* is a record of the notice of intent to excavate given by the excavator to a notification center in conformance with state one-call regulations.

supervision and the Enterprise land management department for additional instructions and documentation review.

The damage prevention program articulated that after receiving a one-call notice for a large project that could potentially impact pipeline facilities, Enterprise and the excavator may jointly establish an excavation protocol agreement to protect company pipelines near the excavation site. Such protocol agreements must detail the scope of work and include GPS coordinates for the beginning and ending points of the planned project.

The program required that temporary markings used for locating pipelines must follow APWA uniform color code. The program stated that where applicable, temporary markers such as buoys, poles, or PVC markers should be used to indicate the location of underwater pipelines. If necessary, these markers could be supplemented with mapping, GPS coordinates, and/or fixed high-bank marks.

The Orion Group was listed in the Enterprise public awareness stakeholder database and had received annual pipeline safety brochures over the past 5 years.[33] Enterprise had published and distributed a separate encroachment guidelines brochure that directed excavators not to perform excavation activities on rights-of-way without Enterprise's approval (Enterprise 2019). The guidelines explained the information excavators must provide in connection with 811 one-call notifications, such as a description of the project, map of the project location, and detailed construction plans depicting existing and proposed surface elevations, pipeline location, and depth. The guidelines also advised that in some cases Enterprise may determine that an adjustment, relocation, or lowering of a pipeline may be necessary to ensure the safety of a proposed project and the integrity of the pipeline.

The encroachment guidelines further stated that mechanized equipment is not allowed to conduct excavation activities within a tolerance zone, defined by Enterprise as 18 inches from the outer edge of the pipe in all directions, or as defined by state regulations.[34] The guidelines stated that any excavation taking place within the tolerance zone must be done by hand. General excavation guidelines add that all

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[33] The Enterprise Products stakeholder database also contained the email addresses of five Orion Group officials.

[34] Title 16, Part 1, Chapter 18.2 of the TAC defines a tolerance zone as half the nominal diameter of the underground pipeline plus a minimum of 18 inches on either side of the outside edge of the pipeline on a horizontal plane.

mechanical digging equipment must dig parallel to pipelines and have the teeth removed or barred with a plate welded across the bucket.

1.10.3.2 Orion Marine Group Procedures for Avoiding Infrastructure Damage

Although Orion did not have written procedures describing the protection of utilities and infrastructure located outside of the excavating area template on DREDGEPACK, Orion representatives told the NTSB that the company's general operating practices included the following:

- Review dredging plans as provided by client
- Perform one-call notifications
- Gather information from pipeline controllers
- Make sure the line is marked and get details of markings from pipeline controllers
- Information sent to captain and relayed verbally regarding pipeline details
- If GPS coordinates are provided, upload onto the digging screen
- No digging within 10' of any permanent structures

The *Waymon Boyd* deck captain was unaware of any company policy governing how close cutterhead dredging may be performed near a pipeline. According to crewmembers, the precautions that they normally took when dredging near or over pipelines involved turning off the cutterhead motor and securing the cutterhead with line to prevent it from rotating; thus, only the suction head was used to remove sediment near the pipeline. This method was primarily used when the pipeline was buried well beneath the maximum dredging depth. The cutterhead was not secured during dredging operations leading up to the accident.

The Orion HSE director stated that Orion defers to the utility owner when establishing the tolerance zones for working near pipelines. He stated that the company prefers to dredge no closer than 20 feet from pipelines, despite the general operating practices stated above. He added that Orion has no written policy addressing tolerance zones. When questioned whether the company follows dredging best practices published by such organizations as the CDMCS, the HSE director responded that Orion uses its own internal methods and best practices for avoiding pipelines while dredging, which he stated are very similar to the CDMCS checklist and standard throughout the industry. The company did not have an emergency procedure for dredges in the event of a pipeline strike.

Occasionally for other projects, pipeline company technicians boarded the dredge to observe when operations came close to pipelines. However, there were no Enterprise employees aboard the *Waymon Boyd* during the EPIC dock project dredging.

1.11 Electronic Data

1.11.1 Pipeline Location Data

The NTSB obtained location data for pipeline TX219 from multiple sources to include Enterprise in-line inspection (ILI) data, the 2018 TMI Solutions utilities survey, a postaccident survey performed by Orion personnel, and a postaccident survey performed by Enterprise contractor SAM LLC. The location data varied among all sources. At the point of damage to the pipeline, none of the data showed the pipeline within the DREDGEPACK dredge template in use by the *Waymon Boyd* at the time of the accident.

With the assistance of a HYPACK technical representative, the NTSB imported the TMI Solutions survey data (the data provided to Orion and Schneider for planning the EPIC dock project) into DREDGEPACK and used the system's tools to measure the distance between the center of pipeline TX219 and the southern edge (top of the slope) of the EPIC East Dock dredge template in use by the *Waymon Boyd* at the time of the accident (see figure 30). At its nearest point, the center of pipeline TX219 was shown as being 0.8 feet from the DREDGEPACK dredge template (left image), and at the accident location, the center of the pipeline was shown as being 1.9 feet from the template (right image).

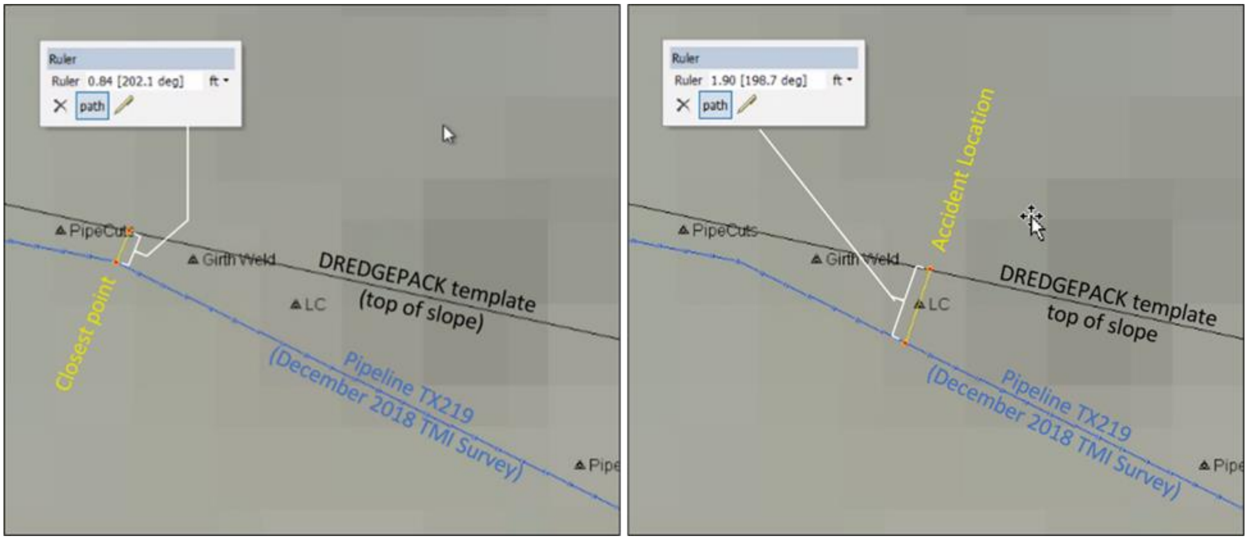

Figure 30. Screen captures from DREDGEPACK dredge template for the EPIC dock project.

A similar projection of the data from the 2016 Enterprise ILI assessment (the most recent assessment by the pipeline owner), showed the distance from the pipeline's center to be about 1.0 foot from the dredge template at the accident location.

1.12 Tests and Research

A 14-foot 4-inch segment of the damaged pipe was sent to the NTSB Materials Laboratory for examination. During the examination, the NTSB noted the pipeline segment damage consisted of five gouges, three dents, and two punctures with a fracture that intersected both punctures (see figures 31 and 32). Two halves of a 1-foot-long concrete exterior coating separated at the accident site (during the recovery operation) from the west end of the pipe segment.

The punctures contained evidence of inward-bending deformation. All damage to the pipe, including punctures, gouges, dents, and the fracture, occurred within a region between 25.5 and 57.8 inches east of the girth weld. As much as a 10-foot 5-inch length of the concrete coating was missing from the pipe in the general area of the damage. Based on orientation marks found on the pipe, the two punctures were located approximately at the 7 o'clock position looking east.

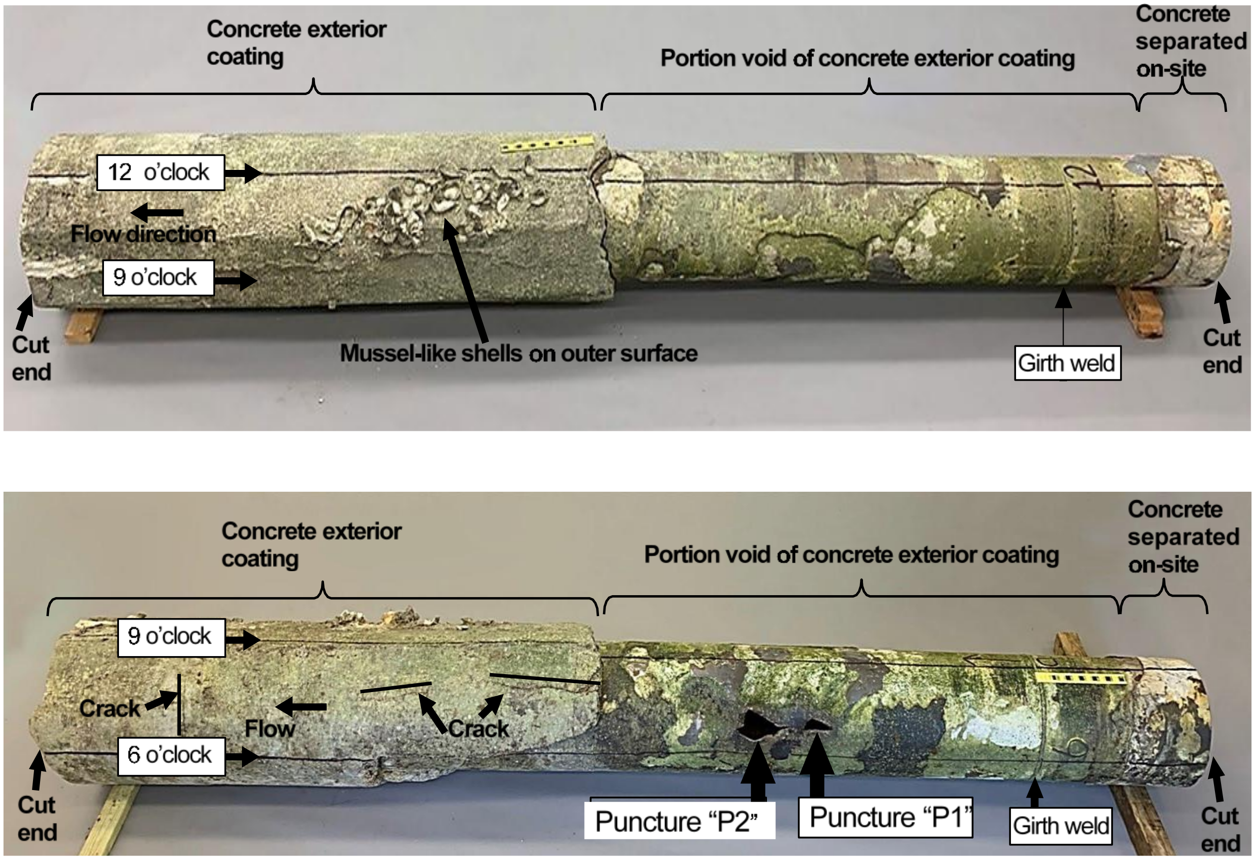

Figure 31. Damaged pipe segment showing the top side (12 o'clock) and the bottom side (6 o'clock). Clock positions are while looking east.

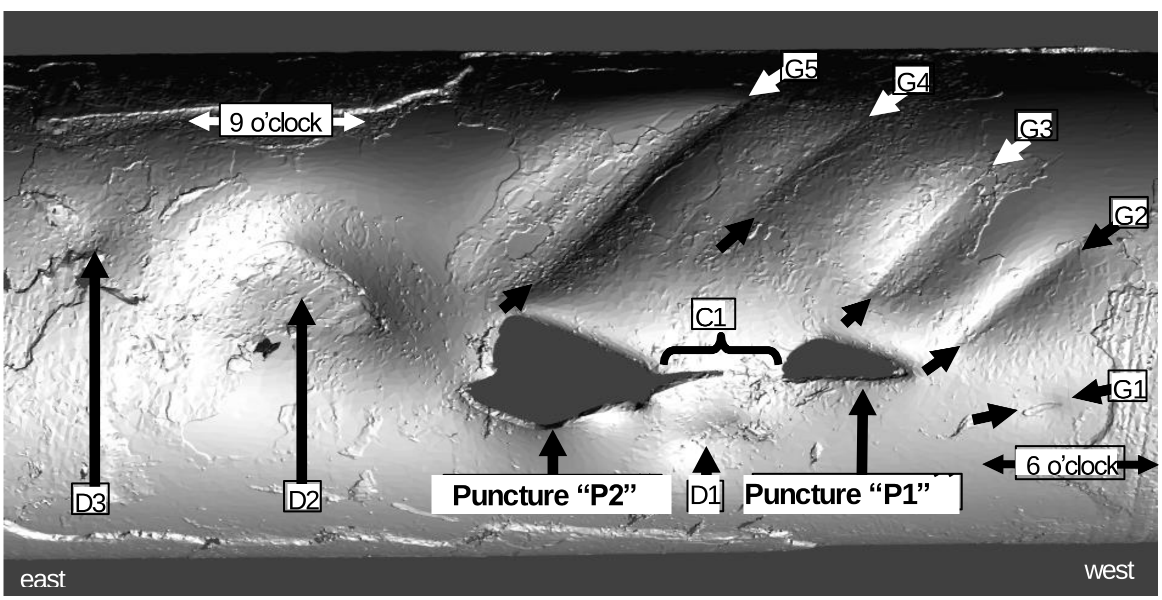

Figure 32. Three-dimensional laser-scanned image of the damaged pipe. Clock positions are while looking east. (Source: Enterprise Products, annotated by NTSB)

Fit Test (Inserting a Tooth into a Puncture). The tip portion of the tooth removed from blade C of the cutterhead was placed on the outer surface of the pipe in the area adjacent to the larger puncture "P2". The tip portion was then partially inserted into the puncture (see figure 33). When the tooth was inserted into the puncture, there was room for the entire width portion at the tip to enter the puncture.

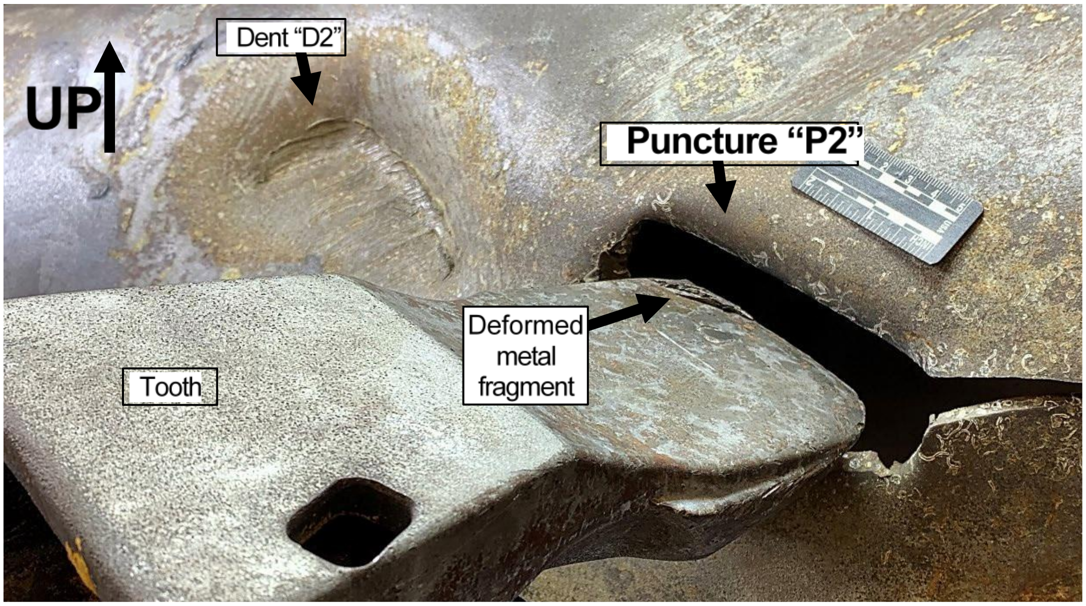

Figure 33. Oblique view of puncture "P2" with the tip portion of the tooth from cutterhead blade C facing the puncture, after cleaning.

The fitting procedure was repeated for the smaller puncture "P1". The tip portion of the tooth was placed on the outer surface and adjacent to puncture "P1". Only a tip corner portion of the tooth and a portion of the tooth width (about 50% of the width portion of the tooth) extended into the puncture.

The tip portion of the cutterhead tooth was placed on the outer surface of the pipe in the area adjacent to dent "D2". The width of the tooth was specified as 109 millimeters (4.3 inches). The width of the cluster of gouges associated with dent "D2" measured as wide as about 4.4 inches.

Teeth. The tip portion of each tooth removed from the cutterhead and analyzed by the NTSB contained evidence of wear (abrasion) marks. A deformed metal fragment (also referred to as metal buildup) was embedded at the tip and back side of the tooth from blade C.

Metal Transfer. The tip portion of the blade C tooth contained evidence of metal transfer in an isolated area. Energy dispersive spectroscopy (EDS) analysis is a microanalysis technique that can identify which chemical elements are present in a sample. The NTSB Materials Laboratory found that EDS spectrum of metal buildup in the tip portion of the tooth was similar to the EDS spectrum of the pipe.

Metallurgical sections were made through the wall of the pipe and through the metal buildup at the tip of the blade C tooth that incorporated a portion of the tooth. The section from the pipe exhibited a microstructure of banded pearlite and ferrite grains, which is typical of hot-rolled steel, whereas the tooth showed evidence of a cast microstructure. The metal buildup contained no trace evidence of tooth material.

The surface of gouge “G5” was analyzed to determine whether material from a tooth had transferred to the pipe. The tooth removed from blade C was selected for comparison analysis. The tooth contained evidence of chromium, an element that was not present in pipe material, and greater amounts of silicon than that found in the pipe. EDS spectrum of material found on the surface of gouge “G5” was similar to the EDS spectrum for the tooth.

1.13 Related Accidents and NTSB Recommendations

1.13.1 Matagorda Bay, Texas, 2018

On April 17, 2018, the cutter suction dredge *Jonathon King Boyd* punctured a submarine natural gas pipeline with a spud during dredging operations in Matagorda Bay, Texas (NTSB 2019). A gas plume ignited and engulfed the dredge and its accompanying towboat, the *Bayou Chevron*. All 10 crewmembers abandoned the vessels uninjured.

Investigators found that the dredging company, RLB Contracting Inc., did not alert the Texas Notification System before commencing dredging near the pipeline. Furthermore, while the *Jonathon King Boyd* crew relied solely on its HYPACK software while conducting dredging operations, RLB Contracting did not incorporate the location of utilities into the software.

The captain and the levermen told the NTSB that had they known a pipeline was present, they would not have allowed the spuds to freefall from their stowed position. Instead, they would have pinned the spud higher and performed a controlled lowering of the spud over the pipeline, if required, to limit the spud’s penetration into the channel bottom. The cutterhead would have been secured and the jet pump would have been used when crossing over the pipeline. Also, the dredge would have been repositioned to the other side of the pipeline.

The NTSB determined that the probable cause of the fire aboard the cutter suction dredge *Jonathon King Boyd* was RLB Contracting’s failure to inform the crew about utilities in the area due to ineffective oversight, which led to dropping a spud onto a buried submarine pipeline, causing natural gas to release and ignite.

1.13.2 Tiger Pass, Louisiana, 1996

On October 23, 1996, in Tiger Pass, Louisiana, the crew of a Bean Horizon Corporation dredge dropped a stern spud into the bottom of the channel in preparation for dredging operations (NTSB 1998). The spud struck and ruptured a 12-inch-diameter submerged natural gas pipeline owned by Tennessee Gas Pipeline Company. The pressurized natural gas released from the pipeline and enveloped the stern of the dredge and accompanying tug, then ignited, destroying the dredge and tug. No fatalities resulted from the accident.

The safety issues identified in the NTSB report on this accident included, among other concerns, the Tennessee Gas Pipeline Company's practices and procedures for locating, marking, and maintaining markers for gas transmission pipelines through navigable waterways. The NTSB found that Tennessee Gas Pipeline Company took inadequate steps to precisely identify and mark the location of its pipeline through Tiger Pass before dredging operations were undertaken in the pipeline area. Additionally, the NTSB found that had the Research and Special Programs Administration (RSPA) not revoked federal requirements for installing and maintaining markings of pipeline crossings of navigable waterways, the pipeline involved in this accident may have been accurately marked, and the accident may have not occurred.[35]

The NTSB issued the following safety recommendations pertinent to marking pipelines that cross navigable waterways:

> To RSPA:
>
> Require pipeline system operators to precisely locate and place permanent markers at sites where their gas and hazardous liquid pipelines cross navigable waterways. (P-98-25, Closed–Acceptable Alternate Action)
>
> To the Tennessee Gas Pipeline Company:
>
> Develop formal, written company procedures for identifying the precise locations of your pipelines that traverse navigable waterways before

[35] In 2005, as a result of the *Norman Y. Mineta Research and Special Programs Improvement Act*, the DOT's pipeline and hazardous materials safety programs were reorganized into the newly created PHMSA.

> dredging or similar activities are commenced in the pipeline area. (P-98-26, Closed–Acceptable Action)

To the Interstate Natural Gas Association of America:

> Inform your members of the circumstances of the pipeline rupture and fire in Tiger Pass, Louisiana, and urge them to take the actions necessary to ensure that all their pipelines that cross navigable waterways are accurately located and marked. (P-98-28, Closed–Unacceptable Action/No Response Received)

To the American Petroleum Institute:

> Inform your members of the circumstances of the pipeline rupture and fire in Tiger Pass, Louisiana, and urge them to take the actions necessary to ensure that all their pipelines that cross navigable waterways are accurately located and marked. (P-98-29, Closed–Acceptable Action)

1.13.3 NTSB Excavation Damage Prevention Safety Study, 1997

In response to concerns about the number of excavation-caused pipeline accidents, the NTSB and RSPA jointly sponsored an excavation damage prevention workshop in September 1994. In 1997, the NTSB published a safety study to analyze the findings from the workshop (NTSB 1997). The safety issues discussed in the study included:

- Essential elements of an effective excavation damage prevention program
- Accuracy of information regarding buried facilities
- System measures, reporting requirements, and data collection

Among the findings cited in this study, the NTSB stated that pre-marking an intended excavation site to specifically indicate the area where underground facilities need to be identified is a practice that helps prevent excavation damage. According to the study, pre-marking allows the excavators to specifically inform facility owners where they intend to dig. The study noted that some states require the use of white marking to indicate the boundaries of planned excavations.

The NTSB issued the following safety recommendation to RSPA:

> Initiate and periodically conduct, in conjunction with the American Public Works Association, detailed and comprehensive reviews and evaluations of existing State excavation damage prevention programs and recommend changes and improvements, where warranted, such as full participation, administrative enforcement of the program, pre-

marking requirements, and training requirements for all personnel involved in excavation activity. (P-97-15, Closed—Acceptable Action)

1.14 Postaccident Actions

1.14.1 Orion Marine Group

Following the accident, Orion Marine Group instituted "underwater utilities" awareness training for all dredge crews and shoreside support staff, including dredge superintendents, project managers and engineers, safety and survey personnel, and company leadership. The training included general requirements for excavating near pipelines and other utilities, questions company personnel should ask when planning and working around utilities, emergency procedures in the event of a pipeline strike, and hazards to be addressed in JHAs. According to a company representative, the training is conducted twice a year, with additional training as directed by management or as required by a project. An underwater utilities training aid was posted on Orion dredges in the lever room, galley, and captain's office. The company representative stated that emergency procedures for a pipeline strike are exercised during periodic fire and abandon ship drills on its dredges.

Since the accident, Orion has also assigned dedicated safety supervisors to each of its dredges. According to the company representative, the safety supervisor's duties include:

- Facilitating the HSE program for the project, vessel, and equipment/sites to which they are assigned, including participation in daily safety meetings, equipment inspections, and all JHAs.
- Communicating with, instructing, training, and listening to the crews and leadership to continuously improve the safety culture at Orion.
- Managing and mitigating hazards, risks, and incidents, including informing the regional HSE manager of any utilities in the area that may present a risk so that they can be included in the SSSP.
- Controlling HSE documentation; ensuring captains are completing and submitting HSE documents such as JHAs, safety meetings, equipment inspection checklists, etc.
- Managing emergency drills.
- Assisting with client relations and acting as a regulatory agency liaison for the dredge and project alongside the captain.

- Inspecting for, auditing, and assisting with the identification and correction of HSE issues that may arise throughout a project.
- Working alongside the dredge captain, dredge superintendent, project manager, regional HSE manager, and director of operations to ensure the dredge and project site are working at optimal safety.

The safety supervisor is on site 5 days a week for the duration of each dredging project.

In addition to these formal measures, the Orion survey superintendent told the NTSB that "all the information that we can get anywhere in the area, we're putting that on [DREDGEPACK] now." This information includes any pipeline location data.

1.14.2 Enterprise Products

On May 24, 2021, EPIC notified Enterprise that it cancelled the East Dock project that would have provided a bulkhead and backfill to protect the shallow pipelines near the accident scene. As a result, Enterprise has retained engineers to evaluate alternatives to mitigate the potential of third-party damage to pipeline TX219. These include (a) protecting the pipeline in place by constructing a bulkhead and/or riprap on the water side of the pipeline; (b) installing a new segment of pipe by horizontal drilling under the EPIC and other affected sites; or (c) re-routing the pipeline around the area.[36] Enterprise continues to evaluate these options and is coordinating with landowners, the Port of Corpus Christi, and the Corps of Engineers to further explore options and permitting requirements. Enterprise told NTSB investigators that once an alternative is selected, they will develop detailed engineering plans and obtain any required permits and/or approvals of other parties, including property owners and other stakeholders. Enterprise will develop a timeline for completion once they decide on the course of action.

[36] *Riprap* is a foundation or sustaining wall of stones or chunks of concrete thrown together without order (as in deep water).

2. Analysis

2.1 Introduction

On August 21, 2020, about 0802 central daylight time, the US-flagged, nonpropelled, 152-foot-long cutter suction dredge *Waymon Boyd* struck a submerged 16-inch liquid propane pipeline during dredging operations adjacent to the EPIC Marine Terminal, located on the Corpus Christi Ship Channel in Corpus Christi, Texas. A geyser of propane gas and water erupted adjacent to the vessel. Shortly thereafter, propane gas engulfed the vessel and ignited, and an explosion occurred. Fire damaged the vessel and surrounding shoreline. A total of 18 personnel employed by Orion Marine Group were working or resting on the dredge and assist boats (tender boats, anchor barges, booster barges, and a supply barge) on the day of the accident. Three crewmembers aboard the *Waymon Boyd* and one on an adjacent anchor barge died in the explosion and fire. Six crewmembers aboard the dredge were injured. First responders located the injured and transported them to local hospitals. They were eventually transferred to burn units in San Antonio, Texas, where one of the crewmembers later died from his injuries. The *Waymon Boyd*, valued at $9.48 million, was a total loss. The cost of pipeline damage was $2.09 million. The cost of physical damage to the EPIC facility was $120,000.

The following analysis discusses the accident sequence and evaluates the following safety issues:

- Inadequate project planning and risk assessment (section 2.3)
- Ineffective pipeline damage prevention (section 2.4)
- Lack of pipeline hazard training (section 2.5)

Having completed a comprehensive review of the circumstances that led to the accident, the investigation identified none of the following as causal issues:

- *Experience and qualifications of the vessel and pipeline personnel*. The *Waymon Boyd*'s dredge captain had 20 years' experience on dredges, 10 years as either a deck captain or dredge captain. The vessel's leverman, who was at the controls at the time of the accident, had 40 years' experience on dredges, with over 20 years as a leverman. Experience levels of other crewmembers varied but were commensurate with their positions and responsibilities on the vessel.

  While the pipeline controller ashore did not have previous experience handling any pipeline breaching incidents or in-service failures during his

5-year tenure in his position with Enterprise, he effectively managed the circumstances by communicating the incident to managers and quickly dispatching technicians to confirm anomalous pressure readings and automatic pipeline isolation measures. He then added redundant valve closures as a further guarantee of pipeline isolation. The two pipeline technicians who were involved in reviewing the one-call tickets and were responsible for conducting the courtesy-locate marking were both experienced in reviewing one-call notifications. Each technician reviewed about a dozen projects per week over a 4-year period.

- *Fatigue.* The accident occurred in the morning, near the beginning of the day shift. *Waymon Boyd* crewmembers stated that they got 7–9 hours of sleep each night.
- *Distraction from cell phone use.* Cell phone records for the leverman do not indicate use just before the accident.
- *Vessel mechanical and electrical systems failures.* The crew reported no major equipment problems before or during the accident, other than the sheared shaft coupling that was repaired the night before. The leverman stated that all equipment was operating correctly at the time the pipeline was breached.
- *Environmental conditions.* The accident occurred during daylight, and weather conditions at the time of the accident were mild.
- *Leak detection systems on pipeline TX219.* Timely leak detection is critical because an operator's emergency response cannot begin until the leak has been identified and communicated to those responsible for prompt mitigation. Continuous pipeline pressure monitoring by the SCADA system quickly identified and generated low-pressure alarms within seconds following the accident. The pipeline was also protected by a software-based pipeline monitoring leak detection tool that responds to changes over longer time periods, which functioned as designed and assisted with the detection of the accident.
- *Pipeline operating history and operating pressure.* Enterprise generally operated the pipeline between 250 and 300 psig, well below its maximum operating pressure of 787.5 psig. While the maximum operating pressure was 63% of the pipe's specified minimum yield strength, Enterprise records indicated that TX219 was typically operated about 24% of the specified minimum yield strength.[37] In addition, Enterprise records indicate the pipeline was subjected to relatively light pressure cycling, which minimized

[37] Pipelines will begin to deform if operated at the specified minimum yield strength. As a result, pipelines operate at a percentage of the level of pressure that will cause the pipe to deform.

stresses that could have led to crack growth by fatigue mechanisms. ILI data from 2016 did not identify any indications of corrosion in or near the segment of pipe in which the breach occurred. Furthermore, the pipe segment exhibited no evidence of seam-related failures.

- *Pipeline integrity*. Enterprise had an integrity management program that included a baseline integrity assessment, periodic patrols, inline inspections, cathodic protection for corrosion prevention, and periodic risk assessments with information analyses. Before the accident, there were no unresolved pipeline integrity indications such as corrosion, metal loss, dents, cracks, or previous mechanical damage that contributed to the breach.
- *Transport of non-odorized propane in the pipeline*. The product transported in pipeline TX219 was non-odorized propane, an odorless, tasteless, and colorless gas with no physical or chemical properties that can warn of the presence of hazardous concentrations. Previous NTSB investigations have not identified incidents in which odorants in a transmission pipeline would have alerted the public in time to prevent the incident. Given the high pressures at which transmission pipelines are operated, even a small hole in a pipeline would cause a tremendous disturbance to surrounding earth or water such that people will hear and see evidence of the leak. Additionally, pipeline operators use tools such as electronic leak detection and remotely controlled valves to detect potential leaks and shut down the pipeline if needed. Such was the case when the breach of pipeline TX219 resulted in a geyser of water erupting taller than the dredge itself. At the scene, the dredge crew's full attention was immediately drawn to the incident. Also, odorant should not have been necessary because industrial dredge workers are expected to have greater knowledge of pipeline hazards than the lay public. A 2018 US Government Accountability Office report to Congress cited adverse chemical reactions during processing for industrial uses other than fuel as the primary reason for not using odorants in transmission pipelines transporting combustible gas products (USGAO 2018).
- *Pipeline depth of cover*. Soil cover over pipelines is intended to protect pipelines from impact from activities such as soil cultivation, equipment movements, or navigation around or over the pipeline. However, in this accident, the *Waymon Boyd*'s cutterhead hit the pipeline from underneath. Any sediment covering the pipeline would quickly have been vacuumed away by the suction head as the cutterhead broke up the soil.

Thus, the NTSB concludes that none of the following were safety issues for the accident: (1) experience and qualifications of the vessel and pipeline personnel; (2) fatigue; (3) distraction from cell phone use; (4) vessel mechanical and electrical systems failures; (5) environmental conditions; (6) leak detection systems on pipeline TX219; (7) pipeline operating history and operating pressure; (8) pipeline integrity; (9) transport of non-odorized propane in the pipeline; or (10) pipeline depth of cover.

Because alcohol testing of the entire surviving crew was not conducted and drug testing was not completed within the 32-hour maximum time window required by 46 *CFR* 4.06-3, evidence was insufficient to determine whether alcohol or other drug use played a role in this accident. Ethanol in the deceased crewmembers was most likely from postmortem production.

2.2 Accident Sequence

Based on the time of the SCADA system low-pressure indication at the Enterprise control center, pipeline TX219 was breached at 0802, releasing propane into the environment. After escaping the pipeline, the liquid propane vaporized to a gas, rose to the water's surface, and began spreading throughout the EPIC marine terminal and surrounding waters. In the moments before the breach, AIS data show the *Waymon Boyd* moving in an arc toward the shoreline near the pipeline at speeds between 0.1 and 0.3 knots (see figure 9), which is consistent with the leverman's statement that he was slowly swinging the vessel to port while operating the dredge. The distance from the last AIS position recorded during the swing to port to the damaged point of the pipe was 118.8 feet, and the distance between the AIS antenna and the cutterhead was 119.1 feet, placing the cutterhead in the location of the pipeline where the damage occurred. The leverman further stated that he was excavating the top layer of material, which would have brought the rotating cutterhead to the edge of the dredge template as it approached the top of the slope.

The night before the accident, all teeth on the cutterhead were reported to be in place; however, during postaccident examination, one tooth was missing and another was fractured, indicating that the cutterhead had made hard contact with a stationary object. Gouges on the outer surface of the pipe contained evidence of metal transfer from the cutterhead teeth. A deformed metal fragment found at the tip of one of the cutterhead teeth was identified as having similar microstructure and elemental signature as those of the pipe, and the size of the punctures and deformation pattern found on the pipe were consistent with the size of the cutterhead teeth. Evidence indicates the two punctures, dents, and elongated dents on the pipe (as shown in figures 31, 32, and 33) were caused by the cutterhead teeth contacting the pipe. One tooth penetrated the pipe, another tooth partially penetrated the pipe, and other teeth caused dents that did not puncture the pipe. The NTSB concludes that Enterprise's pipeline TX219 was struck by the dredge *Waymon Boyd*'s rotating cutterhead, causing a breach in the line that allowed propane to escape and form a gas cloud that surrounded the dredge.

Although the *Waymon Boyd* leverman attempted to swing the dredge away from the geyser of water that was carried with the escaping propane, the vessel was less than 200 feet away from the pipeline breach, and the expanding gas cloud enveloped it. Engine room ventilation supply fans located above the aft end of the main diesel generator likely drew the gas into the space.

One minute six seconds after the pipeline breach, the propane gas ignited. The shaking of the ground as described by witnesses and as viewed on a security camera, as well as the accompanying large "boom" sound heard throughout the area, indicate that the ignition triggered a violent explosion. To create the violent explosion described by witnesses, combustion of the propane gas would have had to occur in a confined area, not in the open atmosphere. Postaccident examination of the *Waymon Boyd* revealed that the engine room bulkheads were severely bowed outward, and the exterior doors and a patch panel for the space were missing. Bent railing near the missing patch panel suggests that the panel was blown outward. The berthing and galley space above the forward end of the engine room was displaced, and the deck over the aft end of the engine room, on which the stack and ventilation fans were mounted, was bent upward and forward. The door to an electrical box on the forward bulkhead of the engine room was caved inward. The overall evidence points to an extreme overpressurization that occurred in the engine room, indicative of an explosion. Although investigators could not conclusively determine the source of ignition for the explosion, several potential sources existed in the engine room, including high heat from the diesel generator turbo and exhaust manifold, arcing in the electrical ventilation fans, and sparks from other electrical components. The NTSB concludes that propane gas that had released from pipeline TX219 was drawn into the *Waymon Boyd*'s engine room by the ventilation fans and was ignited, causing the explosion.

Enterprise's records indicate that the pipeline controller acknowledged the SCADA system alarm on pipeline TX219 within 10 seconds of the first indication of a pressure drop on the pipeline at the Viola Meter Station; the SCADA system annunciated a low-pressure condition about 44 psi below the company's desired static pressure threshold of 200 psig. A second low-pressure alarm occurred, followed by automatic control valve closure on the pipeline near the point where propane was introduced from the Flint Hills Refinery. As the pipeline controller observed this sequence of events, he formulated a plan to investigate the circumstances. SCADA records indicate the entire sequence from first indication of a pressure drop to control valve closure took 2–3 minutes. This automatic pipeline isolation process would have occurred irrespective of any action taken by the pipeline controller.

Within 4 minutes of the control valve beginning to close, the Enterprise pipeline controller in Houston contacted local Enterprise pipeline technicians in Corpus Christi and directed them to respond to the Viola and Origin Stations to investigate the situation and verify if the SCADA alarms were valid. About 10 minutes after control valve closure, the pipeline controller directed a local pipeline technician to manually close downstream isolation valves to eliminate the possibility of inadvertent backflow from storage into the pipeline. After a second pipeline technician arrived at the Viola Meter Station and confirmed low-pressure gauge readings on the pipeline, about 36 minutes after the control valve closure, the pipeline controller initiated closure of two additional redundant isolation valves to further secure the pipeline.

Enterprise's most recent risk analysis on the pipeline before the accident noted that operating procedures and systems were designed to have rupture detection within 5 minutes, pipeline shutdown within 15 minutes, and an on-scene response time of 30 minutes. Following the breach of pipeline TX219, the pipeline controller identified the pressure drop within seconds, the pipeline was shut down within 3 minutes, and technicians responded to valve control facilities within 13–29 minutes. Thus, the NTSB concludes that the Enterprise pipeline controller's and pipeline technicians' actions to secure the pipeline were appropriate and facilitated a timely shutdown.

The *Waymon Boyd* was equipped with a 400-hp mechanically rotating cutterhead. As stated above, the cutterhead, which is a large, powerful excavating device that operated beneath the water's surface and was controlled from an elevated distance, breached the pipeline and caused the catastrophic accident. Because of the characteristics of the cutterhead and how it is operated, there is a margin of error associated with cutterhead dredging.

The leverman used the DREDGEPACK software to guide him as he operated the cutterhead and dredged to the template. The source of location data for the software was a GPS receiver, which was accurate to within 1 meter. Thus, the location of the cutterhead could vary by as much as 3.3 feet based on GPS margin of error alone. The accuracy of the cutterhead location also depended on accurate configuration inputs to DREDGEPACK, including the cutterhead and ladder dimensions, the GPS antenna location, and the proper calibration of the inclinometer on the ladder. Investigators could not verify the configuration information or inclinometer calibration following the accident because the equipment was damaged, but any error involving one or more of these measurements would have offset the cutterhead's apparent position in DREDGEPACK from its actual physical location. Additionally, the symbology for the cutterhead shown in DREDGEPACK was an "X," and the leverman stated that when excavating a slope, he put the center of the X on the slope template. The cutterhead measured 3.6 feet long by 6.5 feet wide; thus, the center of the symbology would not have reflected the full reach of the cutterhead as it was raised and lowered. Finally, DREDGEPACK software was displayed for the leverman on a single computer monitor in the lever room. The display was divided into overhead and cross-sectional views, along with a panel or panels displaying parametric data. In this configuration, the scale of the display would have been relatively small, with a foot of distance measured in pixels. Describing the accuracy of dredging operations, the project manager told the NTSB that "it's not scalpel surgery under water," a sentiment repeated by a HYPACK representative.

Multiple sources of location data put the pipeline TX219 within feet or inches of the dredge template. The 2018 TMI Solutions utilities survey data (used by Schneider for the EPIC dock project drawings), put the location of the center of pipeline TX219 within 2 feet of the dredge template at the point of damage; the distance between the outside diameter of the pipe and the dredge template was 1.2 feet. The GPS margin of error alone (1 meter or 3.3 feet) could have put the cutterhead within striking distance of the pipeline without the leverman knowing that he was operating outside the template. If the GPS margin of error was exacerbated by other positional errors, the probability is even greater that the *Waymon Boyd*'s cutterhead could be operated outside the planned dredging area while still appearing to be within the DREDGEPACK template.

Figure 34 is an NTSB depiction of the dredge template, including the slope being dredged, along with the pipeline locations according to the 2018 TMI Solutions utility survey data. In this depiction, both the larger graphic and inset clearly identify the proximity of the dredge template at the top of the slope to pipeline TX219.

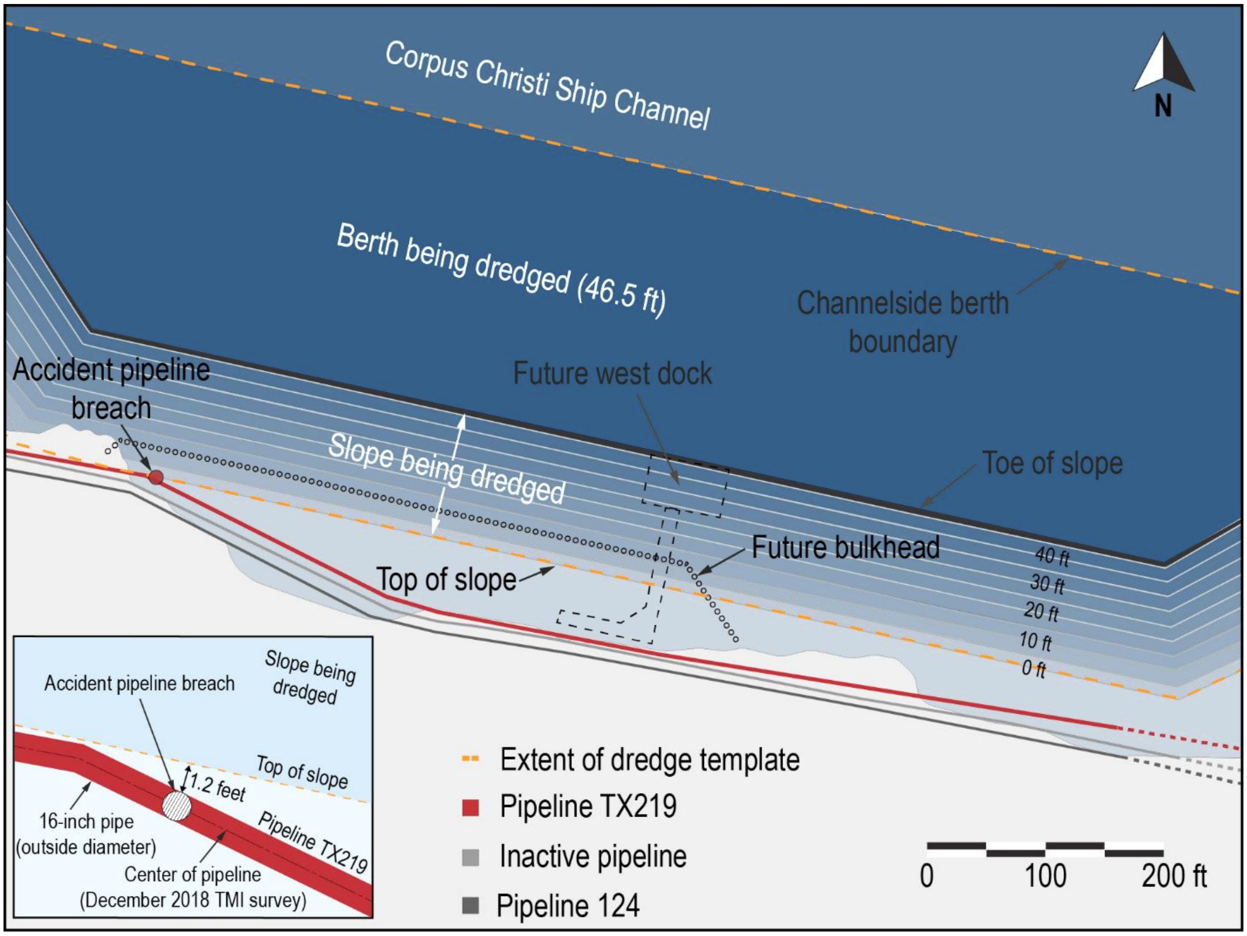

Figure 34. NTSB depiction showing comprehensive view of dredge template and pipeline locations.

As noted by both CDMCS and CAMO, dredging companies typically establish a 75-foot tolerance zone (within which additional protective provisions are needed before dredging) because of the lack of precision in controlling an underwater cutterhead. Thus, the proximity of the cutterhead to the pipeline that was at the edge of the dredge template presented a critical hazard.

Although pipeline TX219 was outside of the dredge template, its location (1.2 feet from the top of the slope on the template, according to the TMI survey data) was within the margin of error for the cutterhead. Thus, the NTSB concludes that given the GPS margin of error, potential inaccuracies in the dredging configuration information, and the resolution of the DREDGEPACK display, the dredging area specified in the Schneider Engineering and Consulting plans was too close to pipeline TX219 for safe excavation using a cutterhead dredge.

A dredge operator, such as a leverman on a cutterhead dredge, depends largely on visual cues provided by dredge control software such as DREDGEPACK;

thus, having accurate pipeline location data incorporated into the software on board the dredge is a critical tool for avoiding pipeline strikes and other potential hazards. The Orion project engineer did not provide available pipeline location information to the survey superintendent for inclusion in the DREDGEPACK dredge template for the EPIC dock project. Orion did not have any written procedures requiring that pipelines or other utilities be entered in DREDGEPACK software. Consequently, the leverman had nothing in DREDGEPACK, his principal source of dredging location information, to indicate the danger he faced on the morning of the accident. The NTSB concludes that Orion Marine Group did not have adequate procedures to require that pipelines be identified and included in DREDGEPACK; thus, the *Waymon Boyd*'s leverman was unaware how close he was operating the cutterhead to the pipeline. Section 2.4 of this report addresses Orion Marine Group's policies and procedures for planning dredging operations.

2.3 Dredging Project Planning and Risk Assessment

Orion had location data for pipeline TX219 from the TMI Solutions utility survey before dredging operations began. The Schneider design engineer recalled discussing the pipeline in weekly "design phase" meetings, where attendees included various stakeholders from Schneider, EPIC, and Orion Marine Group; the meetings did not include Enterprise. The EPIC facilities engineering manager, who attended these meetings, requested that the pipeline be shown on the engineering plans. Thus, there was clearly an awareness of the pipeline and concern that it could present a hazard. Knowing that the pipeline was near the dredging area, Orion and its design engineers should have taken measures before dredging started to address the risk of dredging near the pipelines, including consulting with Enterprise representatives, conducting a formal risk assessment, and implementing effective engineering controls; they did none of these.

The PHMSA-sponsored *Common Ground Study* as well as the CDMCS and CAMO guidance stress the importance of pre-excavation meetings and work site reviews early during the project planning process. Orion's engagement with Enterprise earlier in the planning of the EPIC dock project could have fostered greater awareness of the pipelines' proximity to the dredging area among all involved parties, starting with the design engineers and project managers. Orion and its design engineers could have sought feedback from Enterprise on the location of their planned dredging template with respect to the location of Enterprise's pipelines. Had Enterprise been invited to participate in preconstruction and kickoff meetings, they may have been more aware that the dredging area was unacceptably close to their pipelines and could have suggested safer alternatives. Based on the proximity of the pipeline, the project would have been considered an encroachment, requiring special provisions to protect the pipeline, such as using non-mechanized excavation methods, relocating the pipeline, or modifying the dredging plans to provide a more reasonable standoff distance.

A formal risk assessment, which involves identifying hazards and estimating the risk they pose, is a critical component of accident prevention. By considering likelihood against severity for each risk, risk matrices increase the visibility of risks and help managers select controls commensurate with the risk level. With such information, a hazard control plan can be developed and implemented. Yet, no formal risk assessment was conducted for the EPIC dock project. Had one been performed, the consequence of the cutterhead impacting pipeline TX219 would likely have been identified as high, given the catastrophic severity (because of the hazardous flammable liquid propane carried in the pipeline) and high likelihood of occurrence (because of the proximity of the dredge template and pipeline and lack of precision in controlling the cutterhead). Risks with high consequences and likelihood require strong controls to prevent accidents. According to the Occupational Safety and Health Administration, "Effective controls protect workers from workplace hazards; help avoid injuries, illnesses, and incidents; minimize or eliminate safety and health risks; and help employers provide workers with safe and healthful working conditions" (OSHA n.d.).

Because Orion did not complete a formal risk assessment for the EPIC dock project, the hazard presented by conducting dredging operations near pipeline TX219 was never formally identified or documented, and the risk was not completely understood. For example, several Orion employees were aware of the pipeline but provided varying estimates of how far it was from the boundary of the dredge template (see table 3).

Table 3. Perceptions of distance between the pipelines and dredging area.

Individual	Understanding of Distance between Dredge Template and Pipelines
Schneider design engineer	8-10 ft
Orion regional HSE manager	Not aware of pipeline TX219
Orion project manager	30 ft
Orion project engineer	60 ft
Waymon Boyd dredge captain	Instructed to remain 20 ft from pipelines
Waymon Boyd deck captain	Instructed to remain 20 ft from pipelines
Waymon Boyd accident leverman	Not aware of pipeline TX219
Majority of *Waymon Boyd* crew	Not aware of pipeline TX219
Enterprise one-call technicians	55 ft

Note: Actual distance between dredge template and accident location was about 1 foot, per the Enterprise 2016 ILI survey.

Although Orion's risk management processes included site-specific safety plans, the Orion regional HSE manager, who was responsible for developing the SSSP for the EPIC dock project, said that it was essentially an emergency response plan. He said he was unaware of pipeline TX219 altogether; therefore, the regional HSE manager did not list the pipeline as a hazard when he developed the SSSP. The SSSP did not discuss the pipelines or any other site-specific risks; thus, the SSSP did not help the captains, crew, or, most importantly, the leverman, manage the risk associated with dredging near the pipelines in the area.

Identifying, mitigating, and documenting risks in the SSSP and JHAs (which are also supposed to be part of Orion's risk management process) are critical steps for effective project risk management. Orion's own policy required the HSE department to participate in the development of a JHA during the "preplanning" phase of the project, which would have been an opportune time for them to become aware of the location of pipeline TX219. However, no such "preplanning" JHA was completed for the EPIC dock project.

The Orion HSE director asserted, "You can't mitigate for hazards until you're actually on the project identifying what the hazards are." As indicated by Orion's own policy, however, it is vital that the HSE department contribute to project risk management through their meaningful participation in the company's risk management processes and carefully evaluate all known risks *before* on-site work starts. Before dredging started, the regional HSE manager should have made an effort to identify project risks, such as those presented by pipeline TX219, and helped develop a hazard control plan.

Had a formal risk assessment been completed for the EPIC dock project, controls could have been put in place to mitigate the risk posed by dredging near pipeline TX219. For example, Orion could have established a tolerance zone around the pipelines in the engineering plans. Moreover, project safety could have been enhanced by inserting a physical barrier between the cutterhead and pipeline TX219, which could have been accomplished by deliberately sequencing the completion of a planned bulkhead before dredging. By first covering the pipeline with sand and building a bulkhead, the pipeline would been protected from a cutterhead strike. As this bulkhead was already planned for the project, it would not have required additional work beyond coordination between Orion's dredging and construction departments.

The NTSB concludes that Orion Marine Group's planning and risk management process was inadequate, which resulted in their failure to identify and mitigate the risk of a cutterhead impact with pipeline TX219. Including a risk matrix and hazard control plan in the risk assessment makes the overall risk assessment more robust by incorporating concrete project planning steps. Accordingly, the NTSB recommends that Orion Group Holdings require Orion Marine Group to, for all future dredging projects, conduct a formal, documented risk assessment with risk analysis, such as a risk matrix, before starting work, and based on the risk assessment, develop a hazard control plan.

2.4 Pipeline Damage Prevention

2.4.1 One-Call Process

Given Orion Marine Group's inadequate planning and risk management process, dredging safety and pipeline protection were solely dependent on the one-call system to identify the location of potential hazards, including pipeline TX219. The Orion Marine Group project engineer was responsible for initiating the one-call notification and coordinating with Enterprise and other utility operators to ensure safe dredging operations.

The Orion project engineer used the June 2020 Schneider engineering drawings when coordinating with Enterprise pipeline technicians to address the one-call tickets. The first drawing, "Existing Site Plan," included pipeline location data. This dredge plan also showed the boundary of the area that was to be dredged to a 46.5-foot depth for the berth but did not show the slope that would have to be dredged shoreside of this boundary to support the berth depth. Thus, the Existing Site Plan did not depict the full dredging area nor how close the pipelines would be to that area.

In the second Schneider drawing, "Dredge Site Plan," the pipeline location data were not included. Further, the 46.5-foot-deep berth area was shaded, and the drawing's legend labeled the shading as "dredge limits" (see figure 25). The drawing showed a partial depiction of the slope to be dredged, but the sloped area was not shaded. A table in the drawing, which provided the location of the corners of the berth, was labeled "dredge limit coordinates." Based on the Orion project engineer's email and verbal communications to the Enterprise technicians about the distance from the proposed dredging area to the pipeline (about 60 feet in her estimation), it is apparent that the Orion project engineer misinterpreted the full extent of the dredging work, likely due to the characterization of the boundary of the berth as the "dredge limits" in both the legend and coordinate table in the Schneider drawings. Her supervisor, the more-experienced project manager, also reviewed the drawings and did not expect that the excavation would be near the pipelines; he only raised concern about the placement of anchors during dredging operations.

The pipeline location information that appeared in the Existing Site Plan was not shown in the Dredge Site Plan nor was it shown in the cross-sectional drawings provided in the engineering plans. Thus, even if the Orion project engineer had properly interpreted the full extent of the dredging area, including the slope, she had no drawings that showed the proximity of the pipeline to the top of the slope. The project engineer told investigators that she had to estimate the distance by flipping back and forth between the Existing Site Plan and the Dredge Site Plan.

Had the Dredge Site Plan been drawn and labeled to clearly indicate the full extent of the dredging area and had pipeline location data been included in all the dredging plans, the proximity of pipeline TX219 to the dredge area would have been apparent to the project engineer.

The Orion project engineer's estimate that dredging operations would be 60 feet from shoreline and thus "far enough away" from the pipeline was inaccurate—the actual distance between the dredge template and the center of the pipeline at the accident location was about 1 foot. The project engineer provided the inaccurate distance information to the Enterprise technicians, who then cleared the one-call ticket based on this information.

Furthermore, the one-call notification and follow up communications and plans did not provide a complete description of all areas, including slopes, to be dredged outside of the berth. In an email to the Enterprise technician, the Orion project engineer stated, "[T]he areas where the shoreline and pipelines are furthest in the water (closest to the new template), we have already completed dredging to grade [dredging the slope] … so there shouldn't be a need for concern." The Enterprise technician stated that he "looked at the EPIC's plans and saw the prism where [the Orion project engineer] said that we're going to be working, and it was well offshore. And with the knowledge that EPIC wanted to put in a bulkhead and cover our lines with sand, we knew we were okay with clearing that ticket." Thus, in addition to unclear engineering drawings, communications from the Orion project engineer left Enterprise technicians under the impression that the dredging work would be 60 feet from the shoreline, that dredging of the slope was already completed, and that a bulkhead covering the pipelines would be in place before the dredging began, contributing to Enterprise's misunderstanding of the situation.

Because Orion provided the incorrect distance between the dredging area and the pipelines and the Enterprise technician closed out the ticket as clear of the pipelines with no marking required, the one-call system did not identify that the TX219 pipeline was within the zones established by the Enterprise damage prevention program that would have required pipeline locating, marking, and the presence of technicians on site to watch and protect the pipelines during dredging activity. Not only was the proposed dredge template located inside of the 50-foot zone where formal pipeline marking is required, the dredge template was inside a 12-foot zone from the pipeline that required Enterprise's on-site monitoring of the encroachment. At a minimum, Enterprise pipeline technicians would have more visibly marked the pipeline at 20-foot intervals (in contrast to the courtesy marking performed by Enterprise with cane poles about 50 feet apart) and would have watched and protected the pipelines while dredging occurred near the accident location (see section 2.4.2 for more information about pipeline and dredging area marking).

The NTSB concludes that the Schneider Engineering and Consulting plans provided to Orion Marine Group for the EPIC dock project were deficient because they did not clearly depict the extent of the dredging area or the pipeline location in all drawings, which resulted in the Orion Marine Group project engineer misinterpreting the information, overestimating the distance between the dredging area and pipeline TX219, and communicating incomplete and inaccurate information during the one-call process, which dissuaded Enterprise from protecting pipeline TX219 in accordance with the company's damage prevention program.

Large marine-based projects pose different safety and damage prevention challenges than land-based excavation. For example, the CAMO best practices guide suggests that marking pipelines in marine areas is very challenging because markers can be accidently moved or removed by weather events, wave action, vessels, and erosion. Because of these challenges, CAMO suggests that dredging and pipeline companies should communicate and work closely during all phases of the project to ensure sufficient damage prevention provisions are in place.

To underscore the cursory nature of the review provided by one-call processes (compared to detailed project reviews and excavation protocol agreements required by TAC 18.9, detailed in section 1.10.1.2), most state laws (including those in Texas) allow only 48 hours for a pipeline operator to provide a positive response to an excavator's notice, to include time for reviewing project plans and determining if circumstances warrant locating and marking a pipeline. Within this short period of time, line-locating technicians are expected to rely on information provided by the excavator to evaluate third-party damage potential and implement appropriate protective measures. The pipeline technicians who reviewed the EPIC dock project plans were not trained to review dredging plans and were more familiar with land-based pipeline locating and marking activities. Thus, marine construction plans, such as the Schneider plans for the EPIC dock project that were not explicit as to where dredging would occur near the shoreline, require supplemental engineering review and oversight before an accurate determination of potential pipeline impacts can be made. A higher-level engineering review by the pipeline operator could ensure that appropriate damage avoidance procedures are implemented.

Therefore, the NTSB concludes that marine dredging projects require a greater level of collaboration and review between pipeline operators and dredging companies than the one-call process provides because of the challenges associated with marking marine pipelines and the lack of precision associated with dredging operations. The *Common Ground Study*, CAMO, and CDMCS guidance already stress the need for pre-project planning, appropriate timelines, and detailed plan reviews for projects occurring within marine environments. The deficiencies associated with Orion's pre-project planning, including the lack of coordination with Enterprise, are further addressed in section 2.4.4.

Subject to appropriate confidentiality agreements, accurate utility locations could have been added to the DREDGEPACK software as an additional damage prevention measure. If such utility information had been available on board the *Waymon Boyd*, the dredge crew could have identified the pipeline near the planned dredge area before the cutterhead struck the pipeline. Therefore, the NTSB concludes that third-party damage prevention efforts would be improved if dredging companies obtained accurate location data from pipeline operators for pipelines within and near dredging project boundaries to incorporate into dredge control software files. Therefore, the NTSB recommends that PHMSA, in collaboration with CAMO and CDMCS, develop recommended practices and processes for pipeline operators and dredging companies to obtain and use accurate pipeline location data during planning and one-call locating activities for pipelines both in and near project locations. Further, the NTSB recommends that CAMO and CDMCS work with PHMSA to develop recommended practices and processes for pipeline operators and dredging companies to obtain and use accurate pipeline coordinates during planning and one-call locating activities for pipelines both in and near project locations.

2.4.2 Pipeline and Dredging Area Marking

Proper line locating and marking by the pipeline operator following a one-call notification are necessary to ensure that an excavation will be sufficiently clear of buried pipelines. Because Enterprise relied on incorrect and incomplete information about the location of proposed dredging activity provided by Orion in the one-call notification, Enterprise did not mark the pipeline in conformance with APWA guidelines or Enterprise standards for compulsory marking.

Two weeks after Enterprise closed out the one-call tickets, Orion requested that Enterprise mark the pipeline with cane poles to assist their crews in avoiding the placement of swing anchors too close to the pipeline. Enterprise pipeline technicians courtesy-marked the pipeline with unflagged cane poles because of their understanding that Orion's dredging work would be clear of the pipelines by 60 feet, greater than the 50-foot zone where formal pipeline marking is required by the Enterprise damage prevention program. According to the leverman, he was not told that the purpose of the cane poles was to mark the pipeline. However, even if he had been informed of the purpose of the cane poles, it is unlikely that it would have changed the outcome of the accident. The leverman told investigators that there were no cane poles in the area where he was dredging and that all the markers were "behind the dredge" to the east. Statements about the spacing and location of the cane poles by Orion, Enterprise, and EPIC personnel support the leverman's observation. The leverman stated that he could see one pipeline in the water, but the NTSB noted that the most visible pipeline was the unused pipeline that was farther outside the dredging area than pipeline TX219. The NTSB concludes that although Enterprise courtesy-marked the pipelines with cane poles, the markers did not meet pipeline excavation damage protection standards, nor were they required to, based on the incorrect information provided by Orion, and therefore were insufficient to visually warn the leverman of the danger of the pipeline.

In a 1997 safety study, the NTSB concluded that pre-marking an intended excavation site to specifically indicate the area where underground facilities need to be identified is a practice that helps prevent excavation damage (NTSB 1997). Thus, a technique known as white-lining could have been used on this project as an added measure of communicating the precise location of proposed excavation/dredging activity to pipeline technicians in advance of their one-call review. The practice, which involves placement of white paint or flags to delineate the boundary of proposed excavation areas, helps prevent excavation damage to pipelines by providing visual notice to the pipeline company of the excavator's intent, thereby reducing the potential for errors, and removing ambiguity about what underground facilities need to be located.

Although most states, including Texas, have requirements for white-lining, the practice is generally limited to on-land excavation activities. In shallow water, such as where cane poles were used to courtesy-mark the pipeline, Orion could have delineated the boundary of the dredge template with poles or stakes before making the one-call, which could have had the added benefit of communicating potential hazards of the dredging plan to other involved personnel. In the case of deeper water that is not conducive to marking, the dredging company could provide the pipeline operator geographic coordinates of proposed dredging boundaries in addition to project plans.

The one-call tickets for the EPIC dock project acknowledged that the dredging boundaries were not white lined. TAC states the following:

> When an excavation site cannot be clearly identified and described on a line locate ticket, the excavator shall use white-lining to mark the excavation area prior to giving notice to the notification center and before the locator arrives on the excavation site.

TAC specifies the use of white paint, flags, or stakes for marking an excavation area. However, for dredging projects where stakes or flags are not always practical due to deep water, providing the geographic coordinates of the planned excavation area to the utility is equivalent to the physical placement of stakes.

TAC also stipulates that when a project is too large to mark using white-lining or is so expansive that a full description cannot be provided on a line-locate ticket, then the operator and the excavator shall conduct a face-to-face meeting to discuss the excavation activities and to establish excavation protocols. Given the complexity of this project, scheduling a face-to-face meeting was prudent. However, due to suspected personnel COVID-19 exposures, Orion and Enterprise did not conduct the on-site review of the project plans.

However, when the Orion project engineer and Enterprise technicians met on site 2 weeks later to courtesy-mark the pipelines for anchor avoidance, the presence of white-line markers inside of the Enterprise 50-foot and 12-foot protective zones could have prompted a new one-call review. Instead, the project engineer reiterated erroneous verbal information that dredging would be conducted away from the pipelines. The NTSB concludes that project boundary marking requirements for dredging projects (equivalent to land-based white-lining requirements) would provide utility operators with additional visual information about the location of dredging projects to confirm any encroachment of the proposed project on pipelines. Therefore, the NTSB recommends that PHMSA, in collaboration with CAMO and CDMCS, develop guidance for excavators to clearly identify proposed dredging boundaries for dredging projects before notifying one-call centers by either physically marking the boundaries where practicable, or identifying the boundary with accurate location data. The NTSB further recommends that CAMO and CDMCS work with PHMSA to develop guidance for excavators to clearly identify proposed dredging boundaries for dredging projects before notifying one-call centers by either physically marking the boundaries where practicable or identifying the boundary with accurate location data.

2.4.3 Tolerance Zones

Although the Enterprise encroachment guidelines publication provides general procedures to be followed when planning construction activities near a pipeline, it does not provide specific guidance applicable to dredging projects over or near underwater pipelines. The publication's general excavation guidance identifies a tolerance zone of 18 inches from the outside edge of the pipeline, inside of which mechanized equipment is not allowed. The Enterprise tolerance zone guidelines were consistent with protocols provided by TAC 18.9, "Options for Managing an Excavation Site in the Vicinity of an Underground Pipeline."

According to CDMCS and CAMO, some pipeline operators may request a clearance of up to 500 feet on each side of a pipeline for dredging but, depending on the magnitude and scope of work, may agree to closer distances. The Enterprise damage prevention program would not have required Enterprise technicians to monitor mechanized excavations outside of a 12-foot distance from their pipelines. Given the lack of precision and potential for location errors when operating a rotating cutterhead (as described in section 2.2), it is unlikely 12 feet is safe clearance distance for operating a rotating cutterhead near a pipeline without special excavation conditions and close pipeline company surveillance.

Pipeline Incident Prevention, the best practices guide for dredging near pipelines issued by CDMCS in January 2020, explained that statutory tolerance zones around pipelines, ranging between 18 and 30 inches, were intended for land-based excavation and not suited for marine applications like dredging.

Orion Marine Group was a member of CDMCS, but did not follow the guidance issued by the organization. Orion's HSE director stated that the company used its own internal procedures that were similar to the CDMCS guidance. However, Orion did not have written procedures for planning dredging operations near pipelines. The contract proposal for the EPIC dock project stated that no dredging would be done "within ten (10) feet of any structure."

Federal damage prevention requirements of 49 *CFR* Part 196 are silent with respect to tolerance zones in any circumstance, including dredging. However, tolerance zone distances are specified by most state damage prevention laws. The Texas tolerance zone requirement is consistent with most other state damage prevention laws, which establish tolerance zones of 18–30 inches (Hartman 2017).[38] These state damage prevention requirements do not address dredging and marine construction scenarios.

Title 49 *CFR* Part 198, Subpart D specifies how PHMSA provides oversight for state damage prevention enforcement programs. In evaluating a state's program, PHMSA considers several factors about the state's authority to enforce its damage prevention laws and whether these laws provide for one-call notification systems, marking of pipeline facilities, and reporting damage. If PHMSA determines a state's damage prevention enforcement program is inadequate, it can take action that may result in lost grant funding. Otherwise, PHMSA does not stipulate the content of state damage prevention programs as they apply to establishment or enforcement of tolerance zones.

Thus far, PHMSA's approach to addressing pipeline safety concerns in marine environments has largely been focused on its participation and funding of voluntary best practices organization efforts (PHMSA n.d.). This reliance on industry best practices assumes that dredging operators and pipeline companies will police themselves and follow appropriate internal safety policies designed to prevent accidents.

While the State of Texas-mandated 18-inch tolerance zone is probably adequate for the digging precision obtainable by the operator of a small backhoe, it

[38] In all, 39 states have established special digging requirements within the tolerance zone. Hawaii and Michigan have implemented larger tolerance zones of 30 inches and 48 inches, respectively.

is insufficient for marine dredging situations. For example, the 18-inch tolerance zone does not account for the achievable accuracy of a 6.5-foot-diameter rotating cutterhead controlled by a leverman seated on the top deck of a dredge over 100 feet away from the dredging location. Consequently, CDMCS and CAMO both maintain that such tolerance zones are intended for on-land application and are too small for marine activities. Thus, the NTSB concludes that the clearance required by existing state-regulated tolerance zones is not adequate for large-scale dredging activities because of the inherent inaccuracies associated with operating a cutterhead dredge. Yet, there is no consistent guidance or rule that specifies what constitutes a safe tolerance zone, or clearance distance, when dredging near a pipeline. The NTSB believes that dredging safety would be improved if guidelines identified consistent dredging tolerance zones, within which special provisions and procedures are enacted for pipeline avoidance. The PHMSA annual state pipeline safety program evaluation includes an examination of state agency policies, plans, procedures, and records but does not include factors specific to tolerance zones or safety zones, including dredging operations. Therefore, to ensure that state regulations provide for adequate protections against mechanical dredging near pipelines, the NTSB recommends that PHMSA include criteria for minimum tolerance or safety zones for dredging in state pipeline safety program evaluation guidelines.

Furthermore, the NTSB concludes that the Enterprise damage prevention program did not provide for an adequate tolerance zone for dredging projects. Therefore, the NTSB recommends Enterprise Products revise its damage prevention program guidelines to include a larger tolerance zone for dredging operations.

2.4.4 Guidance for Dredging

Orion Marine Group did not have written policies or procedures for planning dredging operations near pipelines. Written policies and procedures could have enabled the company and its personnel to establish effective pipeline damage prevention measures and share them among key employees involved in the EPIC dock project. The NTSB concludes that written policies and procedures could have eliminated confusion about the pipeline TX219 location and minimum tolerance distances for pipeline damage prevention. Therefore, the NTSB recommends that Orion Group Holdings require Orion Marine Group to develop standardized, written policies and procedures for planning dredging operations near pipelines that include pipeline operator engagement on pipeline avoidance measures, minimum tolerance zones, minimum requirements for marking and verifying pipelines, and uploading of pipeline information into DREDGEPACK or other navigation software.

As described in section 2.4.1, the drawings for the EPIC dock project that were produced by Schneider Engineering and Consulting (which was a subsidiary of Orion Group Holdings) did not clearly depict the location of pipeline TX219 in relation to the dredging area. The pipeline location information from the 2018 TMI Solutions survey could have been imported into all of the engineering drawings, which would have assisted the Orion project engineer in recognizing the danger posed by the pipeline. Inclusion of tolerance zones for dredging would have further assisted the project engineer and the Enterprise pipeline technicians in identifying the hazard. Therefore, the NTSB concludes that because Schneider Engineering and Consulting did not have company specifications, quality control measures, or best practices for including pipeline hazards and tolerance zones in their engineering plans and drawings, the engineering plans and drawings did not clearly reflect the proximity of the pipeline to the full dredging area. The NTSB recommends that Orion Group Holdings require Schneider Engineering and Consulting to develop specifications and quality control measures to ensure pipeline and other hazard data is included and clearly represented in engineering plans and drawings, to include depicting tolerance distances from underwater pipelines.

2.5 Pipeline Hazard Training

The *Waymon Boyd* was configured to allow the crew to quickly stop operations and shut down ignition sources such as the diesel generator exhaust manifolds, the electrical ventilation fans, or other electrical components. From the lever room, the leverman could shut down winch motors and other equipment. In the engine room, the control console had an "emergency voltage disconnect" switch, which allowed the engineer to cut off all electrical loads from either the main or standby generator. The generators could also be shut down from the control station or via emergency fuel cutoffs.

Although 8 months before the accident CDMCS had published recommended actions for a dredge crew in the event of an emergency involving a pipeline breach, Orion Marine Group did not have an emergency procedure or crew training for a pipeline breach. When pipeline TX219 was breached, the leverman stopped the cutterhead but did not secure other motors or order the engineer to shut down all power systems. Instead, the leverman increased power to the anchor winch and attempted to swing the dredge away from the geyser of water spraying up in front of him. These actions did not reduce the number of ignition sources or provide additional time for the crew to evacuate.

With only 1 minute 6 seconds between the pipeline breach and the explosion, the crew may not have had sufficient time to recognize that a propane pipeline had ruptured and attempt to eliminate sources of ignition. Drifting away from the area in any reasonable time was not an option for a barge anchored on spuds and tethered by cable to swing anchors. Regardless, a trained crew would have shut down ignition sources upon recognizing a gas pipeline strike. The dredge captain told the NTSB he did not actuate an electrical kill-switch to cut off the dredge's power because he believed the geyser was merely water. Instead of taking actions to secure the dredge, the dredge captain was in the process of reporting a water leak to EPIC when the explosion occurred. Had the leverman called the engineer as soon as he realized a pipeline had been struck and directed him to shut down all mechanical and electrical systems, the ventilation fans drawing the propane gas into the engine room would have stopped, and the number of ignition sources would have been significantly reduced. Had there been procedures and training in place, the crew would have had specific guidelines to follow. Therefore, the NTSB concludes that the dredge crew lacked function-specific pipeline safety training and emergency procedures that could have prepared them to react quicker and more effectively to the gas pipeline strike.

After the accident, Orion addressed this issue by instituting semiannual utilities awareness training, which includes emergency procedures in the event of an accident. The training is provided to all employees operating dredges or supporting dredge operations. A training aid for utilities awareness and emergency procedures has been posted in several locations throughout the company's dredges. Additionally, emergency procedures in the event of a pipeline strike have been integrated into periodic fire and abandon ship drills conducted on Orion dredges.

In addition to Orion, the entire dredging industry would benefit from training on utilities awareness and emergency procedures in the event of a pipeline strike. The circumstances of this accident also provide several lessons learned, for both dredging and pipeline companies, in the planning and safe execution of dredging operations near pipelines. In July 2020, CAMO released "Working Safely Near Underwater Pipelines," interactive online pipeline safety training that covers such topics as how working safely near underwater pipelines and utilities differs from land-based excavation; how to communicate the location of pipelines in one-call notifications; pre-project research and planning steps for pipeline and marine construction personnel; project design implementation and pipeline avoidance; and daily safety and emergency checklists (CAMO 2020). This training could be further enhanced with examples and lessons learned from the *Waymon Boyd* pipeline strike and explosion. Accordingly, the NTSB recommends that CAMO modify the existing "Working Safely Near Underwater" Pipelines online pipeline safety training to incorporate lessons learned from this accident.

3. Conclusions

3.1 Findings

1. None of the following were safety issues for the accident: (1) experience and qualifications of the vessel and pipeline personnel; (2) fatigue; (3) distraction from cell phone use; (4) vessel mechanical and electrical systems failures; (5) environmental conditions; (6) leak detection systems on pipeline TX219; (7) pipeline operating history and operating pressure; (8) pipeline integrity; (9) transport of non-odorized propane in the pipeline; or (10) pipeline depth of cover.

2. Enterprise's pipeline TX219 was struck by the dredge *Waymon Boyd*'s rotating cutterhead, causing a breach in the line that allowed propane to escape and form a gas cloud that surrounded the dredge.

3. Propane gas that had released from pipeline TX219 was drawn into the *Waymon Boyd*'s engine room by the ventilation fans and was ignited, causing the explosion.

4. The Enterprise pipeline controller's and pipeline technicians' actions to secure the pipeline were appropriate and facilitated a timely shutdown.

5. Given the GPS margin of error, potential inaccuracies in the dredging configuration information, and the resolution of the DREDGEPACK display, the dredging area specified in the Schneider Engineering and Consulting plans was too close to pipeline TX219 for safe excavation using a cutterhead dredge.

6. Orion Marine Group did not have adequate procedures to require that pipelines be identified and included in DREDGEPACK; thus, the *Waymon Boyd*'s leverman was unaware how close he was operating the cutterhead to the pipeline.

7. Orion Marine Group's planning and risk management process was inadequate, which resulted in their failure to identify and mitigate the risk of a cutterhead impact with pipeline TX219.

8. The Schneider Engineering and Consulting plans provided to Orion Marine Group for the EPIC dock project were deficient because they did not clearly depict the extent of the dredging area or the pipeline location in all drawings, which resulted in the Orion Marine Group project engineer misinterpreting the information, overestimating the distance between the dredging area and pipeline TX219, and communicating incomplete and

inaccurate information during the one-call process, which dissuaded Enterprise from protecting pipeline TX219 in accordance with the company's damage prevention program.

9. Marine dredging projects require a greater level of collaboration and review between pipeline operators and dredging companies than the one-call process provides because of the challenges associated with marking marine pipelines and the lack of precision associated with dredging operations.

10. Third-party damage prevention efforts would be improved if dredging companies obtained accurate location data from pipeline operators for pipelines within and near dredging project boundaries to incorporate into dredge control software files.

11. Although Enterprise courtesy-marked the pipelines with cane poles, the markers did not meet pipeline excavation damage protection standards, nor were they required to, based on the incorrect information provided by Orion, and therefore were insufficient to visually warn the leverman of the danger of the pipeline.

12. Project boundary marking requirements for dredging projects (equivalent to land-based white-lining requirements) would provide utility operators with additional visual information about the location of dredging projects to confirm any encroachment of the proposed project on pipelines.

13. The clearance required by existing state-regulated tolerance zones is not adequate for large-scale dredging activities because of the inherent inaccuracies associated with operating a cutterhead dredge.

14. The Enterprise damage prevention program did not provide for an adequate tolerance zone for dredging projects.

15. Written policies and procedures could have eliminated confusion about the pipeline TX219 location and minimum tolerance distances for pipeline damage prevention.

16. Because Schneider Engineering and Consulting did not have company specifications, quality control measures, or best practices for including pipeline hazards and tolerance zones in their engineering plans and drawings, the engineering plans and drawings did not clearly reflect the proximity of the pipeline to the full dredging area.

17. The dredge crew lacked function-specific pipeline safety training and emergency procedures that could have prepared them to react quicker and more effectively to the gas pipeline strike.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the hazardous liquid pipeline breach, propane release, and subsequent explosion and fire aboard the dredging vessel *Waymon Boyd* was Orion Marine Group's inadequate planning and risk management processes, which failed to identify the proximity of their dredging operation to Enterprise Products' pipeline TX219 and resulted in the absence of effective controls to prevent the dredge's cutterhead from striking the pipeline. Contributing to the accident were deficient dredging plans provided by Schneider Engineering and Consulting, which resulted in incomplete and inaccurate information communicated to Enterprise Products by Orion Marine Group during the one-call process, which resulted in insufficient measures to protect the pipeline from excavation damage.

4. Recommendations

4.1 New Recommendations

As a result of this investigation, the National Transportation Safety Board makes the following new safety recommendations.

To Pipeline and Hazardous Materials Safety Administration:

In collaboration with Coastal and Marine Operators and the Council for Dredging and Marine Construction Safety, develop recommended practices and processes for pipeline operators and dredging companies to obtain and use accurate pipeline location data during planning and one-call locating activities for pipelines both in and near project locations. (P-21-018)

In collaboration with Coastal and Marine Operators and the Council for Dredging and Marine Construction Safety, develop guidance for excavators to clearly identify proposed dredging boundaries for dredging projects before notifying one-call centers by either physically marking the boundaries where practicable, or identifying the boundary with accurate location data. (P-21-019)

Include criteria for minimum tolerance or safety zones for dredging in state pipeline safety program evaluation guidelines. (P-21-020)

To Coastal and Marine Operators:

Modify the existing "Working Safely Near Underwater Pipelines" online pipeline safety training to incorporate lessons learned from this accident. (M-21-022)

To Coastal and Marine Operators and the Council for Dredging and Marine Construction Safety:

Work with the Pipeline and Hazardous Materials Safety Administration to develop recommended practices and processes for pipeline operators and dredging companies to obtain and use accurate pipeline coordinates during planning and one-call locating activities for pipelines both in and near project locations. (M-21-023)

Work with the Pipeline and Hazardous Materials Safety Administration to develop guidance for excavators to clearly identify proposed dredging boundaries for dredging projects before notifying one-call centers by either physically marking the boundaries where practicable or identifying the boundary with accurate location data. (M-21-024)

To Orion Group Holdings:

Require Orion Marine Group to, for all future dredging projects, conduct a formal, documented risk assessment with risk analysis, such as a risk matrix, before starting work, and based on the risk assessment, develop a hazard control plan. (M-21-025)

Require Orion Marine Group to develop standardized, written policies and procedures for planning dredging operations near pipelines that include pipeline operator engagement on pipeline avoidance measures, minimum tolerance zones, minimum requirements for marking and verifying pipelines, and uploading of pipeline information into DREDGEPACK or other navigation software. (M-21-026)

Require Schneider Engineering and Consulting to develop specifications and quality control measures to ensure pipeline and other hazard data is included and clearly represented in engineering plans and drawings, to include depicting tolerance distances from underwater pipelines. (M-21-027)

To Enterprise Products:

Revise your damage prevention program guidelines to include a larger tolerance zone for dredging operations. (P-21-021)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JENNIFER HOMENDY
Chair

MICHAEL GRAHAM
Member

BRUCE LANDSBERG
Vice Chairman

THOMAS CHAPMAN
Member

Report Date: December 7, 2021

Appendixes

Appendix A: Investigation

The NTSB was the lead federal agency in this investigation. The NTSB was notified of this accident on August 21, 2020, and the investigative team did not launch due to elevated COVID-19 cases in Corpus Christi, Texas.

Investigative groups were formed for Nautical Operations and Pipeline Operations. Also, specialists were assigned for System Safety and Human Performance and Research and Engineering Materials Lab.

Orion Group Holdings Inc.; Enterprise Products; Coast Guard Sector Corpus Christi; Pipeline and Hazardous Materials Safety Administration; the Railroad Commission of Texas; and HYPACK, a Xylem brand, were parties to the investigation.

Appendix B: Consolidated Recommendation Information

Title 49 *United States Code* 1117(b) requires the following information on the recommendations in this report.

For each recommendation–

(1) a brief summary of the Board's collection and analysis of the specific accident investigation information most relevant to the recommendation;

(2) a description of the Board's use of external information, including studies, reports, and experts, other than the findings of a specific accident investigation, if any were used to inform or support the recommendation, including a brief summary of the specific safety benefits and other effects identified by each study, report, or expert; and

(3) a brief summary of any examples of actions taken by regulated entities before the publication of the safety recommendation, to the extent such actions are known to the Board, that were consistent with the recommendation.

To Pipeline and Hazardous Materials Safety Administration:

P-21-018

In collaboration with Coastal and Marine Operators and the Council for Dredging and Marine Safety, develop recommended practices and processes for pipeline operators and dredging companies to obtain and use accurate pipeline location data during planning and one-call locating activities for pipelines both in and near project locations.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.1, One-Call Process. Information supporting (b)(1) can be found on pages 88-89; (b)(2) can be found on page 90; and (b)(3) is not applicable.

P-21-019

In collaboration with Coastal and Marine Operators and the Council for Dredging and Marine Safety, develop guidance for excavators to clearly identify proposed dredging boundaries for dredging projects before notifying one-call centers by either physically marking the boundaries where practicable, or identifying the boundary with accurate location data.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.2, Pipeline and Dredging Area Marking. Information supporting (b)(1) can be found on pages 91-93; (b)(2) can be found on page 92; and (b)(3) is not applicable.

P-21-020

Include criteria for minimum tolerance or safety zones for dredging in state pipeline safety program evaluation guidelines.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.3, Tolerance Zones. Information supporting (b)(1) can be found on pages 93-95; (b)(2) can be found on pages 93-95; and (b)(3) is not applicable.

To Coastal and Marine Operators:

M-21-022

Modify the existing "Working Safely Near Underwater Pipelines" online pipeline safety training to incorporate lessons learned from this accident.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.5, Pipeline Hazard Training. Information supporting (b)(1) can be found on pages 96-97; (b)(2) can be found on pages 96-97; and (b)(3) can be found on page 99.

To Coastal and Marine Operators and the Council for Dredging and Marine Construction Safety:

M-21-023

Work with the Pipeline and Hazardous Materials Safety Administration to develop recommended practices and processes for pipeline operators and dredging companies to obtain and use accurate pipeline coordinates during planning and one-call locating activities for pipelines both in and near project locations.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.1, One-Call Process. Information supporting (b)(1) can be found on page 88-89; (b)(2) can be found on page 90; and (b)(3) is not applicable.

M-21-024

Work with the Pipeline and Hazardous Materials Safety Administration to develop guidance to clearly identify proposed dredging boundaries for dredging projects before notifying one-call centers by either physically marking the boundaries where practicable or identifying the boundary with accurate location data.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.2 Pipeline and Dredging Area Marking. Information supporting (b)(1) can be found on pages 91-93; (b)(2) can be found on page 92; and (b)(3) is not applicable.

To Orion Group Holdings:

M-21-025

Require Orion Marine Group to, for all future dredging projects, conduct a formal, documented risk assessment with risk analysis, such as a risk matrix, before starting work, and based on the risk assessment, develop a hazard control plan.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3, Dredging Project Planning and Risk Assessment. Information supporting (b)(1) can be found on pages 84-87; (b)(2) can be found on pages 84-86; and (b)(3) is not applicable.

M-21-026

Require Orion Marine Group to develop standardized, written policies and procedures for planning dredging operations near pipelines, that include pipeline operator engagement on pipeline avoidance measures, minimum tolerance zones, minimum requirements for marking and verifying pipelines, and uploading of pipeline information into DREDGEPACK or other navigation software.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.4 Guidance for Dredging. Information supporting (b)(1) can be found on page 95; (b)(2) is not applicable; and (b)(3) is not applicable.

M-21-027

Require Schneider Engineering and Consulting to develop specifications and quality control measures to ensure pipeline and other hazard data is included and clearly represented in engineering plans and drawings, to include depicting tolerance distances from underwater pipelines.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.4 Guidance for Dredging. Information supporting (b)(1) can be found on page 96; (b)(2) is not applicable; and (b)(3) is not applicable.

To Enterprise Products:

P-21-021

Revise your damage prevention program guidelines to include a larger tolerance zone for dredging operations.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.3, Tolerance Zones. Information supporting (b)(1) can be found on pages 93-95; (b)(2) can be found on pages 93-95; and (b)(3) is not applicable.

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Accident type	Fire/Explosion
Location	EPIC Marine Terminal, Corpus Christi Ship Channel, Corpus Christi, Texas 27° 48.97′ N, 97° 28.13′ W
Date	August 21, 2020
Time	0802 central daylight time (coordinated universal time –5 hrs)
Persons on board	18 (including assist boats)
Injuries	6 (injured); 4 (fatal)
Property damage	$11.69 million
Environmental damage	6,024 barrels of propane released from the pipeline
Weather	Clear visibility and skies, winds southwest 9 kts, air temperature 83°F, water temperature 88°F
Waterway information	Channel, depth 47 ft, length 9 mi

NTSB investigators worked closely with our counterparts from **Coast Guard Sector Corpus Christi** throughout this investigation.

The National Transportation Safety Board (NTSB) is an independent federal agency dedicated to promoting aviation, railroad, highway, marine, and pipeline safety. Established in 1967, the agency is mandated by Congress through the Independent Safety Board Act of 1974, to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The NTSB makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

The NTSB does not assign fault or blame for an accident or incident; rather, as specified by NTSB regulation, "accident/incident investigations are fact-finding proceedings with no formal issues and no adverse parties … and are not conducted for the purpose of determining the rights or liabilities of any person" (Title 49 *Code of Federal Regulations* section 831.4). Assignment of fault or legal liability is not relevant to the NTSB's statutory mission to improve transportation safety by investigating accidents and incidents and issuing safety recommendations. In addition, statutory language prohibits the admission into evidence or use of any part of an NTSB report related to an accident in a civil action for damages resulting from a matter mentioned in the report (Title 49 *United States Code* section 1154(b)).

For more detailed background information on this report, visit the NTSB investigations website and search for NTSB accident ID DCA20FM026. 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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