Abstract No. 687018
2020 INTERNATIONAL OIL SPILL CONFERENCE

NOAA Scientific Support for a Natural Gas Pipeline Release During Hurricane Harvey Flooding along the Neches River near Beaumont, Texas

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ABSTRACT:

During the height of historic flooding from Hurricane Harvey's rainfall, a rupture occurred in a 16-inch, 80 psia (65 psig) natural gas pipeline crossing the Neches River east of Beaumont, Texas. Over the preceding five days, Hurricane Harvey stalled over the area, generating rainfall totals between 35 and 60 inches. The storm broke the record for rainfall totals in the U.S., with 60.58 inches reported in Nederland, Texas and 60.54 inches near Groves, Texas. The Neches River was in extreme flood conditions, cresting the day after the pipeline rupture at a historic high of 19.59 feet (nearly 10 feet above major flood stage and nearly 7 feet above the former historic record from 1994). At the request of the U.S. Coast Guard Marine Safety Unit (MSU) Port Arthur, NOAA's Emergency Response Division provided scientific support for the incident including on-scene support from the NOAA Scientific Support Coordinator (pre-deployed in Port Arthur, Texas for disaster response) as well as technical assistance from the NOAA Scientific Support Team in Seattle and Baton Rouge. Products and support provided by NOAA included air hazard modeling using ALOHA (Areal Locations of Hazardous Atmospheres) as well as the overall hazards assessment. ALOHA modeling indicated that several significant ignition sources were located within the specific threat zone identified. However, no ignition occurred and no injury or further damage resulted from the release. This incident highlights the advantages and limitations of using

ALOHA to model a subsurface natural gas release from a large underwater pipeline provided in the context of an ongoing response to historic flooding and high intensity search and rescue and emergency port operations resulting from a natural disaster.

BACKGROUND:

Harvey started as a typical weak August tropical storm that affected the Lesser Antilles and dissipated over the central Caribbean Sea. However, after re-forming over the Bay of Campeche, Harvey rapidly intensified into a category 4 hurricane (on the Saffir-Simpson Hurricane Wind Scale) before making landfall along the middle Texas coast. The storm then stalled, with its center over or near the Texas coast for four days, dropping historic amounts of rainfall of more than 60 inches over southeastern Texas. Only around 10 percent of the river forecast points in southeast Texas remained below flood stage due to the event, and approximately 46 percent of the river forecast points reached new record levels. Harvey maintained tropical storm intensity the entire time while inland over the Texas coastal bend and southeast Texas. After moving offshore, Harvey made a third landfall just west of Cameron, Louisiana on the morning of the 30th and brought more heavy rainfall to the Northern Gulf States. These rains caused catastrophic flooding, and Harvey is the second-most costly hurricane in U.S. history, after accounting for inflation, behind only Katrina (2005). At least 68 people died from the direct effects of the storm in Texas, the largest number of direct deaths from a tropical cyclone in that state since 1919.

Rainfall and Flooding:

Harvey was the most significant tropical cyclone rainfall event in United States history, both in scope and peak rainfall amounts, since reliable rainfall records began around the 1880s.

The highest storm total rainfall report from Harvey was 60.58 inches near Nederland, Texas, with another report of 60.54 inches from near Groves, Texas. Both of these values (and from five other stations) exceed the previously accepted United States tropical cyclone storm total rainfall record of 52.00 inches in August of 1950 from Hurricane Hiki in Hawaii. For the continental United States, the previous tropical cyclone rainfall record was 48.00 inches in Medina, Texas from Tropical Storm Amelia in 1978. It is remarkable that during Harvey, eighteen values over 48 inches were recorded across southeastern Texas, with 36 to 48 inches recorded in the Houston metro area. These rains caused catastrophic flooding in Harris and Galveston counties, with 9 out of the 19 official river gauges in Harris County (which includes the city of Houston) recording all-time high flood stages.

Due to the severe limitations of measuring rainfall of this magnitude (e.g. many standard rain gauges filled up to a ~12 inch maximum and were unable to be emptied due the extreme rain rates), it is useful to look at the peak rain totals in other ways. The rainfall estimates generated by the multi-radar, multi-sensor quantitative precipitation estimation method were as high as 65-70 inches in southeastern Texas. Interestingly, there were few rainfall reports near the center of the radar-estimated maximum during Harvey in the vicinity of Port Arthur and the Lower Neches Wildlife Management Area, and these radar estimates represent the highest rainfall that could have occurred (outside of the actual measurements).

While the peak rainfall amounts were exceptional over Texas, the areal extent of heavy rainfall is truly overwhelming, literally and figuratively. A comparison of historic United States tropical cyclone rainfall, with Harvey being compared to previous record breaking storms (Allison, 2001 and Beulah, 1967), shows that large sections of southeastern Texas received 3 ft or more of rainfall in Harvey, whereas only very small portions of the Houston metro area had those totals in previous record storms. NOAA recently completed an analysis of annual exceedance probabilities for southeastern Texas after Harvey, with a large portion of that area experiencing a flood with less than a 1-in-1000 (0.1%) chance of occurring in any given year (e.g., a 1000-year or greater flood). While established records of this nature are not kept, given the exceptional exceedance probabilities, it is unlikely the United States has ever seen such a sizable area of excessive tropical cyclone rainfall totals as it did from Harvey.

Search and Rescue (SAR) Operations:

During Hurricane Harvey, the USCG deployed 2,060 personnel, 50 aircraft, 75 boats and 29 cutters, rescuing 11,022 people and 1,384 pets in Texas. FEMA assigned 28 Urban Search and Rescue (USAR) teams from across the nation and deployed to Texas to assist state and local agencies with the lifesaving mission. These teams rescued 6,453 people and 237 animals, using boats and high-water trucks. Search and rescue (SAR) efforts involved USAR, National Parks Service, U.S. Fish and Wildlife Service, Customs and Border Patrol and the Department of Defense. Private citizens including groups affiliated with the Cajun Navy conducted significant SAR operations. It is unknown how many were rescued by these nongovernmental groups and citizens, but the effort is widely understood to have been very significant. One report indicated that the Cajun Navy group assisted in the rescue of 5,000 throughout Texas. The State of Texas reported that Local, state and federal first responders rescued 122,331 people and 5,234 pets. Over 270,000 homes were impacted with nearly 80,000 homes having at least 18 inches of floodwater, and 23,000 of those with more than 5 feet.

NOAA Support:

In anticipation of potential impacts to the enormous oil storage facilities in the Port Arthur and Beaumont area, the NOAA SSC deployed to the Marine Safety Unit (MSU) in Port Arthur on 28 August as requested by the MSU Command and in coordination with USCG District 8. The MSU in Port Arthur falls under the Command of the Sector Houston-Galveston Captain of the Port. The MSU Area of Responsibility (AOR) includes the Beaumont and Nederland areas, one of the 5 largest oil storage terminals in the U.S. with over 30 million barrels of oil storage and includes the largest oil refinery in the U.S. with a reported capacity of 600,000 barrels per day.

Due to the historic nature of flooding beginning on the evening of August 28th, the USCG mission was highly focused on very intense and increasing requests for search and rescue (SAR) primarily focused on the high population density areas of Port Arthur, Nederland, and Beaumont. Inundation of these areas began on the afternoon of the 28th with about 5-7 inches of rain. In the 24 hours that followed, the area received an additional 20-30 inches of rain leading to historic flooding over a vast area including the MSU building serving as the Incident Command Post (ICP) along with much of the adjoining urban areas and waterfront. Consequently, SAR operations were essentially nonstop beginning on the 28th with all available USCG, local, and State resources being utilized to support the exceptional demand. Four USCG Strike Teams launched flood punt assets directly from the flooded parking lot of the MSU building. A SAR helipad for USCG and National Guard as well as local assets was established on what remained as nearly the only dry ground in Port Arthur located at the Central Mall just north of the MSU. All major roadways into and out of Port Arthur were flooded and most were not trafficable by any vehicles other than high water vehicles.

Over the period between the 28th and the 31st, the NOAA Scientific Support Coordinator (SSC) worked out of the nearly flooded USCG building providing coordination on weather related products primarily in support of the intense and continuous SAR operations conducted by USCG and others. It was unofficially reported that through the evening of the 29th , several thousand 911 calls for assistance were received per hour in Jefferson County and overwhelmed the call center as well as severely impacted both local, state, and federal resources dedicated to the SAR mission. To complicate issues further, news media and other information sources began reporting that controlled emergency discharges were necessary from dams upstream on the Sabine and Neches Rivers to keep the dams from being over-topped or compromised. This information paired with the current status of flooding and the river forecasts indicating rising water levels led to a great deal of concern in the command post and emergency operations centers in the area. Understandably, the conclusion was drawn by many that additional releases upstream would result in greater flooding throughout the area as rivers were already well over their banks. Subsequently, misinformation regarding the severity of consequences related to the increased release from the dams caused a great deal of confusion and concern within the community and resulted in another surge in SAR requests that may have otherwise been unnecessary. Nonetheless, SAR operations or requests for rescue were nearly non-stop from the 28th to the 31st.

During this time, the onscene NOAA SSC, with support from the NOAA Scientific Support Team (SST) modelers in Seattle, provided scientific support at the USCG Incident Command Post (ICP). This support focused primarily on putting into context the myriad National Weather Service (NWS) products and additional sources of data and forecasts to aid in decision making for directing SAR resources and planning for the earliest possible assessment of the Port and Waterways and pollution impacts throughout the area. The NOAA SSC coordinated with the NWS Lake Charles office and the NOAA River Forecast Center (RFC) to confirm that river forecasts issued for the area were incorporating increases in discharge from the dams provided directly from the dam operators. This allowed USCG Command to determine that evacuations from the ICP, EOC, and other critical evacuation shelters would not be necessary based on river crest forecasts combined with inundation flooding projections. These critical command and control facilities were expected to remain operational as water levels reached a steady state. SAR operations in Port Arthur began to subside and resources from Port Arthur deployed to Beaumont and Orange in anticipation of increased river flooding in those areas.

A Marine Environmental Response (MER) Branch consisting of members from the MSU Incident Management Division (IMD), Gulf Strike Team, and Texas General land Office (TGLO) was established in Port Arthur on the 31st to begin pollution assessment operations. TGLO and USCG IMD personnel conducted an overflight in the afternoon and identified a heavy sheen in Brakes Bayou and along the Neches River south of I-10 in Beaumont. The source was unknown at the time, and no large sources were identified in the immediate vicinity. The Exxon refinery in Beaumont was heavily flooded but no sheen or discharges were observed. Additional overflights were conducted by the MER group with the NOAA SSC on the morning of the 1st and covered the Neches/Sabine River corridor from Beaumont south to the Sabine Pass. Remarkably, no significant discharges from oil storage facilities or vessels was observed. The Port was reopened with heavy restrictions by mid-morning on the 1st and primary roads into and out of Port Arthur and Beaumont began to open to response personnel.

SAR operations slowed considerably over the afternoon of the 1st and more resources became available to support assessment of the area to determine the integrity of oil infrastructure and identify potentially vulnerable areas, as well as active or unreported discharges or releases.

River and port conditions were still heavily challenged by historic river cresting and very high currents.

At approximately 7:00 PM on Sept 1st, USCG watchstanders at the Command Center in Port Arthur observed on the VTS cameras an apparent rupture of a suspected pipeline in the Neches River near centerline in the river approximately 2 miles south of Interstate 10 near the Exxon refinery. Command Center radio calls received from nearby vessels and tugs located in the vicinity reported an apparent substantial discharge of unknown material (bubbling gas) in the river. As the sun was setting an ominous glow appeared on the water indicating a potential fire in the immediate vicinity of the release. Immediately, USCG watchstanders and response personnel began trying to identify the source of the release and gather pertinent information on potential ownership. USCG requested assistance from the onscene NOAA SSC in identifying the source of the release and assessing any potential threats to vessels and facilities in the immediate area. A natural gas pipeline was identified in the vicinity of the release on NOAA's Environmental Response Management Application (ERMA). Subsequent calls to the Exxon facility and the listed owner of the pipeline indicated the likely source of the discharge as a natural gas pipeline that crossed under the Neches River.

Communications with representatives of the pipeline were established around 7:30 PM. Initial information provided to NOAA from the USCG indicated that source of the release was an 18-inch natural gas transmission pipeline and that efforts were underway to secure the nearest control valve located on the south bank of the river near the Exxon facility. Reports from the USCG Command Center indicated that three tugs were in the immediate vicinity of the release (within 300-500 meters). Automatic Identification System (AIS) feeds from vessels in the port did not identify these vessels or their positions relative to the release. A USCG assessment team dispatched from the MSU arrived near the Exxon facility at 7:45 PM indicating an active flare at the Exxon facility nearby. Due to flooding conditions, nighttime limitations on visibility, and unknown threats associated with the release, the assessment team was unable to get close enough to the source to verify the release was ongoing or confirm the location of the nearby vessels.

NOAA provided an immediate assessment of the natural gas release based on recommendations for methane (the primary compound in natural gas) in the Department of Transportation (DOT) Emergency Response Guidebook (ERG). Based on the ERG, the recommended evacuation for a “large spill” (defined as generally greater than 55 gallons, 200 pounds, or 200 cubic feet of a gas) of methane (and other flammable gases under Guide 115) is to consider initial downwind evacuation for at least 800 meters (1/2 mile). The ERG also recommends as an immediate precautionary measure, to isolate the spill or leak area for at least 100 meters (330 feet) in all directions. Based on this initial threat assessment, it was apparent that the vessels in the vicinity were within the threat zone and could potentially serve as a source of ignition, thus endangering the crew and others in the area.

To better understand the potential threat associated with the release, NOAA also ran several scenarios in the ALOHA (Areal Locations of Hazardous Atmospheres) model using the limited initial information available and assumed various source strengths. The initial model scenarios, assumptions used, and results of the model were as follows:

Atmospheric conditions (based on nearby NWS observations at time of incident):

- 6 mph wind from S at 10 m
- Open Water
- Temp 78F

- Stability Class E (Slightly stable atmospheric conditions)
- Cloud cover 5/10
- Humidity 87%

Pipe dimensions:

- 18” diameter (initial report)
- 10,000 ft length (assumed)

ALOHA Assumptions/ Inputs:

Four Scenarios based on Pressure and Release conditions:

- Pressure:
  - 150 psia
  - 600 psia
- Release conditions:
  - Moderate case: Closed 10,000 ft pipe (i.e. 10,000 ft from closed shutoff valve to release point) with 20 sq. in. hole (2.5” diameter) – “Finite Source”
  - Worst case: Open pipe (i.e. continuous flow of gas) with sheared end (i.e. 255 sq. in. hole, 18” diameter) – “Infinite Source”

ALOHA Results:

1) 150 psia – Moderate Case

   High Threat Zone-Red (60% LEL): 391 meters

   Low Threat Zone-Yellow: (10% LEL): 886 meters

2) 150 psia – Worst Case

High Threat Zone-Red (60% LEL): 745 meters

Low Threat Zone-Yellow: (10% LEL): 2,249 meters (1.4 mi)

3) 600 psia – Moderate Case

High Threat Zone-Red (60% LEL): 767 meters

Low Threat Zone-Yellow: (10% LEL): 1,773 meters (1.1 mi)

4) 600 psia – Worst Case

High Threat Zone-Red (60% LEL): 1,609 meters (1.0 mi)

Low Threat Zone-Yellow: (10% LEL): 6,117 meters (3.8 mi)

The outputs from the ALOHA modeling indicated a high threat zone (methane concentration at 60% of its Lower Explosive Limit [LEL]) downwind of the release for a low pressure line (150 psia) extended to about 400 to 800 meters. Consequently, the model indicated that the vessels in the vicinity were within the threat zone distance, but were located crosswind of the threat zone. However, given the potential for changes in wind directions as well as atmospheric stability and the uncertainty surrounding the actual release conditions, NOAA continued to gather more information for inputs to the modeling effort. At approximately 9:00 PM, the pipeline representative corrected a previously misunderstood detail and indicated that the pipeline was actually 16 inches in diameter and operated at 80 psia (65 psig). Additionally, the pipeline representative reported that the valve on the Exxon side of the pipeline had been successfully secured. Based on this information, NOAA ran another series of scenarios in ALOHA to assess the threat zone as follows:

<u>Updated info:</u>

Atmospheric conditions *(Spot forecast from NWS for the next 6 hour period overnight):*

- 2.24 mph wind from S at 10 m
- Open water
- Temp 72F
- **Stability Class F**
- Cloud cover 5/10
- Humidity 87%

Pipe dimensions:

- 16” diameter (confirmed by RP)
- 2,000 ft (distance from valve to opposite bank of river)

ALOHA Assumptions/Inputs:

Scenarios:

- Pressure: 80 psia (65 psig)
- Release conditions:
    - Moderate case: Closed 2,000 ft pipe (i.e. max 2,000 ft from shutoff valve to release point) with 20 sq. in. hole (2.5” diameter)

ALOHA Results:

1) 80 psia – Moderate Case

   High Threat Zone-Red (60% LEL): 310 meters

   Low Threat Zone-Yellow: (10% LEL): 606 meters

Thus, despite a decrease in the actual reported pressure of the line than previously assumed, and the secured valve eliminating an “infinite source” of the release, the results of the ALOHA model still indicated a potential threat to the vessels near the release. The threat area remained about 300-600 meters downwind primarily due to increasing atmospheric stability (typical of overnight conditions) and forecasted low winds. Additionally, the NWS forecaster indicated that the winds might die down and become light and variable in the early morning. Thus, the threat zone might become more of a radius around the source to account for changing wind directions. Accordingly, these potential threats were communicated directly to the nearby vessels. USCG also continued to work with the RP to identify resources available to locate and secure the second valve on the opposite side of the river in an area that was flooded and would potentially require dive operations.

CONCLUSION:

As an event such as this unfolds, significant details of the nature of the release can be hard to determine. Moreover, when these events occur in the midst of an ongoing response to a natural disaster, the environment is not conducive to quickly ascertaining reliable information. Furthermore, the ability to employ standard resources is often greatly diminished and options for minimizing the potential threats are often very limited.

Consequently, generating a reliable hazard assessment and taking appropriate action based on a threat analysis is very challenging. In order to generate very quick assessments of the threats at least the name or type/properties of the material released and the relative amount of the release must be known. In the case of this event, those two details were determined fairly quickly and the ERG guide was employed as a quick tool to assess the threat. However, the ERG tool is somewhat generic in nature and tools such as ALOHA can offer a more detailed understanding of critical details needed to more fully assess the threat and evaluate reasonable actions to reduce, minimize, or eliminate them.

In the case of the threat to the nearby vessels, the ERG guide clearly indicated a potential for harm and a basic recommendation to mitigate the threat by removing them from the threat zone. However, after further inquiry, it was determined that the vessels were being used to secure a DOD vessel at its dock and could not evacuate the area without threat of the DOD vessel losing its mooring and becoming a potential greater threat to life and property.

So, in this specific incident, following the initial listed recommendations was unachievable without introducing other significant threats. When this is the case, further assessment, to include modeling and monitoring of actual release conditions is deemed as necessary to make highly consequential decisions. As monitoring was not achievable in this instance, response personnel had to rely more on modeling to assess the threat. To aid in this assessment NOAA and other response personnel have used the ALOHA model as a customizable decision support tool. As with any model, the inputs such as the conditions of the release and environmental conditions must be known, or at least, assumed. Given the serious potential consequences of making decisions based on incorrect assumptions or bad information, NOAA SST often runs the ALOHA model under multiple scenarios with reasoned assumptions and any known details, and continues to work to understand and incorporate any significant changes to site conditions into modeling results and hazard assessments as the spill response progresses. This requires a robust and highly engaged assessment team and close communications with onsite personnel as well as any available technical resources that can provide critical updates and detailed information on the source of the spill.

Given the uncertainty and dynamics of a situation such as this incident, the outputs of these models must always be put in the context of what is known and what is assumed. Additionally, the model predictions should be looked at as an adjustable scaling tool to understand the relative size of a threat and are best viewed in the context of other complementary data such as any actual monitoring that is being conducted or observations being made. Again, this complementary data was not available for this incident. Thus, the final ALOHA model outcomes were based on some confirmed details such as the contents and two components of the source strength (pressure and volume), but still some key assumptions such as forecasted weather and release rate (pipe opening) were required.

As with any incident, there are always complexities inherent in getting timely and accurate information and making good decisions. Consequently, any tools used to understand the nature of the associated threats and the best course of action will always be imperfect. However, if used with a full understanding of its limitations, models such as ALOHA can provide a reasonable science-based approach to timely well-supported decision making.

In the case of this incident, enough details of the release were obtained for decision makers to understand at least the potential consequences of actions and to highlight the need to focus efforts on securing the second valve thereby minimizing a threat that might otherwise increase with worsening weather conditions. Consequently, a dangerous operation was pursued to put a diver in the water to locate and secure the second valve on the opposite side of the river at around 11:00 PM on the 1st. Given the identified threat of not taking this action and the threat posed by evacuating the vessels, this action was considered the best alternative, but also a very high-risk operation.

At approximately 12:00 AM, reports were received that the diver was able to locate and secure the second valve with assistance from the local fire department boat crew who navigated the flooded area along the river in very dangerous conditions, thus reducing the threat. No reports of impacts to the nearby vessels were received, and by morning of the following day, the release was no longer observed.

As with all response tools, models such as ALOHA can be very useful if employed correctly and with the limitations fully understood. Models tell us what **can** happen and are a valuable tool to assess threats and make reasonable decisions based on science. However, no model can predict the future. We have to take into consideration that there are many variables, any one of which can significantly change the predicted outcome. Often these variables are the details that only come to light after the event has run its course. However, there are times when we cannot, with good conscience, take no action and must thereby rely on our best judgement. This judgement is best crafted when it is grounded in reason and can be supported by sound science. It is the intent of this paper to highlight the complexities of gathering the essential information to effectively use and understand the limitations inherent in ALOHA as a scientific tool which supports timely decision making associated with a hazardous release. Specifically, it is intended to demonstrate the use of ALOHA in the context of a large release of natural gas from a pipeline in the midst of significant impacts from a natural disaster. In light of the positive outcome associated with this event, it seems safe to assume that the tool was useful in supporting an informed decision and taking the most reasonable course of action.

REFERENCES:

Blake, Eric S. and Zelinsky, David A. May 2018. National Hurricane Center Tropical Cyclone Report Hurricane Harvey (AL092017).

Federal Emergency Management Agency (FEMA). August 8, 2018. 2017 Hurricane Season FEMA After-Action Report.

FEMA Press Release HQ-17-133. September 22, 2017. Historic Disaster Response to Hurricane Harvey in Texas.

Pearce, M. August 30, 2017. "A 'Cajun Navy' of volunteers descends on Port Arthur, Texas, to rescue people". Los Angeles Times.

Texas Commission on Environmental Quality. April 3, 2018. Hurricane Harvey Response 2017 After Action Report.