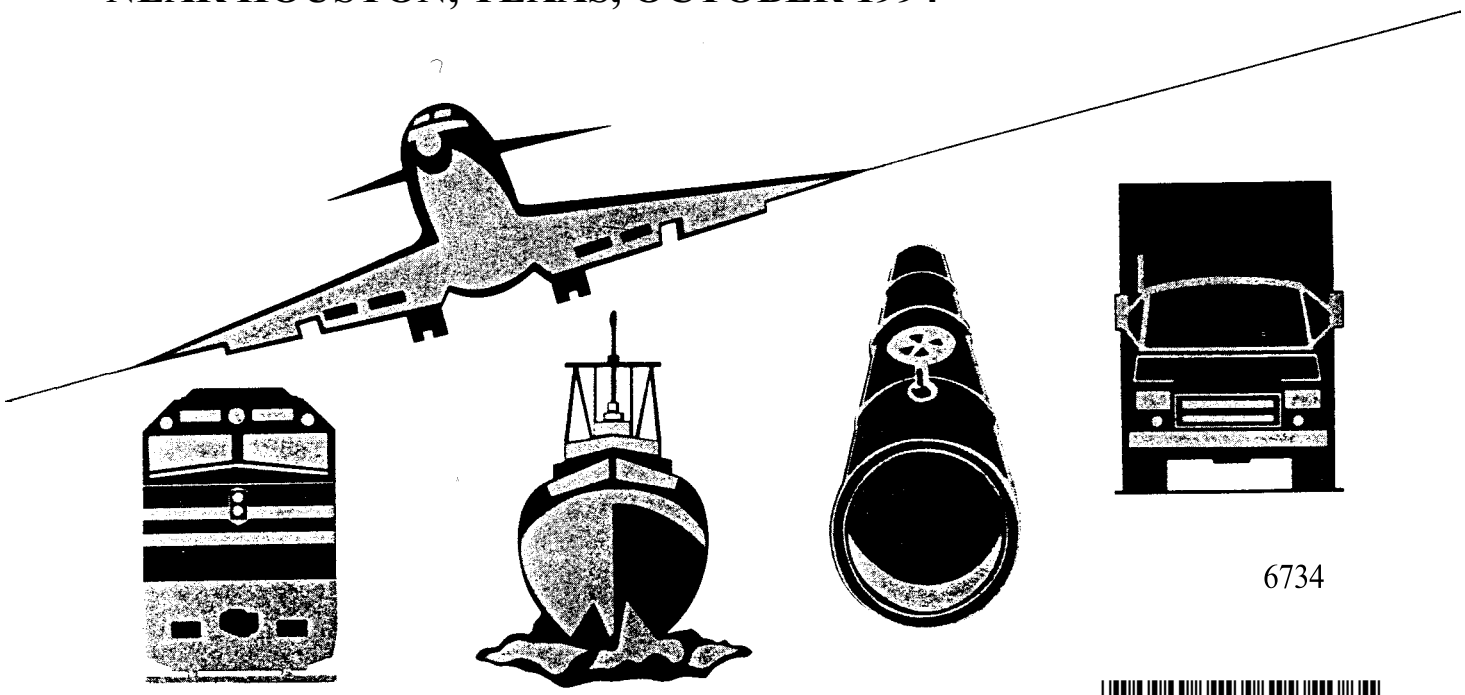
PB96-917004
NTSB/SIR-96/04

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

PIPELINE SPECIAL INVESTIGATION REPORT

EVALUATION OF PIPELINE FAILURES DURING FLOODING AND OF SPILL RESPONSE ACTIONS, SAN JACINTO RIVER NEAR HOUSTON, TEXAS, OCTOBER 1994



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Abstract: In mid-October 1994, major flooding occurred in the San Jacinto River flood plain near Houston, Texas. Due to the flooding, eight pipelines ruptured and many others were undermined. Ignition of petroleum and petroleum products released into the river resulted in 547 people receiving (mostly minor) burn and inhalation injuries. The Safety Board undertook a special investigation that focused on the following safety issues: (1) the adequacy of Federal and industry standards on designing pipelines in flood plains, (2) the preparedness of pipeline operators to respond to threats to their pipelines from flooding and to minimize the potential for product releases, and (3) the preparedness of the Nation to minimize the consequences of petroleum releases. The report also addresses the need for effective operational monitoring of pipelines and for the use of remote- or automatic-operated valves to allow for prompt detection of product releases and rapid shutdown of failed pipe segments. The Safety Board made nine safety recommendations: one to the Research and Special Programs Administration, five to the National Response Team, and one each to the American Petroleum Institute, the Association of Oil Pipe Lines, and the Interstate Natural Gas Association of America.

The National Transportation Safety Board is an independent Federal agency dedicated to promoting aviation, railroad, highway, marine, pipeline, and hazardous materials 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 Safety Board makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

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Adopted: September 6, 1996
Notation 6734

National
Transportation
Safety Board

Washington, DC 20594

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EXECUTIVE SUMMARY

Between October 14 and October 21, 1994, some 15 to 20 inches of rain fell on the San Jacinto River flood plain near Houston, Texas, resulting in dangerous flooding that far surpassed past flooding experience in the region. The floods forced over 14,000 people to evacuate their homes and resulted in 20 deaths.

Due to the flooding, 8 pipelines ruptured and 29 others were undermined both at river crossings and new channels created in the flood plain. More than 35,000 barrels (1.47 million gallons) of petroleum and petroleum products were released into the river. Ignition of the released products within flooded residential areas resulted in 547 people receiving (mostly minor) burn and inhalation injuries. The spill response costs were in excess of $7 million and estimated property damage losses were about $16 million.

With respect to this accident, the Safety Board undertook a special investigation that focused on the following safety issues: (1) the adequacy of Federal and industry standards on designing pipelines in flood plains, (2) the preparedness of pipeline operators to respond to threats to their pipelines from flooding and to minimize the potential for product releases, and (3) the preparedness of the Nation to minimize the consequences of petroleum releases. The report also addresses the need for effective operational monitoring of pipelines and for the use of remote- or automatic-operated valves to allow for prompt detection of product releases and rapid shutdown of failed pipe segments.

As a result of its investigation, the Safety Board makes nine safety recommendations: one to the Research and Special Programs Administration, five to the National Response Team, and one each to the American Petroleum Institute, the Association of Oil Pipe Lines, and the Interstate Natural Gas Association of America.

INTRODUCTION

Serious flooding in the San Jacinto River flood plain near Houston, Texas, in October 1994 caused 8 pipelines to rupture and 29 others to be undermined both at river crossings and new channels created in the flood plain.

The high number of pipelines ruptured and damaged during this incident, and the magnitude of the petroleum releases and spill response efforts emphasized the threats posed to public safety and the environment by petroleum transportation by pipeline. Although pipeline transportation is one of the safest means for transporting petroleum, it poses great risk potential to the environment because of the large volumes of hazardous liquids that can be released when a rupture occurs.

In a pipeline transport situation, as opposed to other transport options, there is greater likelihood of releasing petroleum into environmentally sensitive areas. Concerns about the environmental consequences of releases from pipelines have been expressed by the Congress, the States, and local interests.

Because so many pipelines were damaged during this flood and such large volumes of petroleum and petroleum products were released — requiring a massive environmental response in terms of personnel and equipment — the Safety Board undertook this special investigation to assess the adequacy of Federal and industry standards on designing pipelines in flood plains, the preparedness of pipeline operators to respond to threats to their pipelines from flooding and to minimize the potential for product releases, and the preparedness of the Nation to minimize the consequences of petroleum releases.

In the course of the investigation, the Safety Board also discovered evidence reinforcing the need for effective operational monitoring of pipelines and for the use of remote- or automatic-operated valves to allow for prompt detection of product releases and rapid shutdown of failed pipe segments.

PIPELINE FAILURES AND RESPONSE ACTIONS

Flooding

Between October 14 and October 21, 1994, the remnants of Hurricane Rosa caused heavy rainfall in a 38-county area of southeast Texas. On October 18, the President issued a disaster declaration covering 26 counties (later extended to include 38 counties). The San Jacinto River basin in eastern Harris County received 15 to 20 inches of rain during this week-long period. (See figure 1.)

The United States Geological Survey (USGS)[1] made numerous measurements of stream stage[2] and stream flow during flood conditions at 43 stations in 29 Texas counties. A USGS official observed that:

> By any measure, the flooding of October 1994 was an extreme and dangerous event. Historical peak stream flows were exceeded at 23 of the 43 stations monitored in the area. The 100-year-flood, which is defined as the peak stream flow having a 1 percent chance of being equaled or exceeded in any given year, was equaled at 1 and exceeded at 18 of 43 stations. For those stations where the 100-year-flood was exceeded, the flood was from 1.1 to 2.9 times the 100-year-flood.

The flooding caused major soil erosion in the flood plain and river channel, including the creation of water channels outside the San Jacinto River bed. The flood waters scoured[3] the riverbed and banks, destabilized roads and bridges, and inundated area homes. The largest new channel (approximately 510 feet wide and 15 feet deep) was created when the river cut through the Banana Bend oxbow[4] just west of the Rio Villa Park subdivision. A second major channel cut through Banana Bend just north of the channel through the oxbow. Both these channels cut through areas where sand mining had been performed previously.

Beginning on October 16, 1994, weather forecasters began issuing flash flood warnings for the Houston area, and, on October 17, river flood warnings were issued for the San Jacinto and other area rivers. Heavy rainfall was expected to continue for several days.

The San Jacinto River, which normally flows at about 2.5 feet above sea level, crested at 28 feet above mean sea level on October 21. The peak discharge was more than 350,000 cubic feet per second, about 58 percent greater than the 100-year-flood. The highest velocity measured was 16.6 feet per second—approximately 11 miles per hour.

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[1]The U.S. Geological Survey, U.S. Department of the Interior, develops and disseminates relevant, policy-neutral water data and information to support water-resource planning and management needs nationwide. Part of the USGS mission is to operate the country's stream flow-gauging network, in cooperation with other Federal, State, and local agencies.

[2]Water-surface elevation of a stream with respect to a reference elevation.

[3]To wash or clear a riverbed by a swift current of water.

[4]A U-shaped bend in a river.

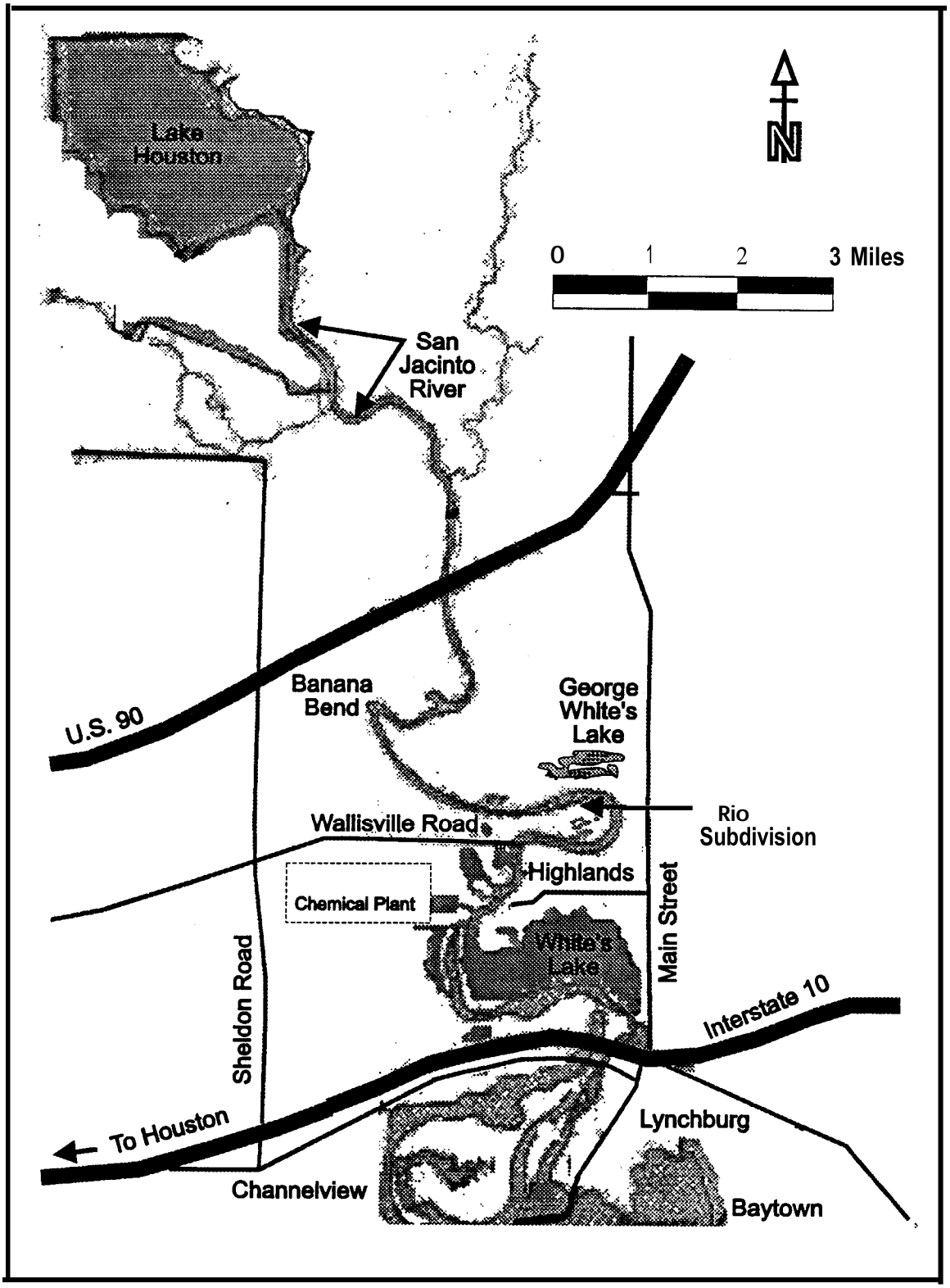

Figure 1 – San Jacinto flood plain

Figure 2 – View of the flooded community

Historically, this area has been prone to severe flooding. The major and more destructive floods have occurred in the long summer seasons from April through October in 1907, 1929, 1932, 1935, 1940, 1941, 1942, 1943, 1945, 1946, 1949, 1950, 1959, 1960, 1961, 1972, and 1978.

Evacuations

On October 17, the Harris County Office of Emergency Management opened an emergency operations center to coordinate the evacuation of low-lying areas along the San Jacinto River between Wallisville Road and Interstate 10. The U.S. Coast Guard (Coast Guard), already securing drifting barges, hazardous materials containers, and other items in response to the emergency, was requested by Harris County to assist in evacuating the Banana Bend area.

The Coast Guard's life-saving search and rescue operations were used to assist in removing more than 580 people from the flood waters. (See figure 2.) The majority of evacuations in Harris County occurred along the San Jacinto River.

Initial Pipeline Failures

Exxon Rupture – At 6:50 p.m. on October 19, an area resident telephoned the Exxon Pipeline Company (Exxon) control center to report a gas odor. At 6:53 p.m., Exxon shut down[5] the pumps on its 8-inch-diameter liquefied petroleum gas (LPG) pipeline that crossed beneath the San Jacinto River about 450 feet south of the Interstate 10 bridge. (Earlier that afternoon, the Coast Guard had reported sighting gas bubbling through the water and forming a gas vapor cloud just south of the Interstate 10 bridge.)

[5]The words "shut down" indicate that an operator stopped pumping product through the pipeline. When pipelines are shut down, they remain under pressure and valves remain open, unless otherwise stated.

Remote-operated valves on both sides of the river crossing were closed to isolate the leak to within an 11-mile segment of the pipeline. By 7:30 p.m., Exxon personnel had closed a manual valve on the river's east bank and isolated the leak to an 8-mile pipeline segment. By 7:45 p.m., Exxon personnel observed that the rate of product bubbling within the water had decreased, indicating to them that Exxon's pipeline was the source of the LPG release.

Exxon crews worked through the night installing equipment to enable the company to release and burn the LPG in the isolated pipeline segment. They could not close the west bank manual valve because it was under water; however, in the evening of October 19, they closed a manual valve farther west of the crossing to isolate the leak to a 4-mile segment. Exxon crews visually inspected areas adjacent to its other pipeline crossings south of the Interstate 10 bridge and decided that they too could be threatened by the flood waters. At 8:15 p.m. on October 19, Exxon shut down pumps on its three additional operating pipelines—20-inch, crude oil; 10-inch, refined petroleum products; and 8-inch, turbine fuel. Products in the pipeline segments crossing the river were then removed and the lines were purged using nitrogen. Once the lines had been purged, the manual valves nearest the river were closed, isolating those segments.

On October 20, Exxon notified the appropriate Federal, State, and local government agencies of the LPG pipeline failure, provided information on the actions it was taking to shut down and isolate all its pipeline crossings, and established a repair command center on the east bank of the river. Also on October 20, Exxon USA provided a spill response command center at its Baytown refinery for the use of the unified response team. (See upcoming section on *Federal Management of the Spill Response*.)

First Colonial Rupture -- Colonial Pipeline Company (Colonial) operates two pipelines—40-inch and 36-inch—that cross the flood plain and the river at the oxbow just south of Banana Bend. Colonial shares a right-of-way in this area with pipelines operated by Texaco Pipeline, Inc., (Texaco) and Valero Transmission L. P. (Valero). The pipeline right-of-way crosses the river about 4 miles north of the Interstate 10 bridge. The Rio Villa Park subdivision is located within the oxbow. Shallow sand pits, where a sand mining operation had been conducted several years earlier, lie to the west of the subdivision.

About 8:31 a.m. on October 20, the operator of Colonial's Houston, Texas, pump station, (located about 12 miles west of the San Jacinto River) telephoned the controller at Colonial's Atlanta, Georgia, control center. He advised the controller that the rate of flow in the 40-inch pipeline, which was transporting gasoline, had increased significantly. At 8:32 a.m., while the controller and the Houston operator were discussing the increased flow rate, an alarm came from the Shiloh pump station, located about 29 miles east of the San Jacinto River. The alarm told the controller that suction pressure in the line had fallen from normal pressures of about 40-50 psig[6] to 23 psig.

The controller told the Houston operator to shut the 40-inch pipeline down. About 8:33 a.m., the operator did so. The operator also closed the Houston mainline pump station valve and valves to shipper locations. (Later, the mainline valve at the Shiloh pump station was closed.)

At this time, a shift supervisor who had been observing the activities of the controller for the 40-inch line initiated Colonial's emergency response procedures. The shift supervisor advised the controller for Colonial's 36-inch pipeline of the problems being experienced on the 40-inch line and cautioned the controller of the 36-inch pipeline to watch indications on that line closely. (The 36-inch pipeline segment between the Houston and Beaumont stations had been shut down at 11:06 p.m. on October 19, in

[6]Pounds per square inch, gauge.

the course of normal pipeline operations, but the pipeline segment still contained low-sulfur diesel fuel under pressure.) The Houston operator dispatched Colonial personnel from Houston to the suspected rupture area to search for the site of any product release.

Gasoline flowed from the ruptured 40-inch Colonial pipeline into the swift-flowing flood waters and pooled in areas of slower water flow. Residents evacuating the Rio Villa Park subdivision reported that they detected the odor of gasoline about 9:00 a.m. on October 20 and observed oil and vapors south of Wallisville Road. A River Road resident on the south side of White's Lake near Interstate 10 observed that gasoline fumes had collected near boathouses. At 9:37 a.m. (about 1 hour after the rupture), a Colonial employee performing an aerial patrol observed gasoline in a new channel that had been cut through the sand pit area of the oxbow.

About 9:40 a.m., a Colonial employee notified Harris County Sheriff's Department officers located at the Interstate 10 San Jacinto bridge that Colonial's pipeline had ruptured in the San Jacinto River. (The Interstate 10 San Jacinto bridge had been closed in both directions at 11:30 a.m. on October 18, when flood waters rose to the elevation of the approaches to the bridge.)

The Harris County Communications Center first learned of the gasoline release at 9:41 a.m., when a resident called 911 reporting an odor of gasoline from White's Lake in the River Road area. That call was transferred to the Channelview Fire Department, which advised the Communications Center that personnel at a chemical plant on the west bank of the river were checking for a possible leak at or near the plant. At 9:51 a.m., the Harris County Office of Emergency Management ordered the evacuation of Wallisville Road west of the river due to the strong fumes in the area.

Fire on the River

About 9:51 a.m., explosions and fires erupted on the river and began moving slowly southward towards the Interstate 10 bridge. Witnesses reported hearing a series of five distinct explosions and observing balls of fire and smoke rising just north of Interstate 10. After the first explosion, fire and smoke rose about 300–400 feet into the air. A second explosion, located about 200–300 feet to the west of the first, occurred about 10 seconds later, and a third explosion occurred about 600–700 feet to the west of the second. Minutes later, two more explosions were heard as the fire advanced across the lake and the stream flow carried the petroleum toward the Interstate 10 bridge.

A Colonial supervisor conducting an aerial survey from a helicopter observed the ignition of the fire. He stated that he could see product spewing up from the ruptured pipeline and being carried downriver as far as the Interstate 10 bridge. He saw the fire flash above the product floating on the water. The fire appeared to him to have begun along the river's eastern bank.

Harris County Emergency Response

The Harris County Sheriff's Department District Commander stated that he observed a large black cloud and fireball to the northeast while he was crossing the (closed) Interstate 10 bridge about 10:15 a.m. He could not identify what was burning. He advised his dispatcher that a major event was underway, and he requested assistance.

In accordance with the Harris County Disaster Plan, the predesignated Sheriff's Department Incident Commander was dispatched immediately to the scene, as were additional patrol units. Upon his arrival at 10:30 a.m., the Incident Commander requested county

mobile command vans[7] to be dispatched, and he established a temporary command post about ¼ mile west of the bridge on the south side of Interstate 10. Several minutes later, a representative of Colonial identified himself to the Incident Commander and advised him that Colonial's 40-inch pipeline had ruptured and was releasing gasoline. The Incident Commander requested that the Colonial representative stay at the command post to provide information.

About 10:50 a.m., Colonial advised the Harris County Command Center that it had closed valves at each side of the river on its 40-inch pipeline to isolate the rupture. It advised that the isolated pipeline segment contained 65,338 bbls[8] (2.74 million gallons) of gasoline. Colonial employees had closed the manual valves nearest each side of the river; the west valve was closed at 9:59 a.m., and the east valve was closed at 10:13 a.m.

Second Colonial Rupture

About 11:30 a.m., Colonial's shift supervisor told the controller of its 36-inch pipeline to close the remote-operated mainline valves between the Houston and Shiloh pump stations and all remote-operated valves on lines to shippers. (The controller later stated that he did not close the valves on either side of the San Jacinto River, as such action would have isolated the pipe segment crossing the river from the rest of the system and prevented him from monitoring the pressure in the pipe beneath the river, since pressure monitors were located only at the pump stations.)

About 1:00 p.m. on October 20, the Incident Commander extended the evacuation to all persons within 9 miles of the failed 40-inch Colonial pipeline.

Colonial's 36-inch petroleum pipeline ruptured about 2:00 p.m. The Colonial shift supervisor directed that personnel travel to and close the manual valves at the river crossing and that the failure be reported to local officials. About 2:30 p.m., the line failure was reported to the Incident Commander by Colonial.

About 2:45 p.m., the Incident Commander requested the Channelview Fire Department to call DIGTESS, a local pipeline one-call notification system,[9] to obtain a listing of companies that operated pipelines adjacent to the river that might be affected by the flooding. He learned from the Colonial representative that the mainline valves on Colonial's failed 36-inch pipeline had been closed at Pasadena and Trinity, Texas, isolating the failure to a 30-mile-long segment of the pipeline (containing about 196,000 bbls or 8.2 million gallons of petroleum). By 3:00 p.m., representatives of many local and State agencies arrived at the Interstate 10 command post.

At 6:30 p.m., the Texas Railroad Commission, the agency responsible for safety oversight of intrastate pipeline operations, reported to the Incident Commander that 25 operators of pipelines north of the Interstate 10 bridge had shut down operations and secured their pipelines under pressure. At 8:00 p.m., in the belief that the situation was safe, the Harris County Office of Emergency Management advised flood evacuees that they could return to their homes. However, a health advisory was issued for all persons to stay indoors until further notice due to the air quality. During the night, the Texas Department of Public Safety monitored U.S. Route 90 for driver visibility and placed lighted caution signs on both of the U.S. Route 90 bridges. Throughout the night, the Harris County Sheriff's Department

[7]Harris County provided 2 mobile command vans, 69 patrol units, and 2 boats.

[8]Barrels. Barrel capacity is 42 U.S. gallons.

[9]There are three one-call systems in the State of Texas: DIGTESS, LONESTAR, and TEXAS. Pipeline operators must register with at least one of these systems so that the utility companies can be notified of planned excavations and mark the location of buried pipelines prior to excavation.

monitored a barge burning on the river, the size of the spill, and the highway traffic. In addition, it maintained security for residences in the flooded and evacuated areas.

Texaco and Valero Ruptures

About 10:30 a.m. on October 20, the operators of the Texaco and Valero pipelines had learned through news media reports that a Colonial pipeline had apparently ruptured at the river. At 3:45 p.m., Valero's 12-inch natural gas pipeline ruptured.

Texaco had shut its 20-inch pipeline down the previous August, leaving crude oil in the pipe under no pressure. Consequently, Texaco was unable to monitor this pipeline to detect a leak or rupture. Texaco considered repressurizing the pipeline, but eventually rejected this idea because if a leak existed, repressurizing the line would cause the release of more oil. Texaco also considered the options of using nitrogen or water to displace the crude oil from the pipe segment, and cutting into its pipe (tapping) to draw oil from the pipe segment in the flooded area. Of all available options, Texaco determined that the latter action provided the least uncertainty.

Texaco employees were dispatched to close manual valves east of the river. After the valves were closed, Texaco operated pumps at its East Houston Station to draw as much product as possible from the pipeline crossing the river. Texaco could remove only 260 bbls of crude oil at that time. About 6:30 p.m. on October 20, a Texaco representative conducted an aerial patrol of the pipeline and observed crude oil leaking. During a second aerial survey on October 21, a Texaco representative observed what he believed was crude oil on the water near Texaco's pipeline right-of-way. Texaco assumed that the leaking crude oil came from its own pipeline. Texaco activated a district emergency response team to begin its spill recovery response.

About 2:00 p.m., Texaco dispatched employees to both sides of the San Jacinto River to cut into the pipe and remove as much product as possible. About 3:00 p.m., Texaco notified local, State, and Federal agencies that its pipeline had likely ruptured at an undetermined time and that it was taking response actions, which it detailed.

By 1:20 a.m. on October 22, the pipe on both sides of the river was tapped. Using vacuum trucks, Texaco personnel applied suction to the line at both ends of the crossing, resulting in the recovery of 40 bbls and 370 bbls of crude oil from the west and east ends of the line, respectively.

Federal Management of the Spill Response

National Response System Structure -- The National Response System (NRS) is a national mechanism for coordinating response actions by all levels of government in support of an On-Scene Coordinator (OSC) when discharges of oil and releases of hazardous substances, pollutants, and contaminants occur. The National Response Team (NRT) of the NRS is responsible for providing national planning and coordination for responding to such emergencies.

The NRT consists of representatives from the Environmental Protection Agency (EPA)—which serves as its chairman, the Coast Guard—which serves as its vice chairman, the Federal Emergency Management Administration (FEMA), the Nuclear Regulatory Commission, the General Services Administration, the U.S. Public Health Service, and the U.S. Departments of Defense (through the U.S. Corps of Engineers and U.S. Navy Supervisor of Salvage), Energy, Commerce (through the National Oceanic and Atmospheric Administration), Interior, Justice, Labor, and Transportation.

Among its other responsibilities, the NRT must evaluate methods of responding to discharges or releases; recommend to the EPA Administrator changes needed in response organizations and the National Contingency Plan (which appears in Section 105 of the Comprehensive Environmental Response Compensation and Liability Act of 1980, 42 United States Code 9605, as amended); provide policy and program direction to Regional Response Teams; make recommendations to appropriate agencies as to training, equipping, and protecting response teams; and direct organization planning and preparedness.

As the functional arms of the NRS structure, the Regional Response Teams (RRTs) are responsible for the planning and coordination of preparedness and response actions. RRT membership parallels the NRT's, but also includes State and local representation. Each RRT provides appropriate regional mechanisms for developing and coordinating preparedness activities before a response is undertaken, coordinating assistance and advice to the OSC during responses, and providing advice to area committees to ensure consistency of area contingency plans with the National Contingency Plan. An RRT may be activated, at the request of the OSC, during any discharge situation. Texas is within the jurisdiction of Federal RRT Region VI.

Lead Agency and Management Structure – In the case of the San Jacinto product release situation, the liquid products being released north of the Interstate 10 bridge were in an area for which the EPA has spill response management responsibility. However, the products flowed south and contaminated the coastal zone south of the Interstate 10 bridge, an area for which the Coast Guard has spill response management responsibility.

About 10:00 p.m. on October 20, representatives of the Coast Guard, the EPA, and other concerned agencies met to discuss the management of the oil spill recovery actions. While both the Coast Guard and the EPA had personnel qualified to serve as a Federal On-Scene Coordinator (FOSC), the agencies decided that the Coast Guard would be the lead agency in a unified Federal response[10] to manage the spill cleanup. This decision was made primarily because the Coast Guard had a significantly larger presence in the area and had already established effective communications with local and State authorities during its response to the flood emergency.

The Coast Guard FOSC stated that he established a unified command/incident command system to ensure that his decisionmaking included the knowledge, experience, and concerns of the Texas General Land Office (TGLO), as the representative for State and local agencies, and of the two pipeline companies whose products were the focus of the cleanup. (See figure 3.)

The unified command's Planning Section, managed by a Coast Guard officer, was responsible for researching issues and developing plans on activities that might later be implemented. The Operations Section, managed by a Coast Guard Reserve officer, was responsible for handling current activities, such as the placement of booms and product recovery equipment.

The Operations Section had five divisions within its Cleanup Branch, each managed by Coast Guard personnel. Division I included Banana Bend and the adjacent oxbow meander.

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[10]See Incident Command Technical Assistance Document: *Managing Responses to Oil Discharges and Hazardous Substance Releases Under the National Contingency Plan*.

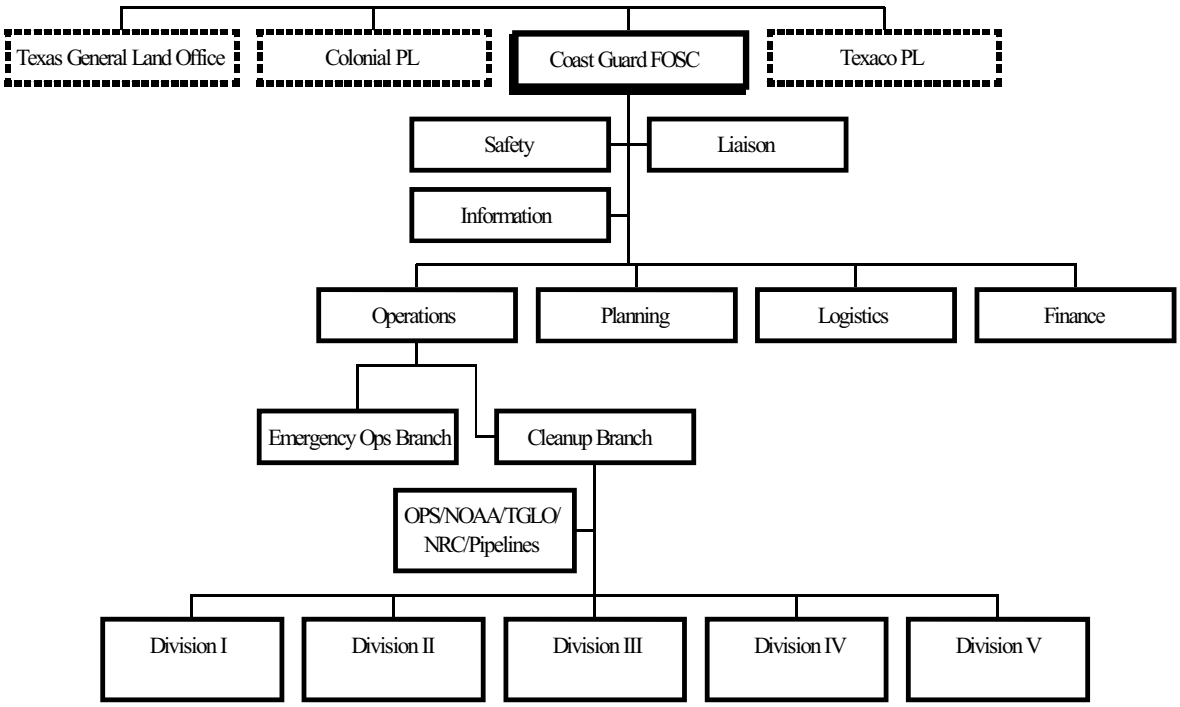


Figure 3 – Unified command management structure

(See figure 4 for areas under Divisions I through III authority.)

The FOSC held meetings each morning and evening, at which time he and others were briefed on the activities taken, planned, or under consideration.

Operations – *General.* One of the first actions of the FOSC on October 20 was to ask the Texas Railroad Commission to identify and secure all pipelines along the San Jacinto River as far north as Lake Houston. The FOSC also requested all operators of water systems south of the Lake Houston Dam to close and secure their water intakes. He directed the Vessel Traffic Control System to close the Houston Ship Channel to all but emergency vessels. In addition, the Texas Railroad Commission suspended all railroad traffic crossing the San Jacinto River. Throughout the morning of October 21, petroleum products from several pipelines, as well as a barge, were on fire on the river. (See figure 5.)

About 9:00 a.m. on October 22, the Coast Guard's unified command center advised the Harris County Sheriff's Department that high levels of jet fuel vapors were being detected in the River Bend area near Wallisville Road, and directed evacuation of the area. The Channelview Fire Department began to evacuate the affected area, but about 1:00 p.m., the Coast Guard advised the Sheriff that the earlier readings had been in error, so the evacuation order was lifted.

Several isolated small fires were burning on October 23 where Colonial's and Texaco's pipes on the east bank of the new channel were releasing crude oil and diesel fuel, and where Colonial's and Texaco's ruptured pipes at the west channel bank were releasing diesel fuel, crude oil, and some gasoline.

San Jacinto River Spill

Waste Tracking Map (1)
prepared by NOAA

Date/Time: 24 OCT 94,2100
Platform
Observers:

USE ONLY AS A GENERAL REFERENCE

Graphic does not show precise locations or amounts of waste

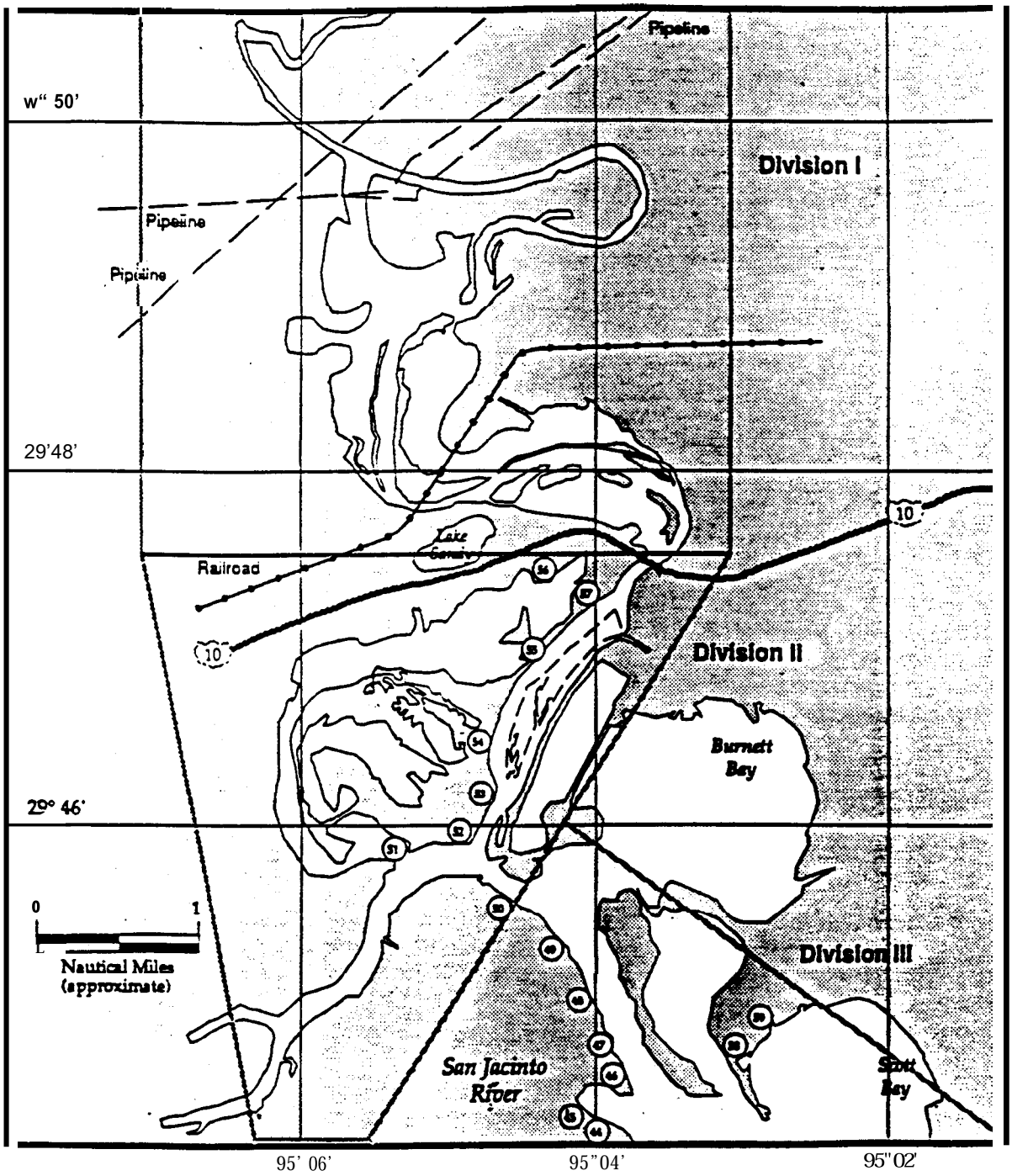


Figure 4 – Areas of responsibility for Coast Guard operations divisions

Figure 5 – Fire at ruptured pipeline on east bank of new channel

Planning Section Activities. On October 23, in anticipation of an in-situ burn[11] being conducted to clean up the pipeline release situation, National Oceanic and Atmospheric Administration representatives within the FOSC's unified command structure developed a discussion paper that reviewed various available burn options. This draft paper was intended to be discussed later within the Planning Section and then to be presented to the FOSC.

The cover memorandum for the draft National Oceanic and Atmospheric Administration document outlined six actions that should be taken or considered before conducting an in-situ burn. They were to:

1. Discuss and finalize the working document;
2. Decide on "go/no go";
3. Secure RRT approval, put equipment on standby;
4. Plan burn specifics;
5. Carry out the in-situ burning;
6. Monitor, review, and correct if needed.

The draft document stated that it had been prepared in anticipation of conducting in-situ burning of oil or oil products in the San Jacinto River and described the products in the water as gasoline, diesel, LPG, and light Arabian crude oil. It related that:

- The fire was of much smaller scale than it had been;
- Some of the fuel continuing to be released from the pipelines was still burning;
- The spontaneous in-situ burning (that had occurred on October 20) on the river had greatly reduced the amount

[11] The ignition and burning of a product in (its original) place.

of pollution, although some fuel escaping the fire was contaminating the beaches; and

- Means were being considered to minimize further environmental damage by enhancing ongoing burning or initiating in-situ burning of oil currently escaping or that might escape from future ruptures.

The draft listed items to consider based on the approved in-situ controlled checklist developed by RRT VI and RRT Alaska, and included a discussion on the pros and cons of conducting an in-situ controlled burn.[12]

That draft document concluded that enhancing ongoing in-situ burning or initiating in-situ burning of the products released would be more desirable than using mechanical recovery or dispersant techniques. The draft stated that the purpose of in-situ controlled burning is to:

> Reduce the overall duration and effort invested in the cleanup operation.

It stated that an in-situ controlled burn might pose risks to personnel and cautioned that:

> In-situ controlled burning operations should not commence until an operation safety plan is prepared. It should address personal safety, firefighting, ignition hazard, evacuation, and other aspects needed in order to protect personnel conducting the burn. The possible impact of the smoke plume should be assessed. If needed, the public should be notified and the possibility of evacuation should be considered.

The paper listed pros and cons of in-situ burning of oil as:

Pro

- In-situ burning should minimize the environmental damage of the spilled oil by burning the oil at the source of the spill;
- In-situ burning should reduce the amount of toxic, volatile compounds emitted from the oil by burning them at the source;
- In-situ burning should reduce the overall duration and effort invested in the cleanup operation and minimize the risk of personnel injury associated with this effort.

Con

- In-situ burning may temporarily increase the level of air pollution, especially the concentration of PM-10 (small soot particulates that can be inhaled);
- In-situ burning may pose risks to personnel conducting the burning;
- In-situ burning requires specialized equipment not readily available.

Operations Section Activities. **In-Situ Burn Plan**. A short time after the FOSC completed his October 23 morning status meeting, the TGLO representative developed and presented to the Operations Section chief a handwritten proposal not discussed in the meeting. The proposal, dated October 23, 1994, was entitled *Burn Enhancement Proposal* and called for deployment of 500 feet of fire boom[13] just south of (Texaco's) 20-inch ruptured

[12]The RRT VI In-situ Burn Plan stated that near-shore, inshore, or onshore burns are not addressed within the response plan. The RRT VI In-situ Burn Plan also emphasized the requirement to monitor air pollution as a means by which to gauge and control the boom effectiveness, and the importance of being able to extinguish the fire at any time by releasing the boom.

[13]A fire boom is a floating containment device constructed of fire-resistant materials and used to capture and contain petroleum (or other flammable materials to be burned) on the water surface.

pipeline at the east channel bank "...as close/far as safety considerations allow." (See figure 6.)

The fire boom was to be anchored to the east channel bank and have an opening of about 100 to 150 feet. The proposal stated that the objective was to:

> …contain and remove, by the burning process, additional unburned crude/oil at the pipe (20") rupture site. Operation to be conducted as outlined and sketched below with Coast Guard on-site oversight.

The schedule called for the action to be taken between 10:00 a.m. and noon of that day (October 23). The TGLO was to supply the fire boom, Oil Mop, Inc., was to be the contractor to carry out the work, and the Coast Guard was to have oversight responsibility. No provisions were included to provide air monitoring, notice to local response agencies, alternate action (should the planned timeframe not be met), or a site safety plan covering the safety of fire boom crews.

Plan Approval. The FOSC and the TGLO representative reviewed and, by affixing their signatures to the draft, approved implementation of the in-situ burn plan. Next, the Operations Section chief and a second TGLO representative performed an aerial evaluation of the new channel to determine if the proposed position of the fire boom was practical. Based on their aerial observations, they agreed that the approved plan was feasible. Among other information, Colonial's noon status report to the unified command center stated:

> Colonial crews working on west side of the river will be using a National Response Center barge (currently being assembled at Lyondell [Petrochemical Company]) for the purpose of ferrying equipment across the new channel to the island. The barge will be available for service at 2:00 p.m.
>
> Our surveillance info indicates that a single fire remains on the east side of the new channel. It also indicates that all four lines crossing the channel are completely severed.
>
> Our local personnel have the understanding that the Coast Guard will be deploying a boom for the purpose of containing and recovering crude oil and fuel oil leaching from the Texaco and Colonial line on the west side.

Plan Implementation. The Coast Guard's Operations Division I supervisor was told that the EPA OSC would visit the equipment staging area to pick up 500 feet of fire boom. He was not told of any plan or proposal for using the fire boom. While he was aware that the EPA OSC was on the scene to handle the recovery of hazardous materials containers, he was not aware that the EPA OSC was conducting petroleum product recovery activities in Division I.

Instead of the EPA OSC picking up the fire boom, the TGLO arranged for the boom to be picked up and transported to an area near the channel. When the fire boom was delivered, the EPA OSC, his EPA contract assistance team, and the two Coast Guard personnel with them completed the placement of conventional booms in the new channel, several hundred feet downstream of the ruptured pipelines, to divert petroleum products for future collection. About 2:00 p.m., after deploying the conventional booms, the EPA OSC and his workcrew returned to their equipment staging area, where the EPA OSC was told that a fire boom had been delivered and that he was to call the unified command center for instructions.

SAN JACINTO RIVER INCIDENT

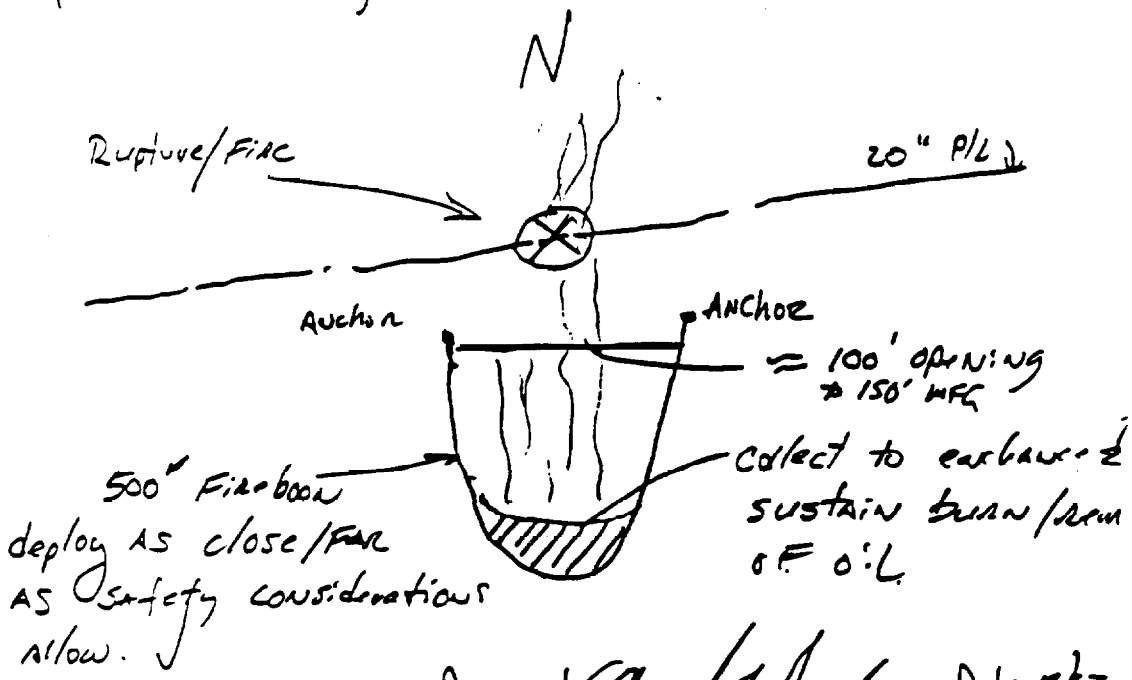
BURN ENHANCEMENT PROPOSAL

Approval is REQUESTED to conduct an operation to contain & remove, by the burning process, Additional un-burned crude/oil at the pipe (20") rupture site. Operation to be conducted AS outlined & sketched below, with U.S CG on-site oversight.

Time: 1000-1200 hrs. 10/23/94

Contractor: OILMOP

Fireboon by: Texas General Land Office



Approved [illegible] Date [illegible]

Figure 6 – Burn enhancement proposal approved by the FOSC and the TGLO

The EPA OSC telephoned the unified command center as directed. His call was answered by the Planning Section chief, who was in the Command Room. The EPA OSC asked if a plan had been approved for deploying the fire boom. Without consulting anyone in the Operations Section, the Planning Section chief went to the Operations Section, found a copy of the plan approved by the FOSC and the TGLO, and read the plan notations to the EPA OSC. He instructed the EPA OSC to call the unified command center again when the boom had been deployed.

The EPA OSC and his EPA contract team supervisor discussed the plan for the in-situ burn. Both stated that they were concerned about carrying out an in-situ burn in the channel because of the quantity and volatility of petroleum products in the area, and because they had not had the usual opportunity to discuss plan details and safety precautions with those who had developed and approved the plan. They, with the two Coast Guard strike team personnel accompanying them, discussed how and where to best deploy the fire boom. The southern end of the new channel had two outlets into the main river, forming an island between them. They decided to place a conventional boom near Wallisville Road across the west channel outlet, as this channel was not flowing as rapidly as the east outlet. The fire boom was then to be placed across the east outlet, about 500 yards south of the pipeline breaks, where they believed it would be safe to operate their boat engine.

Meanwhile, after noon on October 23, the Operations Section chief and the second TGLO representative made a second aerial observation of the channel. During that trip, the Operations Section chief observed that the water level in the channel had dropped drastically and that the west outlet no longer appeared to be flowing. Based on this observation, the Operations Section chief advised the TGLO representative that the petroleum products could be removed by mechanical means and that the Burn Enhancement Plan should be canceled. When the Operations Section chief returned to the command center, however, he did not inform either the FOSC or the Division I supervisor of the decision to cancel the in-situ burn, nor did he determine what, if any, action had been initiated to implement the plan.

About 3:00 p.m., the EPA OSC and the EPA contract crew began deploying additional booms in the channel outlets. Highly volatile products were in the area where they were installing the fire boom. Some areas reportedly contained up to 10 inches of petroleum products on top of the water. The EPA OSC estimated that, when fully deployed, the fire boom was holding back more than 2,800 bbls of a low flashpoint mixture of oil, gasoline, and diesel fuel.

After placing the fire booms, the EPA OSC sent most of the contract workers back to the staging area. Two EPA contract employees and one Coast Guard strike team member were left on the east bank of the channel outlet to anchor the end of the fire boom. The EPA OSC told them to await his radio instructions. The EPA OSC, the EPA contract supervisor, and the other Coast Guard strike team member then flew by helicopter to the west bank of the new channel to warn Colonial and Texaco workcrews about the pending in-situ controlled burn. The three-person joint Coast Guard and contractor crew that remained on the east channel outlet bank checked nearby areas for people in potentially dangerous sites. They found several persons in the Rio Villa Park subdivision and told them to leave the area.

From the west bank of the new channel, Colonial's on-site safety coordinator watched the helicopter land and the EPA OSC get out. The EPA OSC told him that the Coast Guard had approved in-situ controlled burning of the accumulated product at the pipeline openings. The EPA OSC advised that this type of burning was a routine procedure for the disposition of accumulated product. The Colonial safety coordinator told the EPA OSC that ignition of the product should be delayed until the Texaco crews finished closing the end of their pipeline,

the Colonial work crews in the area could be alerted, and the operator of a small boat (later identified as a Coast Guard patrol boat) on the river could be alerted and evacuated.

In-Situ Burn. One of the EPA contract employees left on the east side of the fire boom stated that while the EPA OSC and the Colonial safety coordinator were on the west bank of the new channel discussing the proposed in-situ controlled burn, he and the others heard the question "What are you waiting for?," over the EPA contractor's mobile radio. The EPA contract employee stated that the east bank team believed that the question signaled them to ignite the accumulated petroleum products. He stated that he tried three times unsuccessfully to make radio contact to confirm that the product should be ignited. Then, the three employees on the east bank agreed that they had been signaled to ignite the accumulated products. Flares were lit, placed on a trashcan lid, and floated into the area of accumulated petroleum products adjacent to the fire boom.

The EPA contract supervisor who went to the west side of the channel later stated that he heard no radio transmissions from any of the three personnel left on the east bank. The Colonial representative stated that as he and the EPA OSC were talking, the EPA OSC made no radio communications until the flames were seen coming from the east bank towards them.

At 6:03 p.m., the products ignited and rapidly flashed across the channel and shoreline south of the channel. One of the three persons on the east side of the boom announced over the radio that the products had been lit.

The EPA OSC recounted that, about 6:00 p.m., after warning the Colonial representative of the planned in-situ burn, he heard a transmission on his EPA contractor radio reporting that the fire had been lit. He looked to the southeast and saw the flames traveling towards him. The EPA OSC and others who had gotten out of the helicopter on the west bank ran from the oncoming flames while the pilot flew the helicopter to safety and announced over its public address speaker that all persons in the area should evacuate. All of the people at the work site ran from the oncoming flames. The resulting fire sent flames about 100 feet into the air. The smoke plume rose about 1,500 feet vertically and, when it came into contact with an inversion layer, the smoke traveled horizontally. According to the Colonial representative, the fire never approached any of the site workers, and the Texaco employees returned to complete their work about 15 minutes later. Afterwards, all pipeline employees left the area. No injuries resulted from this in-situ burn.

Minutes after 6:00 p.m., the Coast Guard operations center received a report of the eruption of a large fire on the river from unknown causes. More than an hour afterwards, the unified command center learned that the fire had been the result of a deliberately initiated in-situ burn. The FOSC stated that he had not been aware of any approval given to ignite the accumulated product, and that he had understood that he was to have been consulted before the product was ignited. He stated that it had been his intent, once he had been advised that everything was ready and atmospheric conditions were favorable, to alert both local government and private interests of the intended burn. He expressed no knowledge of his Operations Section chief deciding against implementing the Burn Enhancement Plan.

By 9:00 p.m. on October 23, the height of the flames from the in-situ fire had reduced to 60 feet. By 6:00 a.m. the next day, the fire was moving south, away from the new channel. The Coast Guard monitored the progress of the fire, and the EPA assessed the airborne pollution threat until the fire self-extinguished about 10:00 p.m. on October 24.

Injuries

	Residents	Employees	Others	Total
Fatal	0	0	0	0
Serious	1	1	0	2
Minor	544	1	0	545
Total	545	2	0	547

Medical and Pathological

On its Office of Pipeline Safety (OPS)[14] incident report for the gasoline release, Colonial recorded that 925 persons had been injured. On its report for the diesel fuel release, Colonial reported that 926 persons had been injured. However, the Safety Board's investigation indicated that a total of 547 persons were treated at 4 local hospitals, primarily for smoke and vapor inhalation complaints.

Two of the injured were residents of River Road, who sustained burn injuries while returning to their residences. A 64-year-old woman sustained serious second- and third-degree burns over 18 percent of her body; face, arms, ankles, and legs. A 65-year-old man sustained minor first-degree burns to his arms. Two pipeline workers were injured on October 27, during the removal of the damaged Valero pipe. One sustained a contusion to his right leg and the other sustained a serious injury, a fractured left jaw.

Damages

In addition to the damage to buildings and equipment caused by flooding, the Harris County Fire Marshal estimated that the petroleum fire heavily damaged at least four houses, six mobile homes, one commercial building, nine automobiles, eight boats, and four houseboats. Colonial reported that it had received about 3,000 reimbursement claims for fire damages, soot deposits, and temporary housing. Spill response costs were in excess of $7 million. In addition, pipeline operators reported product losses of more than 35,000 bbls and property damage losses of about $16 million.

Although a total of 37 pipelines were ruptured or undermined during the flood, the incident reports filed with the OPS covered only 5 of the 8 ruptured pipelines; those operated by Colonial (2), Exxon, Texaco, and Valero.[15] Of the other three pipelines that ruptured, one had been taken out of service and purged of crude oil by Citgo Pipeline Company in August 1994. The other two pipelines had been taken out of service and purged of crude oil and turbine fuel by Exxon during the evening of October 19.

Colonial reported property damage losses of $10 million and product losses of 20,000 bbls of gasoline resulting from its 40-inch pipeline failure. Colonial reported property damage losses of $0 and product losses of 10,000 bbls of gasoline from its 36-inch pipeline failure. Exxon reported property damage losses of $610,000 and product losses of 492 bbls of LPG. Valero reported property damage losses of $800,000 and product losses of 7,000 million cubic feet of natural gas. Texaco estimated that it suffered about $4.5 million in property damages and lost 5,350 bbls of crude oil.

[14]The OPS is a part of the Research and Special Programs Administration of the U.S. Department of Transportation. The OPS is responsible for administering the Federal pipeline safety program.

[15]While the failure of at least three pipeline operators to file reports with the OPS raises some questions as to the seriousness with which pipeline operators view this filing responsibility, it should be noted that a number of factors, including the operators' differing means of gauging the value of their losses, may have persuaded some operators that they were not legally obligated to file in this instance.

Emergency Organization and Participation

The Oil Pollution Act of 1990 (OPA 90; Public Law 101-380) and the National Oil and Hazardous Substances Pollution Contingency Plan require establishment of RRTs to plan and coordinate regional preparedness and response actions, including procedures and techniques to be employed in identifying, containing, dispersing, and removing oil. In this incident, RRT VI's involvement was limited to approval of the in-situ burn plan.

The primary mechanism or plan governing the environmental response activities in the region of this accident is the Galveston Bay Area Contingency Plan. The plan was approved in 1994 by the Captains of the Ports for the Galveston and Houston Coast Guard commands. The contingency plan is designed to handle emergency responses to releases of petroleum products and to establish the Coast Guard's Captain of the Port as the FOSC for managing the activities of Federal, State, and local emergency response agencies.

The local fire and medical responses were coordinated by the Channelview and Highland Fire Departments. Approximately 12 mobile intensive care units and advanced life support ambulances were used to transport injured patients to local hospitals. The fire departments responded to structural fire alarms but made no attempt to extinguish on-river petroleum fires.

Local area response organizations and officers included the Houston Fire Department Hazardous Materials Team and Fire Marshal, the Channelview Volunteer Fire Department, the Highland Fire Department, and the Harris County Pollution Control and Office of Emergency Management. Medical command posts were established near Interstate 10, and the Sheldon and Redbud Roads.

The following agencies were involved in the unified command center response:

ORGANIZATION	RESPONSIBILITY
U.S. Coast Guard	Oil spill cleanup and environmental restoration
Texas General Land Office	Oil spill cleanup and environmental restoration
U.S. Army Corps of Engineers	Channel and river obstructions
Texas Natural Resource Conservation Commission	Oil spill and hazardous material response
National Oceanic and Atmospheric Administration	Scientific support and shoreline assessment
U.S. Environmental Protection Agency	Inland oil spill and environmental restoration/air and water sampling
U.S. Department of Transportation, Office of Pipeline Safety	Federal pipeline safety
Railroad Commission of Texas	State pipeline safety
Texaco Pipeline, Inc.	Information and assistance
Colonial Pipeline, Inc.	Information and assistance

The Coast Guard managed the cleanup efforts, which involved laying booms downstream of the area where the pipelines ruptured to protect sensitive areas and deflect and collect the liquids released from the pipelines. Oil deflected to narrow areas in the river and gathered within booms was retrieved from the water surface using skimmers or vacuum trucks.

The EPA managed air quality monitoring through October 26 and obtained and analyzed numerous water and soil samples. The EPA found that the contaminants released during the event did not pose a health risk to the public.

Disaster Preparedness

The Coast Guard's Houston command last held a drill to test the area's emergency organization capabilities and preparedness for responding to a major spill with fire during severe weather on February 10, 1994.[16] Many of the scenarios (including in-situ burning) tested during that exercise occurred during the response to the October 1994 flood. The February exercise included use of an in-situ controlled burn protocol. The April 29, 1994, critique on the February exercise reported:

> *Performance*
>
> Planning section personnel were slow in advancing the in-situ burn application. This was caused by considerable internal debate over "required" information for RRT in-situ burn application submission and by diverting technical resources to evaluate the dispersant option.
>
> The Area Contingency Plan should recognize the possibility that FOSC may want to consider processing simultaneous response tool applications to RRT for approval (in-situ, dispersants, etc.). Guidance should be included to the Area Contingency Plan to handle simultaneous/multiple response tool applications to RRT (that is, division of labor, two review teams, etc.).
>
> *Enhancements*
>
> The in-situ burn checklist needs to be incorporated into the Area Contingency Plan. It's essential that the RRT identify what information to be provided in the checklist is "required" or "supplemental" to support a decision by the RRT. Use the Area Contingency Plan to prioritize application work based on acceptable response techniques within a specific geographic area. Encourage area committee members to explore preapproval response options.

The Harris County Disaster Plan was approved by the Texas Department of Public Safety on August 10, 1994, as meeting all applicable State and Federal requirements. The last Harris County disaster drill was conducted in May 1994. It simulated a natural disaster. The disaster plan was activated on October 17, in response to the flooding, and stayed in effect until the fires were extinguished on October 24. Hazardous materials training simulations had been conducted by the Harris County Office of Emergency Management in September and November 1993 and in April 1994.

One of the problems that the Harris County public safety officials identified during this accident was the need for improved emergency communication links between Harris County, the Coast Guard, and the TGLO. They recommended that a universal emergency radio band frequency be used on-scene to improve communications.

[16] A similar table-top exercise was planned to be conducted in the Houston area on November 5, 1994, and would have included most of the agencies that responded to the October 1994 emergency.

In-Situ Controlled Burning Approvals

As already stated, Texas is within the jurisdiction of RRT VI. Policies governing Region VI operations grant preapprovals for in-situ controlled burning of spills that are 3 miles or farther offshore and require that specific approval be obtained for all other proposed in-situ controlled burning. To obtain approval for an in-situ controlled burn, the Galveston Bay Area Contingency Plan (which was the plan controlling the response actions of the unified command during the October 1994 cleanup activities in Texas) requires that the FOSC consult with the Texas Air Control Board on all requests regarding in-situ controlled burns. The purpose of consultation is to provide the Air Control Board opportunity to consider potential hazards of a proposed burn based on its location relative to populated areas and on the likely harm it might do to air quality, given the expected wind speed and direction, atmospheric conditions, and other factors at the time of the proposed burn.

The in-situ controlled burn plan developed by the Region VI RRT preapproves the use of in-situ burning in offshore Gulf Coast areas by a FOSC under specified conditions, but it does not address in-situ controlled burning for near-shore, inshore, or onshore areas. However, it cautions that if :

> A deliberate burn were planned for near-shore areas, along a shoreline or riverbank, in a marsh, or onshore, the potential for secondary fires would have to be considered very carefully. The proximity of ignitable vegetation, trees, docks, and other facilities would need to be examined with respect to the initial movement of vapors (prior to ignition) and the potential movement of burning oil.

Although the plan was not applicable to in-situ controlled burns in near-shore areas, it contained (in its appendix) a checklist of information that should be considered before carrying out an in-situ controlled burn. The eight-page list included numerous weather and other factors that should be considered before performing an in-situ controlled burn, and recommended product-specific safety equipment and procedures. The last item in the list (page A-8) was a note stating that:

> If the FOSC approves of in-situ burning, local media and residents in areas within the potential smoke plume trajectory must be notified prior to initiating the burn.

Spill Response Overview

After the emergency, when the FOSC was reflecting on the events of October 23, he stated that it had become apparent to him that the policy of enhancing ongoing fires had drifted into an in-situ burn procedure without the emergency managers recognizing the transition and its ramifications. Consequently, they did not follow established in-situ controlled burn procedures. They did not develop a safety plan, put required safety controls in place, evaluate the need to evacuate adjacent residents (even though residents had been allowed to return to their homes on the morning of the burn), or give notice about the in-situ burn to local governments and private companies taking part in the response.

Immediately following this incident, neither the Coast Guard nor the EPA conducted an in-depth, comprehensive critique of the response operations to learn why established procedures were not followed relative to the in-situ burn, or to review other problems experienced. The Coast Guard and several other organizations conducted individual assessments of their activities, but no overall critique was carried out to obtain the collective feedback of the EPA, local governments, private companies, contractor groups, etc.

The FOSC stated that, because no one was injured and the burn was technically effective and the “right thing to do,” he did not aggressively pursue the matter. His only

explanation for the errors made relative to the in-situ burn was that all emergency personnel had been working 18-22 hour shifts since the flood began and that mistakes are far more likely to be made under such conditions. Overall, he believed that operations had been effective, and that few mistakes had been made during the response.

In his March 9, 1995, memorandum to the Coast Guard Commandant on lessons learned from the San Jacinto River response, the FOSC characterized the response effort as "extraordinarily successful" and provided the "lessons learned" based on comments from the various Coast Guard groups[17] that participated in the response. Among the recommendations made in response to the lessons learned, he included:

> The Commandant should specify use of a standard skeletal incident command organization nationwide to facilitate transitions from local to larger response organizations when organizational personnel are brought in from outside the area and from industry. It was found that some personnel brought in were familiar with the Incident Command System as defined in the Area Contingency Plan while others were not and the differences in command system knowledge create a degree of confusion.

(See appendix A for additional material regarding the lessons learned.)

Although the Coast Guard brought many of its commands together to critique the events of October 1994, it did not include all that participated in the response, nor all personnel who had served in management response positions. Specifically, the Pacific, Gulf, and Atlantic Strike Teams, and the Operations Section chief and Operations Division I supervisor did not participate.

On August 1, 1995, the EPA's contracted Technical Assistance Team issued its report on the "controlled burn" of October 24 (the actual date was October 23). The report stated that the burn was performed to eliminate a large pool of oil wastes and flood debris near the burned pipelines and the Rio Villa Park subdivision that was not accessible except by using a small boat. It stated that the EPA OSC requested and received permission from the FOSC to conduct an in-situ burn, and that about 7:00 p.m. (actual time was about 6:00 p.m.), the in-situ burn was initiated. The EPA reported that the burn lasted about 2 hours (actual duration was about 28 hours), was monitored throughout, self-extinguished, and affected about 0.25 acre (actually more than 15 acres). The report repeated that the event was an approved in-situ burn and acknowledged that it had not been publicly announced.

[17]The Coast Guard commands that participated in the response critique were the Marine Safety Office Houston; the Marine Safety Office Galveston; the Vessel Traffic Service Houston-Galveston, Group Galveston; the U.S. Coast Guard Cutter CLAMP; and the U.S. Coast Guard Cutter HATCHET.

The Coast Guard, in conjunction with the Research and Special Programs Administration (RSPA), conducted an Incident Specific Preparedness Review of the response to the October 1994 petroleum spills in the San Jacinto River. The report of the review was issued on July 30, 1996. It identified many aspects of the response that had been successful, such as making effective use of the unified command management process, and other features that required improvement, such as the need for the Coast Guard to have a common response management system. However, the Coast Guard review, like those conducted by the FOSC and the EPA Technical Assistance Team, did not include among those persons interviewed all who had served in key response management positions. For example, the Operations and Planning Section Chiefs—two of the Coast Guard personnel who knew most about the October 23 in-situ burn—were not interviewed. Also not interviewed were the Division I leader, the TGLO representative who had initiated the in-situ burn proposal, the EPA OSC, and management personnel from the companies that had been contracted to assist in conducting the burn.

SUPPLEMENTARY INFORMATION

The River Basin[18]

Stream Behavior -- The San Jacinto River, located just east of Houston, Texas, is a meandering, alluvial stream with a flood plain extending from the river eastward approximately 2 miles and westward approximately ¾ mile. With time, alluvial stream system banks will erode, sediments will be deposited, and flood plains, islands, and side channels will undergo modification. Alluvial channels continually change position and shape due to the water flow exerted on the streambed and banks. These changes may be gradual or rapid, and may result from natural causes or human activities.

The behavior of a stream at a specific location depends not only on the stability of the stream at that location, but on the stream system of which it is a part. Upstream and downstream changes may affect the future stability of a site. Natural disturbances, such as floods, droughts, earthquakes, forest fires, etc., may result in large changes in the quantity of sediment moved by a stream and thereby cause major changes in the stream channel. Such changes can be reflected in the buildup or reduction of a streambed due to sediment disposition or scouring, respectively. They also can be reflected in the lateral migration of the stream channel.

Human-made changes in the drainage basin and the stream channel, such as alteration of vegetation cover and construction of bridges and other structures, can alter the hydrology of a stream, its transportation of sediment, and its channel geometry. Such changes will affect the magnitude, frequency, and other characteristics of future floods.

Changes in channel geometry over time are particularly significant during periods when alluvial channels are subjected to high water. Erosive forces during periods of high water flow may have a capacity as much as 100 times greater than those acting during periods of intermediate or low flow. The full-channel flow rate in many natural channels generally occurs about every 1.5 years, during which about 90 percent of all changes in channel geometry occur.

Alluvial channels deviate from a straight alignment, causing the deepest portion of the channel to oscillate transversely. This behavior forms bends in the stream. When the current is directed toward a bank, the bank is eroded in that area, and the current is deflected and impinges on the opposite bank farther downstream. Scour in the bend causes the bank to migrate farther downstream and sometimes laterally.

As a meandering stream system moves laterally and longitudinally, meander loops move at unequal rates because the differing compositions of the banks result in differing erosion rates. Channel sections appear as slowly developing bulb forms. On highly meandering streams, elongated, bulb-shaped loops are likely to form with the narrowest land area (neck) gradually eroding until the stream cuts directly across it. The cutoff meander loop, no longer a part of the active stream channel, becomes an oxbow lake. Oxbow lakes are indicative of meandering streams but are not necessarily

[18]Information on stream characteristics, behavior, and stability was compiled from *Stream Stability at Highway Structures*, U.S. Department of Transportation, Federal Highway Administration Publication No. FHWA-IP-90-014, Hydraulic Engineering Circular No. 20, February 1991.

indicative of the channel migration rate. The cutoff of a meander loop causes a local increase in the channel slope and a more rapid growth rate of adjoining meanders. When engineers are designing structures across streams, information about the probable way the loop will migrate or develop, as well as its likely growth rate, would be useful.

Stream Stability -- The stability of a stream is dependent on a number of interrelated variables, including natural or imposed changes in a stream system, evolution of stream channel patterns, channel geometry, and watershed hydrology. Human activities can produce major changes in stream characteristics locally and throughout the stream system. All too frequently, the net result of stream "improvement" is departure from stream equilibrium. Human activities are a major cause of changes to streambeds. The most common human-caused activities that result in streambed changes are channel alteration, streambed mining, construction of dams and reservoirs, and land-use changes.

Table 1 (see next page) lists the effects of some common activities, as well as activities in the San Jacinto flood plain, that might have altered the streambed.

Pipeline Operator Survey

After the flood, the Texas Railroad Commission and the OPS surveyed operators of pipelines that cross the San Jacinto River and gathered information on the pipelines and the actions that operators took during and after the flood. Safety Board staff analyzed the surveys to learn about pipeline designs and installations within the flood plain, and actions taken by operators at the onset of and during the flood to prevent failures and product releases. Thirty pipeline operators provided information on 69 pipelines that they operated across the flood plain.

Damages --Thirty-seven of the 69 pipelines that cross the flood plain were either ruptured or undermined during the flood; 13 at river crossings only, 18 at locations within the flood plain not at crossings, and 6 in both locations. Eight of the 69 pipelines ruptured during the flood; 4 at river crossings and 4 in the flood plain.

Only 12 of the 25 operators that provided information on the design bases of their pipelines indicated that they had performed some type of study of the river crossing to augment their design decisions. (Survey responses did not include details on the types of studies performed.)

The other 13 operators cited industry codes, Federal regulations, or both as the bases of their pipeline designs. No operator indicated that it had used the American Petroleum Institute's Bulletin 1105, *Bulletin on Construction for Oil and Products Pipe Lines* (first edition, 1955) or performed a comprehensive study of the flood plain.

Spill Prevention -- Fifty of the 69 pipelines were regularly patrolled during the flood by employees in aircraft, walking the pipeline route, or stationed on either side of the flood. While the operators' efforts to patrol the flooded pipelines were reasonably uniform, their actions to minimize the potential consequences of a pipe rupture were not.

Table 1 - Effects on stream stability

Modification	General Action	Impact on San Jacinto Flood Plain
Channel Alterations	Include constrictions to maintain a navigation channel and highway crossings, both of which increase water velocities and the rate of sediment transport.	In 1940, the San Jacinto was a lazy meandering river unspoiled by development. The Lake Houston Dam was completed in 1954. The eastbound Interstate 10 bridge span was constructed in 1951–55 and the westbound bridge was built in 1971. The new U.S. Route 90 was constructed in the 1980s, and other road crossings were also constructed across the San Jacinto flood plain.
Streambed Mining for Sand and Gravel	Usual result is streambed degradation. Dam and reservoir effects on downstream stability depend on stream flow characteristics caused by stream flow regulation. Postconstruction flows during floods tend to be of lesser magnitude but longer duration. Can be beneficial or detrimental, depending on the balance between sediment supply and transport capacity.	The Corps of Engineers issued several permits over the years for streambed mining, both upstream and downstream of Banana Bend. Sand mining began in 1944 and continued up to 1989. The result was formation of lagoons along and adjacent to the streambed.
Land-Use Changes	Such changes include agricultural activities, urbanization, commercial development, and road construction, which can accelerate erosion, causing streams to overload with sediment and lowering the ground water table, resulting in subsidence. However, once an area is fully developed, the watershed becomes a low sediment producer due to the higher number of lawns and other rain-impervious areas that increase rain runoff. This reduces the time needed for runoff to reach the stream, resulting in larger quantities of water massing at a point in the watershed. The downstream effect generally is channel widening and increased stream meandering.	The change in the flood plain from rural to suburban land use began occurring gradually in the 1950s, with substantial changes occurring in the 1960s and 1970s. Open-pit sand mining in the flood plain flourished in the 1960s and 1970s, with large open-pit mining taking place in historic riverbeds and oxbows in the Banana Bend area and the oxbow that encompassed the Rio Villa Park subdivision.

On October 18, as a precaution, one operator shut down five pipelines. On October 19, an operator shut down four operating pipelines and purged them after another of its pipelines failed. A different operator shut down its pipeline because no deliveries were scheduled.

Eleven operators reported shutting down a total of 14 pipelines on October 20 for widely varying reasons; 1 shutdown was ordered after a pipeline failure, 1 after the flood damaged the operator's control system, 2 because no deliveries were scheduled, 5 as a safety precaution (with 1 operator stationing personnel at its river valves to close them should the pipe fail), and 5 in response to the Texas Railroad Commission's request to discontinue operations and purge products. Six pipelines shut down on October 20 were purged of product, and the internal pressure of a seventh was reduced substantially.

On October 21, two operators shut down seven pipelines, purged the pipelines after shutdown using nitrogen, and notified the Texas Railroad Commission of the shutdowns. On October 22, an operator shut down his pipeline after experiencing an electrical problem caused by the flood. On October 24, an operator shut down his pipeline, purged it, and installed a closure cap at the crossing, after learning that the pipeline had been undermined.

No special measures were taken during the flood for 36 of the 69 pipelines. Twenty-nine were operated throughout the flood, three contained products under pressure with no transportation being performed because no deliveries were scheduled, and three were empty of products and maintained as extra lines. Pipeline operators reported that 24 mainline valves near the river were inaccessible because they had been flooded, and 1 operator reported the loss of its SCADA[19] system because of flooding. Operators reporting the least difficulty were those whose pipelines had been "directional drilled"[20] beneath the river crossing, at elevations significantly lower than the riverbed. Even so, some operators of directionally drilled pipelines experienced erosion of the pipeline segments in the flood plain.

Factors Influencing Failures -- Safety Board staff identified each pipeline's location across the flood plain, defined six areas along the river where pipelines were likely subjected to similar forces and conditions, and looked at the pipes' construction dates; sizes, wall thicknesses, and specifications; crossing anchorages; operating and design pressures; design bases; and performance in each area. This process helped to identify common factors that might have contributed to the damages during the flood. The six areas were as follows:

Area 1 – Lake Houston Dam to Banana Bend, containing 13 pipelines: reasonably straight alluvial stream segment having banks steeper than average for this stream;

Area 2 – Banana Bend, containing 17 pipelines: meandering alluvial stream segment having lower than average banks with adjacent areas being oxbow lakes or streams likely created by previous changes in the river channel and significant areas where sand had been mined;

[19]A computerized supervisory control and data acquisition (SCADA) system. SCADA screens continually display operational data, such as product pressure and flow rates for pump stations and other locations throughout the pipeline system.

[20]Directional drilling involves the use of auger-type boring machines to drill an opening beneath a stream or road and placing either the pipe or a casing in the opening as it is being bored. Some equipment used can be guided remotely to achieve a specified depth and curvature beneath an object.

Area 3 – Banana Bend Oxbow, containing 4 pipelines: meandering alluvial stream segment having lower than average banks with adjacent areas being oxbow lakes or streams likely created by previous changes in the river channel and significant areas where sand had been mined;

Area 4 – South of oxbow to Interstate 10 bridge, containing 4 pipelines: a significant widening of the river with steeper than average banks with adjacent areas more densely populated or industrialized;

Area 5 – Near Interstate 10 bridge substructure, containing 6 pipelines: an area subject to scour as a result of the substantial reduction in effective stream width due to the Interstate 10 bridge and its substructure; and

Area 6 – Downstream of Interstate 10 bridge, containing 25 pipelines: a substantially widened stream segment with no significant downstream reductions in effective stream width.

(See figure 7 for specific siting of the six areas.)

The damage to pipes and their supports occurred all along the river south of the Lake Houston Dam; however, the major damages occurred in areas that included maximum stream meandering (Areas 2 and 3) or contained significant narrowing of the stream by a human-made obstruction (Area 5). Substantial sand mining had also been done in Areas 2 and 3.

Table 2 (see pages 30-31) reflects the findings of the Safety Board staff with respect to information obtained from pipeline operators through the pipeline survey conducted by the Texas Railroad Commission and the OPS following the 1994 San Jacinto flood.

Federal Requirements

Administration **--** RSPA, through the OPS, is responsible for developing and enforcing minimum Federal safety standards for the transportation of natural gas and hazardous liquids by pipeline. Title 49 *Code of Federal Regulations* (CFR) Parts 192 and 195 contain the primary requirements for natural gas and hazardous liquids transportation, respectively. Title 49 CFR Part 194 establishes spill prevention and response requirements applicable to operators of liquid pipelines.

Natural Gas Pipelines **--** The first Federal natural gas pipeline regulations were issued as Title 49 CFR Part 192 on November 7, 1968. The OPS adopted as Federal standards the requirements of an industry code—the *B31.8 Code for Gas Transmission and Distribution Piping Systems*. Today, many provisions of the 1968 edition of the B31.8 Code remain in the Federal minimum pipeline safety requirements.

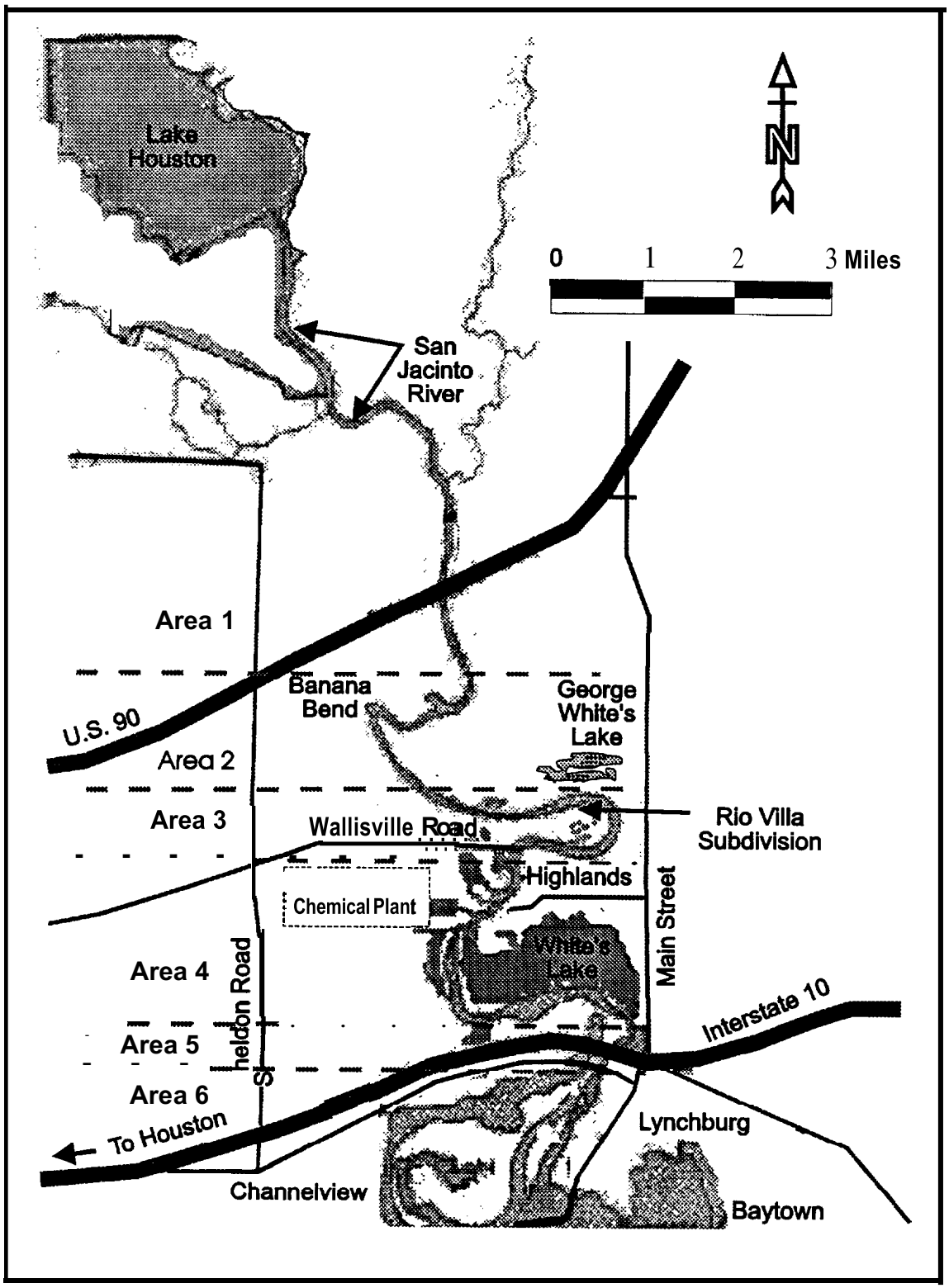


Figure 7- Six areas identified along the San Jacinto River

Table 2 – Pipeline survey findings

AREA	PIPE FAILURES		*PIPE UNDERMININGS		STUDY OF CROSSING	YEAR INSTALLED	LINE OPERATOR
	Flood Plain	Crossing	Flood Plain	Crossing			
1						1982	Midcon
1					YES	1970	Mobil
1			X (35ft.)	X (60ft.)	YES	1957	Texas Eastern
1		X		X	NO	1954	Citgo
1				X (200ft.)	NO	1958	Tejas Gas
1					YES	1947/1979	Mobil
1					YES	1982	Midcon
1					NO	1985	Midcon
1				X (110ft.)	NO	1948	Houston Pipe Line
1					YES	1979	Mobil
1					YES	1952	Midcon
1				X (85ft.)	NO	1931	Shell
1				X (25ft.)	NO	1964	Tejas Gas
2			X (240ft.)		NO	1985	Enerfin
2			X (219ft.)	X (18ft.)	NO	1957	Chevron
2					NO	1992	Enterprise
2			X (173ft.)	X (22ft.)	NO	1975	Chevron
2			X (313ft.)		YES	1971	Explorer
2					NO	1992	Enterprise
2			X (233ft.)		YES	1977	Chevron
2			X (160ft.)		NO	1977	Arco
2			X (160ft.)		YES	1975	Air Liquide
2			X (160ft.)		YES	1975	Air Liquide
2			X (134ft.)		NO	1980	Seminole
2			X (160ft.)		NO	1975	Arco
2			X (160ft.)		NO	1966	Arco
2			X (182ft.)		YES	1977	Phillips
2			X (160ft.)		NO	1966	Arco
2			X (160ft.)		NO	1975	Arco
2			X (160ft.)		NO	1975	Arco
3	X		X		NO	1952	Valero
3	X		X		NO	1948	Texaco
3	X		X		YES	1962	Colonial
3	X		X (587ft.)		YES	1979	Colonial
4						1990	Old River
4				X (20ft.)	NO	1956	Lyondell

AREA	PIPE FAILURES		*PIPE UNDERMININGS		STUDY OF CROSSING	YEAR INSTALLED	LINE OPERATOR
	Flood Plain	Crossing	Flood Plain	Crossing			
4				X (20ft.)	NO	1956	Lyondell
4						1990	Cowboy
5		X	X	X		1946	Exxon
5		X	X	X	YES	1947	Exxon
5				X (25ft.)	YES		Exxon
5				X	YES	1960	Exxon
5				X (120ft.)	YES	1960	Exxon
5		X	X	X	YES	1937	Exxon
6					NO	1987	Amoco
6					YES	1992	Praxair
6						1957	EGP Fuels
6				X (120ft.)		1948	Houston
6				X (390ft.)	NO	1952	Chevron
6					NO	1993	Chevron
6				X (120ft.)	NO	1968	Chevron
6					NO	1954	Chevron
6			X (120ft.)		NO	1970	Chevron
6					NO	1982	Midcon
6					NO	1952	Midcon
6					NO	1952	Midcon
6					NO	1952	Midcon
6						1959	EGP Fuels
6					YES	1980	Praxair
6						1952	Midcon
6					YES	1955	Channel
6						1955	ATTCO NGL
6					YES	1975	Houston L&P
6					NO	1971	Air Products
6					NO	1971	Air Products
6						1971	Air Products
6					YES		Praxair
6						1959/1980	EGP Fuels
6						1959	EGP Fuels
TOTAL	4	4	24	19	23	---	---

* The number in parenthesis is the length of the pipe undermining as provided by operators. For some pipes, the length of undermining approached or exceeded the maximum unsupported length of pipe for continued safe operation.

Design. The Federal regulations concerning pipe design include general requirements that pipelines be able to withstand anticipated external pressures and loads that will be imposed on the pipe after installation (CFR Part 192.103); mainline valves be installed at intervals ranging from 5 to 20 miles, depending on the population density along the route of the pipeline (CFR Part 192.179); pipelines be protected from washouts, floods, and other hazards that may cause them to move or to sustain abnormal loads (CFR Part 192.317); and pipe installed in a navigable river, stream, or harbor have a minimum cover of 48 inches in soil or 24 inches in consolidated rock (CFR Part 192.327). No requirement specifically addresses design of pipelines in flood plains.

Liquid Pipelines -- The first Federal liquid pipeline regulations were issued by the Federal Railroad Administration and became effective on December 31, 1967. The authority for liquid pipeline safety was later transferred to the OPS. Title 49 CFR Part 195, which now contains the minimum pipeline safety requirements governing liquid pipelines, was and continues to be based on an industry standard—the *B31.4 Code for Liquid Transportation Piping*.

Design. The regulations concerning liquid pipeline design require that pipelines be capable of withstanding anticipated external loads, such as earthquake, vibration, and thermal expansion and contraction (CFR Part 195.110); have 48 inches (18 inches in rock excavations) of cover when crossing water bodies that are 100 feet or more across (CFR Part 195.248); and have mainline valves at locations where they will minimize damage or pollution from accidental discharges, including at each side of water crossings that are more than 100 feet wide and on each side of reservoirs holding water for human consumption (CFR Part 195.260). No requirement specifically addresses the design of pipelines in flood plains.

Response Plans for Onshore Oil Pipelines -- Among other provisions, Section 4202 of Public Law 101-380 (OPA 90), states:

> The President shall issue regulations which require an owner or operator of a tank vessel or facility[21] …to prepare and submit [for review and approval] to the President a plan for responding, to the maximum extent practicable, to a worst-case discharge, and to a substantial threat of such a discharge, of oil or hazardous substance.

On October 18, 1991, by Executive Order 12777, the President delegated to the Secretary of Transportation the responsibility for complying with OPA 90 provisions as they relate to operators of onshore pipelines. Acting on behalf of the Secretary, on January 5, 1993, RSPA issued 49 CFR Part 194, *Response Plans for Onshore Oil Pipelines*.

Plan Requirements. Plan requirements apply to operators of onshore oil (natural gas, highly volatile liquids, and carbon dioxide pipelines are not included) pipelines that, because of their locations, could reasonably be expected to cause significant and substantial harm to the environment by discharging oil into or on any navigable waters or adjoining shorelines. Among other requirements, and with few exceptions, Part 194 requires operators of affected pipelines to submit to RSPA a response plan that defines the operator's planned resources for responding, to the maximum extent practicable, to a (1) worst-case discharge and (2) substantial threat of such a discharge.

Plan Approval. To assist operators in complying with the planning requirement, RSPA included appendix A to Part 194, setting forth a recommended format (including specific types of information to be included in each plan

[21] An onshore facility that, because of its location, could reasonably be expected to cause substantial harm to the environment by discharging into or on the navigable waters, adjoining shorelines, or exclusive economic zone.

section) for operators to use in preparing their plans. RSPA also met with groups of operators, provided examples of "best practices," and communicated in writing and by telephone with operators to assist them in preparing acceptable response plans.

After operators submitted response plans to RSPA, its staff and contract personnel compared the plan content against a checklist developed to assist them in quickly identifying plans that did not contain all required sections or that did not include all required information. When a plan did not pass this initial completeness check, RSPA notified the operator of the items omitted. This completeness check did not entail a specified assessment of the plan for adequacy. Plans passing the completeness check were reviewed in detail, this time using a 37-page checklist, to assess whether the plan adequately addressed required response issues, such as procedures, notifications, equipment and materials, and training. Operators of plans found unacceptable were notified of noncomplying provisions.

Plan Content. Examination by Safety Board staff of plans prepared by 10 operators, including the plans of all those operators whose pipelines failed during the 1994 San Jacinto flood, revealed that all but 1 operator conditioned the implementation of response actions on its becoming aware of an actual release of product from its pipeline. Responding to a substantial threat of a release was not addressed. The plan of one operator included plans for responding to substantial threats of discharges, and cited preparations and actions to take in the event of earthquakes, hurricanes, tornadoes, bomb threats, etc., but flooding was not included.

RSPA advised Safety Board staff that it had not informed operators during the plan development phase that their plans must include provisions on responding to events that might pose a substantial threat of pipeline discharge. RSPA staff stated that they had focused their reviews on an operator's ability to respond to an actual release of oil, and acknowledged that RSPA had not examined the plans to confirm that they contained provisions on responding to substantial threat of discharge. RSPA staff have stated that they intend, after the Safety Board issues its report on the 1994 pipeline ruptures at Houston, Texas,[22] to send a letter to all plan holders reminding them of the importance of being prepared to respond to a substantial threat of a worst-case discharge, even in the absence of an actual release. RSPA staff have also stated that RSPA will conduct a public meeting in fall 1996 to receive comments on changes required in Part 194 to meet OPA 90 requirements.

Industry Design Standards and Guidance

Gas Pipelines* -- *B31.8 Code. In 1952, the American Standards Association issued *Gas Transmission and Distribution Piping Systems* (B31.1.8-1952) as the first code applicable solely to gas piping. It contained no standards or cautions on constructing pipelines across rivers or flood plains, nor did it include information about operating and maintaining these systems while in service. (Later editions addressed flooding and washouts as hazards to pipelines and identified actions, such as increasing the pipe wall thickness, that might protect the pipe against failure.)

In 1969, the code was updated to recognize the need to anchor pipelines that are normally under water and to provide specific design attention to pipelines that may be subject to washouts due to natural hazards caused by streambed changes, channel deepening, and changes in the location of the channel in the streambed. It also recognized that the design had to be unique and based on the specific characteristics of the stream being crossed. While several editions of the code have since been issued, no significant changes to the design provisions have been made.

[22] This report.

Gas Pipe Design Manuals. *The Gas Engineers Handbook*,[23] which was first published in 1934 and went out of print in 1978, was an aid to gas engineers who were designing gas piping systems. The handbook advised that pipelines under rivers might be subjected to loads caused by bank recession, streambed scour and fill, buoyancy, drag, movements of debris and sand, and temperature changes. It recommended that designers consider the effects of river traffic and future improvements likely to be made affecting navigation and flood control and, so far as possible, to eliminate such exposures. Among other advice, the handbook stated that the designer should:

- Obtain a complete historical survey detailing movements of banks and "thalweg,"[24] determine recorded depths of scour, and review the hydrograph of the stream (the information obtained should cover a considerable distance on each side of the proposed crossing location);
- Perform soil borings along the proposed crossing location; and,
- Provide flexibility for the crossing pipe sufficient to allow it to resist subsequent forces.

The handbook provides typical cross-section and plan diagrams for stream crossings, but gives no information specific to the design of pipelines crossing flood plains.

Beginning in 1987, the American Gas Association began publication of its *Gas Engineering and Operating Practices Series* to fill the void left when the *Gas Engineers Handbook* stopped being published and to provide more current information to member gas companies on many aspects of the gas distribution, storage, and transmission business. The American Gas Association book *Transmission Pipelines/Planning and Economics* (Book T-1), published in 1989, advises operators to use weights and coatings for pipes crossing rivers and discusses general installation methods for installing river crossings, but it provides no specific design recommendations for pipelines that cross flood plains or rivers. The book advocates using directionally drilled (or bored) crossings for rivers because this method has the advantages of impacting the environment less, causing no disruption to navigation, and allowing installation of crossings from beyond levees.

Guide for Gas Transmission and Distribution Piping Systems. The Natural Gas Pipeline Safety Act became effective on August 12, 1968. This act required the Secretary of Transportation to adopt, within 3 months, interim safety standards for gas pipelines, and to establish, within 24 months, minimum Federal standards for gas pipelines. Representatives of the American Society of Mechanical Engineers discussed with the Secretary what future role its B31.8 Committee might have in pipeline safety. Based on that discussion, the society decided to form a Gas Piping Standards Committee (later renamed the Gas Piping Technical Committee) to develop and publish "how to" specifications for complying with Federal gas pipeline safety regulations.

The 1973 edition of the *Guide for Gas Transmission and Distribution Piping Systems*, as well as its current edition (1995–1998), recommends installing sufficient weights or anchorage to prevent the flotation of pipelines in areas normally under water or subject to flooding. It also cautioned that pipelines crossing rivers may be subject to washouts as a result of streambed changes, high water velocities, channel deepening, or changing of the channel location in the streambed. Because of such hazards, operators were advised to give design attention to protecting such pipelines by locating them in the more stable areas of the riverbank and bed, and that factors such as line

[23]Sponsored by the American Gas Association and published by The Industrial Press, New York, New York.

[24]The line extending down a channel that follows the lowest elevation of the streambed.

depths, pipe bend locations in the riverbanks, wall thickness, and pipe weightings be based on the individual characteristics of the river.

Liquid Pipelines -- *API Bulletin 1105.* In March 1955, the American Petroleum Institute (API) issued API Bulletin 1105, *Bulletin on Construction Practices for Oil and Products Pipe Lines*, as a tentative document. It was effective for 1 year unless approved again by the API. The API did not renew the bulletin because the guidance it contained was expected to be included in a soon-to-be developed standard on liquid pipelines (B31.4 Code).[25] The bulletin advised pipeline operators to survey each water course crossing to obtain all information needed to design the crossing. It stated that a major water crossing must be the subject of a special study to design the proper type of installation. It advised that the width of the valley and the flood plain, the height of the river's banks, the width of the streambed, and the type of soil in the area must be considered in developing crossing designs. This bulletin provided considerable guidance on designing and installing pipelines crossing water courses and flood plains.

B31.4 Code. The development of the liquid pipeline industry's pipeline code followed a pattern similar to that of the gas pipeline code. The American Standards Association B31.1.1 code served as the standard for liquid pipelines until December 13, 1966, when the American Standards Association issued the B31.4 code. Like its gas code counterpart, this code stated that its design requirements were adequate for public safety under conditions usually encountered, and it cautioned design engineers that they needed to "provide reasonable protection to prevent damage to the pipeline from unusual external conditions which may be encountered in river crossings" and other locations (paragraph 402.1). Although the API Bulletin 1105 had not been in effect since March 1956, the liquid pipeline code still referenced the bulletin. It stated that the bulletin was a guide for developing specifications and practices, and that its use would contribute to safety and sound engineering practices when constructing liquid petroleum pipelines.

The liquid piping code required that all river crossings be surveyed and profiled after construction (436.5.1 (b)(14)), that all underwater crossings be inspected for conditions that might affect the safety and security of the crossings, and that inspections be performed any time an operator felt that a crossing might be endangered by floods, storms, or suspected mechanical damage (451.5 (b)). The 1979 update of the code removed the references to API Bulletin 1105, which had not been renewed for 23 years. Other applicable code sections previously referenced have since remained unchanged.

Pipe Failures During Floods

Flooding during summer 1993 in Iowa, Missouri, and Nebraska caused significant damage to pipelines in those States, including pipeline ruptures. On April 1, 1993, in Sioux City, Iowa, a 6-inch AMOCO pipeline ruptured in the Big Sioux River due to scouring along the riverbed. Three hundred and ninety barrels of LPG were released. On July 26, 1993, a 6-inch MAPCO pipeline was exposed by scour in a creek bed and its banks, and was struck by flood debris, which caused it to rupture. The rupture resulted in the release of 2,203 bbls of anhydrous ammonia. On December 1, 1993, a 10-inch Conoco pipeline ruptured in a flooded area near Franklin, Missouri, resulting in the release of 200 bbls of gasoline.

Safety Board staff reviewed pipeline accident reports submitted to RSPA by the pipeline industry for the years 1991 through 1993 to help assess the magnitude of damages caused to pipelines and communities during intervals of flooding. During the 3-year period examined, 21 pipelines ruptured during floods; 5 were liquid pipelines (3 of which transported

[25] See following section.

highly volatile liquids), 13 were natural gas transmission pipelines, and 3 were gas distribution pipelines. The diameters of the ruptured pipelines ranged from 4 to 30 inches.

Property damages for the 5 liquid pipeline accidents were estimated by their operators to total more than $1.7 million. The 13 natural gas transmission accidents were estimated by the gas operators to have caused about $700,000 in property damages, and the 3 gas distribution operators estimated their losses to be about $9,000.[26]

After the 1993 flooding in the midwestern States, RSPA issued Advisory Bulletin ADB-93-03 to pipeline operators in those flooded areas to advise them of measures they should consider to ensure the safety of their pipelines. Among others, the bulletin contained the following suggestions for preventive actions:

- Deploy personnel so that they will be in position to take emergency actions, such as shutdown, isolation, or containment;
- Extend regulator vents and relief stacks above the level of anticipated flooding;
- Evaluate the accessibility of pipeline facilities that may be in jeopardy;
- Perform frequent patrols to evaluate right-of-way conditions at water crossings during flooding and after waters subside. Determine if flooding has exposed or undermined pipelines as a result of new river channels cut by the flooding or by erosion or scouring;
- Coordinate with emergency and spill responders on pipeline location and condition, and provide maps and other relevant information to them; and,
- Coordinate with other pipeline operators in the flood area and establish emergency response centers to act as liaison for pipeline problems and solutions.

On October 25, 1994, RSPA issued Pipeline Safety Advisory Bulletin ADB-94-05 (see appendix B), which provided observations on the flooding near Houston, Texas, and actions it believed pipeline operators should take to ensure the integrity of pipelines in case of flooding. That bulletin includes essentially the same suggestions for preventive actions as did Advisory Bulletin ADB-93-03.

Also on October 25, 1994, the RSPA Administrator stated that RSPA must determine what changes may be necessary to ensure that pipelines have the best chance possible of withstanding inevitable, but often unpredictable, natural disasters. He advised that RSPA would accelerate the completion of a pending rulemaking that would propose new requirements for hazardous liquid pipeline valves and leak detection systems. He further advised that final rules were scheduled for issuance by December 1995. Also, the Administrator stated that RSPA would perform a comprehensive study of the ability of the Nation's pipeline systems to withstand the risks posed by natural disasters. He advised that issuance of the report findings and recommendations was planned for summer 1995.

On June 7, 1995, in response to significant pipeline accidents that had been caused by natural disasters, including the flooding of the San Jacinto River near Houston, RSPA entered into an agreement with FEMA. The agreement called for FEMA to conduct a study on the design, construction, and operating methods that

[26]Based on previous Safety Board reviews of property damages reported to RSPA by pipeline operators, the total property damages reported are likely significantly less than actual losses to all parties. They also likely do not include environmental damages and losses, or losses due to community disruptions.

pipeline operators use to counter the effects of natural hazards on pipelines. In so doing, FEMA was to perform the following tasks:

1. Using the San Jacinto River basin, perform a prototype study of tasks 2 through 5 (see following) to validate the feasibility of applying the study results nationwide;
2. Provide exposure risk analysis for natural disasters, including floods, earthquakes, landslides, tornadoes, hurricanes, forest fires, and blizzards, in the Nation;
3. Provide an analysis of high consequence areas in the United States by considering deaths and fatalities, disruption of commerce, damage to environmentally sensitive areas, and damage to property;
4. Identify pipelines in geographical areas that have high exposure risk to natural disasters and high consequence. FEMA is also to develop a listing of pipeline segments, pipeline operators, commodities transported, and worst-case discharge estimates for liquid pipelines;
5. Identify 10 areas of high pipeline concentrations in the high exposure/consequence areas.

The FEMA study is still in progress. It is expected to be completed in fall 1996.

RSPA had previously contracted with Texas A&M University to provide technical engineering support with respect to pipeline research. One element of that contract had called for the university to:

> Conduct an analysis regarding the probability and the consequences of pipelines being seriously affected by natural disasters and propose potential measures to prevent leaks or spills and to mitigate the consequences of leaks and spills resulting from natural disasters.

With the issuance of the FEMA contract, RSPA revised this element of the Texas A&M contract. The revised task called for the university to:

> Analyze the potential effects of natural disasters on the physical and operating characteristics of pipelines in various geographical areas, and provide recommendations that will prevent or mitigate ruptures resulting from exposure to these events.

In making this modification, RSPA observed that:

> Safety programs for pipelines have often focused on preventing third-party and corrosion damage. While these types of events may account for the majority of serious damages to pipelines, potential catastrophic damage to pipelines due to natural disasters needs to be analyzed so that measures can be developed that would prevent or mitigate the consequences.

The report on this modified requirement of the Texas A&M contract will likely be available in fall 1996.

Tests and Research

Metallurgy -- On-site examinations of the exposed portions of the 4 pipes that ruptured in the new channel formed when the San Jacinto River cut through the oxbow (Colonial's 40- and 36-inch, Texaco's 20-inch, and Valero's 12-inch pipelines) revealed that each pipe had a buckle deformation in several areas consistent with each pipe bending southward in the direction of the water flow. Laboratory examination of the failures indicated that each pipe contained fatigue cracks emanating from multiple origins.

Riverbed Examinations -- The Texas Department of Transportation evaluated the extent of scour around the substructure of critical sections of the two Interstate 10 bridges (east- and west-bound). The results of the sonar tests performed on October 21–22, 1994, documented 12 locations in the main channel for distances up to 130 feet south of the east-bound Interstate 10 bridge.

Those tests indicated that the main channel in the area of the Exxon pipelines experienced about 10–12 feet of scour. Water velocities measured during the testing were found to be 13 feet per second—approximately 8.9 miles per hour. A previous Safety Board report[27] indicated that stream velocities of this magnitude can generate forces sufficient to move 5,000-pound rocks within a stream.

[27]Highway Accident Report--*Collapse of New York Thruway (I-90) Bridge Over The Schoharie Creek, Near Amsterdam, New York, April 5, 1987* (NTSB/HAR-88/02).

ANALYSIS

Pipeline Ruptures

Examination of four of the eight pipe failures from the San Jacinto flood plain showed that their fracture faces included fatigue cracks that had originated from multiple origins. Those pipes were uncovered and their foundations were undermined when the new channel cut through the oxbow. This situation allowed the flood waters to oscillate the unsupported pipelines and deflect them southward in the direction of the water flow. These forces caused the pipe walls to bend and buckle, creating fatigue cracks at multiple origins. The fatigue cracks continued to grow, decreasing the effective thickness of the sound pipe wall remaining, until the pipe could no longer contain the internal pressure of the gas or liquid.

Design of Pipelines in Flood Plains

The location of the pipelines within the flood plain and the design of the pipelines in this location appear to have been the most relevant factors affecting their survival. The pipelines that were ruptured or damaged most severely in the flood plain were those installed in areas where the river course meandered the most, where significant mining operations had been conducted, and where streambed scouring could be expected.[28]

Based on the information operators provided about the 21 pipelines in Areas 2 and 3, 11 were designed using only the Federal regulations and/or industry codes as the bases for their design and construction. The design bases for only 7 of the 21 included some study of the river to supplement the design and installation practices for their construction. The Safety Board concludes that the design bases of most pipelines undermined or ruptured during the flood did not include study of the flood plain to identify potential threats; rather, operators used only general design criteria applicable at the time the pipelines were installed.

Three of the four pipelines that ruptured in river crossings were operated by Exxon and were located at the Interstate 10 bridge where the river width is constricted and the streambed is subject to scour, especially during flooding. Exxon reported that it had studied the river conditions to supplement its design and installation decisions, but did not indicate performing any study of the flood plain or of the effects of scour.

After 1934 and until 1978, designers of the gas pipelines installed across the San Jacinto flood plain had the *Engineers Handbook* available to them. It advised them to develop a complete historical survey of areas where streams were to be crossed and to consider during the design process those future changes that might occur in navigation, river traffic, and flood control. Designers of liquid pipelines had the 1955 API Bulletin 1105 available to them for a brief time. The bulletin provided comprehensive guidance on designing pipeline crossings of streams and flood plains. It included explicit cautions and advice on the types of studies, tests, and historical reviews that should be performed as integral parts of the designing of pipelines crossing flood plains. Nevertheless, no San Jacinto pipeline operator cited either of these guidance documents in response to the survey questions about the design bases of their pipelines.

[28] Particularly where the river width constricted.

Had the API Bulletin 1105 been maintained as a permanent design support document, the information it contained would have raised serious reservations to designers against installing a pipeline across the San Jacinto flood plain in areas of significant stream meanders. Moreover, such information would have strongly recommended against installing a pipeline in such an area, especially since previous sand mining operations had made the route less stable. If no other cost-effective routes had been available, then extensive testing and research to define the potential safety threats and provide protection against such threats would certainly have been indicated.

If unacceptable threats of failure remained for pipe segments in the flood plain after design modifications had been made, a plan should have been developed for shutting down and purging the pipeline of product any time projected environmental conditions were likely to exceed the design limitations of the pipeline. The need to periodically reassess the forces that might be imposed on the pipeline by changes within the flood plain should also have been recognized through the use of API Bulletin 1105.

The propensity of alluvial streams to meander, to cut off oxbows during floods, and to change stream flow characteristics in response to human-made and natural changes in flood plains has been well-documented for many years. However, only the 1955 API Bulletin 1105, a tentative standard in effect for only 1 year, provided reasonable guidance on designing pipelines that cross flood plains. Other than providing general cautions about the need to protect pipelines from unusual external conditions that may be encountered in river crossings, neither Federal requirements nor other industry codes have provided guidance to designers on the types of threats posed to pipeline integrity when pipelines are located in flood plains.

Furthermore, the Federal regulations, industry codes, and present-day design and guidance manuals do not give adequate guidance to designers on the types of studies of flood plains that should be performed. Designers are not sufficiently warned of the specific hazards to pipelines, such as riverbed scour, that can occur during flooding where a channel is narrowed by obstructions like bridges. Also, current documents do not address the need for pipeline operators to monitor changes within flood plains that might increase the threat potential beyond that evaluated at the time the pipeline was designed and installed.

While multiple pipeline failures such as occurred in the San Jacinto flood plain are infrequent, individual flood-caused failures are not. No effective standards or guidance currently exist for designing pipelines that cross flood plains or river crossings. This deficiency is especially significant with respect to pipelines located near bridges and other locations where the potential for streambed scour is greatest. Consequently, such standards are needed to identify to designers the many threats posed to pipelines when crossing rivers and flood plains, and to define the types of research, study, and future design considerations that must be conducted preparatory to designing pipelines that cross flood plains.

The Safety Board concludes that standards for designing pipelines across flood plains are needed to define the multiple threats posed to pipelines and to address the research, study, and future considerations that must be used for designing pipelines and periodically reevaluating the integrity of their designs during their operating life. The Safety Board therefore believes that, with the American Petroleum Institute taking the lead in this initiative, the American Petroleum Institute, the Association of Oil Pipe Lines, and the Interstate Natural Gas Association of America should work together to develop design and construction standards adequate for pipelines to safely cross flood plains and streambeds, including the development of recommended practices for periodically reassessing crossing designs in light

of changes that have occurred in the flood plain or streambed.

Pipeline Operator Responses and Oil Spill Response Plans

The many pipeline operators affected by the flood responded to their similar failures of pipelines crossing the flood plain with considerably different strategies. On learning of the failures, a few operators elected to shut down operations, but left products under pressure and valves open in the shutdown pipelines. Some shut down operations, closed valves, and purged the pipelines of products. One operator continued operations for a time, but posted employees at valves near the river crossing to be prepared to close them should a rupture occur. Other operators continued operations as usual, though they were aware of several failures of pipelines across the San Jacinto flood plain. The Safety Board concludes that most operators of pipelines crossing the San Jacinto River flood plain continued operations without evaluating the capability of the pipeline design to withstand the threats presented by the flood. The Safety Board further concludes that few pipeline operators took effective response actions during the San Jacinto flood to minimize the potential for product releases.

Among the objectives sought by the OPA 90 requirements were for RSPA to require (1) that liquid pipeline operators identify events that pose substantial threats to pipelines that might result in product discharges, and (2) that operators have an action plan designed to minimize such threats. Had these objectives been accomplished, the responses of the liquid pipeline operators to the flood and pipe failures would likely have been reasonably uniform.

None of the RSPA-approved operator plans reviewed by Safety Board staff included information on actions that were to be implemented should a flood pose a substantial threat of discharge from a pipeline. Only one operator's plan contained any planning concerning events that might pose a substantial threat to a pipeline.

RSPA staff have acknowledged that they had failed to recognize these OPA 90 objectives and that they had not, through counseling of operators and evaluation of operator plans, checked to ensure that plans met these objectives. With respect to this accident, therefore, the Safety Board concludes that pipeline operators would have been more likely to have implemented early shutdown and/or purging of products from pipe segments crossing the San Jacinto flood plain had RSPA required them to develop plans for responding to substantial threats of a pipeline failure and product discharge.

The Safety Board recognizes that RSPA's failure to ensure accomplishment of these OPA 90 objectives was an oversight. However, it does not view as sufficient the means proposed by RSPA staff to remedy the error. RSPA must do more than send each operator a letter advising that the operator must be prepared to respond to substantial threats to its pipelines.

Recognizing potential threats to pipeline failures and developing means to remedy or minimize such threats require actions significantly different from those needed to develop product cleanup processes. Consequently, for RSPA to cause each operator to recognize and be prepared to respond to substantial threats of product discharges, it must require operators to identify events most likely to pose substantial threats to their pipelines. In so doing, each operator should be able to compare the forces that might be imposed on its pipeline, weigh those forces against the design capabilities of its pipeline, and identify locations where the potential for damage is greatest. Based on such evaluation, the operator would be able to develop action plans to remedy or minimize the identified threats.

The Safety Board believes, therefore, that RSPA must require operators of liquid pipelines to address, in their OPA 90 spill response plans,

identifying and responding to events that can pose a substantial threat of a worst-case product release. The Safety Board considers that it should be possible to have such modifications completed within a year.

Emergency Response to Pipeline Releases

The Safety Board concludes that the response by local, State, and Federal government agencies to the flood emergency was well-managed and effective. Immediately following the first Colonial pipeline rupture, the Harris County Sheriff's Department effectively coordinated the available resources. The early activation of an Incident Command System, as well as the previously conducted drills of the Harris County Disaster Plan, greatly assisted the Incident Commander in maintaining effective management of both local and Federal agencies responding to the flood and the gasoline fire. The success of these efforts was supported by the dedication of the responders, who worked tirelessly around the clock responding to human needs.

However, Colonial's inability to promptly identify the location of the rupture in its 40-inch gasoline pipeline and rapidly isolate the ruptured segment by closing remote-controlled valves unnecessarily endangered area residents. It was fortunate that a large part of the endangered areas had been evacuated earlier (due to flooding) before the pipe ruptured.

The need to improve public safety by requiring effective monitoring of pipelines and remote-controlled or automatic closing valves to rapidly detect and stop the release of hazardous materials from ruptured pipelines has been consistently addressed in Safety Board reports.[29]

In this case too, the lack of effective operational monitoring and of remote- or automatic-operated valves prevented pipeline operators from rapidly detecting and stopping the release of products, which permitted the release of large volumes of products. The pipeline ruptures and releases, and threats of additional ruptures experienced during the San Jacinto flood, further support the necessity for improvements in this regulatory area to minimize the volume of hazardous materials released when pipelines fail.

The RSPA Administrator stated on October 25, 1994, that it was essential to liquid pipeline safety that his Administration implement rulemaking on requirements for valves and leak detection systems for liquid pipelines. He further stated that such action should be completed by December 1995. However, that rulemaking action remains far from complete. The Safety Board concurs with the RSPA Administrator on the need to improve the ability to rapidly shut down failed liquid pipelines and urges RSPA to expedite completion of the rapid detection and shutdown objectives called for in Safety Recommendations P-87-22, P-91-1, and

[29]Pipeline Special Study--*Special Study of Effects of Delay in Shutting Down Failed Pipeline Systems and Methods of Providing Rapid Shutdown, December 30, 1970* (NTSB/PSS-71/01); Pipeline Accident Report--*Phillips Pipe Line Company Propane Gas Explosion, Franklin County, Missouri, December 9, 1970* (NTSB/PAR-72/01); Pipeline Accident Report--*Mid America Pipeline System Liquefied Petroleum Gas Pipeline Rupture, West Odessa, Texas, March 15, 1983* (NTSB/PAR-84/01); Pipeline Accident *Report--William's Pipe Line Company, Liquid Pipeline Rupture and Fire, Mounds View, Minnesota, July 8, 1986* (NTSB/PAR-87/01); Railroad Accident Report--*Derailment of Southern Pacific Freight Train on May 12, 1989, and Subsequent Rupture of Calnev Pipeline on May 25, 1989, San Bernardino, California* (NTSB/RAR-90/02); Pipeline Accident Report--*Liquid Propane Pipeline Rupture and Fire, Texas Eastern Products Pipeline Company, North Blenheim, New York, March 13, 1990* (NTSB/PAR-91/01); Pipeline Accident Report--*Texas Eastern Transmission Corporation Natural Gas Pipeline Explosion and Fire, Edison, New Jersey, March 23, 1994* (NTSB/PAR-95/01); and Special Investigation Report--*Evaluation of Accident Data and Federal Oversight of Petroleum Product Pipelines* (NTSB/SIR-96/02).

P-95-1.[30] (See appendix C for details concerning these recommendations.)

The Safety Board concludes that failed liquid pipelines continue to release excessive volumes of petroleum and liquid products into the environment because RSPA has not established requirements for rapid detection and shutdown of failed pipe segments, and the liquid pipeline industry has not incorporated means for rapidly detecting, locating, and shutting down failed pipe segments.

Environmental Spill Response Oversight

Overall, the spill response efforts undertaken were quite effective, due in large part to interagency coordination in both planning and implementing actions. When petroleum products spilled onto the flood waters from ruptured pipelines in the EPA's assigned inland area of responsibility and flowed into areas in the Coast Guard's assigned coastal zone of responsibility, the two agencies promptly and harmoniously resolved a potentially contentious issue on overall command of the environmental cleanup response. The two agencies' operations continued to be mutually supportive throughout the remainder of the response.

Federal, State, and local agencies and their contractors apparently worked effectively among themselves and with the pipeline operators and other private interests in responding to the pipeline failures and product spills. Improvements were needed in some areas, however, as noted by the FOSC in his March 9, 1995, memorandum critiquing the response. Among the areas noted by the FOSC as requiring improvement were communications, uniformity in incident command systems used by Coast Guard units, personnel training, fatigue countermeasures, and command and control of operations.

Communication **--** The supervisor of Division I's spill response operations, who was located remote from the unified command center, was not aware of many activities occurring in his area of responsibility because he was not kept informed of decisions made by command officials. He was not aware that the EPA OSC and his technical assistance team had been assigned to deploy booms in the area of the new channel, nor was he aware of the plan approved by the FOSC and the TGLO for installing fire booms and enhancing the in-situ burn in his area. For the supervisor of Division I to have carried out his assigned mission successfully, he should have been fully informed of those activities.

In-Situ Controlled Burn Decision -- At the time the FOSC approved the Burn Enhancement Proposal, he did not consider that what was being proposed was technically an in-situ burning. In fact, the proposal was for performing an in-situ burn, but it contained few of the features required to ensure safety during in-situ burning. The FOSC, as well as the TGLO representative who approved the burn, should have recognized that to carry out the proposal safely, it was necessary to:

- Perform several risk assessments for downwind plume monitoring;
- Prepare a detailed safety plan, describing the steps to be taken for protecting the personnel igniting and controlling the burn;
- Put adequate communication procedures in place to minimize the opportunity for incorrect or inappropriate actions; and,
- Notify area fire and police agencies in a timely fashion before conducting the in-situ burn.

Had they taken these steps, the FOSC and the TGLO representative would have learned that the Planning Section had already completed much of the research and planning work

[30] Safety Recommendation P-95-1 was reiterated earlier this year in NTSB/SIR-96/02.

necessary for approving an in-situ burning. A proper review of the proposal should have quickly identified that the proposal was not consistent with the actual conditions because there were three, not one, pipelines releasing products into the water, and because three different products—diesel fuel and gasoline, as well as crude oil—would be involved. Also, a review of the proposal should have speedily revealed that the hazards posed would be significantly different from previously conducted burns because of the site environment (onshore and residential) and because more volatile material (gasoline) would be involved. All of these differences should have been flags cautioning the FOSC of the need for greater deliberation.

Reasonable forethought did not necessarily have to have been a source of delay, but it should have provided responders with sufficient input to properly consider the proposal, to establish adequate controls to meet all requirements, to provide opportunity to inform affected leadership of the plan, and to provide controls and training on implementation to minimize errors. The FOSC's and the TGLO representative's approval of a proposal that did not contain required safeguards significantly increased the risks to those implementing the plan, as well as to the response personnel and the public. Additionally, the approvals did not comply with several requirements of the RRT's operational procedures for conducting in-situ controlled burns.

In hindsight, the in-situ burn was likely the most effective remedy measure that could have been undertaken. However, based on the foregoing facts, the Safety Board concludes that the risks to workers and the public were increased significantly when the unified command conducted an in-situ burn without having in place appropriate checks and balances to ensure that approved procedures and requirements were followed explicitly.

Fatigue --The work environment in a spill response situation calls for the most effective command and control procedures to guard against errors that may endanger responders and the public. The Safety Board recognizes that this environment is especially demanding due to the numbers of people and separate agencies and companies involved, the many hours worked each day by responders, and the constant risks faced by responders. Such environments substantially increase the opportunity for human error by fatigued workers who have worked several days without adequate rest periods. The Safety Board agrees with the FOSC that a single incident command management process should be used to ensure that all response personnel clearly understand the command structure and control functions.

Training -- Based on the FOSC's findings in the critique following the San Jacinto accident, the Safety Board concludes that spill management personnel responding from other regions of the country and trained on different incident command procedures created communications, command, and control difficulties because they were not familiar with the incident command structure and procedures in use in the Galveston Bay area.

Command and control, uniform incident command structure, and responder training were issues raised following the March 1989 accident involving the EXXON VALDEZ releasing oil after striking a reef in Prince William Sound, Alaska.[31] Since that time, the NRT has been working to improve these and other areas identified as requiring improvement. In June 1996, the NRT issued its Technical Assistance Document *Incident Command System/Unified Command.* This document provides guidance on responding to spills, regardless of the spill source or the transportation mode. The purpose of this document is:

[31]Marine Accident Report—*Grounding of U.S. Tankship EXXON VALDEZ on Bligh Reef, Prince William Sound Near Valdez, Alaska, March 24, 1989* (NTSB/MAR-90/04).

> …to educate all responders of the National Response System to the organizational management concept of Unified Command as it fits within the Incident Command System for emergency response. Unified Command is a necessary tool for effectively managing multi-jurisdictional responses to oil spills or hazardous substance releases.

The NRT states that it hopes that this document will increase awareness, improve integration and training, help develop a common language and response culture, and help achieve consistent, effective, and efficient response among National Response System members.

The Safety Board agrees with the NRT's objectives and considers that the technical document will enhance overall response preparedness. The NRT is in a uniquely advantageous position to foster achievement of the stated objectives for all spill responders. The NRT may encourage the Coast Guard and the EPA to integrate into their procedures and training of response personnel the command and control principles of the technical document and provide training to all of their personnel who may occupy management positions during a response. The Safety Board concludes that implementation of the unified incident command structure and operational principles in the NRT's Technical Assistance Document *Incident Command System/Unified Command* will enhance the overall preparedness for responding to petroleum spills. Therefore, the Safety Board believes that the NRT should motivate NRT agencies to integrate into their area contingency plans the command and control principles contained in Technical Assistance Document *Incident Command System/Unified Command* and encourage them to train all personnel assigned management responsibilities in those principles. In addition, the Safety Board believes that the NRT should include procedures for implementing its Unified Command/Incident Command System that will ensure that all safety-critical operations are coordinated with parties at risk.

After-Action Critique – Neither the FOSC's nor the joint Coast Guard/RSPA's after-action critiques were comprehensive or complete because they did not include all responding agencies and interests, nor did several key Coast Guard management personnel participate. These lapses prevented the after-action critiques from addressing and providing insight about the significant command and control deficiencies experienced during this incident. Among the deficiencies not identified by the critiques were communication problems experienced in the Operations and Planning Sections—essential units under the FOSC's command for effectively managing the spill response.

Had the after-action critiques included all agencies participating in the unified command and all personnel functioning as managers, these reports could have made known to the Coast Guard Commandant and the NRT the experiences and views of all participating agencies and organizations on actions that could have enhanced the response effectiveness. Overall critiques of the operation should have identified Harris County's and potentially other agencies' support for improving communications among participating parties, thereby strengthening the FOSC's recommendation to the Coast Guard on communication improvements. Also, the critiques should have provided opportunity for the FOSC, the EPA OSC, and the other response participants to have learned and understood the circumstances leading to the in-situ burn, which would have assisted them in identifying specific command and control improvements that, if implemented, could greatly reduce the potential for similar problems in future responses. The Safety Board therefore concludes that some lessons on improving the area's spill response preparedness were not learned primarily because a comprehensive after-action critique was not conducted.

On September 15, 1994, an amendment to 40 CFR 300.165 of the National Contingency Plan eliminated the requirement for OSCs to prepare reports for every major pollution incident. Instead, to reduce the "burden placed on OSCs and to avoid redundant paperwork," OSCs are now to prepare a report only if requested by the NRT or the RRT. The stated rationale for the amendment was that:

> The most important information contained in OSC reports – lessons learned in specific responses – is expected to be available from other material prepared by the OSC, including the pollution report and the OSC log book.

The Safety Board agrees that the lessons learned from spill responses are important findings developed from after-action critiques that should be shared with all NRT agencies and reviewed by the NRT to assess the need to modify its procedures and guidance documents. Valuable lessons can be learned from each and every response without respect to response size or complexity. Each response should be assessed by the NRT and its member agencies to help identify improvements in procedures and agency guidance.

Therefore, the Safety Board believes that the NRT should establish guidance calling for FOSCs to conduct a comprehensive after-action critique of each spill response to incorporate the observations of all participating agencies to identify improvements needed in equipment, communications procedures, guidance, techniques, and management. The Safety Board further believes that the NRT should request that FOSCs document and forward to NRT headquarters all "lessons learned" developed from after-action critiques for review and implementation nationwide as appropriate.

CONCLUSIONS

1. The design bases of most pipelines undermined or ruptured during the flood did not include study of the flood plain to identify potential threats; rather, operators used only general design criteria applicable at the time the pipelines were installed.

2. Standards for designing pipelines across flood plains are needed to define the multiple threats posed to pipelines and to address the research, study, and future considerations that must be used for designing pipelines and periodically reevaluating the integrity of their designs during their operating life.

3. Most operators of pipelines crossing the San Jacinto River flood plain continued operations without evaluating the capability of the pipeline design to withstand the threats presented by the flood.

4. Few pipeline operators took effective response actions during the San Jacinto flood to minimize the potential for product releases.

5. Pipeline operators would have been more likely to have implemented early shutdown and/or purging of products from pipe segments crossing the San Jacinto flood plain had the Research and Special Programs Administration required them to develop plans for responding to substantial threats of a pipeline failure and product discharge.

6. The response by local, State, and Federal government agencies to the flood emergency was well-managed and effective.

7. Failed liquid pipelines continue to release excessive volumes of petroleum and liquid products into the environment because the Research and Special Programs Administration has not established requirements for rapid detection and shutdown of failed pipe segments, and the liquid pipeline industry has not incorporated means for rapidly detecting, locating, and shutting down failed pipe segments.

8. Risks to workers and the public were increased significantly when the unified command conducted an in-situ burn without having in place appropriate checks and balances to ensure that approved procedures and requirements were followed explicitly.

9. Spill management personnel responding from other regions of the country and trained on different incident command procedures created communications, command, and control difficulties because they were not familiar with the incident command structure and procedures in use in the Galveston Bay area.

10. Implementation of the unified incident command structure and operational principles in the National Response Team's Technical Assistance Document *Incident Command System/Unified Command* will enhance the overall preparedness for responding to petroleum spills.

11. Some lessons on improving the area's spill response preparedness were not learned primarily because a comprehensive after-action critique was not conducted.

RECOMMENDATIONS

As a result of its investigation, the National Transportation Safety Board makes the following recommendations:

-- to the Research and Special Programs Administration:

Require operators of liquid pipelines to address, in their Oil Pollution Act of 1990 spill response plans, identifying and responding to events that can pose a substantial threat of a worst-case product release. (Class II, Priority Action) (P-96-21)

-- to the National Response Team:

Make your membership aware of the circumstances and nature of the events in the October 1994 environmental response at Houston, Texas, specifically in regard to the need for coordinating all planning and operational activities prior to conducting in-situ burn countermeasures. (Class II, Priority Action) (I-96-1)

Motivate National Response Team agencies to integrate into their area contingency plans the command and control principles contained in Technical Assistance Document *Incident Command System/Unified Command* and encourage them to train all personnel assigned management responsibilities in those principles. (Class II, Priority Action) (I-96-2)

Include procedures for implementing your Unified Command/Incident Command System that will ensure that all safety-critical operations are coordinated with parties at risk. (Class II, Priority Action) (I-96-3)

Establish guidance calling for Federal On-Scene Coordinators to conduct a comprehensive after-action critique of each spill response to incorporate the observations of all participating agencies to identify improvements needed in equipment, communications procedures, guidance, techniques, and management. (Class II, Priority Action) (I-96-4)

Request that Federal On-Scene Coordinators document and forward to National Response Team headquarters all "lessons learned" developed from after-action critiques for review and implementation nationwide as appropriate. (Class II, Priority Action) (I-96-5)

-- to the American Petroleum Institute:

Take the lead to develop, in cooperation with the Association of Oil Pipe Lines and the Interstate Natural Gas Association of America, design and construction standards adequate for pipelines to safely cross flood plains and streambeds, including the development of recommended practices for periodically reassessing crossing designs in light of changes that have occurred in the flood plain or streambed. (Class II, Priority Action) (P-96-22)

-- to the Association of Oil Pipe Lines:

Develop, in cooperation with the American Petroleum Institute and the Interstate Natural Gas Association of America, design and construction standards adequate for pipelines to safely cross flood plains and streambeds, including the development of recommended practices for periodically reassessing crossing designs in light of changes that have occurred in the flood plain or streambed. (Class II, Priority Action) (P-96-23)

-- to the Interstate Natural Gas Association of America:

Develop, in cooperation with the American Petroleum Institute and the Association of Oil Pipe Lines, design and construction standards adequate for pipelines to safely cross flood plains and streambeds, including the development of recommended practices for periodically reassessing crossing designs in light of changes that have occurred in the flood plain or streambed. (Class II, Priority Action) (P-96-24)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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September 6, 1996

APPENDIXES

APPENDIX A

Selected "Lessons Learned" Developed by the FOSC (March 1995)

CGULLS LONG REPORT

1. CGULLS Number: N/A, Submitted by Marine Safety Office Houston, Texas, LT LEONARD, COMM: (713) ..671-5171.

2. Operations surrounding the SAN JACINTO RIVER INCIDENT.

3. KEYWORDS: Incident Command System (ICS), Area Contingency Plan (ACP), Training, Key Personnel.

4. TITLE: INCIDENT COMMAND SYSTEM

5. OBSERVATION : Some personnel were familiar with the Incident Command System (as defined in the ACP), others were not. In some cases, personnel were familiar with different versions of the Incident Command System (National Fire Academy, FIRESCOPE, Phoenix Fire Department, District 11, etc.), which increased confusion to a certain degree.

6. DISCUSSION: Personnel from Marine Safety Offices Houston and Galveston were familiar with ICS as defined in the ACP through numerous exercises. In addition, MSOS Houston and Galveston had worked with several of the contractors on these exercises in an ICS environment. Personnel who augmented from outside these commands; including cutters and aviation. units; were not familiar with this type of a command and control system. "'Just-in-time' training had to be provided to assimilate them into the incident command structure. Personnel from MSO Houston served in each of the Unified Command sections as either the Section Chief or as the Assistant Section Chief (Initially, this was not true with the Planning Section, but an MSO Houston officer was quickly assigned as Section Chief). In most cases, the Section Chiefs during the flood response portion became the Assistant Section Chiefs during the busiest portions of the spill response. As the organization began to downsize, the Assistant Section Chiefs again became Section Chiefs. This permitted continuity and local area knowledge within each-section. Division Supervisors were staffed with personnel from outside the MSO Houston command due to no other MSO Houston officers or chief petty officers being available -for assignment. The three offiers assigned Division Supervisor duties performed very well and no loss of effectiveness was realized.

7. WORK-AROUND: The employment of a National Strike Force "organizational expert," nationally certified as an ICS Instructor, facilitated overall ICS operations within the Unified Command Center. This was accomplished by utilizing the ICS organizational model used by the National Strike Force.

8. RECOMMENDED ACTION:

a. Commandant should specify a standard skeletal ICS type of

organization to be employed nationwide. Commandant should consider providing the field with samples of well developed response organizations to assist Area Committees with the organizational development process. Commanding. Officers'of Marine Safety Offices should train personnel within their area of responsibility in the Incident Command System.

b. Area Committees should fully develop the organizations to be used in their areas in accordance with the standard. They should identify the individuals to fill the roles as defined in their ACP. These personnel should be identified by name or source organization. Due to the high turnover of personnel at Coast Guard units, Commanding Officers of Marine Safety Offices should ensure that All assigned officers and chief petty officers be trained as division supervisors. Officers should also be trained to fill a minimum of two other positions (such as logistics officer and operations officer). This would ensure an appropriate mix of personnel at each unit to allow for the organization to grow, stabilize, and downsize.

c. Unified Commanders should assign officers or chief petty officers from the impacted Captain of the Port Zone to serve as Division Supervisors. Assign officers from the impacted Captain of the Port Zone to serve as Section Chiefs or Assistants in the Finance, Logistics, ..Operations, and Planning sections. This would provide continuity and local area knowledge "as the organization grows, stabilizes, and downsizes.

d. "Mobility of management" should be discouraged by personnel serving as Unified Commanders--when a person is assigned to a position within the Unified Command, he/she should remain in this position unless unusual circumstances dictate otherwise. Personnel may fleet up/down as the organization grows or downsizes--this is expected. What is to be avoided is constant reorganization and assigment of new personnel to a particular position on a daily basis. Both require constant retraining and can lead to confusion.

e. A "three tiered" response structure should be developed based on:

1. Responses that can be handled at the local level.

2. Responses that require "additional resources from within the district (i.e. support from other than local units or the District Response Assist Team and Special Forces located within the district)

3. Responses that require support from outside the district's area of responsibility (i.e. resources from units, including the National Strike Force, located outside of the district, logistical support from the appropriate Maintenance and

Logistics Command, or additional Area or Headquarters assistance).

9. COMMENTS: The key to the ICS organizational structure is. that it can continue to expand as the response requires, with minimal disruption to the organization. Incoming personnel should be informed of their assignment prior to arrival. MSO Houston recently published a "Personnel Planning for Contingency Operations" letter letting District (m) ana other MSOS in. the Eighth District know which personnel at this unit are qualified to fill ICS-type positions. This will facilitate trained personnel being dispatched to an incident. Using a standard skeletal organization will help the transition tO larger response organizations when using personnel from outside the area. Also, industry response organizations will know what to expect on a nationwide basis when they become part of an Incident Command System.

CGULLS LONG REPORT

1. CGULLS Number: N/A, Submitted by Marine Safety Office Houston, Texas, LT LEONARD, COMM: .(713) 671-5171.

2. Operations surrounding the SAN JACINTO RIVER INCIDENT.

3. KEYORDS: Personnel, Hour(s), Rest.

4. TITLE: EXCESSIVE WORK HOURS

5. OBSERVATION: Many personnel, especially those in critical command positions, worked excessively long hours.

6. DISCUSSION: The San Jacinto River Incident began as an intensive, 36-hour search and rescue operation. MSO Houston and Air Station Houston together rescued or assisted 574 persons during this time. This was followed by a 22-hour period of extensive port recovery operations (channel, vessel, and bridge inspections and surveys; pollution investigation and response; wreck removal operations). While still in the port recovery phase of operations, the pipeline explosion, fire, and spill occurred. This led to another seventeen days of pollution response. The Unified Commander determined that a,12-on/12-off rotation would provide for. the best' operational control of personnel and resources. It would also allow personnel an adequate amount of rest in between shifts. This policy was not universally observed by key personnel in command and control positions. MSO Houston personnel in key command and control positions worked 20+ hour days during the first seven days, and averaged 14-18 hour days thereafter. Additionally, these personnel 'took only one day off during this nineteen day period (though more days off would have been granted if requested). In at least five instances, officers were~directed to take a day off. Though there was no recognized loss of effectiveness, the decision-making capability of these individuals could have been impaired and stress or safety related problems could have occurred. " COMDTINST M3010.12B', the Contingency Preparedness"and Planning Manual, Volume II "(referencing COMDTINST M5312.llA, the Coast Guard Staffing .Standards Manual) provides workweek planning factors, which were exceeded by the majority of personnel involved in the San Jacinto River Incident. COMDTINST M3010.12B leads one to believe that personnel will work a 40-68 hour work week during contingency operations. This is probably unrealistic, especially prior to any augmenting forces arriving as certain missions still need to be performed. Additionally, senior personnel are reluctant to take time off and depart the command center for fear of being "out of touch" before the situation is under control.

7. WORK-AROUND: The Unified Commander determined that a 12-on/12-off rotation would provide for the best operational control

of personnel and resources and also allow personnel an adequate amount of rest in between shifts. This rotation was not followed by key personnel who continued to work 100+ hour weeks for three straight weeks with minimal rest

8. RECOMMENDED ACTION:

Commandant should publish clearer guidelines than those delineated in COMDTINST M3010.12B. Those provided for aviators in COMDTINST M3710.1C may be used as an example. Leaders must set the example by ensuring their subordinates follow these guidelines

b. All personnel in leadership positions must be cognizant of the amount of time their subordinates are working, especially in an environment as stressful as experienced during the San Jacinto River Incident. They must ensure that their personnel are receiving an adequate amount of rest away from the work site. In addition, these supervisors must also look at their own work hours, and ensure that they too get adequate rest away from the work site.

b. If the command center is relocated to a location more than a one hour drive from the normal worksite (as happened during this incident due to bridge closures and enhanced traffic congestion),the Logistics Section of the Unified command should procure hotel rooms or similar accommodations closer to the new command center. This would assist all individuals in receiving adequate rest.

9. (U) COMMENTS: None.

CGULLS LONG REPORT

1. CGULLS Number: N/A, Submitted by Marine Safety Office Houston., Texas, "LT LEONARD; COMM: (713) 671-5171;

2. Operations surrounding the SAN JACINTO RIVER INCIDENT.

3. KEYWORDS : Coast Guardsmen, Operations Section, Division Supervisors, Foremen.

4. TITLE: SUPERVISORY PERSONNEL

5. OBSERVATION: Coast Guardsmen assigned to cutters, boat crews, helicopters, and operational field divisions received conflicting guidance and orders from the Unified Command Center (Operations Section), Division Supervisors (Coast Guard officers), and civilian foremen (from contractors).

5. DISCUSSION

a. One cutter was given instructions from the Operations Section of the Unified Command to deploy the VOSS. The foreman from a nearby civilian contractor recommended they not deploy the VOSS due to the swift currents and called. District Eight for confirmation.. 3District. agreed with. the foreman. The Operations Section later contacted-the cutter to ask "why the VOSS was' not deployed. After explaining their reasons, they were again directed to deploy the VOSS.

b. In another similar incident, one cutter was directed by an operational Coast Guard unit to stop its current mission, assigned by the Operations Section, and proceed on another mission. The Division Supervisor then asked the vessel where it was going and was informed that it had 'a different mission to complete.

c. In several instances, . helicopters were redirected from their assigned missions (skimmer control, aerial surveys, etc.) to conduct overflights for Division Supervisors or contractor foremen. Very rarely was. this change in mission communicated. to the Operations Section.

In all of the above instances, these redirected resources were not utilized in the manner specified by the Unified Commander (through his Operations Section).

7. WORK-AROUND : On a daily basis, the Operations and Logistics Sections spent a great deal of time trying to determine the location and mission of resources that had been redirected. At one point, the Operations Section had to give orders to individual assets in order to ensure the Unified Commander's plan was followed. Not only did this cost money and time, but it was

frustrating for the crews who had to endure these conflicting orders.

8. RECOMMENDED ACTION:

a. Unified Commanders must explain that, except for reasons of safety, all mission changes should be directed by the Unified Commander or the operations Section. Division Supervisors may modify missions within their area of responsibility, but must inform the Operations Section as soon as practicable.

b. Commanding Officers of Marine Safety Offices should conduct training for senior Coast Guard personnel and contractors on the incident command system. Ensure personnel assigned to key position know and understand their role in the "big picture." Practice the incident command system in exercises.

c. Unified Commanders need to ensure organizational liaison officers are present in the Unified Command Center who represent all parries (Coast Guard, governmental agencies, contractors? and responsible parties) to assist in resolving conflicts.

d. Unified Commanders must emphasize the need to "pass the word", to all personnel who maybe affected by mission changes. Organizational liaisons. can facilitate this.

9. COMMENTS: None.

APPENDIX B

Pipeline Safety Advisory Bulletin ADB-94-05; Pipelines Affected by Flooding

[Federal Register: November 3, 1994]

DEPARTMENT OF TRANSPORTATION

Research and Special Programs Administration

Pipeline Safety Advisory Bulletin ADB-94-05; Pipelines Affected by Flooding

AGENCY: Research and Special Programs Administration (RSPA), DOT.

ACTION: Advisory to each owner or operator of a hazardous liquid or natural gas transmission pipeline operating in areas that may be subject to severe flooding.

Summary: This advisory is for all operators of pipelines which may be affected by flooding. It provides observations from RSPA, Texas Railroad Commission (TRC), and other federal and state agencies as a result of the recent floods near Houston. This advisory also includes actions that operators should consider taking to assure the integrity of pipelines in case of flooding.

Background: As the result of unprecedented flooding of rivers and streams in the Houston area, seven natural gas and hazardous liquid pipelines failed in or near the San Jacinto River over the three day period October 19-21, 1994. These failures included: an Exxon 8-inch diameter LPG line; an Exxon 8-inch diameter fuel line; an Exxon 20-inch diameter hazardous liquid line; a Colonial 40-inch diameter products (gasoline) line; a Colonial 36-inch diameter products (heating oil) line; a Texaco 20-inch diameter crude oil line; and a Valero 12-inch diameter natural gas line. While no determination of cause of failure has been made for any of these lines, RSPA and the TRC believe that the extreme flooding by the San Jacinto River was probably a substantial contributing factor in each of the failures.

The damage to pipelines caused by the flood may have resulted either from the extreme force of the flowing water, as the San Jacinto carved new temporary channels, or from pipelines being struck by heavy debris that was reported as having flowed down river at the height of the flooding. Because RSPA and the TRC cannot at this time determine the exact effects of the flooding, operators should consider the potential effects of flooding as posing a possible threat to the integrity of their lines.

Advisory: As the result of seven natural gas and hazardous liquid pipeline flood-related failures in or near the San Jacinto River in Texas on October 19-21, 1994, operators should consider the actions recommended in this Advisory Bulletin for application to pipelines located in any area of the United States subject to widespread flooding.

RSPA pipeline safety regulations in 49 CFR 192.613 for natural gas pipelines, and 49 CFR 195.401 for hazardous liquid pipelines, require an operator to maintain continuing surveillance of its facilities and to correct damage to its pipeline that could affect the safe operation of the pipeline (such as damage that may result from extreme flood conditions). If the operator of a natural gas pipeline determines that the pipeline is in unsatisfactory condition and no immediate hazard exists, the operator must recondition or phase out the segment involved, or reduce the maximum allowable operating pressure. For hazardous liquid pipelines, if the condition presents an immediate hazard to persons or property, the operator may not operate the affected part of the system until the unsafe condition is corrected. In summary, if the operator has reason to believe that flooding has adversely affected, or will adversely affect, its pipeline, the operator must take corrective or preventative action.

In addition, operators must consider the application of RSPA's reporting requirements in 49 CFR Part 191, and subpart B of 49 CFR Part 195, as well as applicable state requirements, that require operators to submit telephonic and written reports when natural gas or hazardous liquids are released causing damages meeting the reporting thresholds. Finally, RSPA regulations also require operators to submit reports of safety-related conditions involving potentially unsafe conditions on natural gas and hazardous liquid pipelines (49 CFR 191.23 and 191.25, and 49 CFR 195.55 and 195.56). Operators need to direct their resources in a manner that will enable them to determine the potential effects of the flooding on their systems, and take the following actions as appropriate:

- Deploy personnel so that they will be in position to take emergency actions, such as shut down, isolation, or containment.
- Extend regulator vents and relief stacks above the level of anticipated flooding, as appropriate.
- Evaluate the accessibility of pipeline facilities that may be in jeopardy, such as valve settings, needed to isolate water crossings or other sections of a pipeline.
- Perform frequent patrols, including overflights as appropriate, to evaluate right-of-way conditions at water crossings during flooding and after waters subside. Determine if flooding has exposed or undermined pipelines as a result of new river channels cut by the flooding or by erosion or scouring.
- Coordinate with emergency and spill responders on pipeline location and condition, and provide maps and other relevant information to them.

- Coordinate with other pipeline operators in the flood area and establish emergency response centers to act as liaison for pipeline problems and solutions.

- Determine if facilities which are normally above ground (e.g., valves, regulators, relief sets, etc.) have become submerged and are in danger of being struck by vessels or debris; if possible, such facilities may be marked with an appropriate buoy with Coast Guard approval.

- Perform surveys to determine the depth of cover over pipelines and the condition of any exposed pipelines, such as those crossing scour holes. Where appropriate, surveys of underwater pipe should include the use of visual inspection by divers or instrumented detection. Information gathered by these surveys should be shared with landowners. Agricultural agencies may help to inform farmers of the potential hazard from reduced cover over pipelines.

- Assure that line markers are still in place or are replaced in a timely manner, and notify contractors, highway departments, and others involved in post-flood restoration activities of the presence of pipelines and the risks posed by reduced cover.

If a pipeline operator has suffered damage to its line, or has shut in the line, or has operated at a reduced pressure as a precautionary measure during the flood, the operator should advise the State Pipeline Safety Office (for intrastate lines), or RSPA's Regional Pipeline Safety Office (interstate lines) prior to returning the line to service, on increasing the operating pressure, or otherwise changing the operating status of the line. The State Safety Division or the RSPA Regional Pipeline Safety Office, as appropriate, will advise on a case- by-case basis whether, and under what conditions, a line can safely be returned to full service.

Issued in Washington, D.C. on October 28, 1994. George W. Tenley, Jr., Associate Administrator for Pipeline Safety. [FR Doc. 94-27227; Filed 11-2-94; 8:45 am] BILLING CODE 4910-60-P.

APPENDIX C

Safety Recommendations P-87-22, P-91-1, and P-95-1

Safety Recommendation P-87-22

As noted in the Edison, New Jersey, pipeline accident report,[1] the National Transportation Safety Board began in 1970 to address the need for rapid shutdown of failed pipe segments. The Safety Board identified the need to require automatic control valves and/or remote control valves to facilitate rapid shutdown of failed pipelines in five accident investigations dating back to 1970.[2] As a result of its investigation of the 1986 Mounds View, Minnesota, accident,[3] the Safety Board recommended that RSPA:

> P-87-22
>
> Require the installation of remote-operated valves on pipelines that transport hazardous liquids, and base the spacing of remote-operated valves on the population at risk.

To date, RSPA has not implemented any requirements for automatic control valves or remote control valves as means of achieving rapid shutdown of failed pipeline segments. Safety Recommendation P-87-22, which was classified "Closed—Unacceptable Action/Superseded" on February 7, 1995, was superseded by Safety Recommendation P-95-1, which is detailed below.

Safety Recommendation P-91-1

The Safety Board has repeatedly issued recommendations addressing pipeline monitoring and leak detection and the use of remotely operated or automatic valves as methods to achieve a rapid shutdown of failed pipeline segments, to isolate the failed pipeline segments, and to limit

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[1]Pipeline Accident Report--*Texas Eastern Transmission Corporation Natural Gas Pipeline Explosion and Fire, Edison, New Jersey, March 23, 1994* (NTSB/PAR-95/01).

[2]Pipeline Special Study--*Special Study of Effects of Delay in Shutting Down Failed Pipeline Systems and Methods of Providing Rapid Shutdown, December 30, 1970* (NTSB/PSS-71/01); Pipeline Accident Report--*Phillips Pipe Line Company Propane Gas Explosion, Franklin County, Missouri, December 9, 1970* (NTSB/PAR-72/01); Pipeline Accident Report--*Mid America Pipeline System Liquefied Petroleum Gas Pipeline Rupture, West Odessa, Texas, March 15, 1983* (NTSB/PAR-84/01); Pipeline Accident Report--*Williams Pipe Line Company, Liquid Pipeline Rupture and Fire, Mounds View, Minnesota, July 8, 1986* (NTSB/PAR-87/01); Railroad Accident Report--*Derailment of Southern Pacific Freight Train on May 12, 1989, and Subsequent Rupture of Calnev Petroleum Pipeline on May 25, 1989, San Bernardino, California* (NTSB/RAR-90/02); Pipeline Accident Report--*Liquid Propane Pipeline Rupture and Fire, Texas Eastern Products Pipeline Company, North Blenheim, New York, March 13, 1990* (NTSB/PAR-91/01).

[3]NTSB/PAR-87/01.

the release of product from the pipeline. In its 1991 report on the pipeline accident at North Blenheim, New York,[4] the Safety Board recommended that RSPA:

> P-91-1
>
> Define the operating parameters that must be monitored by pipeline operators to detect abnormal operations and establish performance standards that must be met to detect and locate leaks.

In response to this recommendation, RSPA committed to undertake a 2-year study to determine whether SCADA systems and SCADA-based leak detection systems should be required on gas and hazardous liquid pipelines.

In May 1992, RSPA contracted with the Volpe National Transportation Systems Center (Volpe) to analyze SCADA systems and computer-generated leak detection systems to determine (1) the feasibility and costs of requiring operators to use SCADA systems with a leak detection subsystem and, (2) the existing impediments or needed improvements to minimize the time that SCADA systems require to detect and locate leaks. The study was also to recommend resolutions for identified difficulties. On August 31, 1992, the Safety Board classified Safety Recommendation P-91-1 "Open-Acceptable Response."

The Volpe study was completed in September 1995,[5] and it indicated that a SCADA or leak detection system "can be found to suit most pipeline environments." It further stated,

> Field instruments coupled with a telephone line and a personal computer can, in most cases, provide the pipeline operator with reliable status information on the pipeline. Implementation of a system, including dispatcher training, can allow almost any pipeline operator to conduct effective rupture detection.

Safety Recommendation P-95-1

Between 1987 and 1992, RSPA conducted research studies and published several proposed rules in response to Safety Board recommendations and Congressional proposals. The Pipeline Safety Act of 1992 (Public Law 102-508) mandated that RSPA complete a study on emergency flow restricting devices for hazardous liquid pipelines by October 1994 and issue a final rule by October 1996. Under this act, RSPA's study was to assess the effectiveness of emergency flow restricting devices (including remote control valves and check valves) and equipment used to detect and locate pipeline ruptures and minimize product releases from pipeline facilities.

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[4]NTSB/PAR-91/01.

[5]Sherry Smith Borener, et al. *Remote Control Spill Reduction Technology: A Survey and Analysis of Applications for Liquid Pipeline Systems*, U.S. Department of Transportation (Cambridge, Massachusetts: Volpe National Transportation Systems Center, 1995).

On January 19, 1994, RSPA issued an advance notice of proposed rulemaking (Docket No. PS-133, 59 FR 2802) soliciting comments on a series of questions on emergency flow restricting devices and leak detection systems to assist it in developing requirements. RSPA stated that responses received by April 19, 1994, would be used in developing a rulemaking proposal. RSPA further stated that it had been concerned for some time with rapid leak detection on hazardous liquid pipelines and the optimum placement of emergency flow restricting devices. In the advance notice of proposed rulemaking, RSPA reviewed its actions on this issue since 1978, including its March 1991 publication of the *Emergency Flow Restricting Devices Study*. RSPA further indicated that it was soliciting information and data by posing a series of questions, rather than conducting a traditional research survey of a selected number of respondents, so that it could obtain a broader base of data and accelerate the regulatory process.

In the 1995 Edison report,[6] the Safety Board stated its belief that RSPA's 1991 *Emergency Flow Restricting Devices Study* was seriously flawed and caused the Congress, in Public Law 102-508, to inappropriately limit considerations of emergency flow restricting devices to hazardous liquid pipelines. The Safety Board also noted that its review of RSPA's 1991 study and the Edison accident clearly demonstrated that RSPA needed to reconsider its actions on using remote control valves and automatic control valves as main line valves to promptly limit the flow of natural gas to failed pipeline segments, especially in urban or environmentally sensitive areas. To that end, the Safety Board classified Safety Recommendation P-87-22 "Closed-Unacceptable Action/Superseded" and recommended that RSPA:

> P-95-1
>
> Expedite requirements for installing automatic- or remote-operated mainline valves on high pressure pipelines in urban and environmentally sensitive areas to provide for rapid shutdown of failed pipeline segments.

In a May 12, 1995, response to Safety Recommendation P-95-1, RSPA stated that it intended to publish a notice of proposed rulemaking in fall 1995 that would specify those circumstances under which operators of hazardous liquid pipelines would be required to use emergency flow restricting devices. The Safety Board classified the recommendation "Open-Acceptable Response." The Safety Board reiterated Safety Recommendation P-95-1 to RSPA in early 1996.[7]

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[6]NTSB/PAR-95/01.

[7]Special Investigation Report--*Evaluation of Accident Data and Federal Oversight of Petroleum Product Pipelines* (NTSB/SIR-96/02).

GLOSSARY OF ACRONYMS

API	American Petroleum Institute
CFR	Code of Federal Regulations
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Administration
FOSC	Federal On-Scene Coordinator
LPG	Liquefied Petroleum Gas
NRS	National Response System
NRT	National Response Team
OPA 90	Oil Pollution Act of 1990
OSC	On-Scene Coordinator
OPS	Office of Pipeline Safety/ Research and Special Programs Administration
RSPA	Research and Special Programs Administration, U.S. Department of Transportation
RRT	Regional Response Team
SCADA	Supervisory Control and Data Acquisition
TGLO	Texas General Land Office
USGS	U.S. Geological Survey