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Disaster Research Center

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SAN BRUNO CALIFORNIA, SEPTEMBER 9, 2010 GAS PIPELINE EXPLOSION AND FIRE

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ABSTRACT

On September 9, 2010 a buried high pressure 30-inch steel natural gas pipeline exploded in a residential neighborhood in the City of San Bruno, California, a suburb of San Francisco. The explosion and ensuing fire killed 8 and injured 58, and destroyed 38 and damaged 70 homes. During the first 50 hours following the incident, over 500 firefighters and 90 apparatus responded, involving 42 fire agencies. The total cost of the disaster is estimated to be approximately $1.6 billion. Local and regional jurisdictions have been engaged in extensive and sophisticated recovery and reconstruction operations, which continue as of this writing.

This report, funded by the National Science Foundation under a RAPID grant, is based on site visits, interviews, and secondary data collection, and addresses emergency response and recovery from two perspectives—engineering and social science. Causes of the explosion were examined by the National Transportation Safety Board and are not considered in detail. Semi-structured interviews were conducted with public officials of the principal fire and emergency services and with representatives of non-profit organizations active in the area. Team members made several site visits from immediately after the event in September 2010 to February 2011.

Key findings and research issues identified include the following. First, there are difficult theoretical and practical questions about the ability of infrastructure organizations to maintain their attention on their own operations over long periods, resulting in degrading safety and reliability. Second, there are similarities between this isolated event and what may occur in a major earthquake in the San Francisco Bay Area. This event was well responded to; in a major earthquake, similar resources are likely to be unavailable, potentially leading to significant secondary (i.e., fire following earthquake) losses. Third, three current engineering risk methods for estimation of safety zones around gas transmission lines were examined and generally validated vis-à-vis data from the incident. Fourth, detailed timelines and actions by emergency responders and recovery officials are recorded, providing a basis for future research on issues of expedient or spontaneous planning in emergencies. Fifth, a georeferenced database of almost 300 photographs of damage resulting from the incident is appended to the report, for use by researchers in examining fire spread and other issues.

ACKNOWLEDGEMENTS

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Cover Photos:
Top Right: San Bruno Fire Department. *San Bruno Pipeline Explosion.* From Google Images. JPG, http://www.paintsquare.com/news/?fuseaction=view&id=7831 (accessed July 18, 2012)
Bottom Left: Courtesy Charles Scawthorn

EDITOR'S NOTE

This report was substantially completed as of August 2011, and most of the report is from the perspective of that point in time. Final editing occurred in May 2012, and a few comments and data are written as of that point in time.

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1. INTRODUCTION

1.1. Introduction

At 6:11 pm PDT September 9, 2010 a 30-inch steel natural gas pipeline termed Line 132 and owned by Pacific Gas & Electric (PG&E) exploded in flames near the intersection of Glenview Drive and Earl Avenue, in the Crestmoor residential neighborhood of the City of San Bruno, California, a suburb of San Francisco approximately 3.2 km (2 mile) west of the San Francisco International Airport (Figure 1).

The cause of the explosion was initially unknown and, given the loud roar and shaking, for over an hour some residents of the area, first responders, and news media initially believed that it was an earthquake or that an airplane from nearby San Francisco International Airport had crashed (Figure 1). It took crews nearly an hour to determine it was a gas pipeline explosion, 1.5 hours to isolate the ruptured section of pipeline, and more than five hours to shut off pressures in all the pipelines involved (NTSB 2011g).

The rupture created a crater approximately 22 m (72 ft) long by 8 m (26 ft) wide at the intersection of Earl Avenue and Glenview Drive (Figure 3, and Figure 8). A pipe segment approximately 8.5 m (28 ft) long was found about 30.5 m (100 ft) south of the crater. PG&E estimated that 1.35 million m^3 (47.6 million standard cubic ft) of natural gas were released as a result of the rupture. Nearby damaged utilities included a 0.152 m (6 in) cast iron water main, a 0.254 m (10 in) sanitary sewer line and 0.102 m (4 inch) gas distribution line (NTSB 2011b).

The released natural gas was ignited very shortly after the rupture. Eight people died and a total of 58 were injured (ten seriously), and many more were evacuated from the area. The resulting fire also destroyed 38 homes and damaged 70 (NTSB 2011g). Figure 4 shows an aerial view one year before the incident. Figure 5 shows the damage to the surrounding houses, vehicles, and land extending approximately 180 m (600 ft) from the blast center with most of the damage radiating out in a northeast direction away from the center of the crater (NTSB 2011a). Figure 6 provides a close up of some of the damage.

Eyewitnesses reported the initial blast caused a fireball that “shot more than 1000 feet in the air” but which then quickly subsided to flames “as high as 100 feet” (Fox News 2010). Wind

hampered firefighting efforts. There were reportedly numerous reports of the “smell of gas” in the days prior to the explosion. Many fire departments (e.g., San Bruno, Millbrae, Daly City, San Francisco, South San Francisco) responded to the incident. PG&E shares fell 8% on the Friday after the explosion reducing the company's market capital by $1.57 billion. The incident was the subject of a National Transportation Safety Board (NTSB) investigation (NTSB 2011g) as well as an Independent Panel Review by the California Public Utilities Commission (IPR 2011).

Figure 1. (a) San Francisco peninsula and (b) incident location in inset

Figure 2 Gas explosion crater (C. Scawthorn)

Figure 3 Aerial photo of the affected development in 2009

Figure 4 Area of damage (NTSB 2011a)

Figure 5 Houses and vehicles destroyed (C. Scawthorn)

In this report, we document what happened and analyze the radiation effects of the fire and the multi-organizational response to the incident. The cause of the explosion is covered in detail by the NTSB investigation and is not the focus of this report, though we do consider its implications.

1.2. Data collection

Three types of data collection were conducted for this analysis: (1) site visits, (2) interviews, and (3) secondary data collection. Semi-structured interviews were conducted with fire and emergency services personnel as well as public officials and representatives of non-profit organizations active in the area. Most of the interviews took place in person in February 2011, but some follow up interviews were conducted by phone. Most interviews were recorded and transcribed. Human subjects approval was secured as required through the Institutional Review Boards at the University of Delaware and the University of North Texas.

Team members made several site visits from immediately after the event in September 2010 to February 2011. With the cooperation of the San Bruno and San Francisco Fire Departments, one of the authors twice visited the site within days following the explosion and took more than 300 geo-referenced photos of the damage. Team members made two other trips to the area in February 2011 to talk to the personnel involved in the immediate response to the incident and in subsequent recovery efforts and to gather additional data on what had happened.

Relevant secondary reports and data were also collected from a variety of sources. In particular, the NTSB investigation produced many reports with useful information, including a fire scene report and site photos, many interview transcripts, an event timeline report from PG&E, a fire department report and communication transcripts, pipeline maps from PG&E, the survival factors chairman's factual report, and public hearing transcripts (NTSB 2011a to 2011f).

1.3. Outline of report

Following a description of the context in which the gas explosion and fire took place in Chapter 2, Chapter 3 summarizes the incident. Chapters 4 and 5 provide engineering and management analyses of the event, respectively, and Chapter 6 summarizes the key implications.

Figure 6 Site (a) before and (b) after explosion with crater's approximate upper (yellow) and lower (orange) outline

2. PHYSICAL, SOCIAL, AND ORGANIZATIONAL CONTEXT OF THE INCIDENT

2.1. Geography of the City of San Bruno

San Bruno is an incorporated city located on the San Francisco Peninsula 19 km (12 mi) south of San Francisco and adjacent to the San Francisco International Airport (Figure 7). The total land area of San Bruno is 16.6 sq km (6.4 sq mi). Prevailing winds in San Bruno are northwest at about 4.7 m/s (10.5 mph). On average, temperatures are 48◦F to 65◦F. The average annual rainfall is approximately 50.1 cm (19.71 in) with humidity ranging from 83% at 4 am to 62% at 4 pm. Average barometric pressure is 1016.3 millibars (City of San Bruno 2011). On the day of the incident in the several hours following the explosion, based on data from a Citizen Weather Observers Program (APRSWXNET) station in Daly City (ID: AS072) about 8 km (5 miles) north of the accident site at an elevation of 177 m (581 ft), the wind was northerly and northeasterly, with wind gusts to near 12 knots (NTSB 2011e). From 6:01 pm to 11:54 pm (PDT), the relative humidity increased from 55% to 89% and the temperature dropped from 57◦F to 53◦F (NTSB 2011e).

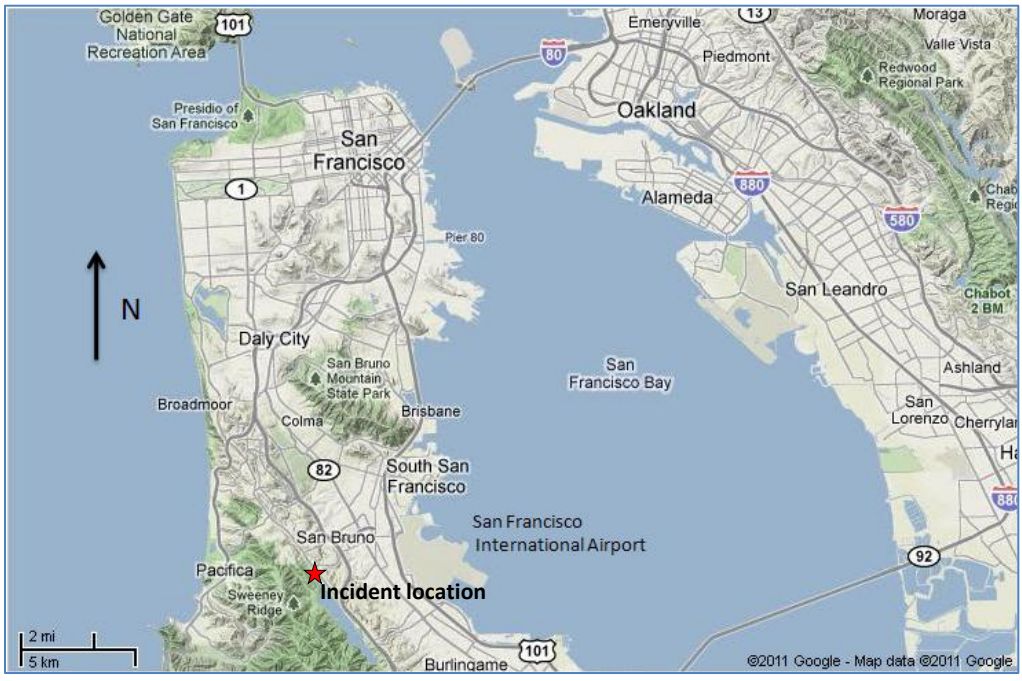


Figure 7 San Bruno, CA. Red star marks the incident location

Topographically, the city may be divided into two parts—flat in the east and hilly in the west, with the elevation varying from 4 m (12 ft) near the Bay to 266 m (875 ft) on the Western side (City of San Bruno 2011). The explosion was located at an elevation of 116 m (382 ft.), marked in Figure 8, 9 and 10 by a red star, and is at or very near a low point of Glenview Drive where it crosses the upper portion of Crestmoor Canyon.

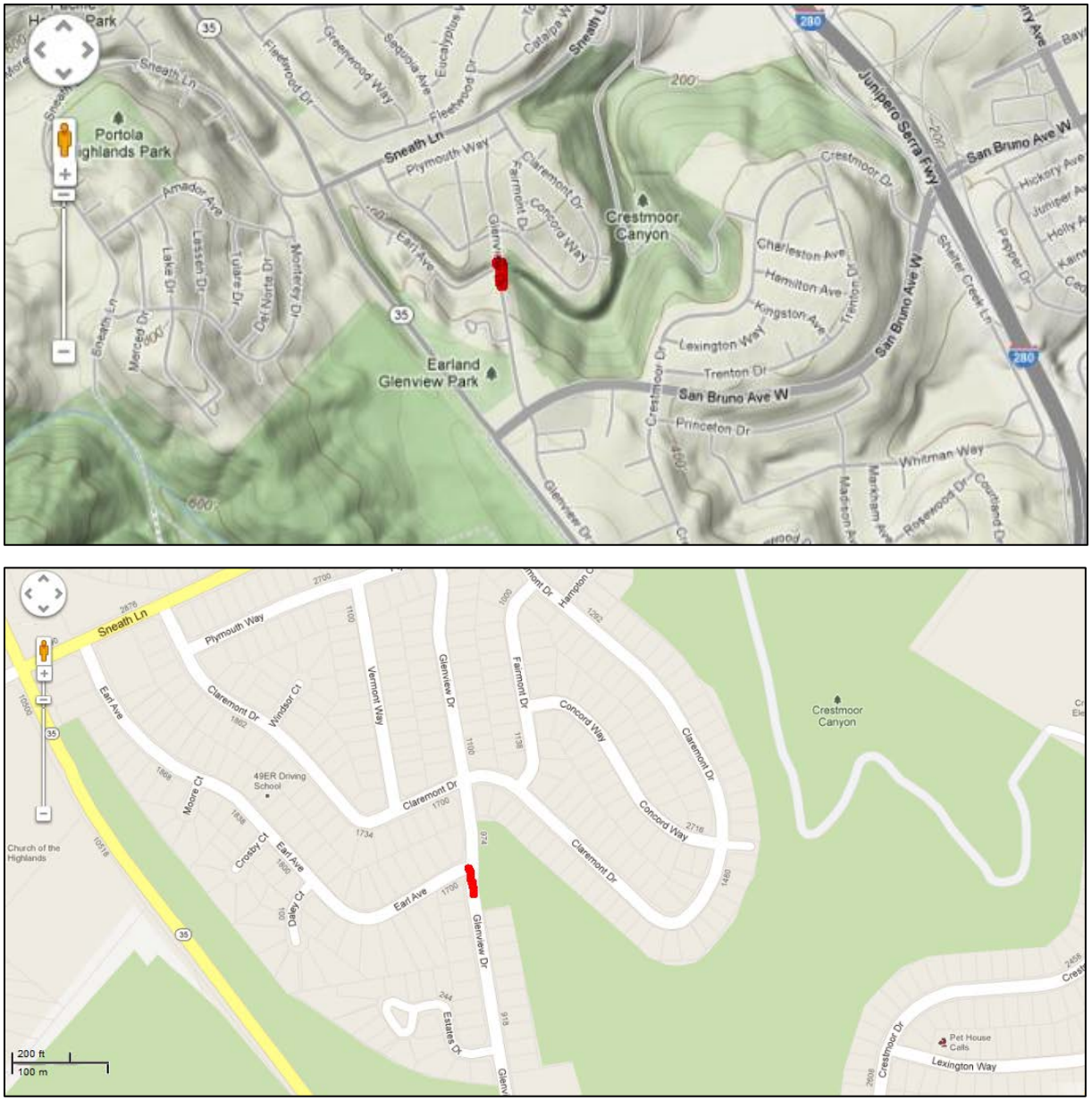


Figure 8 . Location topography and streets (Red dot marks site of explosion) (Base source: Google Maps)

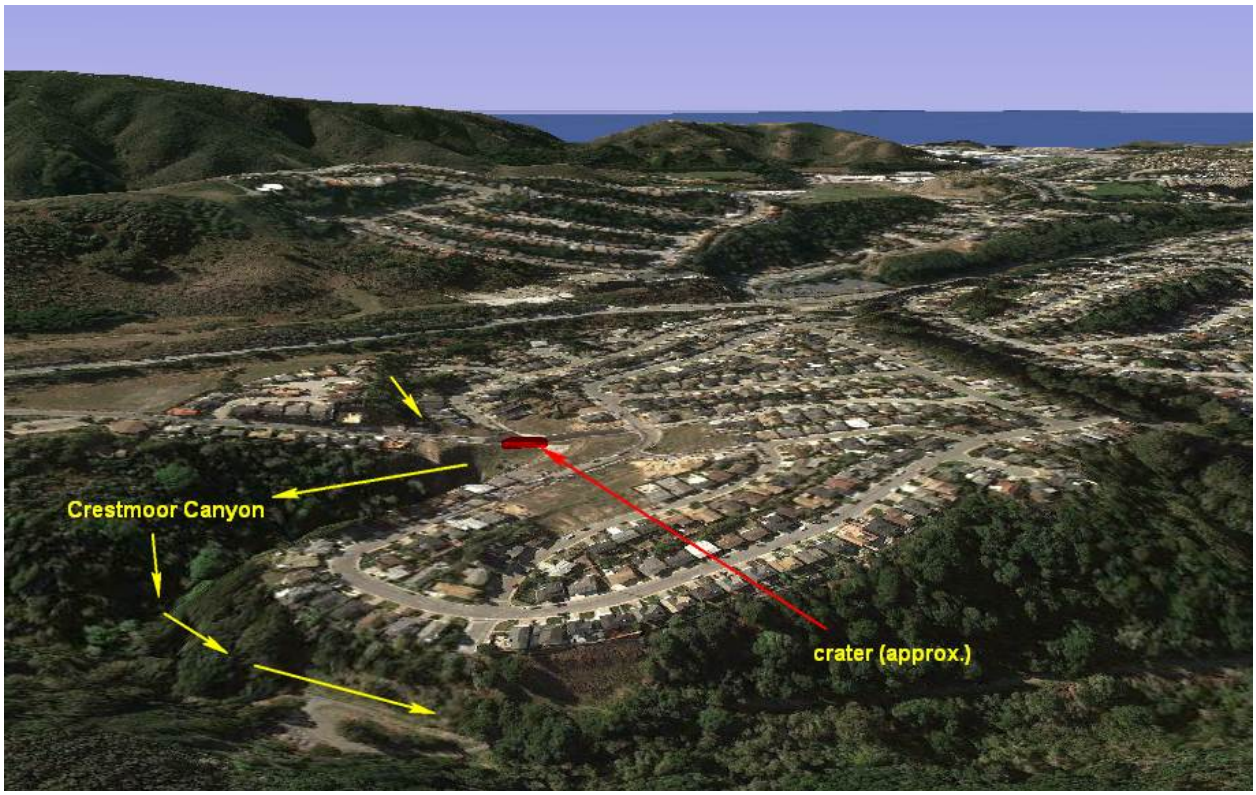


Figure 9 Location perspective looking west (Red dot marks site of explosion) (Base source: Google Earth)

2.2. Social and economic context of the City of San Bruno and Zip code 94066

The City's population is estimated to have averaged 39,909 people between 2005 and 2009, comprising 14,671 households in the city (U.S. Census Bureau 2011). The median age of the population was 38.2 years old. The population is relatively diverse, with 56% of the population being White (vs. 74% for the U.S.) and 26% being Asian (vs. 4% for the U.S.), and with a substantial population of Hispanic or Latino residents as well (26% vs. 15% for the U.S.) (U.S. Census Bureau 2011).

The community is relatively well-off, with a median household income of $74,375 and per capita income of $33,679, both in 2009 inflation-adjusted dollars (vs. $51, 425 and $27,041, respectively, for the U.S.). About 70% of people aged 16+ years were in the labor force with the primary industries being management, professional, and related occupations (32% of employed population); sales and office occupations (30%); and service occupations (20%). The leading industries were educational services, health care, and social assistance (18%), and Retail trade (12%) (U.S. Census Bureau 2011).

Most of the housing units in San Bruno (58%) are single-unit, detached homes or large 20+ unit multi-family homes (20%), and most (89%) were built before 1980. Sixty-two percent are owner-occupied, and 69% of the owner-occupied units are valued from $500,000 to $1 million (U.S. Census Bureau 2011).

The above statistics are generally indicative of zip code 94066, within which the incident occurred. Specific to that zip code, the median house size was 110.7 sq. m. (1192 sq. ft.) and median listing price was $475,000 (as of May 2011).

2.3. Water supply in the city and affected region

The San Bruno water supply system consists of five production wells, 13 pressure zones, eight storage tanks located at six sites, and five connections to major transmission pipelines (four owned and operated by the San Francisco Public Utilities Commission and one by the North Coast County Water District).

The distribution system includes 18 booster pumps, 985 fire hydrants, 9,000 valves, 100 miles of water mains, and over 11,300 metered services (City of San Bruno 2011). Pressure zones are shown in Figure 10, where it can be seen that the Crestmoor neighborhood is located in Pressure Zone 6 (PZ6), with PZs 8~11 uphill, PZ 8 and 10 being closest to the incident site. Figure 11 indicates the hydrostatic relationship of PZs 6 and 8.

2.4. Fire protection in the city and affected region

Fire protection for the City of San Bruno is furnished by the San Bruno Fire Department (SBFD) which shares its Chief of Department and selected other functions with the City of Millbrae Fire Department (MFD). SBFD has two fire stations—Station 52 is on the west side of the city, houses Engine 52 and has three personnel per day, while Station 51 is centrally located and houses Engine 51, Truck 51, Battalion 16, Fire Prevention, and the Fire administration (Figure 12). Station 52 is located at the southeast corner of Earl Avenue and Sneath Lane, approximately 450 m (1,476 ft) northwest of the explosion site on a straight line, and via Earl Avenue at a travel distance of approximately 527 m (1,730 ft.) from the site (Figure 13).

Neighboring MFD consists of five divisions: Administration, Operations, Fire Prevention/Public Education, Emergency Preparedness, and Emergency Medical Services. There

are 27 full time employees, including 12 authorized paramedic positions, which staff the department. The Fire Chief, Division Chief/Fire Marshal, Training Chief and administrative secretary are 40 hour per week employees. All other personnel work a 56-hour per week shift schedule. There are two line-operational Division Chiefs in Millbrae and one in San Bruno that share battalion coverage between the two cities. These three Division Chiefs divide up the aforementioned areas of responsibility as well as being the shift Commander. There are two Captains on each shift for a total of six who are each in charge of an Engine Company. MFD apparatus are three engines, a company for which consists of one Captain, one driver/engineer and one paramedic.

SBFD and MFD are part of San Mateo County's mutual aid system that operates according to its Fire Deployment Plan and consists of 21 departments with a total of 60 fire stations (Figure 12), that house 64 fire engines (i.e., pumpers), 10 trucks (i.e., aerial ladder apparatus), two "Quints" (apparatus that combine pumping and aerial ladder capabilities), four hose tenders and other apparatus such as hazmat, rescue and other equipment, all of which are organized into 16 battalions. There were over 54,000 incidents in 2011 requiring fire department response, of which 241 were structure fires (www.firedispatch.com).

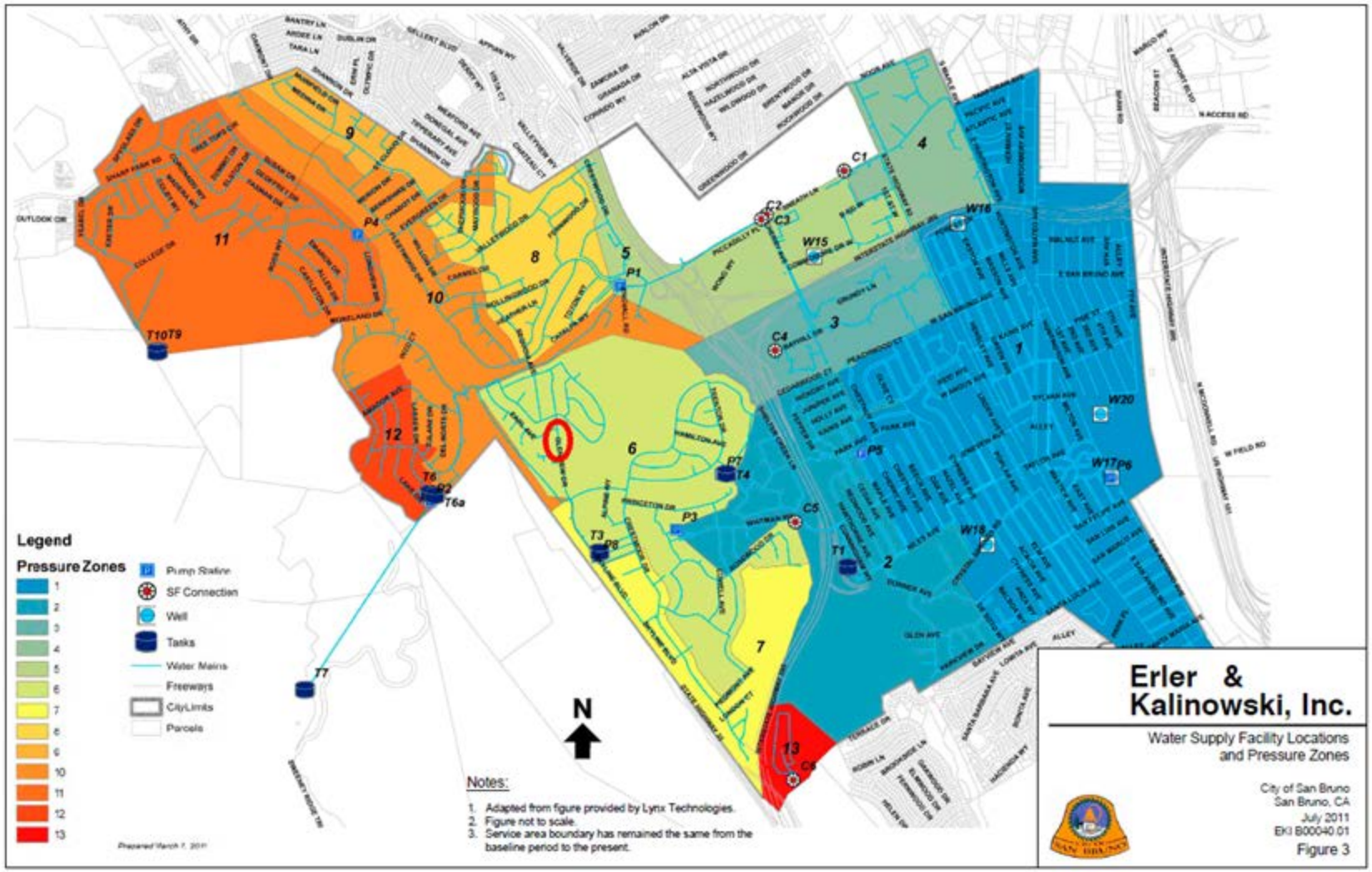


Figure 10 City of San Bruno Water Facility Locations and Pressure Zones – explosion site marked by red oval
(Source: City of San Bruno Urban Water Management Plan, Erler & Kalinowski, Inc. June 2011
http://www.water.ca.gov/urbanwatermanagement/2010uwmps/San%20Bruno,%20City%20of/San%20Bruno%20UWMP%20Complete.Final.2011-06-28.pdf)

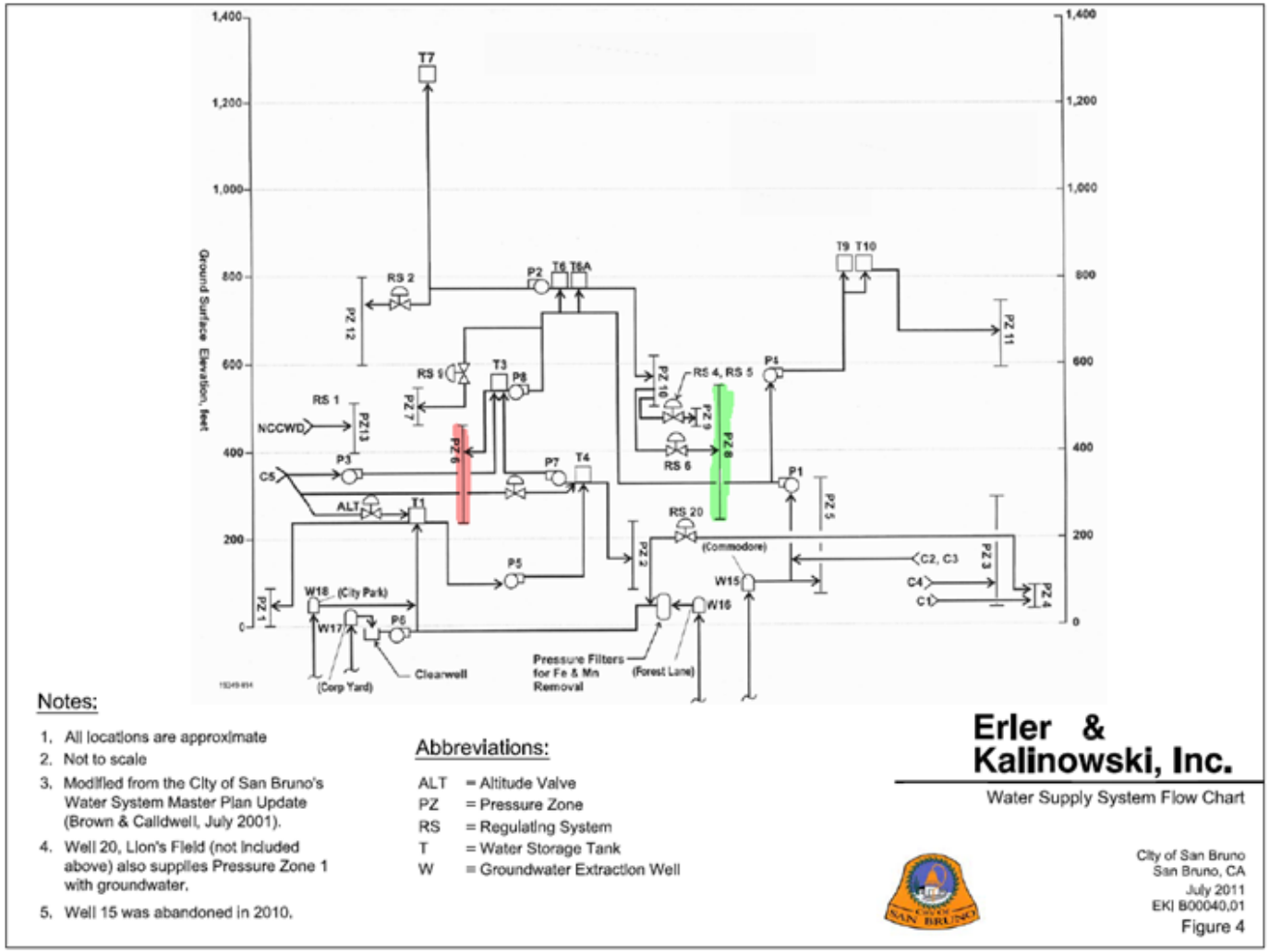
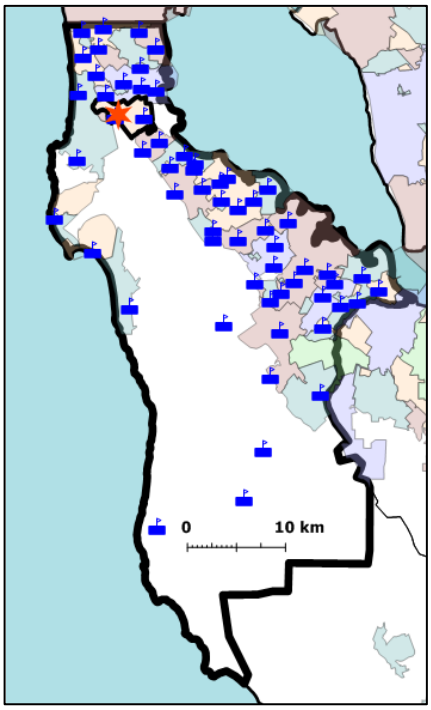
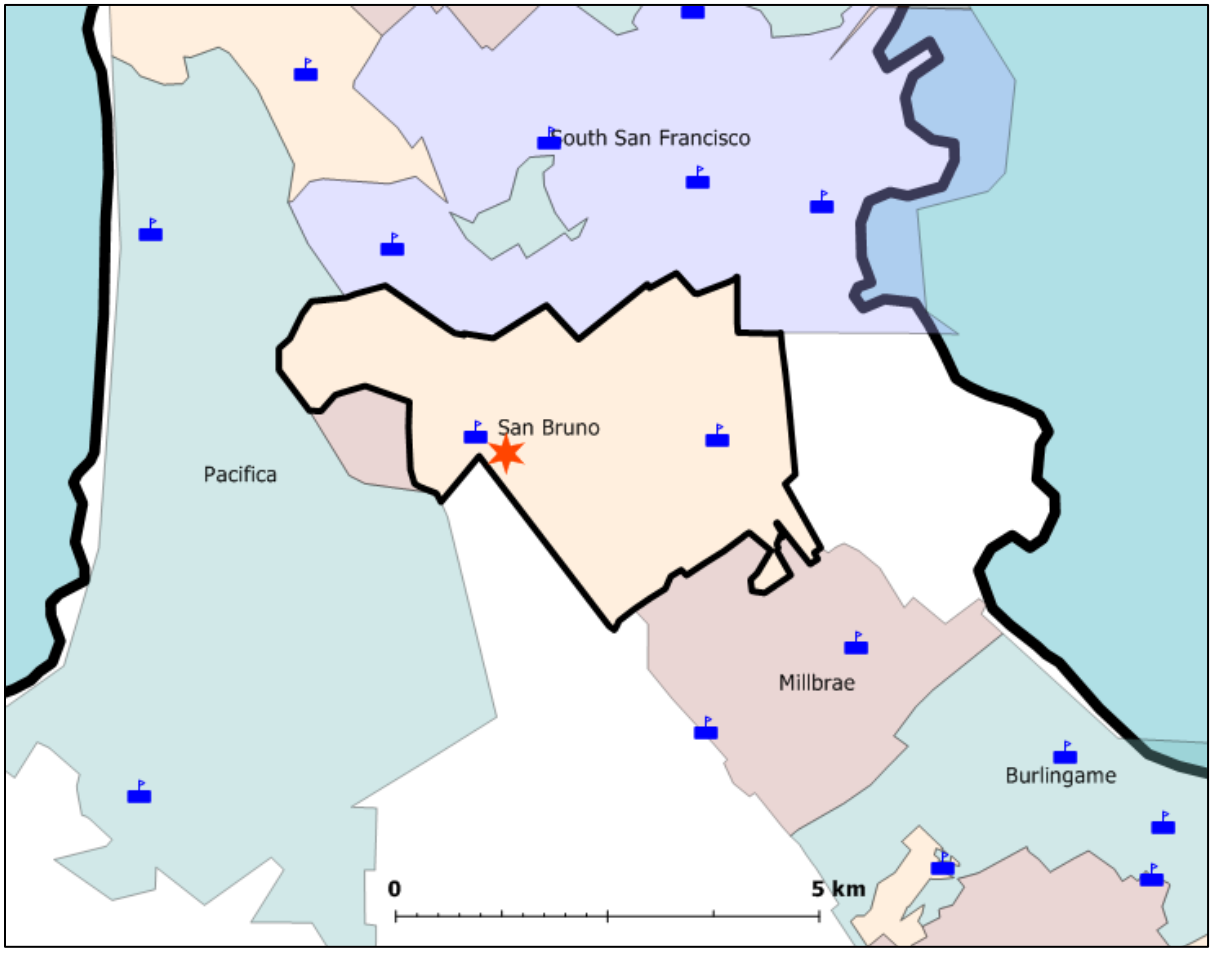


Figure 11 . City of San Bruno Water Supply System Flow Chart – PZ6 highlighted in red and PZ8 in green (source: City of San Bruno Urban Water Management Plan, Erler & Kalinowski, Inc. June 2011 http://www.water.ca.gov/urbanwatermanagement/2010uwmps/San%20Bruno,%20City%20of/San%20Bruno%20UWMP%20Complete.Final.2011-06-28.pdf)

Figure 12 Inset shows San Mateo County (heavy black outline) fire stations. Main figure shows detail of San Bruno FD and Millbrae FD fire stations. Incident location marked by red star





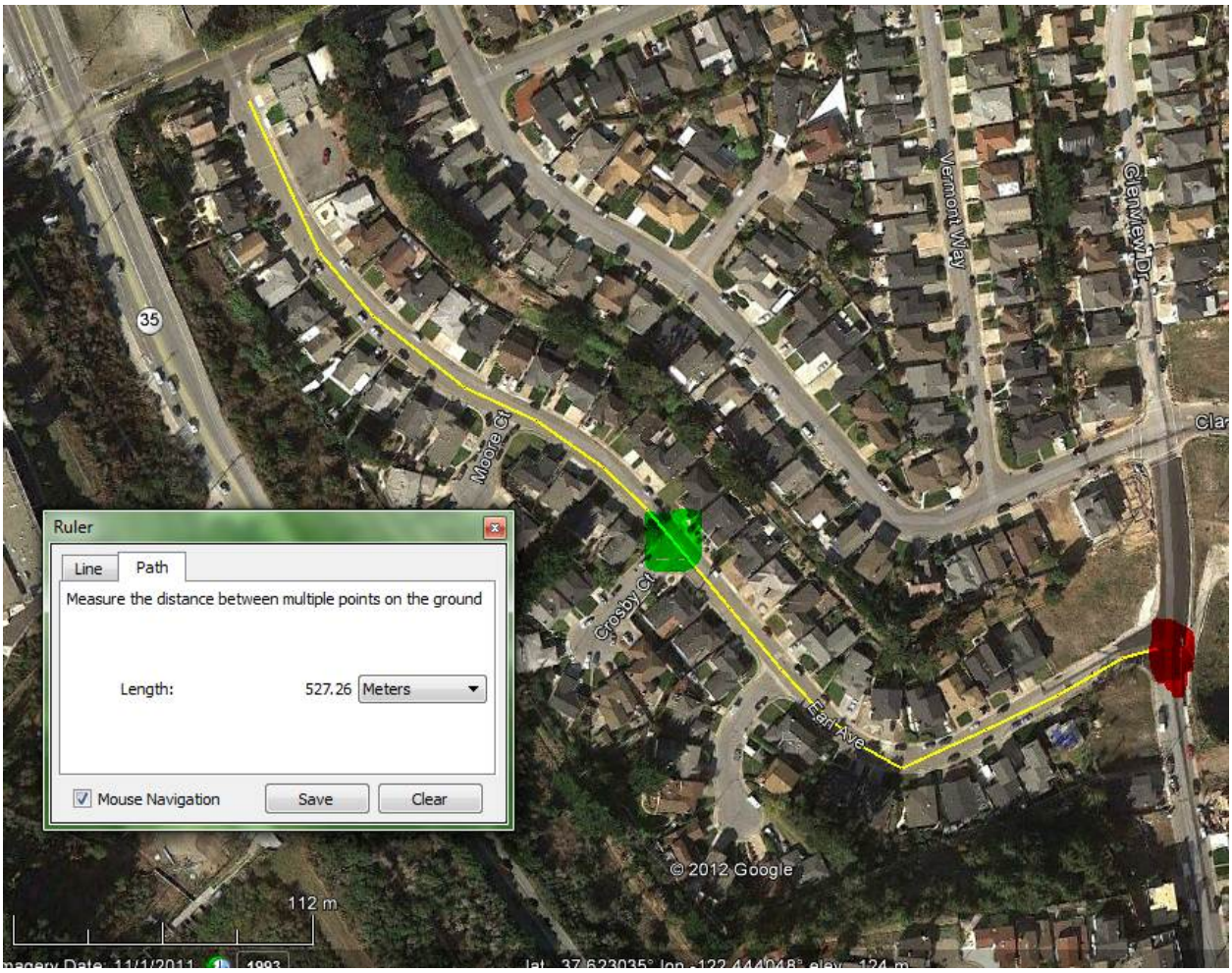


Figure 13 SBFD Station 52 path to the explosion site (red highlight). Engine 52 was only able to proceed to about the green highlighted area before it was forced to reroute via Claremont Drive (i.e., the next street to the northeast). (Base image: Google Earth)

2.5. Other relevant organizations

Many organizations were involved in the response to the pipeline explosion in addition to the local and mutual aid fire departments. While it would be impossible to cover them all in detail, this report will cover the most salient actors involved.

The City Manager's Office in San Bruno was vital in the coordination of the response and recovery operations related to the Crestmoor neighborhood fires. The city manager and small number of office staff worked closely with the mayor and a variety of city departments to oversee a variety of activities such as evacuations, damage assessment, debris removal, and rebuilding.

The San Bruno Police Department is typical of many medium-sized jurisdictions. It provides all types of police services including patrol and investigation. It has 48 sworn police officers and 70 other employees. The department responds to an average of 25,000 calls each year (San Bruno Police Department 2012). After the pipeline explosion, San Bruno police officers assisted with evacuation, traffic control, site security and other services.

The San Bruno Building Department is a small office in the city government that is responsible for building construction, remodeling and demolition. It employs the Chief Building Officer as well as two Community Development Technicians, two Inspectors, and two Enforcement officers (San Bruno Building Department 2012). Responsibilities of this staff include reviewing building permit applications and inspecting buildings for code violations. After the pipeline rupture, the building department conducted damage assessment counts. It has more recently endeavored to speed up the permitting and rebuilding process for those affected in the incident.

San Mateo County Health System is a department that protects public health and provides related services to vulnerable populations. It employs 5,271 and operates under a 2011/2012 budget of $1.69 billion (County of San Mateo 2012). The county health department is concerned with general health status in addition to mental health and substance abuse, disabilities, environmental health and emergency services. As the response to the incident proceeded, the Environmental Health Division played a key role in cleaning up the impacted lots so that rebuilding could occur in an expedited manner.

CalFire (The California Department of Forestry and Fire Protection) provides fire protection services to the state's 31 million acres of wildland. It actively educates the population about fire prevention, trains more than 24,000 fire fighters annually, and responds to an average of 5,600 fires each year (CalFire 2012). When the fires were initiated by the San Bruno pipeline explosion, CalFire provided additional resources (crew, equipment and aerial support) for the local fire department and its mutual aid partners.

CALEMA is a recently created state agency that operates closely with the governor's office. It combines the former Governor's Office of Emergency Services and the Governor's Office of Homeland Security. The mission of this agency is to help the state prepare for and respond to all types of disasters and terrorist attacks. It includes an executive team that works with five units (Prevention, Information Analysis and Operations; Planning, Protection and

Preparedness; Training and Exercises; Grants; and Administration) (CalEMA 2012). During the San Bruno incident, CALEMA provided resources and advisory support to local and county emergency management officials.

CalRecycle (also known as California Resources Recycling and Recovery) is a state agency based in Sacramento. Its goal is to reduce waste and encourage environmental sustainability. CalRecycle operates under the Integrated Waste Management Act and Beverage Container Recycling and Litter Reduction Act. It therefore provides education and enforcement services dealing with used tires, plastic bottles, E-waste, oil/filters, and other recyclable materials. CalRecycle has helped the state reach a recycling rate of 65% (highest in the nation) but is seeking to reach 75% in the near future (CalRecycle 2012). Nearly 700 employees work for CalRecycle. During the recovery operation, CalRecycle worked with contractors to remove debris from affected lots.

In addition to local and state governments, there were also private and non-profit organizations involved in the aftermath of the pipeline explosion. For instance, Pacific Gas and Electric (PG&E) was a fully engaged participant in this incident since it was their pipeline that exploded in the Crestmoor neighborhood. PG&E is one of the largest combined gas and electric utility providers in the United States. Based in San Francisco, the company of over 20,000 employees provides energy to a population of 15 million in Northern and Central California (PG&E 2012). PG&E operates about 160,000 miles of electric lines as well as 50,000 miles of gas lines. After the explosion, PG&E shut down the pipeline, distributed funds to the victims and affected families, and participated in the investigation of the explosion.

The American Red Cross is a well-known humanitarian organization that provides a variety of services including disaster relief, education and training (e.g., first aid and CPR), blood donations and communication for family members associated with the U.S. armed forces. The Bay Area Chapter is located in San Francisco. It has an Advisory Board of over 30 people and coordinates with over 2,000 volunteers to assist a population of 4.5 million people (American Red Cross 2012). The Bay Area Chapter also has 10 local offices, including one in Burlingame (San Mateo County). It was this local branch that took the lead role in mass care and sheltering operations after the pipeline explosion.

3. THE INCIDENT

The gas pipeline explosion, fire, and subsequent response and recovery have involved many participants conducting various tasks during overlapping time periods. In this chapter, we describe the various facets of the event, including (1) fire department operations; (2) mass care operations, (3) intermediate concerns, such as damage assessment, victim re-entry, and debris removal and environmental remediation; and (4) longer-term issues, including victim housing, infrastructure recovery, investigations, legislative and regulatory issues, and PG&E's response. These components of the event are discussed in turn, although they were occurring in parallel and often interacting, as summarized in the timeline of key events in Appendix A.

3.1. Fire department operations

The descriptions in Section 3.1 are heavily based on the NTSB survival factors group chairman factual report – Appendix B, San Bruno fire department incident reports (NTSB 2011c). Moreover, the description provided is intended as an overview of the general nature of response operations; full details comprise many pages in the NTSB report and supporting documents.

3.1.1. Operations overview

The initial responding Battalion 9 (B9) was dispatched on a full assignment from Station 52 (Figure 14 and Figure 15). Engine 52 (E52) was the first engine on scene and watched a large fireball at the intersection of Earl Ave and Glenview Dr. Battalion 18 (B18) responded from the north by way of Sneath Ln. Engine 51 (E51) and Truck 51 (T51) responded to the incident by way of San Bruno Ave to Glenview Dr from the south.

Figure 14 . First responding fire station and rupture site location

Upon his arrival the initial Incident Commander called for five alarms based on the fire scene he observed. B18 was assigned to the northern portion of the affected area. Battalion 20 (B20) was assigned to the western portion of the affected area, which included Estates Dr and Earl Ave. E52 was located on Glenview Dr in the northern portion of the affected area. E51 and T51 were located on Glenview Dr to the south of the fire. A chief from the California Department of Forestry and Fire Protection (Cal Fire) arrived and was assigned to the Crestmoor Canyon area. Battalion 6 (B6) was assigned to the east for fire suppression. Coverage of the southern perimeter was assigned last. Since the north direction had the most potential and building involvement, two strike teams were requested to serve in the north.

Water supply was an immediate problem in the incident since the explosion damaged water lines in the area, effectively depressurizing PZ6. Hoses were laid north on Glenview Drive and across Sneath Lane (more or less on a straight line, passing through some private property) so as to connect to PZ8 fire hydrants that were in service (Figure 17). San Bruno Police Department helped to re-route traffic around the neighborhood so pressurized hoses would be left undisturbed on residential streets and larger roads. In addition, water tenders (also known as tankers) were ordered to replace the loss of water supply lines until a more permanent system could be established. Water shuttles using engines had been temporarily used to replenish water supplies for front line engines until the water tender could arrive. Special airport fire engines stationed at San Francisco International Airport, which had very significant foam capability, and air drop fixed wing aircraft from Cal Fire also arrived. This use of air drops in such close proximity to residential homes was unusual. Table 1 summarizes the aid provided.

Table 1 . List of aid provided

Aid provided	Department
Air drop capabilities	Cal Fire
Foam tanker	SFFD from San Francisco International Airport
Water tenders	Cal Fire, Woodside Fire, San Francisco, and local contractors

The operation plan was to hold the present fire perimeter until the natural gas source could be cut and/or water supply could be increased. Upon the arrival of water tenders, the engine shuttles were replaced with tenders in the south and the north of the fire. Water-holding reservoirs were set up to supply the front line engines. Engine shuttles continued to the West Branch throughout the incident. Large diameter supply lines were eventually established in the north and south of the fire.

The 0.762 m (30-inch) high pressure transmission line was shut off by PG&E at approximately 9 pm. The intense fire ball was reduced and fire companies were able to suppress fire on the involved structures. The 0.1 m (4 in.) domestic supply line was shut off by PG&E at 11:30 pm. Fire crews continued to complete extinguishment and overhaul of the remaining

structure fires, spot fires and hot spots. (Overhaul is the phase of firefighting where final extinguishment and debris removal occurs.)

3.1.2. Operations in the South

At about 6:20 pm, the E51 crews stopped at the fire hydrant at 920 Glenview for water supply. However the hydrant was dry due to the blast damage to the water main along with the gas pipeline (Figure 18). E51 proceeded to the edge of the fire and stopped at 941 Glenview to the left and 950 Glenview on the right. Both houses were starting to burn due to the radiant heat. E51 and T51 crews knocked down these fires with the 500 gallons of tank water. The arrows in Figure 16 show the fire protection target of the E51 and T51. Note the engine names in the maps do not necessarily represent the actual location of the engines. They only show the association between targets and their protectors.

Approximately 25 minutes later, a water supply was established and E51 was back to extinguishment on Glenview Ave. T51 crew used a 2-1/2 in. attack line on the left (west) side of the street and was attacking the involved structure at 951 Glenview. E34 crew used a 2-1/2 in. attack line on the right (east) side of the street and was attacking the involved structure at 960 Glenview (Figure 16). E33 had a 1-3/4 in. pre-connected hose to the backyard of 960 and 970 Glenview for the Crestmoor Canyon vegetation fire (east of the explosion).

E37 arrived and was assigned another 2-1/2 in. attack line for extinguishment of the remains and foundation of 970 Glenview and fire on the ridge of Crestmoor Canyon.
E35 arrived and used the 1-3/4 in. pre-connect to protect exposures to 971 Glenview and used the 24 ft extension ladder to the roof for better access. A SFFD company arrived and another 2-1/2 in. attack line was added to E51 for exposures and fire protection to 971 Glenview. E92 made an interior fire attack at 941 Glenview with a 1-3/4 in. pre-connect. As the roof collapsed at 951 Glenview, whether from the fire or air tanker and helicopter drops, E51 crew had a third 1-3/4 in. pre-connect to protect the roof, eaves and backyard trees of 950, 940, & 930 Glenview (Blue oval in Figure 16) from the burning embers being moved by wind.

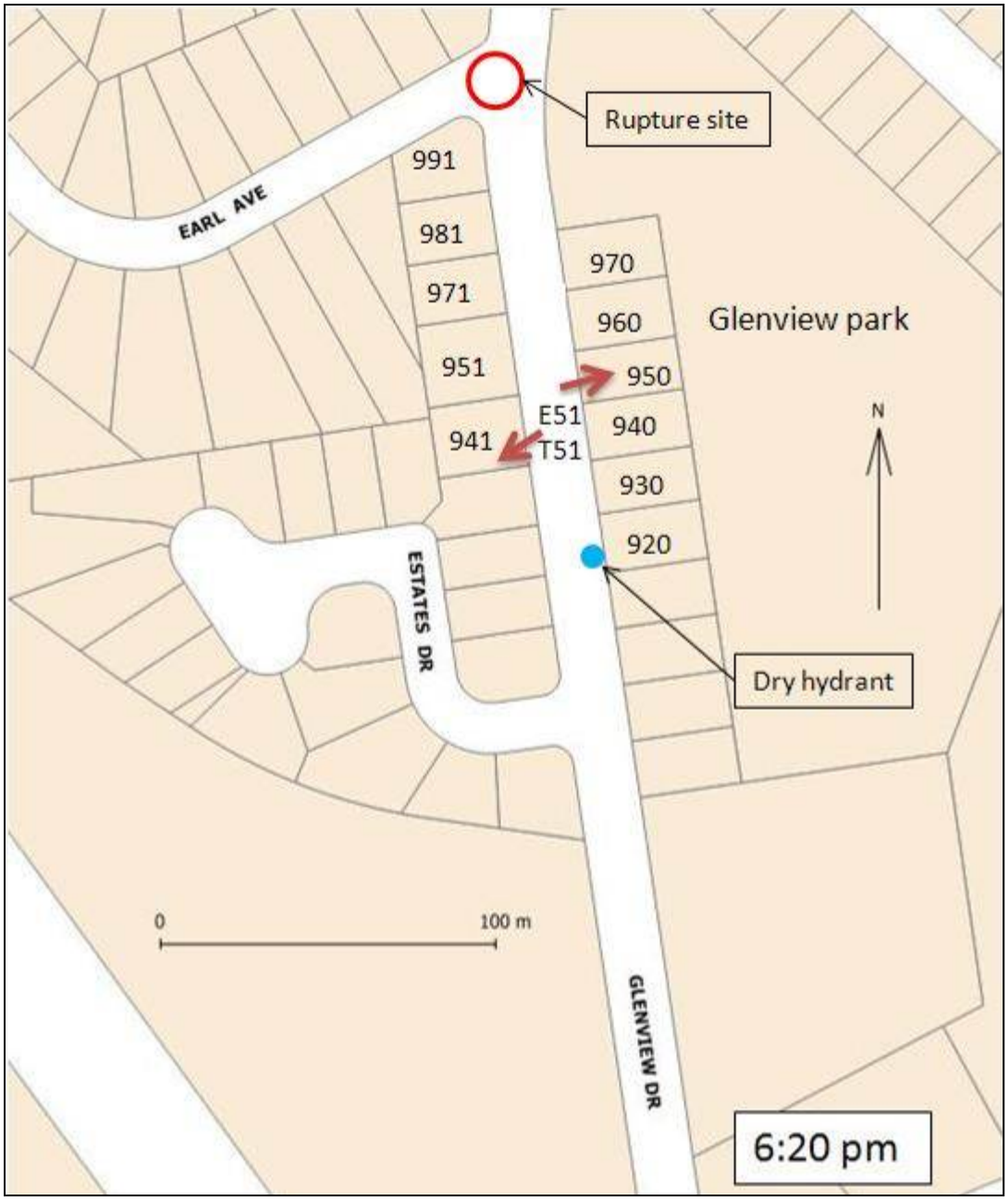


Figure 15 House fires fought by E51 and T41

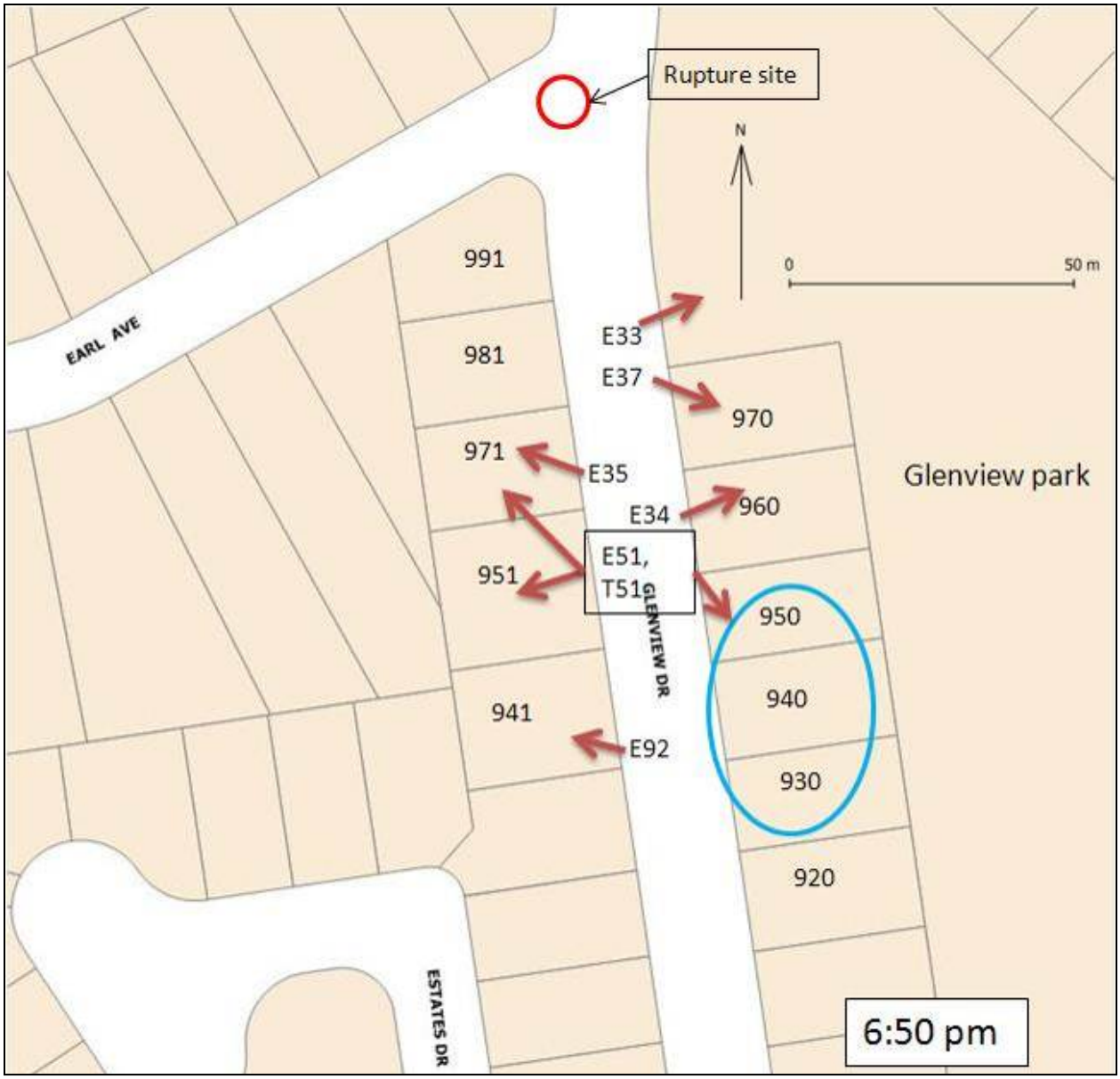


Figure 16 . Fire engine operations in the South

3.1.3. Operations in the North

SBFD Engine 52 and Battalion 9 are located in Station 52 at the corner of Earl Avenue and Sneath Lane approximately 1400 feet from the explosion, Figure 14. They felt and heard the explosion, and within about one minute were responding to the scene from Sneath Lane and upper Claremont Dr. Upon arrival on Claremont Dr., E52 observed the large fire over the entire neighborhood to the south. E52 initiated a second alarm response and proceeded down Claremont to Vermont Dr. At this time E52 noticed a wall of fire and extreme heat conditions

coming from the corner of Claremont and Glenview. Numerous citizens were running from the fire area.

E52 turned up Vermont and proceeded to Plymouth and Glenview and reported multiple homes on fire and possibly several blocks on fire. Due to water line damage, E52 was assisted by South San Francisco fire E61, E63 and Quint 62 (Q62) to supply E52 with water. (A quint is a type of fire truck with five capabilities such as pump, water tank, fire hose, aerial device, or ground ladders.) Fire crews found an alternative water supply at the intersection of Sequoia and Fleetwood Dr (Figure 17) and used approximately 610 m (2000 ft) of supply line to supply E52. E52 was able to operate two 2-1/2 in. hose lines for fire extinguishment of the structures involved on Glenview Dr. E81 and E24 arrived and assisted with extinguishment and overhaul of structures involved.

Figure 17 Alternative water supply location to the North

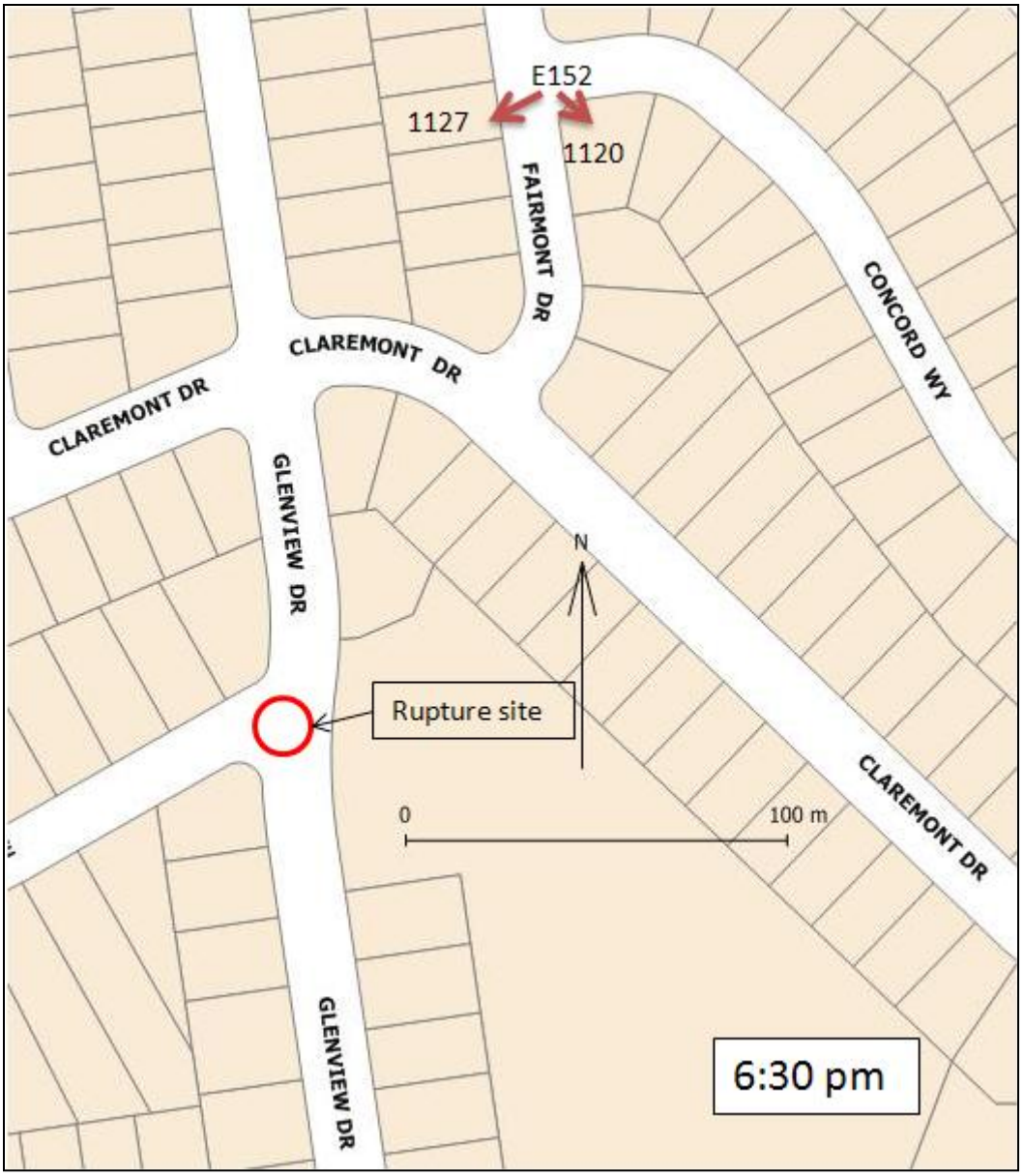


Figure 18 Engine 152 operation

E152 was working at Fairmont Dr. and Concord Way (Figure 18). Portable drafting pools with a float pump supplied E152 with water. (Engines transfer water to these portable pools so that other engines can then draft water from the pool. The process, called a "water shuttle," is used when an engine cannot pump water directly from a hydrant). E152 used a 1-3/4 in. line to fight fire and protect exposures at 1120 and 1127 Fairmont. E152 also supplied an engine on Concord Way with water. No interior firefighting took place and only defensive firefighting occurred. Crews worked in heavy smoke conditions through the night.

3.1.4. Overall fire response

During the first 50 hours following the incident, over 500 firefighters and 90 apparatus responded to the incident, involving 42 fire agencies. The general location of these responders is shown in Figure 19 and the agencies are listed in Table 2.

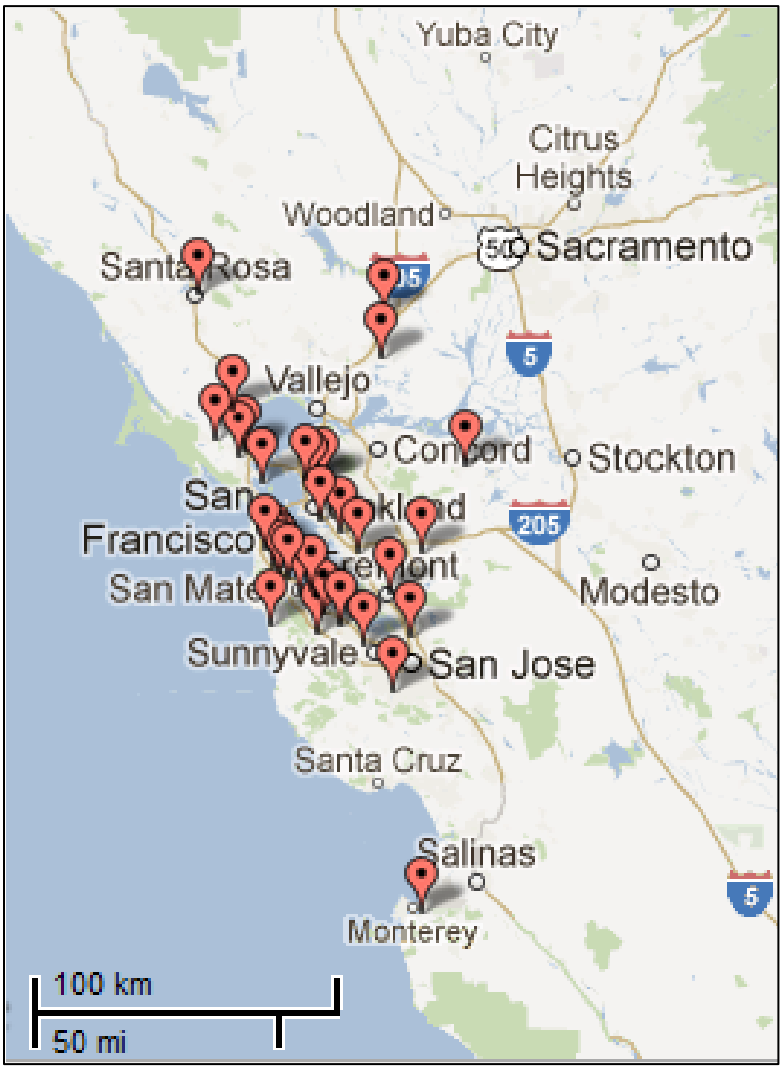


Figure 19 General location of fire agencies responding to the San Bruno incident

Table 2 List of responding Fire Departments
(source: NTSB 2011, Docket No. SA-534, Exhibit No. 4-D)

1. Belmont-San Carlos Fire Department
2. Central County Fire Department
3. CFD - San Mateo County Fire
4. Colma Fire Protection District
5. Foster City Fire Department
6. Coastside Fire Protection District
7. Menlo Park Fire Protection District
8. Millbrae Fire Department
9. North County Fire Department
10. Redwood City Fire Department
11. San Bruno Fire Department
12. San Francisco Airport Fire Department
13. San Mateo Fire Department
14. South San Francisco Fire Department
15. Woodside Fire Protection District
16. Livermore-Pleasanton Fire Department
17. Albany Fire Department
18. Alameda Fire Department
19. Berkeley Fire Department
20. Camp Parks RFTA Fire and Emergency Services
21. Hayward Fire Department
22. Fremont Fire Department
23. Alameda County Fire Department
24. East Bay Regional Parks Fire Department
25. Novato Fire Department
26. South Marin Fire Protection District
27. Marin County Fire Department
28. Kentfield Fire Protection District
29. San Rafael Fire Department
30. Sonoma County Department of Fire Services
31. San Francisco Fire Department
32. Suisun Fire Department
33. Mountain View Fire Department
34. Santa Clara County Fire Department
35. Milpitas Fire Department
36. East Contra Costa Fire Protection District
37. City of Santa Rosa Fire Department

38. Vacaville Fire Protection District
39. CalFire Santa Clara Unit
40. San Benito-Monterey Unit
41. Sonoma-Lake-Napa Unit
42. Amador-El Dorado Unit

3.2. Mass care operations

While the response to the explosion was underway with first responders, mass care operations were beginning to unfold. Organizations like the American Red Cross and other local non-profit organizations were beginning to establish shelters and provide for immediate emergency needs. Initial funds were provided by PG&E and donations began to pour in from people and organizations concerned about what had occurred, and this also required some attention on the part of the city and community based organizations.

3.2.1. Sheltering/Local assistance centers

From the beginning, mass care was provided through a two-pronged approach of utilizing an "evacuation center" and traditional sheltering resources. The evacuation center, located at the Bayhill Shopping Center, was described by one informant as a service waypoint or "pit stop" for evacuees. Its goal was to account for affected individuals and collect information about needs before evacuees moved on to the shelters. These shelters were traditional overnight stay facilities similar to what would be found after any disaster. Shelters were established at the Veteran's Memorial Recreation Center in San Bruno (251 City Park Way) and the San Bruno Senior Center (at 1555 Crystal Springs Road) (Figure 20). Work to set up the shelters began within an hour of the Line 132 pipeline rupturing.

However, while these traditional sheltering facilities were available, they were little utilized by the community in this instance. Whether it was the proximity of friends and family, the limited extent of the event, or the use of lodging vouchers paid by Pacific Gas and Electric Company, only about 39 people used the shelters on the night of September 9. No individuals used the shelters during the nights that followed. Following a recommendation from the California Emergency Management Agency (CalEMA), the City of San Bruno and CalEMA worked together to transform the Veterans Memorial Recreation Center facility into what was then called a Local Assistance Center (LAC).

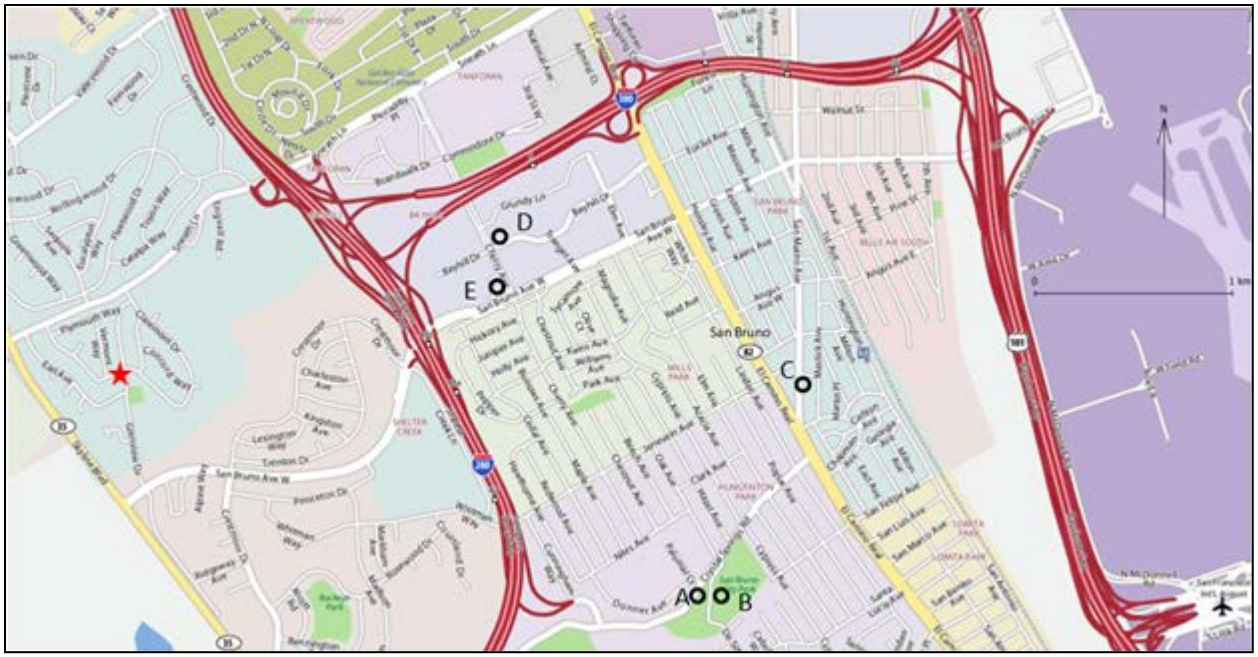


Figure 20 . Locations of the San Bruno Senior Center (A), Veteran's Memorial Recreation Center (B), SBRRC (C, 458 San Mateo Ave, and D, 900 Cherry Ave), and Local Assistance Center (E, Bayhill Shopping Center) relative to the site of the explosion and fire (red star)

The Local Assistance Center (LAC) was a one-stop location where those community members who were affected by the incident could go to receive a variety of supporting resources. Several organizations provided information and services to victims at the LAC including the city of San Bruno, PG&E, the San Mateo County Red Cross, the Thrive Alliance (San Mateo County's Voluntary Organization Active in Disaster (VOAD)), the Lion's Club, the Salvation Army, local community groups, and various faith-based organizations. According to the Red Cross, about 183 individuals passed through the Local Assistance Center on the first day alone. Through November 5, 2010, an estimated 5,130 meals and 12,426 snacks were served at San Bruno's LAC. When the demand for the LAC decreased (about a week after the incident), it was moved to an office building adjacent to the Bayhill Shopping Center, where it housed fewer organizations.

Of note is the efficiency with which information and city resources were made available to community members. On the afternoon of September 11, the first town hall meeting was held at St. Roberts Church, following advice from CalEMA. The meeting was attended by 650 local citizens. PG&E, CalEMA, city staff, police, fire, building, planning, public works, Congresswoman Jackie Speier (who represents the District in which the explosion occurred), the

press and various others also attended. The primary purpose of the meeting was to provide reassurance to the survivors that the community was there to assist them in their time of need. PG&E also distributed pamphlets to ensure victims knew where to get help. The City of San Bruno also held two other town hall meetings over the next few weeks to distribute information through their public information officers, while the San Mateo Red Cross utilized Twitter and Facebook to distribute up-to-date information on mass care services.

On September 15, 2010, San Bruno opened the San Bruno Resource and Recovery Center (SBRRC) at 900 Cherry Street (Figure 21). The San Bruno website describes the San Bruno Resource and Recovery Center as a resource to assist residents impacted by the September 9 fire and explosion with mental health support, housing and health services, and other required needs. On October 25th, 2010, the agencies that had been assisting residents at the San Bruno Resource and Recovery Center made the transition back to their local offices, thus altering the nature of ongoing mass care operations (http://sanbruno.ca.gov/Glenview_assistance.html). However, on March 29th, 2011, the San Bruno Long Term Recovery Committee (LTRC) reopened the San Bruno Resource and Recovery Center at 458 San Mateo Ave for long-term operation (Figure 21).

Figure 21 San Bruno Resource and Recovery Center
(Source: http://sanbruno.ca.gov/pdfs%5Cflyer.pdf on June 28th 2011)

Even six months after the event, the city was still assisting a number of individuals and families in a variety of ways. For instance, the city:

- continued to provide active liaison resources to the fifty-five displaced families and other families that required information services and support;
- coordinated with the long-term recovery group, a consortium of nonprofit service providers (e.g., Red Cross), to assist and guide their efforts in providing support such as food and counseling services to individuals struggling financially;
- collaborated with a variety of individuals and organizations who were assisting the victims (e.g., the United Policy Holders and Rebuilding Together who provided services such as an educational forum on how to select a contractor and architect);
- assisted citizens in acquiring information about permits, beginning the rebuilding process, and normal community development services.

3.2.2. Donations and financial aid

Aid for the victims of the pipeline explosion began to converge in San Bruno. Donations came from various sources and included both in-kind and monetary gifts. For example, almost immediately after the event, many stores extended their hours or opened their shelves to first responders who needed supplies to react effectively to the unfolding emergency. For instance, boxes of Gatorade were available to first responders at the Bayhill Shopping Center. Victims also received donations, and the overwhelming perception of those involved and interviewed was that these early donations were beneficial.

Nevertheless, as is the case in many disasters, in-kind donations in this incident presented challenges. At the Red Cross's staging area in the Bay Hill Shopping Center, citizens began dropping off unsolicited donations of clothing and other miscellaneous goods (including a TV entertainment center). While this is not unusual in emergencies and disasters, the San Mateo County Red Cross did not have the desire, capacity or personnel to deal with such donations and therefore had to release them in bulk to Goodwill stores in the vicinity. Another donation with

limited utility was the gift cards that were given to the Red Cross and victims of the incident by local vendors. These gift cards came from specific stores with limited applicability (e.g., candle store, or gender specific or age specific items). Such donations had to be individually distributed on a case-by-case basis, which was time consuming.

How to properly distribute donated funds became another dilemma for those involved in community recovery. The Glenview Fire Relief Fund alone, which took donations for the victims of the explosion, collected $400,000 for victims. A series of town hall debates ensued as to how this money would be allocated. Some felt the funds should be released immediately to the victims, while others wanted the funds to be conserved to address long-term needs. Ultimately, the funds were released in bulk by the end of 2010 and divided among the disaster victims. Each of the 38 families whose homes were completely destroyed or demolished received $6,000. Owners of each of the 16 properties that experienced moderate to serious damage received $4,000. Owners of each of the 45 properties that experienced minor damage received $1,000. Six thousand dollars was also awarded to 2 families that had special circumstances that were not covered by the aforementioned categories. In addition, another $49,000 was held in reserve for individuals or families who experienced loss of income, medical or hospital bills, and other financial impacts. Grants of up to $2,000 from this pool were distributed after members of City Council and a small group of residents in the affected neighborhood reviewed applications to determine the best use of funds.

PG&E also distributed funds to the victims in the sums of $15,000, $25,000 or $50,000, depending on the level of impact for each individual or family.

3.3. Intermediate concerns and response activities

In addition to first response and mass care, the City of San Bruno, the County of San Mateo and other relevant parties began to address intermediate concerns. This included an assessment of the damages in the Glenview neighborhood, preparation for re-entry into homes and the disaster site, debris management and environmental rehabilitation. These activities began the day after the incident and lasted for approximately one month.

3.3.1. Damage assessment

At about 8:00 am on September 10, 2010, the fire was reported to be roughly 75-80% contained (NTSB 2011c). This suggests that the fire was substantially under control, with the

exception of actual or potential flare-ups. The fire was not officially declared under complete control until 8:00 pm Saturday, September 11, 2010. This timeframe officially marks the beginning of the recovery phase.

However, even before the fire fighters had finished their duties, "a small army of building inspectors," as one interviewee put it, was being assembled to conduct a damage assessment. These inspectors were not limited to San Bruno employees in the building department. Also included were other personnel from mutual aid agencies around the region and state who were certified in post-earthquake safety evaluation of buildings using the *ATC-20 Field Manual* (ATC 1989). The inspectors, largely from municipal engineering departments, met at the town hall on the evening of September 9, anticipating field deployment. These inspectors could not be sent to the affected area that evening since the fire department advised them that the scene was not yet under control. Nevertheless, they did find the downtime useful to gather supplies (e.g., clip boards, flashlights, staple guns and water bottles), copy required forms, and coordinate how they would organize and conduct the damage assessment the following day.

On the morning of September 10, the building inspectors arrived in the field at about 6:30 am and set up operational headquarters in the bay of Fire Station # 52 (located only a few blocks away from the burst pipe) (Figure 14). A building official used his laptop computer with an Excel spreadsheet to divide up the affected neighborhood and make assignments for five damage assessment teams. Inspectors then started to assess damages on foot because cars could not travel in the area for a windshield assessment due to the fire hoses that were strewn about the streets. The inspectors encountered several homes that had been completely gutted by fire. Some were partially burned and others a few blocks away were damaged by flying debris (e.g., chunks of concrete) when the pipe exploded.

Within approximately 45 minutes, the police chief requested that the building inspectors immediately leave the area. The building inspectors were not told why they had to evacuate, but one building official surmised that the police were concerned about safety and uncontrolled access to the neighborhood. There was also a belief that the police wanted to bring in cadaver dogs to retrieve victim remains. This led to some disagreements between the two departments about what was taking place and what needed to happen.

After waiting about three hours, another building inspector with formal search and rescue training arrived. He was allowed to go in with the search and rescue dogs, and he provided

advice on dangerous locations (including hot spots and precarious structures). Shortly thereafter, the damage assessment teams resumed operations and shifted from rapid assessments to more detailed building evaluations. The building inspectors took more time to ensure that their assessments were considering all possible damages and impacts.

By 3:00 pm or 4:00 pm, all homes in the affected area were posted with red, yellow and green tags to denote the extent of the damage. Red tags indicated that the building or lot was destroyed or unsafe to enter. Yellow tags indicated the building was damaged, potentially unsafe to enter, and not suitable for occupancy. Green tags indicated the building was safe for re-entry and occupancy. Based on these decisions, color-coded maps of the disaster site were developed and provided to each department that was working at the scene (e.g., Figure 22). This information proved useful when the first town meeting was held to inform citizens on the conditions of the disaster area. However, damage assessments and changes in the status of buildings continued to occur for several days and weeks.

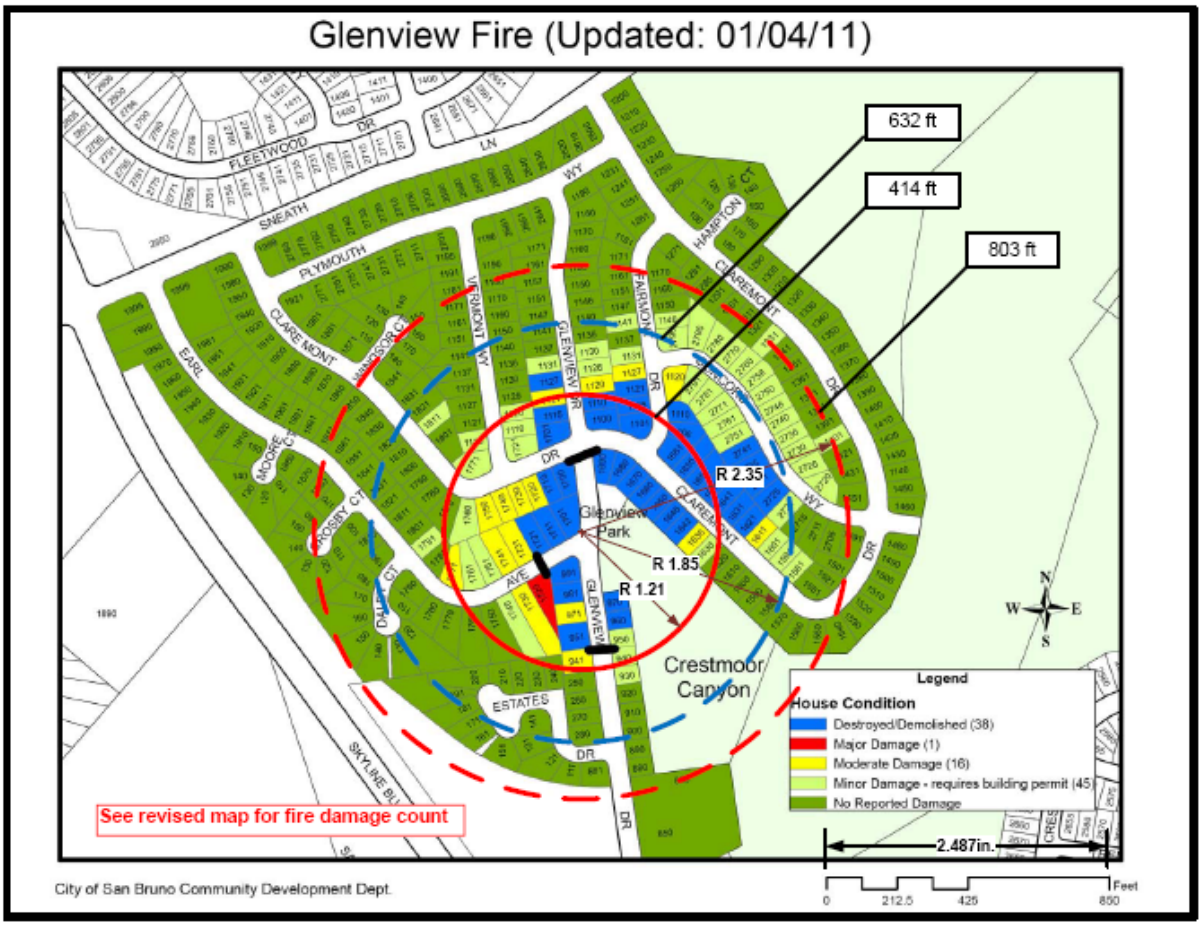


Figure 22 Map showing damage levels by parcel (Source: Map accessed from the National Transportation Safety Board's Docket No. SA-534, Exhibit No. 2-BC)

3.3.2. Victim re-entry

While damage assessment was taking place on Friday, September 10, the Environmental Health Services (EHS) Division of the San Mateo County Health Department was called to assess the hazard conditions of the destroyed buildings and affected lots. City and county officials began planning victim re-entry on Friday, September 10, and this process continued through Saturday, September 11.

Several concerns were evident as discussions on the matter took place. First, the officials recognized that the neighborhood was now a contaminated and dangerous area. City officials wanted to identify those portions of the neighborhood where residents would be able to return to their homes and those locations that were too heavily damaged and not safe to enter. Second, the city wanted to get people back into their homes as soon as possible (assuming the residences

were safe to do so). Finally, there was a desire to allow the survivors who lost their homes on site to retrieve any remaining valuables.

Several emergency orders were declared at this time to control access to the disaster zone. First, on Thursday, September 9 at approximately 9:00 pm, the City Manager declared a state of local emergency. Until a determination could be made as to the cause of the gas line rupture, a portion of the area was declared a crime scene, enabling the City's Police Department to restrict access of unauthorized persons into the affected neighborhood. Due to potential hazardous materials in the disaster zone (including the possibility of asbestos in older homes), the Deputy Health Officer of the San Mateo County Health System issued a Public Health Order on September 11, 2010. This emergency order not only entailed a restriction of unauthorized persons into the affected neighborhood, but enabled authorized personnel the right to access private property to remove any hazardous waste (e.g., paints, propane, pesticides). An additional order was issued on September 14, the Declaration of a Public Health Emergency, further controlling access to the site throughout the duration of the debris clean-up period. Each of these emergency orders included a restriction of unauthorized persons into the affected neighborhood. To assist in the enforcement of these orders, police maintained a presence in the neighborhood to cordon off the area (Figure 23). Higher more substantial fencing (from National Rent-A-Fence) was also ordered and set up within about two weeks to prevent unauthorized entry into the most heavily impacted areas of the neighborhood.

Figure 23 Police fenced cordon, 16 Sept 2010 (Photo: C. Scawthorn)

On Saturday, the San Mateo County Health Department removed hazardous waste from the fire-ravaged homes. This included, for example, household cleaners, paints, pesticides, motor oil, and propane tanks. Ten 55-gallon drums of hazardous materials were eventually collected. The goal was to get the most dangerous hazardous materials away from the site to allow re-entry. Meanwhile, the City of San Bruno surveyed the status of utility services in the neighborhood and worked with the private sector to restore electric and gas service to occupied homes as well. Preparation for neighborhood re-entry operations was coordinated through the City's EOC throughout Friday and Saturday, September 10 and 11.

On Sunday, September 12, when the situation was more stable, the City initiated the re-entry operation. This included the staging of residents at an off-site location (Skyline College), providing vehicle tags to determine re-entry order, and giving permission to residents to enter the neighborhood in stages. Re-entry of approximately 320 green tagged homes took place over a six hour period. Building inspectors and PG& E staff accompanied residents in order to provide them information and support for the re-entry process. Dumpsters were also strategically placed (roughly one for every ten houses), so people could throw away damaged property or food that spoiled in refrigerators. This was important since damages extended well beyond the initial blast zone and because parts of the neighborhood lacked power.

By Tuesday, September 14, the City was also busy scheduling and arranging for property owners to sift through debris and gather personal belongings that could be found at the seriously damaged and destroyed properties. The police department allowed limited entry to the yellow and red tagged properties according to specific guidelines, developed as a result of the expedient (or spontaneous or ad hoc) planning activities that were initiated over the weekend. For instance, those desiring re-entry had to:

- Prove home ownership or rental in the area;
- Attend a briefing session;
- Don personal protective equipment including Tyvek suits, hard hats, gloves, dust masks, goggles, and shoe covers;
- Be accompanied by building officials and fire fighters;
- Clean off shoes in a kiddie pool to avoid tracking contaminated soil away from the scene.

For seriously damaged or destroyed properties, only two adults were allowed in the home or on the lot at one time. Their visit was limited to a two-hour period (although they could return several times over the following week). Visits were also supervised by city and county personnel to ensure safety.

As these survivors sifted through the remains of their homes, a few individuals were able to recover a jewelry box, a ceramic duck (a white elephant gift), and other items including sports memorabilia that fire fighters had locked in a car in a garage in order to protect it (Figure 24). However, most of the home owners near the pipeline were unable to recover any valuables since the fires had destroyed virtually everything near the exploded pipeline.

By September 15, the majority of residents had returned to their homes. Nevertheless, there were still many people who had to wait for re-entry until utilities could be reconnected or their homes were repaired. Others had no home to return to, so they also had to seek temporary housing elsewhere, work with insurance companies to settle claims, and begin the painstaking process of recovery.

Figure 24 Firefighters sifting homeowner (in white Tyvek suit) property recovered from safe (box on right) (Photo: C. Scawthorn)

3.3.3. Debris removal and environmental remediation

Debris and environmental conditions were major concerns for those involved in the response to the San Bruno pipeline explosion. The fires had destroyed many homes and left in their wake damaged concrete foundations, scorched construction materials, standing or collapsed brick chimneys, smoldering furniture and appliances, broken glass, sharp nails and twisted metal objects among other forms of debris. There were also numerous cars that had caught fire, along with trees and other forms of vegetation on a steep hillside nearby.

Officials recognized early on that debris management would have to be addressed quickly and effectively if recovery was to be facilitated. In addition, there was concern that the denuded hillsides and large quantity of ash could result in erosion problems and compromise the San Francisco Bay ecosystem. On September 11, city and county personnel along with environmental agencies began to plan how to remove the debris and protect the natural surroundings. It was determined that San Mateo County would receive assistance from CalRecycle to address these needs. Legal barriers became evident at this time which limited what could be accomplished. For instance, the government could not clean up debris on private property without the owners' permission. Therefore, a Right-of-Entry Permit was quickly drafted by government lawyers and distributed to property owners. A meeting with property owners was also held on September 17 so the city could explain the recovery trajectory and how it would benefit those affected. Some citizens were initially reluctant to sign the documents. To help ease concerns about the waiver to allow right of entry, CalRecycle invited a victim from the 2007 Angora fire (Murphy et al. 2007) to talk to the victims of the San Bruno incident. She described her positive experience with CalRecycle and enthusiastically endorsed their plan. Consequently, all owners of the 38 red tagged homes immediately or eventually agreed to transfer responsibility of debris removal to the county and CalRecycle.

Notwithstanding the above delay, the debris removal and environmental remediation got off to a fortuitous start. PG&E agreed to take on the financial obligations of these functions, thereby speeding up the response significantly since issues of payment were resolved up front. San Mateo County signed the agreement with CalRecycle, which in turn contracted with Pacific States Environmental. Heavy debris removal equipment therefore arrived in the area on September 20, and ingress and egress routes were identified to facilitate the movement of front loaders, scrapers and dump trucks.

During the debris removal process, CalRecycle operated under the incident command system (ICS) (since one of its managers was a former fire fighter). CalRecycle held its first general command staff meeting on September 21, which included contractors as well as multiple personnel from local and state agencies. Several project managers were given responsibility for coordination of debris removal. On September 23, cleanup began on the first five homes that had approved permits.

The process for the debris cleanup included several stages, resulting in the segregation of different types of debris (e.g., wood, concrete, metals, ash and soil) that required their own specific method of waste management. For instance, wood waste and burned trees were removed and recycled. Concrete and metals were also washed and then sent to different recycling facilities (if the presence of ash on these materials was within limited hazardous materials thresholds). Overall, it is estimated that 58% to 65% of the debris was recycled in this manner.

The most problematic aspect of debris management and environmental remediation concerned the ash and soil. The debris removal procedures followed the federal National Emissions Standards for Hazardous Air Pollutants (NESHAP) and Bay Area Air Quality Management District Regulation 11, Rule 2 standards (CalRecycle 2010). Ash was therefore collected and three inches of soil were also scraped from each of the lots to ensure the removal of any hazardous materials. Following the scraping, the soil was tested for levels of hazardous materials. Since two of the 35 properties still exhibited elevated levels of arsenic, additional soil was removed from these lots until the soil could be pronounced clean. The ash and soil was then transported using a licensed hazardous waste hauler to class two or class three waste management facilities.

As these debris management operations were undertaken, strict safety measures were followed. Anyone working in the area had to have the proper personal protective equipment. Property lots were watered down periodically and streets were cleaned with sweepers frequently to keep dust levels down. Air monitoring stations were likewise established throughout the area to ensure that asbestos was not a problem. The goal was to protect workers and avoid creating a nuisance for nearby neighbors alike.

By October 17th, about one month after the incident, it was reported that debris removal was virtually complete. CalRecycle then turned attention to writing reports, including detailed costs for each property should that be called into question by insurance companies or PG&E.

3.4. Longer-term issues

After the immediate and intermediate issues were resolved, attention began to shift to the long process of recovery. A wide variety of individual and family needs was the focus of efforts during this period as well as housing and infrastructure repairs and rebuilding. Recovery activities are ongoing at the time of this writing.

3.4.1. Individual and family recovery

While it was not the central focus of this study, the recovery of individuals and families is likely to be as varied as their individual impact from the incident. For some, recovery will be impossible or incomplete due to the loss of eight lives in this emergency. There were also many injured persons including victims who suffered serious burns. At the April 27th public meeting, it was reported that the last burn victim had healed sufficiently well to be able to leave the San Francisco Burn Center. He and others have gone or are currently going through required rehabilitation treatments.

The San Bruno gas pipeline explosion created additional long-term needs for the victims of this emergency. Recognizing the necessity of having a facility to address the wide array of challenges facing victims, the San Bruno Resource Recovery Center opened its doors at 458 San Mateo Ave on March 29, 2011. Financial support for the facility came from the Peninsula Health Care District's (PHCD's) donations for the City of San Bruno and the American Red Cross. Some of the major services provided at this location include mental health counseling and referral, housing and health services, case management, residential resources, training and the use of computers and office equipment.

3.4.2. Housing recovery

As previously mentioned, the explosion and fire caused by the ruptured gas line resulted in 38 homes being destroyed and another 70 damaged. The initial stages of the housing development process included the removal of debris as discussed earlier. With the assistance of agencies such as CalRecycle, the site clearing and grading process was essentially complete by October 17, 2010. This provided property owners with clean lots for rebuilding. In addition to working collaboratively with outside agencies to assist the residents with the clearing of their properties, city officials established policies and procedures to expedite the permitting process to facilitate the rebuilding of homes within the impacted neighborhood. Public officials also continued to assist residents with a myriad of issues, all with the goal of helping them to regain a

sense of normalcy. For instance, as early as October 12, 2010, the city approved an ordinance waiving all building and planning fees to facilitate the rebuilding process for the Glenview residents (City of San Bruno 2011). The City Council also approved expedited planning processes for Glenview residents reducing the processing period from six months to three months or less. In addition, many informational meetings, such as the October 28, 2011 Insurance Recovery Forum (City of San Bruno 2011), were held to answer questions from the residents and help them get back into repaired or new homes.

As of April 27, 2011, the city had received four applications for rebuilding. Additionally, one yellow tagged home requested a second story addition and another 17 homes were involved in some phase of architectural design.

3.4.3. Infrastructure recovery

Most of the neighborhood's utilities have been restored. Some of them required temporary solutions, but all have since resulted in permanent rerouting. For instance, water and sewer lines that were destroyed by the explosion have been repaired. This includes the repair of lines that feed fire hydrants. However, the recovery of the gas line has been more complicated.

Prior to the natural gas pipeline explosion, the residents of Glenview were unaware their homes were in such close proximity to a high pressure transmission pipeline. When the city staff was questioned about the location of the pipeline, they too appeared to have been unaware of its close proximity to residential buildings. This fact, along with the painful memory of the gas explosion, caused residents and city leaders to express concern following the disaster, demanding that Pacific Gas and Electric (PG&E) relocate the pipeline away from this neighborhood. PG&E agreed to not reinstate Line 132 (the ruptured line) in its pre-existing location and consequently removed it from operation in this neighborhood (San Bruno 2011). However, the crater from the explosion and remaining pipeline remained present on Glenview Drive for over a year, due to the request by NTSB to allow for its ongoing investigations.

3.4.4. Investigations

The National Transportation Safety Board (NTSB) began investigations immediately following the incident. The investigation was completed and the final report was published on August 30, 2011 (NTSB 2011g), almost one year following the incident. The NTSB Docket Management System website contains detailed postings about events leading up to and after the incident (NTSB 2011h).

The NTSB is not the only agency that investigated the incident. On September 23, 2010, the California Public Utilities Commission (CPUC) approved Resolution No. L-403 forming an independent review panel to investigate the pipeline incident and make recommendations for improving the safety and management of PG&E's natural gas transmission lines. Their report (IRP 2011) was published on June 24, 2011. Other investigations are also ongoing regarding the incident. For example, there is a task force comprised of the San Mateo County District Attorney's Office, the state Attorney General, and the U.S. Department of Justice that is collaborating on the criminal investigation of the incident (Worth 2011).

3.4.5. Legislative and regulatory issues

Local, state, and national politicians have taken an interest in the causes and consequences of the San Bruno gas pipeline explosion. For instance, on December 7, 2010, "assembly member Jerry Hill hosted a Legislative Forum on Natural Gas Infrastructure Integrity and Vulnerability with the Assembly Utilities and Commerce Committee and the Assembly Committee on Public Safety" (City of San Bruno 2011). He and other state legislators are attempting to strengthen regulatory guidelines. Legislators are currently debating the type and frequency of monitoring, along with the enforcement measures to be intensified so similar disasters may be prevented.

U.S. Congresswoman Jackie Speier also introduced a national pipeline safety bill containing three components: (1) the local utility is to give notice to all residents within 607 m (2,000 feet) of a transmission line, (2) automatic shut off valves are to be placed in transmission lines that are located in areas of high consequence, and (3) various utilities across the country shall provide training for first responders. The reason for including notice to residents in close proximity to transmission lines is that the community of Glenview was unaware of the existence of Line 132 and its potential risks. Accurate reporting and record keeping of pipeline location (or any underground utility) is also important so the proper precautions may be taken when future development or repair work occurs in the vicinity. Automatic shut off valves are being proposed in high consequence areas, such as residential neighborhoods because it took nearly 90 minutes for the gas supply to be shut off following the San Bruno explosion. Finally, because gas pipeline explosions are somewhat unusual emergencies, additional training and sharing of information to first responders might offer increased effectiveness and efficiency during response operations. Although the proposed bill has not yet passed through the legislative process to become law,

Congresswoman Speier reported that PG&E has agreed to provide all three components (San Bruno 2011). PG&E is also taking additional steps in light of the ongoing investigations and unfolding legislation.

4. ENGINEERING ANALYSIS OF RADIANT HEAT FROM FIRE

4.1. Introduction

The San Bruno incident was a full-bore rupture of a high-pressure gas pipeline with a horizontal release of gas resulting in explosion and fire. The primary hazard associated with such an event is the thermal radiation from a sustained fire fueled by the high-pressure gas from the ruptured pipeline. The fire caused significant damage to the buildings around the rupture site. In the following analysis, we apply three available hazard models to the San Bruno incident and compare the results across models and to observations. The models, developed to determine the high hazard areas associated with natural gas pipeline ruptures, are those in Jo and Ahn (2002), Stephens (2000), and Johnson et al. (1994). Key uncertainties in the analyses and model limitations are also discussed. Note that Kinsman and Lewis (2000) is also a useful reference for comparison.

4.2. Overview of analysis

There are three steps to estimate the hazardous area from a fire caused by a gas pipeline rupture:

1. **Effective release rate of gas**. Apply an effective release rate model to calculate a steady-state approximation of the gas release rate.
2. **Fire model**. Model the flame that results from the gas release rate determined in Step 1 and estimate the thermal radiation flux as a function of distance from the flame.
3. **Hazardous area**. Using a specified heat intensity threshold, determine the high hazard area surrounding the pipe rupture.

Stephens (2000) and Jo and Ahn (2002) provide models that include all the three steps. Johnson et al. (1994) only addressed Steps 2 and 3. In this analysis, we use the effective gas release rate from Jo and Ahn (2002) to apply the Johnson et al. (1994) model. The three steps are discussed in turn in Sections 4.3 to 4.5.

4.3. Effective release rate models

The gas release rate varies with time after a full bore rupture. In fact, the gas pressure can drop drastically within several minutes after the rupture. To estimate the gas rate of flow, we apply the methods described in Jo and Ahn (2002) and Stephens (2000).

In the Jo and Ahn method (2002), the release rate of natural gas from a full-bore rupture depends on the operating pressure, pipeline diameter, and the length of pipeline from the gas supply location to the rupture location. Equation 1 can be used to estimate the effective release rate (Eq. 22 in Jo and Ahn 2000). The equation can be used for full bore rupture of a large diameter (0.1 m to 1 m) natural gas pipeline when the rupture point is not near the gas supply station.

$$Q_P = 0.02161 P_0 d^2 \sqrt{\frac{d}{L}} Q_P = 0.02161 P_0 d^2 \sqrt{\frac{d}{L}} \quad (1)$$

where:

Q_P Gas release rate in pipe (kg/s)

d Pipe diameter (m)

L Pipe length (m) from compressor station to rupture site

P_0 Stagnant pressure at gas supply station or compressor station (N/m^2)

In the San Bruno incident, the pipe diameter is 0.762 m (NTSB 2010d). We assume L is the distance from the upstream valve to the rupture site. The rupture occurred on Line 132 near mile post (MP) 39.33, at the intersection of Earl Avenue and Glenview Drive in San Bruno (Figure 25). The upstream valve was at MP 38.49 and the downstream valve at Healy Station was at MP 40.05 (Figure 25). The distance from the upstream valve to the rupture site is estimated to be 1352 m, the difference between the upstream valve mile post and the rupture site mile post. (Note that the definition of L is not completely clear in Jo and Ahn (2002). For this incident, L could be considered to be 1352 m (distance to closest valve), 11.3 km (distance to Martin station downstream), or some other distance upstream, perhaps as much as 25 km, the distance to Milpitas. After some sensitivity calculations, we decided to use 1352 m in this analysis.)

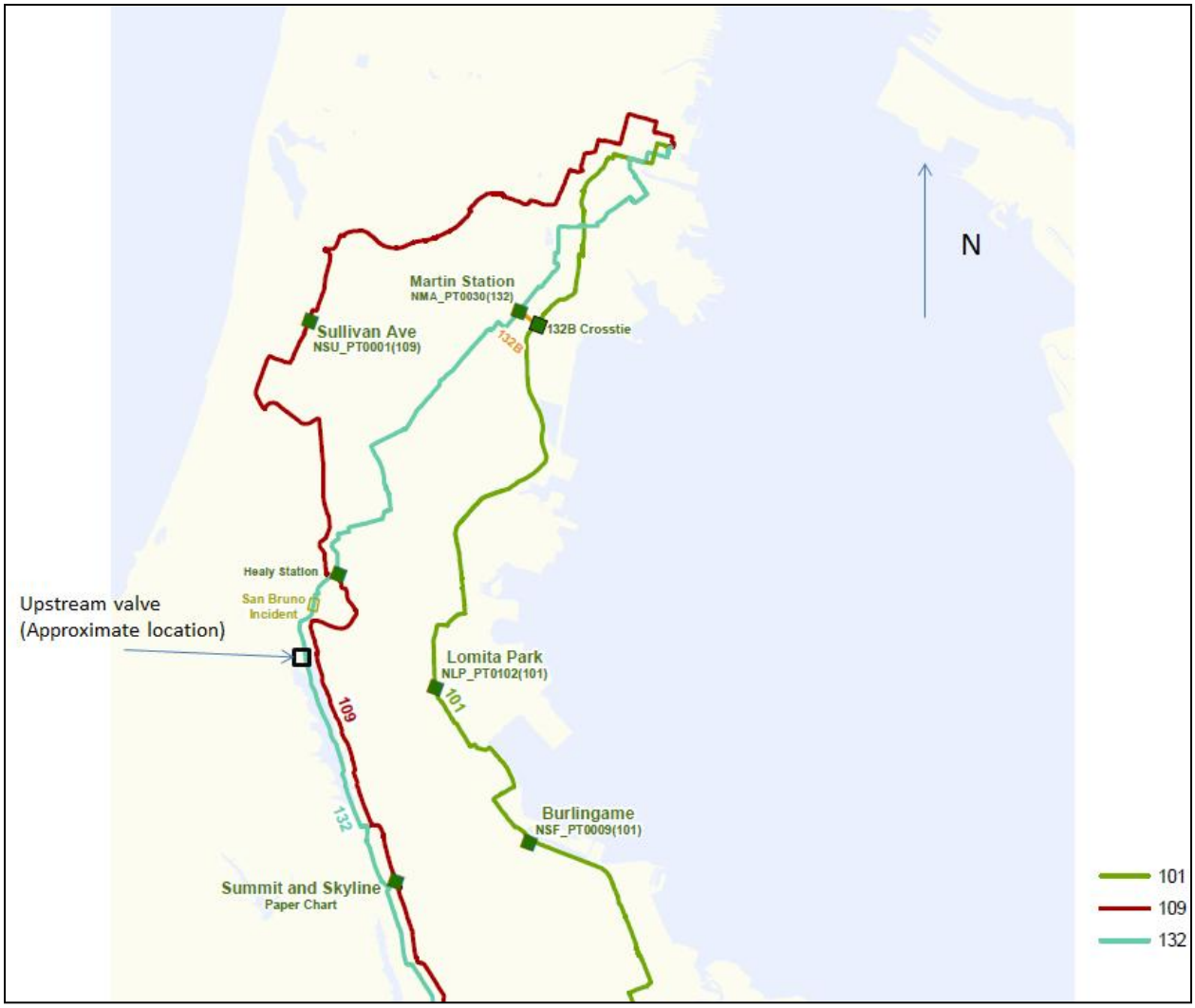


Figure 25 Schematic of pressure points LT system (NTSB 2011f)

At the time of the rupture, the pipeline pressure was estimated to be 2.66(10^6) N/m^2 (386 psi) to 2.73(10^6) N/m^2 (396 psi) (NTSB 2011b). Within a few minutes of rupture, the gas release rate drops to a fraction of its initial peak value. Equation 1 calls for the stagnant pressure at the gas supply station P_0 after that initial pressure drop. Since that value is unknown, we conduct the analysis for two different values, both taken from the records of Martin station, 11.3 km (7 miles) downstream of the rupture site (NTSB 2011g). The values were recorded 1 and 5 minutes after the rupture (Table 3).

Table 3 Gas pressure records at Martin Station (psi)

Time (PDT)	6:12 pm (1 minute after rupture)	6:16 pm (5 minutes after rupture)
Gas pressure P_0 (N/m^2)	2.00(10^6) N/m^2	0.99(10^6) N/m^2

Using these estimated input values (d=0.762 m, L=1352 m, and P_0=2.00(10^6) or 0.99(10^6) N/m^2), the estimated gas release rate using the Jo and Ahn (2002) method is 595 kg/s or 296 kg/s, depending on the assumed pressure P_0 (Table 4).

Table 4 Estimated effective gas release rate (in kg/s), by assumed gas pressure (psi)

Model	Gas pressure	
	2.00(10^6) N/m^2	0.99(10^6) N/m^2
Jo and Ahn 2002	595	296
Stephens 2000	645	320

The Stephens (2000) model accounts for the high variability of gas release rate by approximating the transient jet or trench fire as a steady-state fire that is fed by an effective release rate. The effective release rate is a fraction of the peak initial release rate that can be used to obtain estimates of sustained heat flux that are comparable to those obtained from a more realistic transient fire model. The release rate in kg/s from a full-bore line rupture in the Stephens (2000, Eq. 2.4) model is:

$$Q = 2\lambda C_d \frac{\pi d^2}{4} p \frac{\varphi}{a_0} \qquad (2)$$

where:

φ Flow factor = $\gamma \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{2(\gamma-1)}}$

a_0 Sonic velocity of gas = $\sqrt{\frac{\gamma RT}{m}}$

C_d Discharge coefficient = 0.62

γ Specific heat ratio of gas = 1.306 for methane

R Gas constant = 8310 J/(kg mol)/K

T Gas temperature = 288 K

m Gas molecular weight = 16 kg/mol for methane

λ Release rate decay factor = 0.33

d Effective hole diameter = pipe diameter in m

p Pressure differential = pipe pressure in N/m^2

As in the application of the Jo and Ahn (2002) model, in the San Bruno incident, the pipe diameter was 0.762 m (NTSB 2010d), and two possible estimates were considered for the pipe pressure (Table 3). With the inputs listed, the Stephens (2000) estimates 645 kg/s or 320 kg/s, depending on the assumed pressure p (Table 4). The Stephens results are 8% more than Jo and Ahn's results. Table 5 compares the models in terms of the inputs they require and the factors they consider.

Table 5 Comparison of Jo and Ahn (2002) and Stephens (2000) effective release rate models

	Jo and Ahn (2002)	Stephens (2000)
Inputs	• Gas pressure in supply station P_0 • Rupture hole diameter d • Gas pipe length from pumping station to rupture location L • Physical property of gas	• Gas pressure in pipe p • Rupture hole diameter d • Physical properties of gas
Factors that affect release rate	• Gas is released from one end of pipe. • Gas pressure loss is caused by friction along the pipe.	• Gas is released from both ends of pipe. • A conservative release decay rate factor is used to represent the effective gas release rate.

4.4. Fire models

Stephens (2000) and Jo and Ahn (2002) adopt a similar assumption that considers the actual jet flame to be a point source (Figure 26) that emits thermal radiation at the ground level. The equation for the radiation heat flux I in kW/m^2 at a horizontal distance of r (in m) from the fire center is (Eq. 2.1 in Stephens (2000), based on API RP 521 (1990):

$$I = \frac{\eta X_g Q_{eff} H_c}{4\pi r^2} \quad (3)$$

H_c Heat of combustion = 50,000 kJ/kg

η Combustion efficiency factor, accounts for incomplete combustion of escaping gas stream, assumed to be 0.2 in Jo and Ahn (2002) and 0.35 in Stephens (2000)

X_g Atmospheric emissivity, accounts for absorption of radiant heat into atmosphere before reaching target, assumed to be 1 in Jo and Ahn (2002) and 0.2 in Stephens (2000)

Q_{eff} Effective gas release rate (kg/s), taken from Step 1

r Radial distance from heat source to location of interest (m)

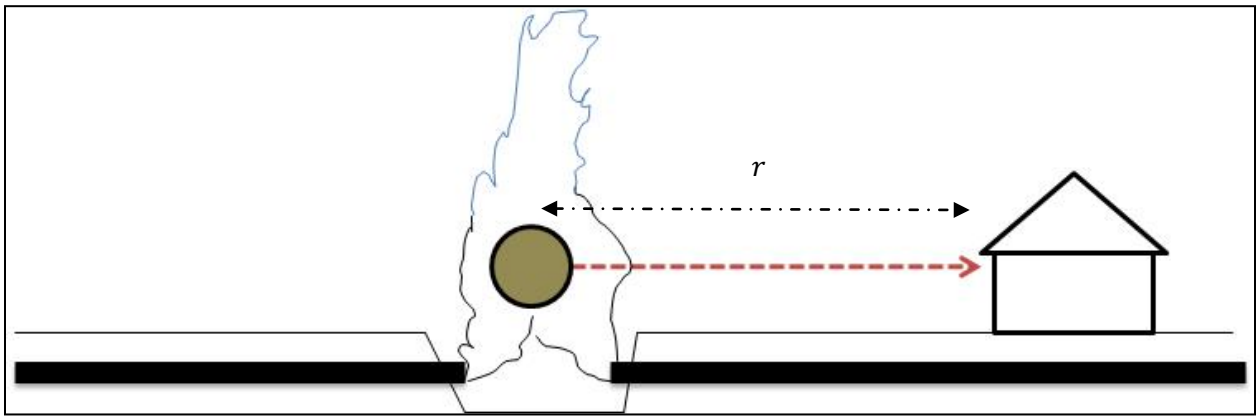


Figure 26 . Point source fire model

Equation 3 describes a relatively simple and conservative method to estimate the hazardous area for a gas jet fire. It does not, however, consider the effects of flame geometry and wind. Johnson et al. (1994) provides correlations to predict flame shape and thermal radiation. In Johnson et al. (1994), the flame is modeled as a truncated frustum of a cone (Figure 27). The variables defining the shapes are the coordinates (x, y, z) of the center of the end of the frustum in m, the maximum flame width W_2 in m, the minimum flame width W_1 in m, and the flame lift-off b in m, as shown in Figure 27. Johnson et al. (1994) require the following inputs to calculate these dimensions: (1) Wind speed and direction, (2) gas release rate from pipe, and (3) physical properties of gas.

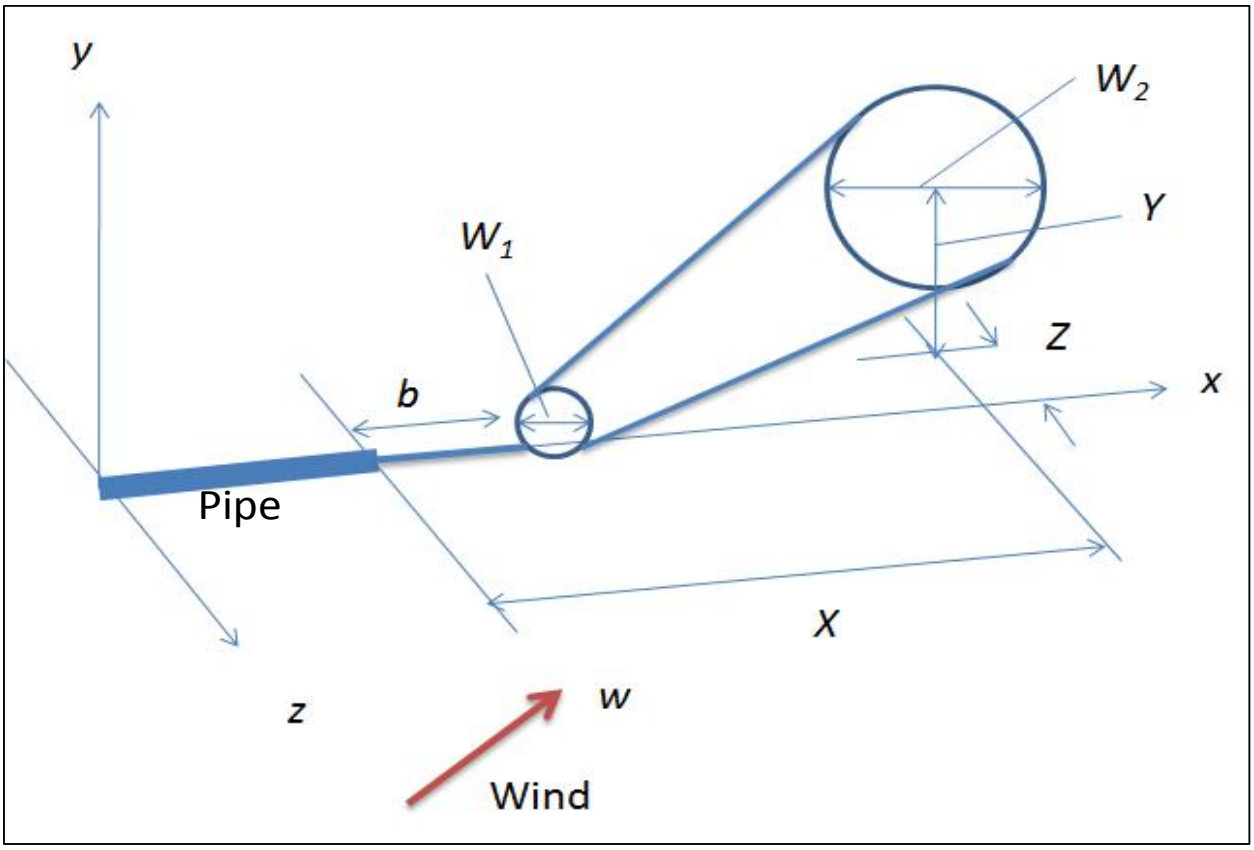


Figure 27 Horizontal release flame shape model (Redrawn from Johnson et al. 1994)

At the San Francisco International Airport (3 miles from the rupture site) at 1756 PDT, the wind was from 270° clockwise from north at 18 knots. In the following 4 hours, measured wind directions remained between 270° and 290°, and wind speeds were above 15 knots through 2156 PDT (NTSB 2011e). Based on those reports from 6pm to 7pm PDT on September 9, 2010, we assumed a wind speed applied of 18 knots, 280° clockwise from the North. Following Lee and Davidson (2010), we assume that the hazardous area is a semicircle with the centerline in the direction of the flame tilt.

Using the gas release rate results from the Jo and Ahn (2002) model (Table 4) and the other inputs, we determined the flame shape using the Johnson et al. (1994) model for each of the two gas pressure values considered (Table 6). Examining an incident photo in which the flame was still burning (ABC News 2010), we estimate the flame height reached 71 m. While this is lower than the model estimation (Y=116 or 148 m), it is in the same range and it is unclear what time exactly the photo was taken. No data is available on the peak flame height.

Table 6 Flame shape geometry using Johnson et al. (1994) model, all values in m

Flame dimension	Assumed gas pressure	
	$2.00(10^6)$ N/m^2	$0.99(10^6)$ N/m^2
X	104	66
Y	148	116
Z	128	107
b	20	14
W_1	16	12
W_2	93	76

In Johnson et al. (1994), the thermal radiation q (kW/m^2) received by a target from the flame is given by Equation 4. (Note that q is the same quantity as the radiation heat flux I in Equation 3.) The surface emissive power S is calculated using Equations 5 and 6 (Eq. 19 from Johnson et al. 1994 and Cook et al. 1987):

$$q = (VF)(S)(\tau) \tag{4}$$

$$S = \frac{FQ}{A} \tag{5}$$

$$Q = \Delta h_c m_j \tag{6}$$

where:

S Surface emissive power (SEP) in kW/m^2

τ Atmospheric emissivity, accounts for absorption of radiant heat into atmosphere before reaching target

VF View factor (or configuration factor), which quantifies the geometry relationship between the flame shape and the receiving target

F Fraction of heat radiated from the surface of the flame

Q Net heat released as combustion in kW

A Total model flame surface area in m^2

Δh_c Heat of combustion = 50,000 kJ/kg

m_j Mass flow rate of gas exiting stack (kg/s), value taken from the Jo and Ahn (2002) model results in Step 1

Johnson et al. (1994) use a numerical contour integration technique (Brian and Bagster 1989) to calculate the view factor of the end and side of the flame. In this analysis, to simplify the calculation of the view factor, we instead assume the flame shape to be a tilted cylinder and use the Mudan (1984) view factor equations (Figure 28). The cylinder geometry is estimated from

the Johnson et al. (1994) truncated cone (Table 6), assuming the conversions specified in Equations 7, 8, and 9.

$$D_R = W_1 \tag{7}$$

$$\theta_R = \operatorname{atan}\left(\frac{Y}{\sqrt{(X\text{-}b)^2 + Z^2}}\right) \tag{8}$$

$$H_R = \sqrt{(X\text{-}b)^2 + Z^2 + Y^2} \tag{9}$$

where:

H_R Flame height

D_R Flame width

L_R Distance from flame center to the receiving target

θ_R Tilt angle of flame

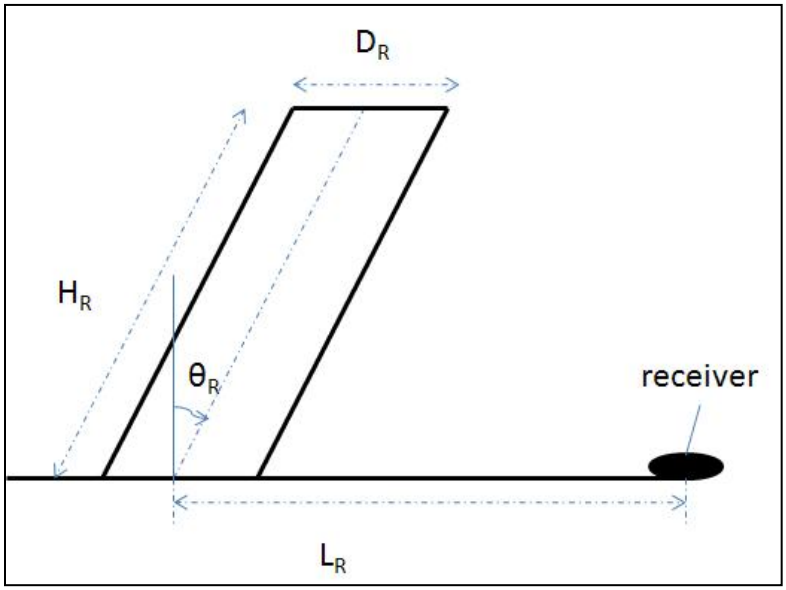


Figure 28 Assumed geometry for tilted cylinder for flame (Mudan 1984)

Table 7 provides a detailed comparison of the three fire models.

Table 7 Comparison of fire models

	Jo and Ahn (2002)	Stephens (2000)	Modified Johnson et al. (1994)
Inputs	Effective gas flow rate	Effective gas flow rate	• Effective gas flow rate • Wind speed and direction
Flame geometry	Point source	Point source	Truncated frustum of a cone/tilted cylinder
Wind effect	No effect	No effect	Flame is diverted from the direction of gas release.
Hazardous area	Circle	Circle	Semi-circle
Atmospheric emissivity	1	0.2	1
Combustion efficiency factor	0.2	0.35	---
Model	API RP 521 (1990)	API RP 521 (1990)	Correlations from experiments.

4.5. Hazardous area

To estimate the hazardous area, we assume a threshold radiation flux value and use the fire models in Step 2 to determine the distance within which that threshold is exceeded. For people, the thermal radiation threshold is represented as that at which people outdoors at the time of failure would be exposed to a finite but low chance of fatality (1%). For a typical wooden property, the threshold is the value below which the property would not be burned. Stephens (2000) adopted 15.77 kW/m^2, Jo and Ahn (2002) used 15 kW/m^2, and Lee and Davidson (2010) used 12.5 kW/m^2 as the thermal radiation threshold values used to define a hazardous area for damage to both people and property. For this analysis, we use 15 kW/m^2. Table 8 summarizes the resulting hazard areas for all three models. Figure 29 and Figure 30 show maps of the resulting estimated hazardous areas.

Table 8 Hazard area shape and radius (in m) for all three models

Model	Hazard area shape	Radius of hazardous area (m)	
		Assumed gas pressure	
		2.00(10^6) N/m^2	0.99(10^6) N/m^2
Jo and Ahn 2002	Circle	178	125
Stephens 2000	Circle	107	75
Johnson et al. 1994	Semi-circle (+/- 90° from the flame tilted direction)	80	51

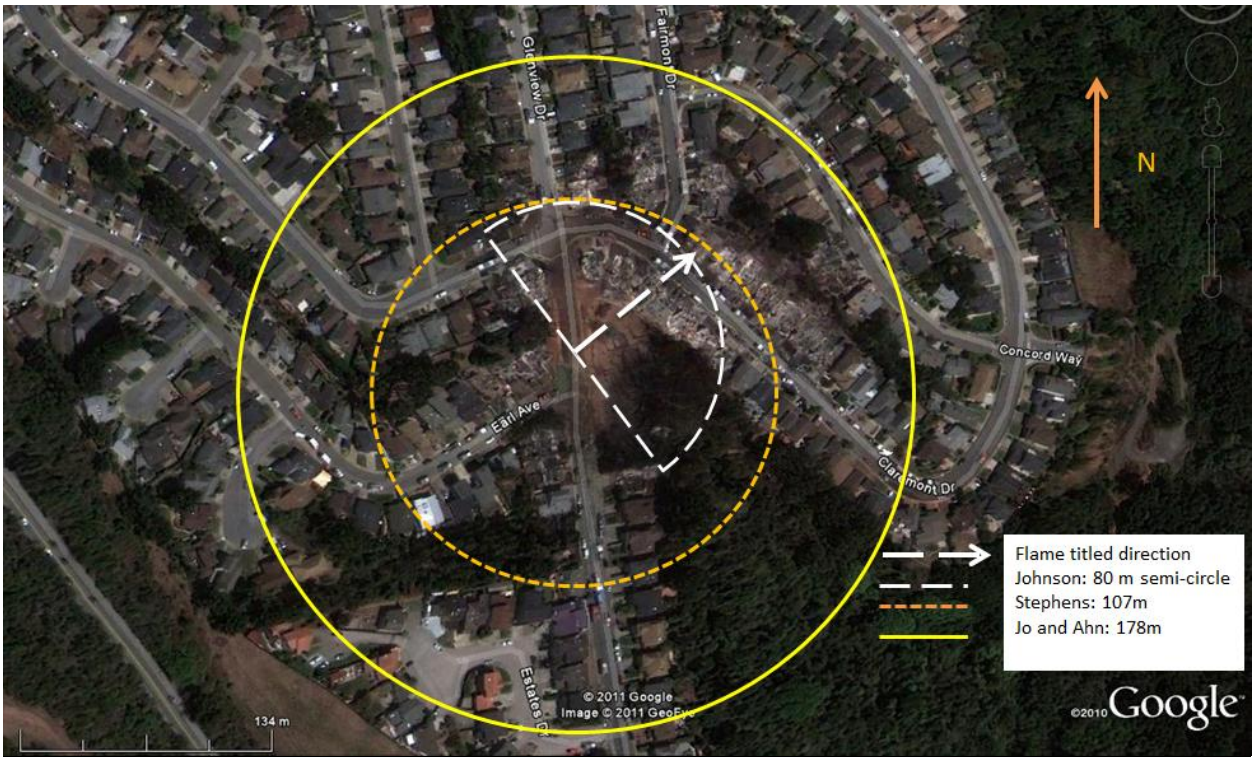


Figure 29 Hazard area when gas pressure was 289.9 psi

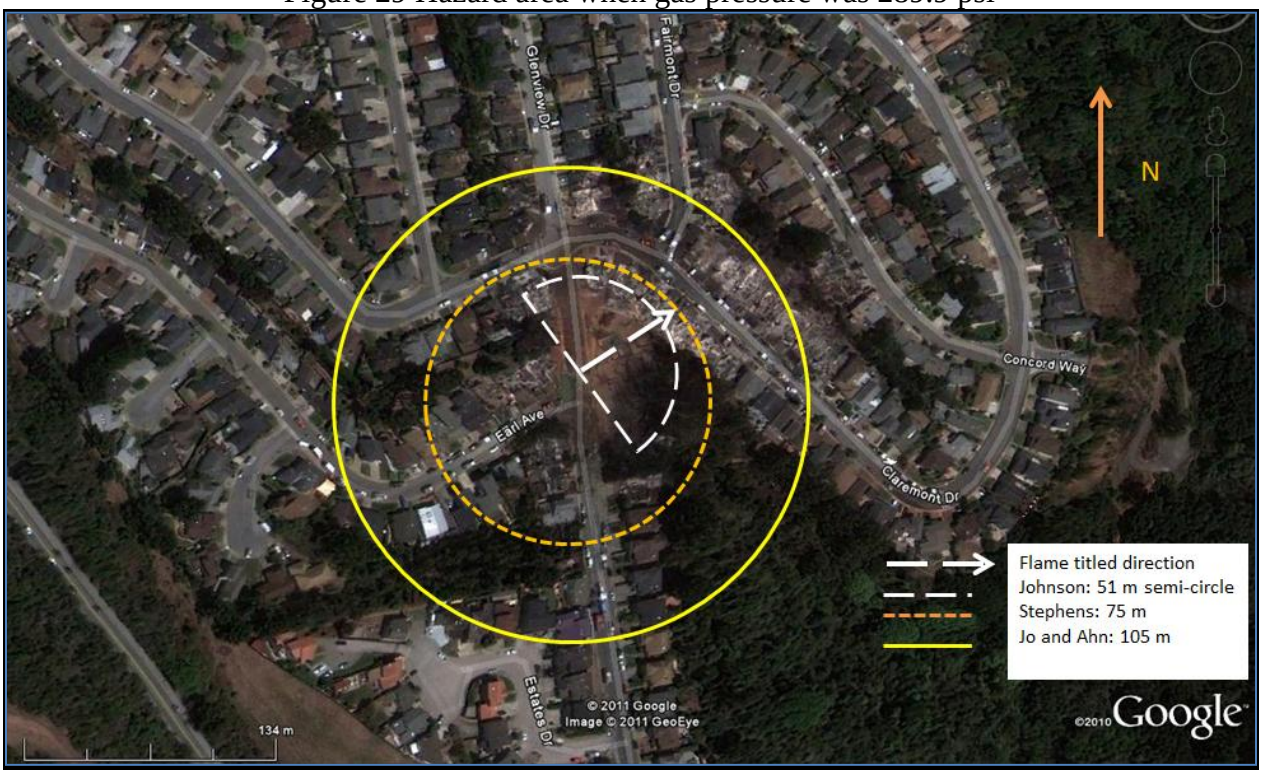


Figure 30 Hazard area when gas pressure was 144 psi

4.6. Discussion

The modified Johnson et al. (1994) model, which results in a semicircular hazard area due to the flame tilt, produced a hazard area slightly smaller than Stephens (2000) model. The Jo and Ahn (2002) model results in an area with a radius about 65% to 150% larger than the other two. They all estimate areas that are similar to the area in which houses actually burned. The direction in which the actual fire tilted can be estimated by looking at the area with the most severely burned pavement in the aerial photo. It appears that that true direction of tilt is within the semicircle estimated by the Johnson et al. (1994) model, but approximately 5◦ west of the centerline estimated by Johnson et al. (1994). That discrepancy could easily be explained by differences in the wind direction at the rupture site and at the airport. Given the uncertainty in the model estimates, it is not clear if all the home ignitions were due directly to the radiation emitted from the gas jet flame or if some houses were ignited by neighboring homes through radiation or branding (termed “exposure fires”). Even if some houses were exposure fires, their number was not large. The fire did not spread very far from the circle of radiant heat ignition, attesting to the rapid and effective fire department response. The three models all provide a quick estimation of the hazardous area associated with a gas pipeline rupture and based on their intended uses for estimating risk, were intended to be conservative.

The following issues represent areas of uncertainty or limitations of the analysis:

- **Initial explosion**. The effect of the initial explosion is not considered in any of the models.
- **Wind condition**. The wind condition at the exact site was unknown. NTSB collected records from several stations near the rupture location. The input used in the calculation is from the record at the San Francisco International Airport, which is about 3 km (2 miles) from the incident site, 114 m (374 ft) lower in elevation.
- **Extrapolation of empirical equations**. When applying the Johnson et al. (1994) model, it should be noted that the correlations are derived from experiments. However, the conditions of the San Bruno incident were not within the range of the experimental conditions. In particular, the maximum pipe diameter in the experiments was 0.152 m while the diameter of the pipe that ruptured in the San Bruno incident was 0.762 m. The interpretation of this application should be treated with caution.

- **Gas release flow rate**. The effective gas release flow rate is only an approximation of actual rate. The real gas flow rate is highly variant and time-dependent. It will decrease as pressure loss with time. The complete pressure records at the site and gas supply station were not available and only two pressure estimates were used.
- **Fire models**. All three models are for quick engineering estimation with satisfactory precision. To obtain a highly precise result, a complicate fire dynamics simulation model and more inputs are needed.

In conclusion, the models all estimate areas that are similar to the area in which houses actually burned. There is, however, uncertainty in the estimates and limitations to the analyses, especially related to representation of the effect of the initial explosion, uncertainty in wind conditions at the site, extrapolation of empirical equations, and estimation of gas release flow rate. With more validation, however, the methods may be useful for regional assessments of the risk associated with natural gas pipeline ruptures.

5. EMERGENCY MANAGEMENT ANALYSIS

The San Bruno gas explosion and subsequent response illustrate important lessons for pipeline safety and future emergency management operations. These lessons have nationwide application and should be considered by government officials and even utility providers. They include strengths, weaknesses, and concerns for the future.

5.1. Strengths

Public, private and non-profit organizations made visible and noteworthy contributions after the San Bruno gas pipeline explosion, and these should be recognized in after-action reports. First, and most importantly, many efforts are being undertaken to better understand the pipeline explosion and prevent a similar occurrence in the future. A number of investigations were initiated and the findings will help to educate the public about what led to the incident and how a similar event could be prevented in the future.

The San Bruno Fire Department and the San Mateo mutual aid system moved swiftly in marshaling resources. Without this type of forward thinking and emergency decision making, the fire spread would have almost certainly been worse. Mutual aid teams in the nearby area also deserve recognition for seamlessly integrating into the ongoing response to the pipeline explosion.

The city, American Red Cross, and faith-based community also worked harmoniously to provide shelters and address victims' immediate needs. The response to the loss of housing was impressively quick, and occurred soon after the explosion. These organizations assessed needs quickly and mobilized to meet them in an impressive manner.

The assessment of damages was both efficient and effective. Although this function was interrupted for a period, homes were evaluated within a relatively short period of time. What is more, those assessing impacts appeared to have been well-trained and understood what to do and how to accomplish their goals. Although this was a small event relative to a possible earthquake for example, damage assessment officials in California are often among the most well prepared (perhaps due to the threat of major earthquakes).

The re-entry of victims was also a function that was performed admirably. City leaders quickly recognized that victims would need to return to the impacted area to gather personal belongings, evaluate losses, and initiate insurance claims.

Those participating in debris management and environmental remediation also exhibited high degrees of professionalism after the San Bruno pipeline explosion. CalRecycle appears to have employed very knowledgeable staff who had gained valuable experience in debris management after prior wildland-urban interface fires in California. The speed of removal and consideration of environmental concerns (e.g., debris sorting and recycling) were exemplary.

The city and many other organizations continue to work diligently to address the long-term needs of victims and the community as a whole. Public officials kept victims and the city informed about what they are doing and how victims can receive help. The city is working hard to help recovery (e.g., by waiving fees and expediting the rebuilding process). Disaster assistance organizations have also maintained continuous operations, thereby doing their best to ensure that victims' long-term needs do not fall through the cracks in the wide number of humanitarian programs.

Finally, it is important to note that political officials, department heads, and other key leaders made good decisions under conditions of uncertainty and dynamic change. They were guided generally by emergency operations plans, but were also willing to adapt, improvise and be flexible as the situation dictated. In particular, the decision makers were able to identify problems and potential solutions, and work through the difficult task of making them work in a short amount of time and with limited resources. Their "expedient planning" is to be commended but also emulated by others.

5.2. Weaknesses

There were a few significant problems evident in the San Bruno gas pipeline explosion. Some of these challenges concern the nature of location of utilities and critical infrastructure. First, there appears to have been a lack of widespread knowledge about the location of pipelines in the jurisdiction, despite the fact that the location was clearly shown on the National Pipeline Management System website (Figure 31). Many public servants and government agencies did not know exactly where major pipelines were present in residential neighborhoods. This may be a result of the installation of the gas infrastructure long before current politicians were in office

and government employees began working in their current jobs. Regardless, urban planning must give more attention to the relation of critical infrastructure and residential proximity. In addition, a greater effort needs to be given to awareness of pipeline location. Politicians, agency officials, and citizens must know the geographic distribution of gas lines in the jurisdiction.

Second, preliminary reports from investigative agencies suggest that there may have been a problem with the welds on the pipe when it was laid in the area and the pipe may have been operating under excessive pressure. If this is proven accurate (and initial reports suggest that this is the case), additional care should be given to pipeline construction and operations when infrastructure projects are undertaken.

Third, the age of the pipeline and the explosion suggest that pipeline maintenance may need to be a higher priority for utility providers. Soil conditions, temperatures, and wear and tear take a toll on utility pipelines. Local, state and federal governments should also monitor this maintenance to ensure public safety to the fullest extent possible.

Finally, the delay in shutting down the pipeline indicates an inadequate number of shut-off valves and/or insufficient preparedness for emergency shut-down. Taking 90 minutes to shut off the flow of gas was unacceptable in this situation. The public and private sectors must work more closely together to install additional valves to minimize exposure, develop standard operating procedures to streamline decision making, and train employees on how best to respond to these types of emergencies.

Other problems in the San Bruno incident were directly related to emergency response and recovery activities. This event, like many other emergencies and disasters, illustrated challenges regarding multi-organizational coordination. For instance, at one point there was some disagreement between police and the engineering department over damage assessment activities. Law enforcement officials were concerned about public safety while inspectors desired to evaluate damages quickly. All organizations must therefore look beyond their own domain and consider how their decisions and operations may adversely affect the functions of others.

Donation management also proved to be problematic after the San Bruno pipeline explosion. Citizens, in an effort to help disaster victims, spontaneously established an unauthorized donation drop-off location in a nearby parking lot while businesses provided gift cards to humanitarian organizations that were not always useful. Public and non-profit organizations should consequently work closely with the media to announce response or victim

needs, donation drop-off preferences, and appropriate types of donations. Although donations are often a challenge after any type of incident or disaster, more can be done to streamline the provision of this type of assistance to those impacted by such events.

Figure 31 National Pipeline Management System map, showing Line 132 on Glenview Drive (https://www.npms.phmsa.dot.gov/PublicViewer/ accessed 18 Sept. 2010)

6. IMPLICATIONS

We conclude with some thoughts on the implications of the San Bruno, CA pipeline explosion and fire for critical infrastructure maintenance, for earthquake risk, and for the notion of expedient planning.

6.1. Critical infrastructure maintenance and reliability

Even though based on preliminary field work, our findings, drawn from interviews and from the extensive documentary resources of the National Transportation Safety Board, suggest the presence of difficult theoretical and practical questions about the ability of organizations to maintain their attention on their own operations over long periods, even decades or more. Indeed, there seems to have been a slow loss of institutional memory at PG&E, which grandfathering probably contributes to, since a matter that is grandfathered can now be set aside in favor of more contemporary compliance concerns. Many locations around the country likely have similar administrative and management slippage in their utility companies, and indeed the location of much infrastructure is known only approximately. The consequence is that infrastructure surprises lie in wait, threaded through the landscape. The importance of time, therefore, should receive enhanced attention in the areas concerned with the management of complex technical systems. For although in some senses gas transmission pipelines are a well-understood technology, in use for well over a century in many places, that extended history also means that much about their early design and installation may well be forgotten, creating an apparent complexity through unexpected proximity to other systems and by limiting the awareness of today's operators of decisions made long ago about the system they manage. In some cases, utility companies use new construction projects as opportunities to map the locations of their infrastructure, essentially re-exploring the built environment that they or their predecessors created in the first place.

The issue of infrastructure safety and reliability is at the crux of the operation of hazardous technologies by for-profit entities. In essence, safety and reliability cost money, and are often in practice implemented to the bare minimum as required by regulation. As the CPUC's Independent Review Panel concluded:

> *The capital investment by PG&E in the gas transmission pipeline system has been minimal. There was no plan to modernize the system and seek opportunities to improve the risk associated with operating the system. Instead, the focus was to provide funding to ensure compliance with the Pipeline Integrity rules.* (IRP 2011).

Not only is this a deadly threat to public safety, but in fact it is bad business. The following data indicate the approximate cost of the disaster for PG&E (only): (a) on September 10, 2010 PG&E's 395 million shares of stock declined from $48.24 per share (price prior to the explosion) to $44.21 per share representing an aggregate loss to shareholders of $1.6 billion or 9% of the value of the company; and (b) on February 17, 2012 PG&E announced "*that the utility's costs of testing and shoring up its gas-pipeline system following a [the] fatal 2010 pipeline explosion could top $1.7 billion through next year, pressuring earnings for the foreseeable future"* (Sweet 2012).

6.2. Earthquake risk

A further implication of this incident is the glimpse it provides into what might occur following a major earthquake in California or elsewhere. In the San Bruno event, although the destruction was substantial, the response was arguably quite effective. It was, however, an isolated incident involving a single location of pipe damage (albeit a complete break of a large transmission line) and the full resources of the county and region were mobilized to respond. As shown in Figure 19, many responding units came from long distances. In a major earthquake, such as those expected in California, the situation could be much worse for a few reasons. First, following a major earthquake, there may be many gas pipeline breaks and leaks at the same time. Following the 1989 Loma Prieta, California earthquake (M7.2), for example, 1,094 leaks were identified in the utility gas system, and 601 were classified as Grade 1, or potentially hazardous to life or property (CSSC 2003). The 1994 Northridge, California earthquake (M6.7) caused 35 failures on older transmission lines, 123 failures of steel distribution mains, and 117 failures in service lines (CSSC 2003). Another 394 corrosion leaks were identified during leak surveys following the earthquake (CSSC 2003). One of those failures, a broken 20-inch gas main under Balboa Boulevard caused a fire that destroyed five homes and caused minor damage to four others (Scawthorn et al. 2005). Each of those gas system damage locations would not only affect

service to customers, but pose a fire risk that under the right conditions—a windy day in a densely populated area—could be catastrophic.

Second, at the same time the gas system damage occurs, the fire departments and other emergency response agencies will have many demands on them. Following the Northridge earthquake, for example, about 110 separate fires ignited as a result of the earthquake (Scawthorn et al. 1998) and in the first 27.5 hours, the Los Angeles Fire Department dispatch center created 2.5 times the normal number of incidents—⅓ fire incidents, ½ EMS incidents, and the rest other types (Borden 1997). These competing demands could prevent the emergency responders from operating as effectively as they did in the San Bruno case.

Finally, an earthquake will not only damage the gas system, but buildings and other utilities as well, further impeding the ability to respond to any gas system damage that does occur. During the Balboa Boulevard fire, for example, some surrounding roads were impassable because of flooding caused by a water main break in the same location and debris from collapsed walls. Water system damage left all surrounding hydrants without water as well, though fortunately there were nearby swimming pools that could be used as water supply sources (Scawthorn et al. 2005).

Importantly, a major earthquake is not unlikely in California. According to a 2008 U.S. Geological Survey report, there is a 63% chance of an earthquake of magnitude 6.7 or larger occurring in the San Francisco area in the next 30 years; and a 67% chance in the Los Angeles area (Field et al. 2008). In summary then, there is a real potential for a post-earthquake situation with many simultaneous gas system breaks and leaks and impaired response capabilities that would result in some of those incidents not receiving adequate response and possibly leading to extremely destructive conflagrations. Urban fires grow in a nonlinear fashion, in that they quickly become much, much harder to extinguish as they spread. The key to limiting damage is responding quickly. That was done in San Bruno (and Loma Prieta and Northridge), but may not be possible following the next earthquake.

6.3. Expedient planning

Also of note is the challenge to building situation awareness in surprising, potentially ambiguous events such as the gas pipeline explosion. Eyewitnesses reported an aircraft crash, in one instance actually stating having observed the fuselage of an aircraft strike the ground.

Obviously that did not happen, but this experience comports with others we have observed when people see sudden and unusual events: they fit their observation into what they consider to be the likely cause of the anomaly. In this case, proximity to San Francisco International Airport suggests an airliner crash, with the huge explosion and fireball. In the 9/11 attacks, eyewitnesses reported actually seeing a small plane strike one of the twin towers. And in the recent August 23, 2011 Mineral, Virginia, earthquake (M5.8), personnel in the Pentagon interpreted it as an attack, while residents in the Mineral area interpreted it as an emergency at the nearby nuclear plant. Sensemaking (Weick 1993, 1995) is a theory of organizational cognition that emphases identity, experience, and environmental cues as the bases for how people interpret a situation, while the "closure" phenomenon (Daft and Noe 2001) is a perceptual process in which, given scant facts, people close the gaps to reach an understanding of them based on previous experience.

Decision making, especially the recognition-primed decision making that scholars (e.g., Zsambok and Klein 1997) argue is the actual decision making habit of firefighting personnel, may therefore be impeded by the unavoidable need to rely on eyewitnesses for initial situation size-up, especially when responding to distant events for which such information is all that is available. For the moment, techniques to ameliorate this challenge remain elusive, but should probably be subjects for future research.

7. EPILOGUE. STATUS AS OF MAY 2012

This chapter summarizes selected aspects of the community as of the end of May 2012, twenty and a half months following the explosion.

7.1. Responsibility

Investigations of the incident have been completed by: (1) the NTSB and (2) the Independent Review Panel (IRP) convened by the California Public Utilities Commission (CPUC).

The National Transportation Safety Board prepared a Pipeline Accident Report which determined "…that the probable cause of the accident was the Pacific Gas and Electric Company's (PG&E) (1) inadequate quality assurance and quality control in 1956 during its Line 132 relocation project, which allowed the installation of a substandard and poorly welded pipe section with a visible seam weld flaw that, over time grew to a critical size, causing the pipeline to rupture during a pressure increase stemming from poorly planned electrical work at the Milpitas Terminal; and (2) inadequate pipeline integrity management program, which failed to detect and repair or remove the defective pipe section…Contributing to the accident were the California Public Utilities Commission's (CPUC) and the U.S. Department of Transportation's exemptions of existing pipelines from the regulatory requirement for pressure testing, which likely would have detected the installation defects. Also contributing to the accident was the CPUC's failure to detect the inadequacies of PG&E's pipeline integrity management program…Contributing to the severity of the accident were the lack of either automatic shutoff valves or remote control valves on the line and PG&E's flawed emergency response procedures and delay in isolating the rupture to stop the flow of gas." (NTSB 2011g)

The **Independent Review Panel** convened by the CPUC focused on Pipeline Integrity Management, finding "PG&E…did not properly account for the threat of failure of a section of pipeline system… the breakdown in PG&E's pipeline integrity management is the result of a series of compromises made in the quantity and quality of resources dedicated to the transmission system. Similarly, the inability of the CPUC's safety organization to understand this breakdown and sound alarms is also the result of compromises made in the resources dedicated to oversight of the gas transmission pipelines of the state. Both organizations failed to understand

the critical technical and managerial nature of the pipeline integrity mandate and neither created an environment in which excellence was demanded... The capital investment by PG&E in the gas transmission pipeline system has been minimal. There was no plan to modernize the system and seek opportunities to improve the risk associated with operating the system. Instead, the focus was to provide funding to ensure compliance with the Pipeline Integrity rules" (IRP 2011).

7.2. Financial cost

The total cost of this disaster includes human fatalities and severe injuries, loss of households, disruption of a community and other costs, and therefore is not susceptible to simple accounting. Focusing solely on the financial cost:

- On September 10, 2010, PG&E's 395 million shares of stock declined from $48.24 per share (price prior to the explosion) to $44.21 per share representing an aggregate loss to shareholders of $1.6 billion or 9% of the value of the company.
- On February 17, 2012, PG&E announced "that the utility's costs of testing and shoring up its gas-pipeline system following a fatal 2010 pipeline explosion could top $1.7 billion through next year, pressuring earnings for the foreseeable future" (Sweet 2012).
- On May 15, 2012, PG&E indicated it expects to pay up to $2 billion over the next two years to cover costs related to the explosion (Ricard 2012, Table 9).

To quote the 2011 PG&E Annual Report (PG&E 2011, p.5):

> *The Outcome of Matters Related to the Utility's Natural Gas System. In 2011, the Utility incurred expenses of $483 million for hydrostatic pressure tests and other pipeline-related activities that will not be recovered through rates. In 2012, the Utility forecasts that it will incur costs associated with its natural gas pipeline system ranging from $450 million to $550 million that may not be recoverable through rates. Although the Utility has requested the CPUC to authorize the Utility to recover certain costs it incurs in 2012 and future years under its proposed pipeline safety enhancement plan, it is uncertain what portion of these costs will be recoverable and when such costs will be recovered. (See ''Natural Gas Matters—CPUC Rulemaking Proceeding'' below.) Additionally, the Utility has incurred a cumulative charge of $375 million ($155 million in 2011 and $220 million in 2010) for third-party claims related to the San Bruno accident and estimates that it is reasonably possible it will incur up to an additional $225 million, for a total possible loss of $600 million. PG&E Corporation and the Utility also believe that it is probable the CPUC will impose penalties of at least $200 million on the Utility as a result of its pending investigations and the*

Utility's self-reported violations and have accrued this amount as of December 31, 2011. PG&E Corporation and the Utility are unable to estimate the reasonably possible amount of penalties in excess of the amount accrued, and such amounts could be material. (See Note 15 of the Notes to the Consolidated Financial Statements.) An investigation of the San Bruno accident by federal and state authorities also may result in the imposition of civil or criminal penalties on the Utility. PG&E Corporation's and the Utility's future financial condition, results of operations, and cash flows will be affected by the scope and timing of the final CPUC-approved pipeline safety enhancement plan, the ultimate amount of pipeline-related costs that are not recovered through rates, the ultimate amount of costs incurred for third-party claims that are not recoverable through insurance, and the ultimate amount of civil or criminal penalties, or punitive damages the Utility may be required to pay.

These numbers are summarized in Table 9. Most of these costs are likely to be non-rate recoverable.

Table 9 Summary of PG&E's costs due to the San Bruno accident (as of May 2012)

Item	Cost ($ millions)
2011 hydrostatic pressure tests and other pipeline-related activities	483
2012 non rate recoverable gas pipeline system costs (est.)	500
Third party claims (charged and estimated)	600
CPUC fines (est.)	200
Total	1,783
Insurance recoveries[1]	- 99
Net	1,684

[1] Recoveries of $99 million as of May 2012. The annual report notes elsewhere that the aggregate amount of this insurance coverage is approximately $992 million in excess of a $10 million deductible and that a significant portion of this will ultimately be recovered.

One of the costs for PG&E was restitution to the City of San Bruno for costs associated with the disasters. A March 12, 2012 City press release announced that the City and PG&E reached agreement on restitution for the San Bruno community to support recovery from the pipeline accident (City of San Bruno 2012a). The settlement agreement is available on the City's website (City of San Bruno 2012c). The City received compensation about 18 months following the disaster. According to an April 17, 2012 press release, the City received $70 million in restitution from PG&E to aid the community's recovery (City of San Bruno 2012b).

7.3. Rebuilding

Figure 32and Table 10 summarize the status of home rebuilding as of May 2012, according to the City of San Bruno Community Development Department (SBCDD 2012). Of the 63 damaged and destroyed homes, after 20 months, rebuilding of 8% of the destroyed homes has been completed, 37% are under construction, 21% are in various stages leading to construction, and 34% are unclear. Damaged homes have been repaired more quickly, with 71% (12/17) already complete. Eight lots are now owned by PG&E or the City and may take longer to be rebuilt.

Table 10 Summary of Crestmoor rebuild (as of May 2012)

	Category	Number	%
Destroyed properties	Construction complete	3	8%
	Building permit issued	14	37%
	Building review	2	5%
	Planning review	3	8%
	Pre-application stage	3	8%
	To be determined	13	34%
	Total	**38**	**100%**
Damaged properties	Repairs complete	12	48%
	Permit issued	5	20%
	Lots now owned by PG&E	3	12%
	Lots now owned by City	5	20%
	Total	**25**	**100%**

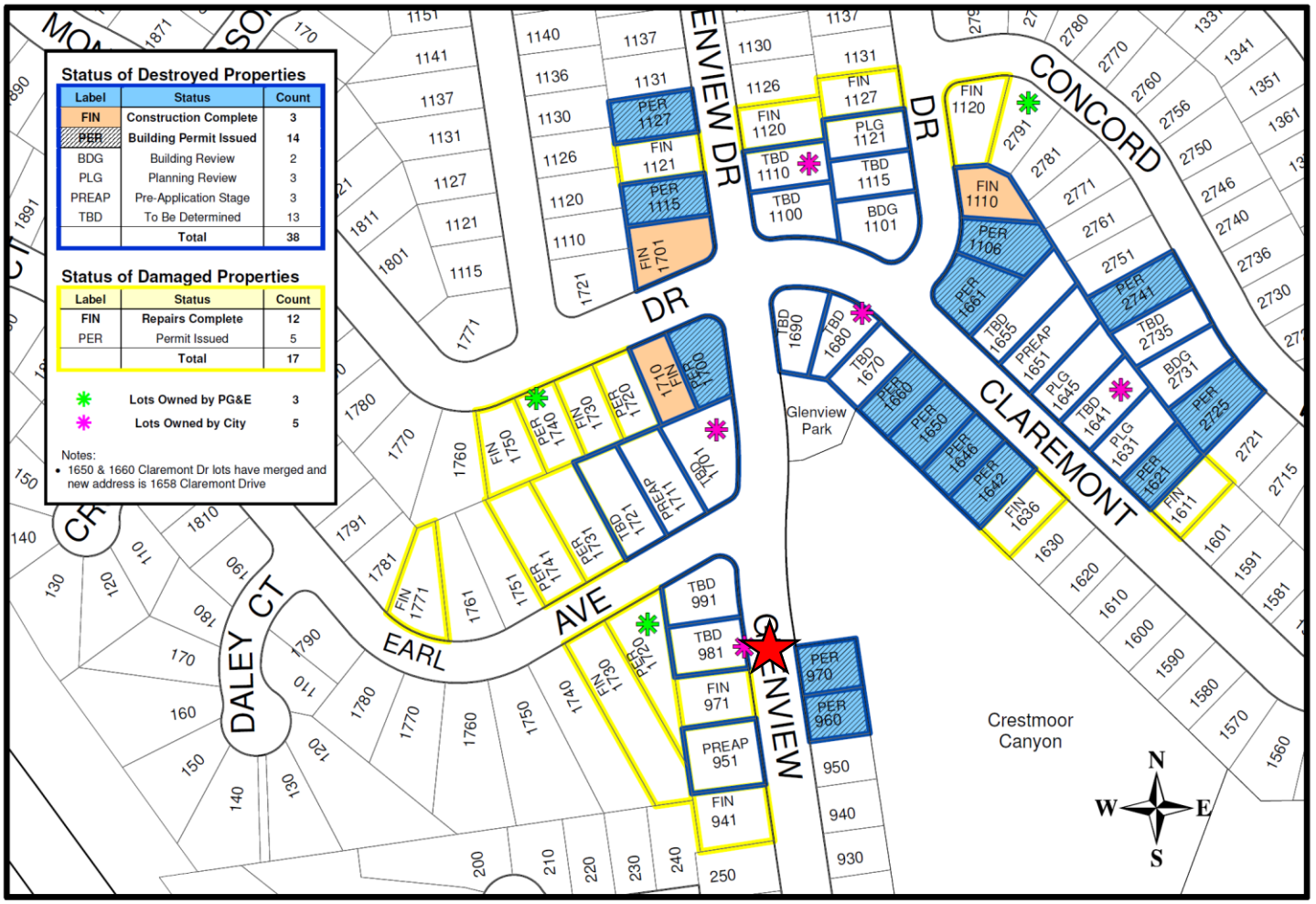


Figure 32 Crestmoor rebuild map as of May 2012
(Source: SBCDD 2012; http://www.rebuildcrestmoor.org/app_pages/view/30)

Figure 33 Panorama (NW to S) from location indicated by red star in Figure 32 (May 30, 2012)

Figure 34 Four houses under construction on Claremont (May 30, 2012)

Figure 35 Looking west from location indicated by red star in Figure 32 (May 30, 2012) – houses at left and right (941 and 971 Glenview Drive) have completed repairs, house in middle (951 Glenview Drive) has yet to begin application process.

REFERENCES

ABC News. (2010). "San Bruno explosion." <http://abclocal.go.com/kgo/gallery?section=news&id=7659542&photo=62> (Jun. 7, 2011).

American Petroleum Institute. (1990). *Guide for pressure-relieving and depressuring systems*, 3rd Ed., API RP 521, Washington, DC.

American Red Cross. (2012). "About the American Red Cross Bay Area Chapter." http://redcrossbayarea.org/general.asp?SN=4922&OP=4923&IDCapitulo=VA24T92924. (Accessed May 29, 2012).

Applied Technology Council (ATC). (1989). *Procedures for post-earthquake safety evaluation of buildings*, ATC-20, Redwood City, Ca.

Borden, F. (1997). "The 1994 Northridge earthquake and the fires that followed." *Thirteenth Meeting of the UJNR Panel on Fire Research and Safety*, NIST, Gaithersburg, Md., Vol. 2, 303-312.

Brian, C., and Bagster, D. (1989). "The computation of view factors of fire models 1. Differential targets." *Journal of Loss Prevention in the Process Industries*, 2(4), 224-234.

CalEMA. (2012). "About CALEMA." http://www.calema.ca.gov/LandingPages/Pages/About-CalEMA.aspx. (Accessed May 29, 2012).

California Department of Forestry and Fire Protection (CalFire). (2012). "About CalFire." http://www.fire.ca.gov/about/about.php. (Accessed May 29, 2012).

California Resources Recycling and Recovery (CalRecycle). (2012). "Welcome to the Department of Resources Recycling and Recovery." (CalRecycle) http://www.calrecycle.ca.gov/. (Accessed May 29, 2012).

California Seismic Safety Commission (CSSC). (2003). *Improving natural gas safety in earthquakes*, SSC-02-03, Sacramento, Ca.

City of San Bruno. (2012a). "City of San Bruno and PG&E Reach Agreement," Press release March 12, 2012, 11:00am. <http://sanbruno.ca.gov/PDFs/Press%20Release_March%2012_2012.pdf> (Accessed May 29, 2012).

City of San Bruno. (2012b). "The City of San Bruno today received $70 million in restitution from PG&E," Press release April 17, 2012, 9:00am. <http://sanbruno.ca.gov/Glenview/PressRelease_Receipt_of_70_million.pdf> (Accessed May 29, 2012).

City of San Bruno. (2012c). "Settlement Agreement," http://sanbruno.ca.gov/Glenview/PGE_Settlement_and_Side_Letter.pdf (Accessed May 29, 2012).

City of San Bruno. (2011). <http://www.sanbruno.ca.gov/> (Jun. 20, 2011).

Cook, D., Fairweather, M., Hammonds, J., and Hughes, D. (1987). "Size and radiative characteristics of natural gas flares. Part 1 – Field scale experiments." *Chemical Engineering, Research and Design*, 65, 318-325.

County of San Mateo. (2012). "San Mateo County Health System." http://smchealth.org/AboutSMCHS. (Accessed May 29, 2012).

Daft, R., and Noe, R. (2001). *Organizational behavior*, South-Western, Mason, Oh.

Field, E., Milner, K., and the 2007 Working Group on California Earthquake Probabilities. (2008). *Forecasting California's earthquakes—what can we expect in the next 30 years?*, Fact Sheet 2008-3027, version 1.0., U.S. Geological Survey.

Fox News. (2010). "Feds Begin Probe of Deadly Gas Explosion Near San Francisco." <http://www.foxnews.com/us/2010/09/09/large-explosion-reported-california-hillside> (accessed May 20, 2012).

Independent Review Panel (IRP) (2011) *Report of the Independent Review Panel San Bruno Explosion*, prepared for the California Public Utilities Commission, Revised Report 24 June 2011.

Jo, Y., and Ahn, B. (2002). "Analysis of hazard areas associated with high-pressure natural-gas pipelines." *Journal of Loss Prevention in the Process Industries*, 15, 179-188.

Johnson, A., Brightwell, H., and Carsley, A. (1994). "A model for predicting the thermal radiation hazards from large-scale horizontally released natural gas jet fires." *Process Safety and Environmental Protection*, 72(B3), 157-166.

Kinsman, P., and Lewis, J. (2000). *Report on a study of international pipeline accidents*. Research Report 294/2000, Mechphyic Scientific Consultants Limited, Chester, UK.

Lee, S., and Davidson, R. (2010). "Physics-based simulation model of post-earthquake fire spread." *Journal of Earthquake Engineering*, 14(5), 670-687.

Murphy, K., Rich, T., and Sexton, T. (2007). *An assessment of fuel treatment effects on fire behavior, suppression, effectiveness, and structure ignition on the Angora fire*. U.S. Department of Agriculture Report R5-TP-025, USDA, Washington, DC.

Mudan, K. (1984). "Thermal radiation hazards from hydrocarbon pool fires." *Progress Energy Combustion Science*, 10, 59-80.

National Transportation Safety Board (NTSB). (2011a). *Fire scene factual report*, Docket No. SA-534, Exhibit No. 5-A, Washington, DC.

National Transportation Safety Board (NTSB). (2011b). *Operations group chairman factual report*, Docket No. SA-534, Exhibit No. 2-A, Washington, DC.

National Transportation Safety Board (NTSB). (2011c). *Survival factors group chairman factual report – Appendix B. San Bruno fire department incident reports*, Docket No. SA-534, Exhibit No. 4-C, Washington, DC.

National Transportation Safety Board (NTSB). (2011d). "Preliminary report." <http://www.ntsb.gov/investigations/2010/sanbruno_ca_preliminary.html> (Feb. 20, 2011).

National Transportation Safety Board (NTSB). (2011e). *Meteorology group chairman factual report*, Docket No. SA-543, Exhibit No. 7-A, Washington, DC.

National Transportation Safety Board (NTSB). (2011f). *Pressure transducer locations along Lines 101, 109, and 132, 2011*, Docket No. SA-534, Exhibit No. 2-M, Washington, DC.

National Transportation Safety Board (NTSB). (2011g). *Pacific gas and electric company natural gas transmission pipeline rupture and fire, San Bruno, California, September 9, 2010*, Pipeline Accident Report, NTSB/PAR-11/01, Washington, DC.

National Transportation Safety Board (NTSB). (2011h). "NTSB docket management systems." <http://www.ntsb.gov/investigations/dms.html> (Jun. 20, 2011).

PG&E. (2012). "About Us." http://www.pge.com/about/. (Accessed May 29, 2012).

PG&E. (2011). "PG&E Corporation and Pacific Gas and Electric Company, 2011 Annual Report." <http://www.pgecorp.com/investors/financial_reports/> (accessed June 1, 2012).

Ricard, M. (2012). "PG&E Looking to Resolve Explosion Lawsuits by Fall." *San Bruno Patch*, May 15, 2012, < http://sanbruno.patch.com/articles/pg-e-looking-to-resolve-explosion-lawsuits-by-fall> (accessed June 1, 2012).

San Bruno. (2011). "April 27, 2011 Town hall meeting video." <http://www.youtube.com/watch?v=isgl81in__o>, (June 20, 2011).

San Bruno Building Department (SBBD). (2012). "Building Permits & Inspections." http://sanbruno.ca.gov/comdev_bldgInspection.html. (Accessed May 29, 2012).

San Bruno Community Development Department (SBCDD) (2012). "Crestmoor rebuild map (Glenview fire)." http://www.rebuildcrestmoor.org/app_pages/view/30. (Accessed May 29, 2012).

San Bruno Police Department (SBPD). (2012). "Welcome to the San Bruno Police Department On-Line." http://www.sanbruno.ca.gov/police_main.html. (Accessed May 29, 2012).

Scawthorn, C., Cowell, A., and Borden, F. (1998). *Fire-related aspects of the Northridge earthquake*, Rep. No. NIST-GCR-98-743, National Institute of Standards and Technology, Building and Fire Research Laboratory, Gaithersburg, Md.

Scawthorn, C., Eidinger, J., and Schiff, A. (2005). *Fire following earthquake*, Technical council on lifeline earthquake engineering Monograph No. 26, ASCE, Reston, Va.

Stephens, M. (2000). *A model for sizing high consequence areas associated with natural gas pipes*, C-FER Report 99068, Alberta, Canada

Sweet, C. (2012). "PG&E Blast Costs May Top $1.7 Billion." *Wall Street Journal*, February 17, 2012, <http://online.wsj.com/article/SB10001424052970204792404577227361408088398.html> (accessed May 20, 2012).

U.S. Census Bureau. (2011). "2005-2009 American community survey 5-year estimates." <http://quickfacts.census.gov/qfd/states/06/0665028lk.html> (June 20, 2011).

Weick, K. E. (1993). "The collapse of sensemaking in organizations: the Mann Gulch disaster." *Administrative Science Quarterly*, 38, 628-652.

Weick, K.E. (1995). *Sensemaking in organizations*, Sage Publications, Thousand Oaks, Ca.

Worth, K. (2011). “San Bruno explosion may be focus of criminal probe.” *San Francisco Examiner*, June 19, 2011.

Zsambok, C. and Klein, G. (1997). *Naturalistic decision making*, L. Erlbaum Associates, Mahwah, Nj.

APPENDIX A. Summary Timeline Of Emergency Response Actions

(Note: this is not a comprehensive timeline of all actions taken, but a synopsis of key events)

To review the coupling of PG&E events which occurred both prior to the accident and in response to it, refer to NTSB documents for accident number DCA-10-MP-008. The two timelines that prioritize PG&E activities include: Docket No. SA-534 Exhibit No. 2-B (PG&E Event Timeline) and Docket No. SA-534 Exhibit No. 2-DX (Timeline of Events Prepared by NTSB).

For more specific detailing of San Bruno Fire Department Response refer to San Bruno Fire Department Incident Report (NTSB Docket SA-534 Exhibit No. 4-C)

Date	**Time (Pacific Daylight Time)**	**Incident/Action**	**Parties Involved** (citizens/victims are often assumed)
9/9/2010			
	18:11 hours	"…a 30-inch diameter section of a multi-diameter intra-state natural gas transmission pipeline (Line 132) owned and operated by Pacific Gas & Electric Company (PG&E) ruptured in a residential area in San Bruno, California."[1] "The rupture occurred at approximately mile point (MP) 39.28, at the intersection of Earl Avenue and Glenview Drive in the city of San Bruno."[2] The gas pipeline explosion also resulted in the rupturing of water and sewer lines located about three feet below the gas pipeline. "PG&E estimated that 47.6 million standard cubic feet (MMSCF) of natural gas were released as a result of the rupture. The rupture created a crater (located near the northwest corner of Earl Avenue and Glenview Drive)[3] approximately 72 feet long by 26 feet wide. A pipe segment approximately 28 feet long was found about 100 feet south of the crater. The released natural gas was ignited sometime after the rupture; the resulting fire destroyed 38 homes and damaged 63.	Owner/Operator: Pacific Gas and Electric Company (PG&E) Residents of San Bruno

[1] http://dms.ntsb.gov/public%2F49500-49999%2F49896%2F460250.pdf Excerpts taken from Docket No. SA-534 Exhibit No. 2-A of the National Transportation Safety Board's records (page 2)

[2] http://dms.ntsb.gov/public%2F49500-49999%2F49896%2F460250.pdf (page 2)

[3] Accessed from the NTSB Fire Scene Factual Report, Docket SA-534 Exhibit 5-A. A photo of the crater is also located within this exhibit. The width prior to excavation of the crater was reported to be 59 feet within this report.

		Eight people were killed, numerous individuals were injured, and many more were evacuated from the area."[4] Received the first 911 call. San Bruno Police Department resources are dispatched.[5]	 San Bruno Police Dispatch
	Immediately following the explosion and fire	Citizens were spontaneously evacuating the area.	Local residents in the area
	18:12	First alarm to dispatch called – a full assignment (three engines, one truck and one BC) to respond to an explosion.[6] First unit of San Bruno Police Department arrives on the scene.[7]	Dispatch San Bruno Police
	18:13	Fire department dispatcher stated there were over 20 calls received regarding the explosion, conversation still includes report of possible plane crash[8] Battalion 9 reports they can see the flames from the station. Engine 52 reported en route to the emergency. Drove up Sneath to Claremont to Vermont… Second alarm called when they reached Claremont (exact time unknown as transcripts did not indicate every time of transmission). The second alarm upgrades the response to a structure fire, which balances out to five engines, a truck, and two BC's. Police officer advised citizens self-evacuating	Dispatch and resident callers Fire Battalion 9 Fire Department Police and citizens
	18: 14	All police personnel on the shift are on scene (assisting with evacuation and perimeter control)	Police Department Citizens
	18:15	Engine 52 stopped at Plymouth as it provided a good vantage point and advises BC9 to request third alarm[9]	Fire Department

[4] http://dms.ntsb.gov/public%2F49500-49999%2F49896%2F460250.pdf (page 2). The Fire Scene Factual Report, Docket SA-534 Exhibit 5-A has a listing of each of the damaged homes and their severity along with some photographs of the damage.
[5] Accessed from NTSB Docket No. SA-534 Exhibit No. 2-DX.
[6] Accessed from NTSB San Bruno Fire Department Incident Reports Docket SA-534 Exhibit 4-C
[7] Accessed from NTSB Docket No. SA-534 Exhibit No. 2-DX.
[8] Accessed from Transcript of Fire Department Radio Communications NTSB Docket No. SA-534 Exhibit No. 4-B
[9] Accessed from Incident Response Timeline Compiled by the City of San Bruno

		Since plane crash was reported, the FAA was immediately contacted, but they said it wasn't an airplane. It was also noted that the flames weren't dissipating at all, so there must have been a fuel source	
	18:16	Police officer requests Mutual Aid to assist in traffic control and evacuation. Request to close off San Bruno Ave. and upper Crestmoor and for CHP to divert freeway traffic from entering the area. Police request medics for burn victim at Glenview and San Bruno Ave. Staging area established at Lunardi's parking lot (San Bruno and Glenview) Engine 52 establishes Crestmoor Incident Command (IC). E52 is laying a supply line north of the fire to protect exposures.[10]	Police Lunardi's parking lot Emergency vehicles Fire
	Respondent did not recall exact times	Shopping centers opened their doors and assisted with donations to first responders on the scene.	Lunardi's and Bayhill Shopping Centers
	18:17	Engine 51 arrived on scene at Glenview Drive and San Bruno Avenue (staffed with engine and truck) Initial mutual aid response from Milbrae. Police Dispatcher requests County Communications activate a Phase 2, Code 3 TAC Alert for Mutual Aid[11]	Fire Mutual Aid Police Mutual Aid
	18:18	Police officers assist in evacuating everything south of Glenview and Earl. The SBPD dispatcher and clerk use their own cell phones, as incoming calls have inundated the phone lines[12] Engine 38 arrived on scene; staged at Glenview and Estates Truck 51 arrived; staged at Glenview and Estates	Police Police Dispatch Fire
	Approx. 18:18 -	Police called in for extra crew to come	Police department EOC: Department heads

[10] Accessed from Incident Response Timeline Compiled by the City of San Bruno
[11] Accessed from Incident Response Timeline Compiled by the City of San Bruno
[12] Accessed from Incident Response Timeline Compiled by the City of San Bruno

			i.e., public works, parks, police, fire, city manager, worked with outside agencies (Red Cross and other nonprofits) and stores (Lowes, Home Depot) San Bruno utilities (water) department
	18:20	BC9 arrived on scene Established Command Post (CP) on Glenview (until 9/11/10) Established Incident Command (IC) just south of Estates PSC initiated South San Francisco alarm as the third alarm to Glenview[13] Battalion 18, North County Fire Authority, arrived at Claremont Drive and Windsor Court. Due to extreme heat, advised IC to call fourth alarm.	Fire Police County Fire
	18:23 As engines arrived…	E51 had no water; T51 reported dry hydrant near Glenview and Estates; reported possible water main break. At about the same time the North Branch also found dry hydrants Engines and crew assisted citizens with evacuation and rescue already in progress. While evacuations were underway, crew also began laying down hoses, but when the lines were opened there was no water – the grid was blown. Relocated lines to other hydrants until active water supply found, approximately three thousand feet away[14] IC contacted the water department, when fire personnel believed the water lines were busted. (Reported in interview with Fire Department personnel). Setting up of command post (CP) at Essex and Glenview[15]	Fire; IC IC and San Bruno Water Dept.
	18:24	As most of south side is evacuated, police move to north to assist with evacuations and maintain perimeter CHP called to close Skyline Blvd. between San Bruno Ave. and Sneath[16]	Police
		PSC advised of senior care facility that needed evacuation	PSC
	18:27	Restricted access to Glenview Drive	Police

[13] Accessed from Incident Response Timeline Compiled by the City of San Bruno
[14] Accessed from interview with emergency responders.
[15] Accessed from Transcript of Fire Department Radio Communications NTSB Docket No. SA-534 Exhibit No. 4-B
[16] Accessed from Incident Response Timeline Compiled by the City of San Bruno

		EOC is opened and running by this time	EOC
	18:28	IC requested Mutual Aid assistance from San Francisco International Airport for Aircraft Rescue Firefighting Apparatus (foam from air support)[17] The action initiated an Airport Box Alarm from San Francisco Fire Department	IC Mutual Aid
	18:30 Approx.	IC requested Level 2 Multi-Casualty Incident response at Glenview and San Bruno Ave. Setting up of medical group in the North Branch in the 1800 block of Claremont Avenue[18]	IC Fire Medical
	18:32	Fifth alarm requested	Fire
		Utilities initial hookup was obtained on Glenview, on the top side; somewhere around 960 (Claremont and Concord) was a working hydrant. They were able to do some valve changes and take other actions to get some water for the fire department[19].	San Bruno Utilities
	18:33	Training 9 arrived at CP and assisted IC Off duty San Bruno officers arriving for deployment	IC
	18:35	IC requested Cal Fire aircraft reconnaissance; triggered a full response bringing in air craft with fire retardant drops Cal Fire Felton Emergency Command Center identifies incident as Mutual Threat Zone (MTZ) following their investigation. Center initiates State response due to threat to State Responsibility Act Initial drops on parkland, but then on structure fires as well. Dropped consistently in the residential areas for about 20 minutes.	IC Cal Fire State Response
	18:37	IC directed Training 9 to establish Operations (Ops) and Communications (Com) centers.	IC
	18:40	Requested two water tenders Discussions with IC, Ops and Com decided on one more alarm in county and requested Mutual Aid with Region II	Fire IC Mutual Aid
	18:41	Public Safety Communications notified other county services (i.e., SPCA, Search and Rescue, NTF, Coroner) Allied agencies began sending strike teams (based on PSC dispatch for assist) PG&E staff are confirmed to be onsite based on call to PG&E Concord Dispatch.[20] No known	Other city and county services and mutual aid agencies PG&E dispatch and GSR

[17] Accessed from Incident Response Timeline Compiled by the City of San Bruno
[18] Accessed from Transcript of Fire Department Radio Communications NTSB Docket No. SA-534 Exhibit No. 4-B
[19] Accessed from interview with fire department personnel

		cause of the flames yet. Dispatch discussions still consider a jet crash causing the gas line to blow.	and on-call supervisor
	"deep into the incident" About ½ hour into the incident	Still getting reports of a plane being down. People reported seeing the plane crash or the fuselage (pipe) Realized there was some supply of fuel, but not necessarily a 30 inch gas line.	Eyewitness reports
	18:46	Two Alameda County Strike Teams requested	County Aid
	18:52	San Francisco Fire Department dispatched Assisted with water trucks (5000 gal trucks) and foamed the houses (Earl Street); much greater quantity than Milbrae's 1500 gal trucks.	San Francisco Fire
	18:54	San Bruno Police calls Concord Dispatch to request gas support. Dispatch reports they are already on scene.	San Bruno Police and Concord Dispatch
	18: 57	Gas control activated OEC in San Carlos and supplied contact number[21] SBA to evacuate elementary school. Crestmoor and lower Claremont to be evacuated as well.	PG&E Elementary School
	19:01	Capuchino High School offers location for evacuation center	High School
	19:02	San Matteo County Sheriff contacts Concord Dispatch to determine if power is shut off in the San Bruno area. Plane crash is still a part of dispatch discussions.[22]	San Matteo Sherriff and Concord Dispatch
	19:03	Bay Hill Shopping Center acted as a staging area for the Red Cross and media. Evacuated residents were routed to Bayhill Shopping Center	Bayhill Shopping Center
	19:12	PG&E shut off power to entire area	
	19:22	Sam Trans (public busing) relocated evacuees from Lunardi's to Bayhill	Sam Trans, Lunardi's and Bayhill
	19:23	Went to six alarms at the county.	
		County Health Department notified; Hazmat responded to fire response	County Health Department
	19:28	Area maps requested from EOC Coroner's unit set up at San Bruno and Glenview	EOC Coroner's
	19:41 PM	Resolution proclaiming the existence of a local emergency	Resolution made by City Manager

[20] Accessed from NTSB 003-002 S3
[21] Accessed from NTSB Docket No. SA-534 Exhibit No. 2-DX.
[22] PG&E Concord Dispatch transcripts (NTSB 003-002 S3)

	19:57	San Bruno Recreation Center acts as LAC and overnight shelter for evacuees; (donations of water, food and clothes begin arriving)[23]	San Bruno Rec. Center Red Cross, PG& E, insurance companies set up desks
	?	Declaration of State of Emergency	Acting Governor of the State of California
		The gas fueled the fire for 89 minutes before PG&E successfully turned off the gas supply. In the end there were 85 companies that assisted with the scene, excluding CalFire. Went to 9 alarms, by end of incident according to San Bruno Fire Department Incident Reports. Police department ended up with about 200 officers[24] working on perimeter control, prevention of looting, automobile identification, search and rescue.	Teams came from nine San Mateo County cities, as well as Alameda county. Assistance also came from San Francisco
9/10/2010	?	Proclamation of the existence of a local emergency with the county of San Mateo	County Manager Director of Emergency Services
	02:01	AT&T setting up mobile telephone stations at Shelter Creek and San Bruno Ave.	AT&T
	02:30 - 02:45	The Lieutenant Governor arrives from LA to discuss possibility of disaster declaration.	
	Until 04:00	Health personnel at county EOC identifying hospital bed resources	
	Early morning	NTSB initiated investigation.	National Transportation Safety Board (NTSB)
	08:00	75-80% fire containment by about 8:00 in the morning. Although fire technically under control (excluding flare-ups), it is kept at 80% to allow fire department the right to continue working on the scene for search and rescue purposes and to be on scene to control for hot spots.	Fire Department
	08:00	First formal press conference to reassure the people of San Bruno that things were under control	
	Midmorning	EOC was firmly established and structure was more organized.	EOC in the basement of Town Hall
	Midafternoon	Called into San Bruno EOC to assist with re-entry plan (check for adequate water and sewer and free of hazardous materials) EOC update/planning meetings at least twice daily (9AM and 4PM)	
		Continue to work on repairing water, sewer lines	San Bruno Public Works

[23] Accessed from Incident Response Timeline Compiled by the City of San Bruno
[24] Accessed from emergency responder interviews.

		Deployed "small army of building inspectors" once the area was safe (this may have been late on the 10th). The inspectors were not limited to San Bruno staff, but included mutual aid communities. The homes were coded in red, yellow and green depending upon the extent of damage. Maps were provided to key personnel. The initial inspections were completed by the 11th prior to the town meeting.	
9/11/2010		Planning for removal of household hazardous waste on property (2:00 PM daily meeting)	County EHS
		A lot of planning regarding search and rescue operations	At command post site.
9/9-9/11/2011		Fire deemed fully under control by day three. It was a fire incident until 20:00 on the 11th then it became a law incident and the command post was changed.	
9/11/2011		Held town meeting at St. Roberts Church in the afternoon (the initial inspections were completed prior to the town meeting) 650 people in attendance/ not just residents – people applauded first responders. Two subsequent town meetings occurred in future days.	Town meeting at St. Roberts Church – organized by Town Staff – attended by PG&E (had small little questionnaire pamphlets CalEMA, city staff: police, fire, building, planning, public works, Congresswoman etc. and the press.
		Public Health Order from the County (EHS needed to enter private property and remove debris).	Deputy Health Officer, San Mateo County Health System
9/12/2010		Physical removal of debris begins (10 drums of material picked up; prioritized picking up of hazardous waste from areas that were free of physical hazards). The removal process took three weeks to complete. Established separate ICS [Note: October 15th begins rainy season – places urgency on hazardous material removal] Re-entry of homes	County EHS Contracted with CalRecycle
9/14/2010		Public Health Declaration to allow state to facilitate contracts[25]	County EHS
9/15/2010		began contract with Cal Recycle	Cal Recycle
		Residents of 320 homes were returned to their homes as of September 15th	
9/16/2010		Local community organizations conducted a fundraiser one week post incident.	i.e. Rotary, Lions Club, St. Roberts Church etc.
9/17/2010		Public Meeting (media excluded) with Mayor and owners/victims. Trying to gain trust in the community. Woman who benefited from Angora fire response acted as spokesperson for Cal	County EHS

[25] Accessed from emergency responder interviews.

		Recycle. Discussed the benefits of allowing Cal Recycle to conduct cleanup operations and how to permit the process.	
9/20/2010		Cal Recycle started rolling out equipment to clear the properties and began watering the lots to keep the dust down. Air sampling placed around worksites and kept running throughout the project.	
9/21/2010		Cal Recycle held first general command staff meeting, with the command staff that came from all sorts of other local agencies and state agencies	
9/21/2010		Went to duty officer status on the twenty-first of September; no longer convening in the EOC. However, for approximately a week prior to that, San Bruno continued EOC operations, convening every morning and every evening with updates/briefings.	EOC officials
9/23/2010		Cal Recycle started first five homes.	Cal Recycle
9/25/ 2011		Cal Recycle had 15 more homes signed up for clearing of property.	Cal Recycle
9/27/2010		"The Red Cross has met with and registered more than 383 families (more than 1,000 individuals) affected by the fire. These families are receiving assistance from the Red Cross to find alternative housing, replace lost items and create long-term recovery plans. Red Cross volunteers continue to conduct follow-up outreach to the affected families to discuss outstanding needs and initiate a long-term recovery process, ensuring that everyone has the assistance and support they require in the coming months."[26] "Ongoing casework with the affected families is also taking place at the San Bruno Recovery Center…several nonprofit and government agencies are co-located at the San Bruno Recovery Center."	American Red Cross San Bruno Recovery Center 900 Cherry Avenue, Suite 332 San Bruno, California
10/12/2010		The City Council "approved an ordinance that waives all building and planning fees for Glenview residents. The City Council also directed that staff prepare new regulations for adoption in the coming weeks that greatly reduces the time it will take for residents to rebuild the Glenview area."[27] Reduced processing period from six months to three months or less.	San Bruno City Council San Bruno City Hall
10/17/2010		Debris removal and site cleanup pretty much completed.	
10/25/2010		Agencies that have been assisting residents at the San Bruno Resource & Recovery Center since mid-September will be transitioning to their local offices	
10/28/2010		**Insurance Recovery Forum -** Representatives from the California Department of Insurance and other agencies were made available to assist and provide answers about insurance, the rebuilding process, or the resources available.[28]	Crestmoor Elementary School - 2322 Crestmoor Drive, San Bruno, CA 94066

[26] Accessed from http://newsroom.redcross.org/?s=San+Bruno+
[27] Accessed from http://www.sanbruno.ca.gov/Glenview_newsandevents.html
[28] Accessed from http://www.sanbruno.ca.gov/Glenview_video_archives.html

10/29/2010		Town Hall Meeting - To discuss Glenview Fire Updates and Long-Term Recovery Efforts. The Town Hall Meeting was also taped and aired on Channel 1 four times daily, at 9:30 am, 2:30 pm, 6:30 pm and 9:30 pm, on November 2, 3 and 4, 2010.	St. Robert's Church - 1380 Crystal Springs Road, San Bruno, CA 94066 <u>Some Attendees:</u> Congresswoman Jackie Speier, (D-San Francisco/San Mateo), Representatives from Pacific Gas and Electric, California Public Utilities Commission, San Bruno Planning and Building Department Personnel
12/7/2010		"Assembly member Jerry Hill hosted a Legislative Forum on Natural Gas Infrastructure Integrity and Vulnerability with the Assembly Utilities and Commerce Committee and the Assembly Committee on Public Safety."[29]	The forum was held at the San Bruno Senior Center, 1555 Crystal Springs Rd, San Bruno, CA 94066-4769.
Six months post	.	City working on dispersing the donations received. ($400,000 Glenview Fire Relief Fund) As per Town Manager report: " (1) continuing to provide active liaison support to the fifty-five displaced families and other families that require information services and support; (2) coordinating with the long term recovery group (the consortium of nonprofit service providers) to assist and guide their efforts, such as the Red Cross and others who are continuing to provide services, including counseling and food to people who are financially squeezed; (3) continuing to coordinate with a variety of organizations and individuals who are providing services to the victims. For example on the United Policy Holders and Rebuilding Together provided an educational forum on how to select a contractor or architect; (4) continuing to conduct town hall meetings and to address a myriad of issues that residents have, IRS and others; (5) continuing to coordinate with PG&E on dozens of topics, having to do with the physical management of the site and the utilities, to planning for relocation of line 132; (6) as party to the NTSB investigation, to the cause of the accident, we are collecting and processing reimbursement claims from all of the mutual aid responders, that's being done under our umbrella and coordinating both with PG&E and with Cal EMA … for efficient and timely reimbursement; (7) assisting them in getting into the rebuilding process, getting information and providing the normal community development services; and we're looking at the long term, big picture issues associated with pipeline safety."	Decision made by Town Council at council meeting
January 2011		NTSB interview of John Hannigan on January 2, 2011 regarding prior excavation at Glenview	John Hannigan San Bruno

[29] Accessed from http://www.sanbruno.ca.gov/Glenview_video_archives.html

NTSB Hearings		and Earl Avenue occurring in 2008 for a sewer improvement project which included a sewer main pipe bursting operation.[30] Inspector stated the sewer line was near the San Andreas fault line, but there was no recall of concern regarding the location of the lines; furthermore, a PG&E representative participated in the monitoring of the excavation and operations. NTSB interview of Mark Reinhardt on January 3, 2011 regarding prior water main leaks. Only one small curb stop leak was reported which occurred 8/23/91, 20 years ago. This leak was located on the east side of Glenview towards San Bruno Avenue. The leak was called in at 12:40 and repaired by 1:20 PM. No prior water main bursts were reported near the 2010 pipeline explosion intersection of Earl and Glenview. Interview also inquired about annual flushing of hydrants (This year the 900 hydrants were flushed between August and September).[31] NTSB interview of Wing Wong on January 3, 2011; inquired about 2008 sewer improvement project.[32] PG&E representative was onsite during operations near the gas pipeline. For complete listing of all hearing transcripts, go to NTSB website.	Inspector/Technician Mark Reinhardt, San Bruno Water System and Conservation Manager Wing Wong, San Bruno Associate Engineer
March 1-3 2011		NTSB Hearings	Washington, DC
As of 5/26/2011		San Bruno website lists San Bruno Resource & Recovery Center (SBRRC) to assist residents impacted by the September 9 fire and explosion with mental health support, housing and health services, and other resources.[33]	San Bruno Resource & Recovery Center (SBRRC) 458 San Mateo Ave. San Bruno, CA 94066 Phone: (650) 588-0940 Hours: 9 am - 5 pm, Monday - Friday

[30] Accessed from NTSB interview of John Hannigan Docket No. SA-534 Exhibit 2-BP.
[31] Accessed from NTSB interview with Mark Reinhardt Docket SA-534 Exhibit 2-BZ.
[32] Accessed from NTSB interview with Wing Wong Docket SA-534 Exhibit 2-CJ.
[33] Accessed from http://www.sanbruno.ca.gov/Glenview_newsandevents.html

APPENDIX B. NTSB Accident Docket Contents

On September 14, 2010 the National Transportation Safety Board (NTSB) created an Accident Docket, accessible via http://www.ntsb.gov/investigations/2010/sanbruno_ca.html . The docket focuses on and contains a wealth of information regarding the causes and selected technical aspects of the incident, some of which has been drawn on for this report. Rather than replicate material in the docket, this Appendix lists the Table of Contents for the docket as of May 20, 2012 (the last modification to the docket having been in August 2011, at which time the docket contained 400 separate entries):

National Transportation Safety Board
Docket Contents

Project Information

Mode		
Pipeline		
NTSB Accident ID	Occurrence Date	Location
DCA10MP008	**Sep 09, 2010**	**San Bruno, CA, United States**

Docket Information

Creation Date	Last Modified	Public Release Date & Time
Sep 14, 2010	**Aug 15, 2011 13:58**	**Mar 01, 2011 09:47**

Comments

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San Bruno Gas PL Expl of 9 Sept 2010 - Scawthorn pix of 18 Sept 2010 - 005

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San Bruno Gas PL Expl of 9 Sept 2010 - Scawthorn pix of 18 Sept 2010 - 022

San Bruno Gas PL Expl of 9 Sept 2010 - Scawthorn pix of 18 Sept 2010 - 023

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San Bruno Gas PL Expl of 9 Sept 2010 - Scawthorn pix of 18 Sept 2010 - 060

San Bruno Gas PL Expl of 9 Sept 2010 - Scawthorn pix of 18 Sept 2010 - 061

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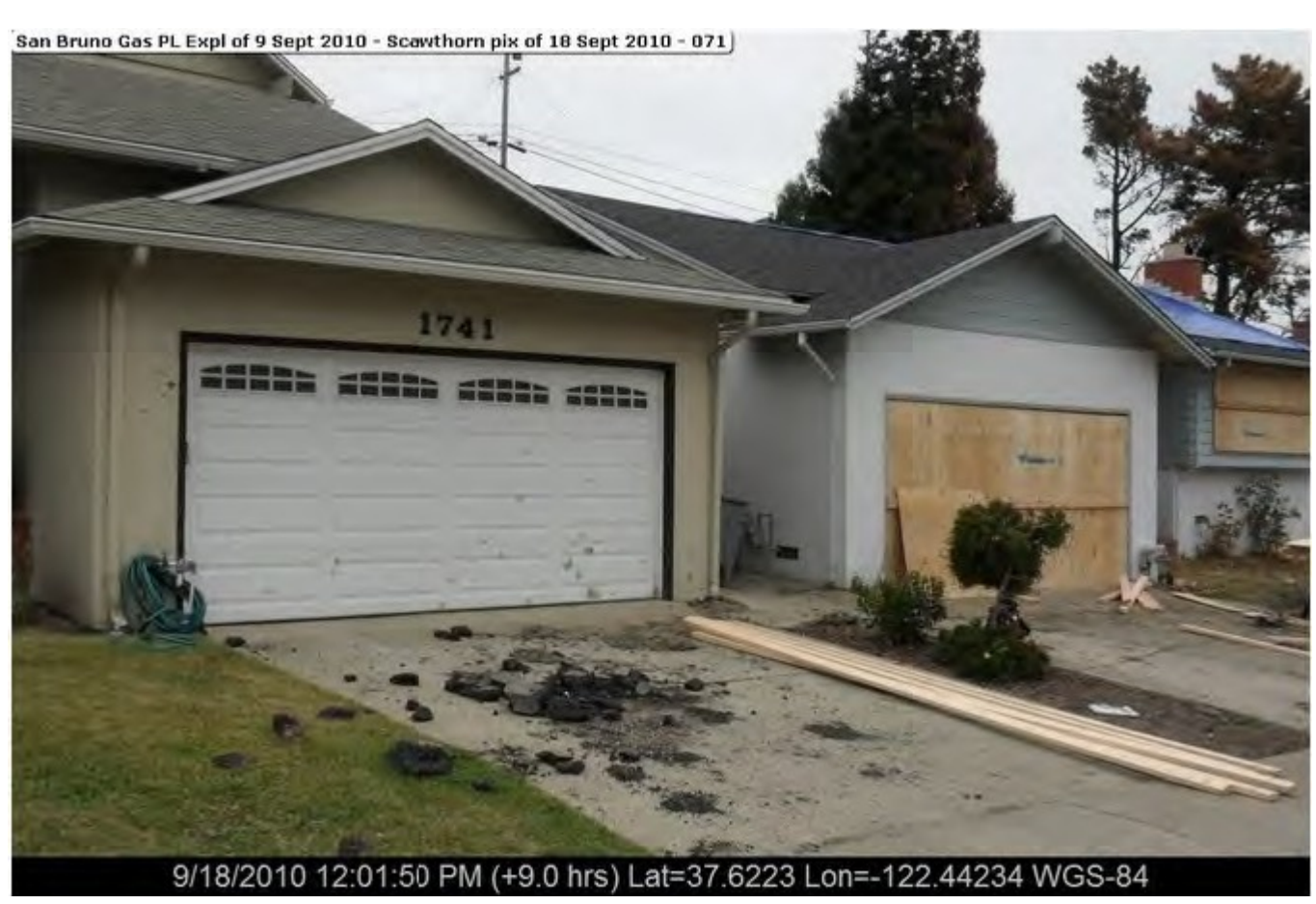

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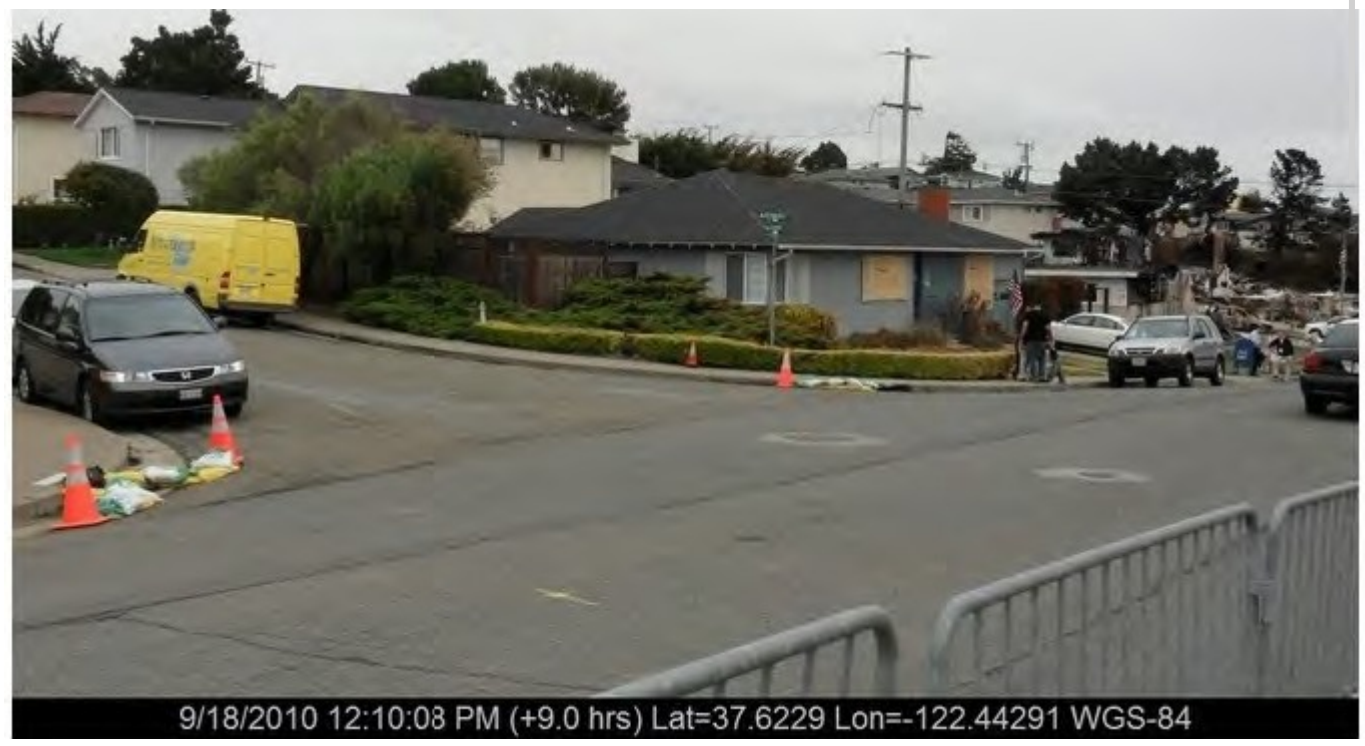

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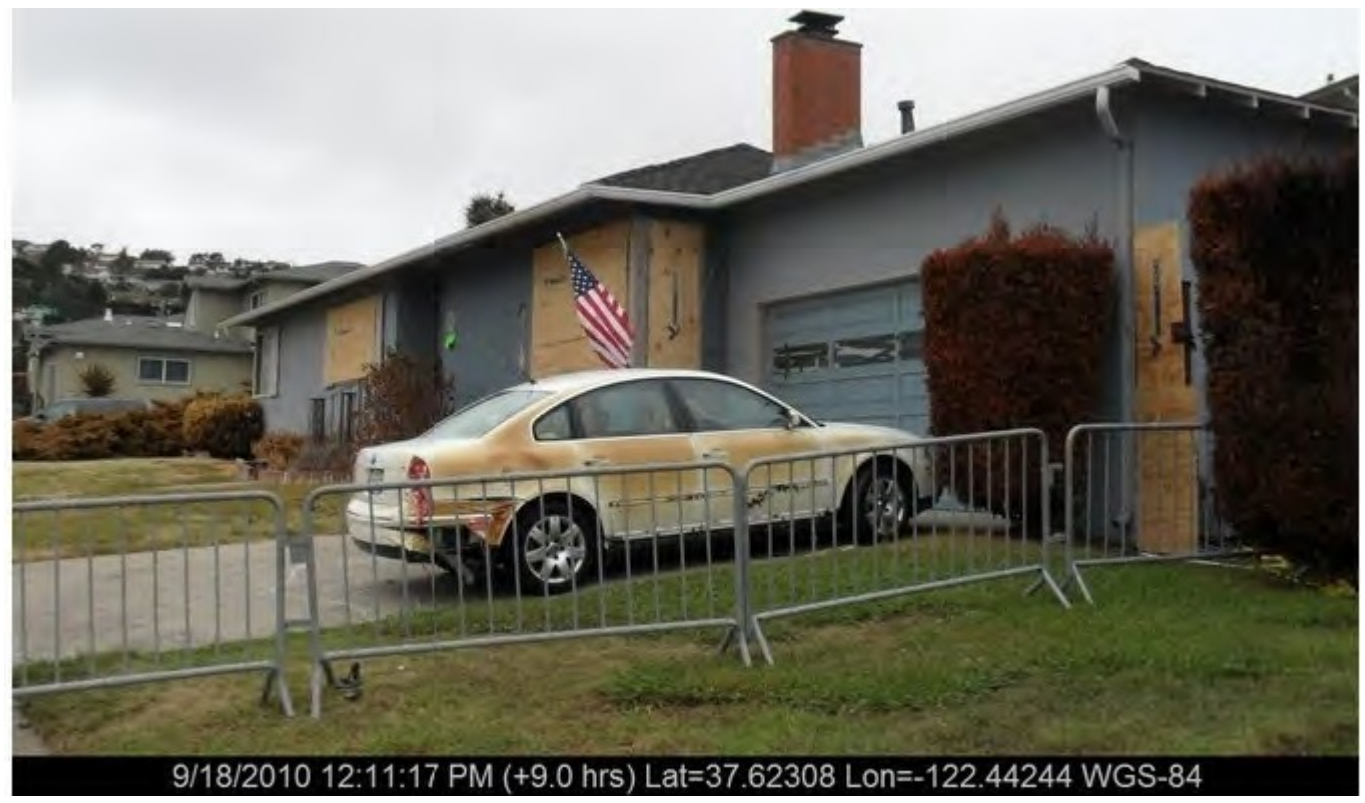

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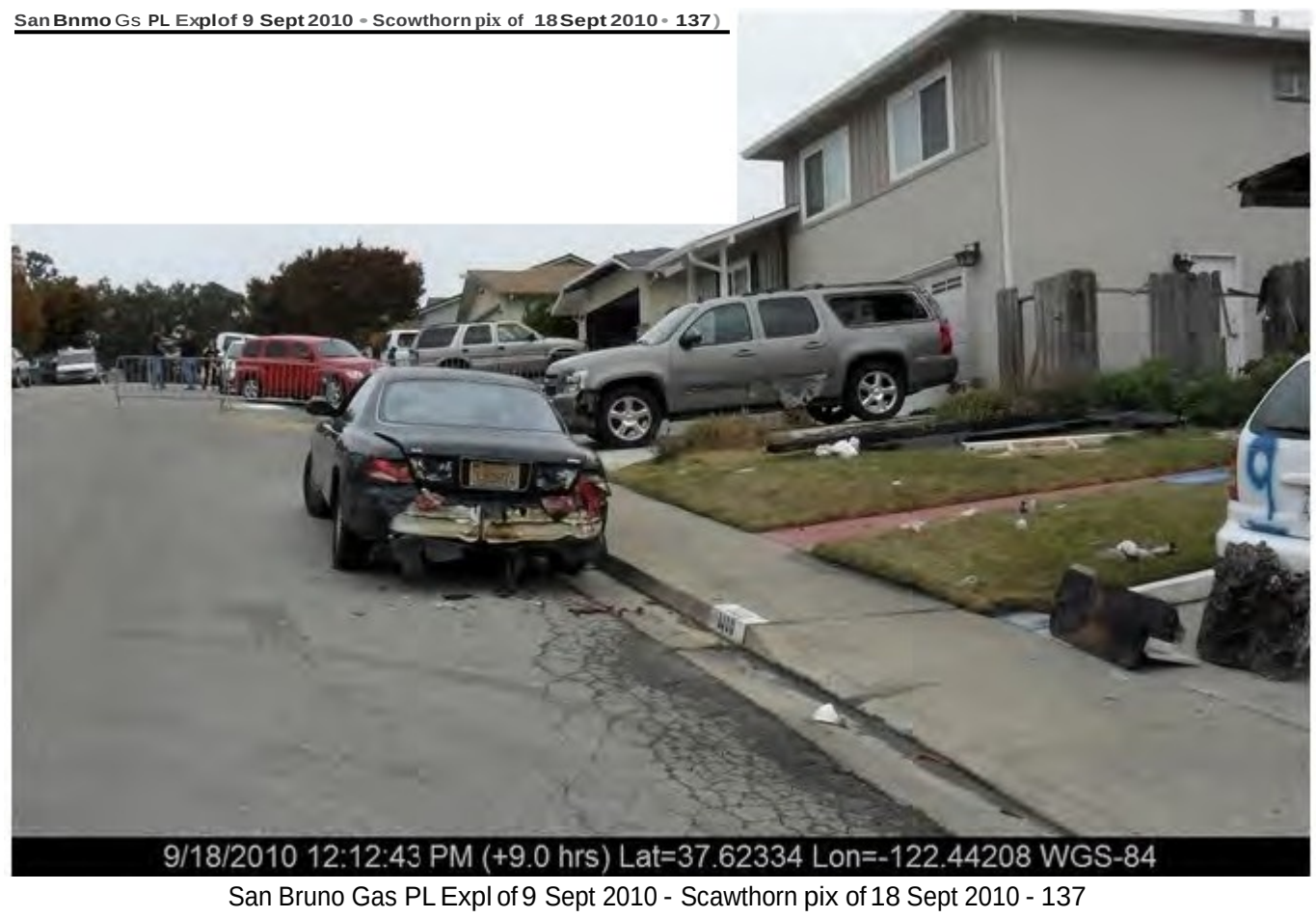

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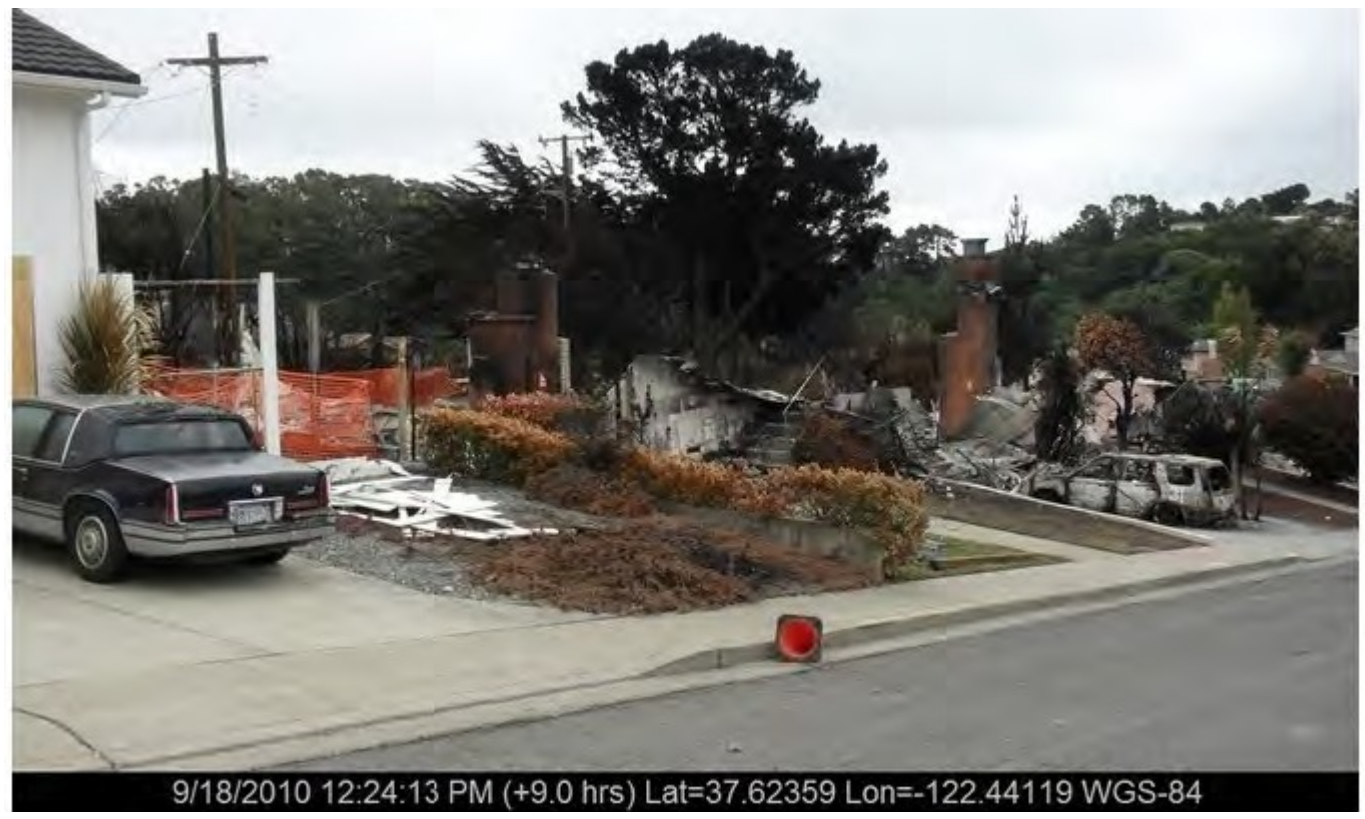

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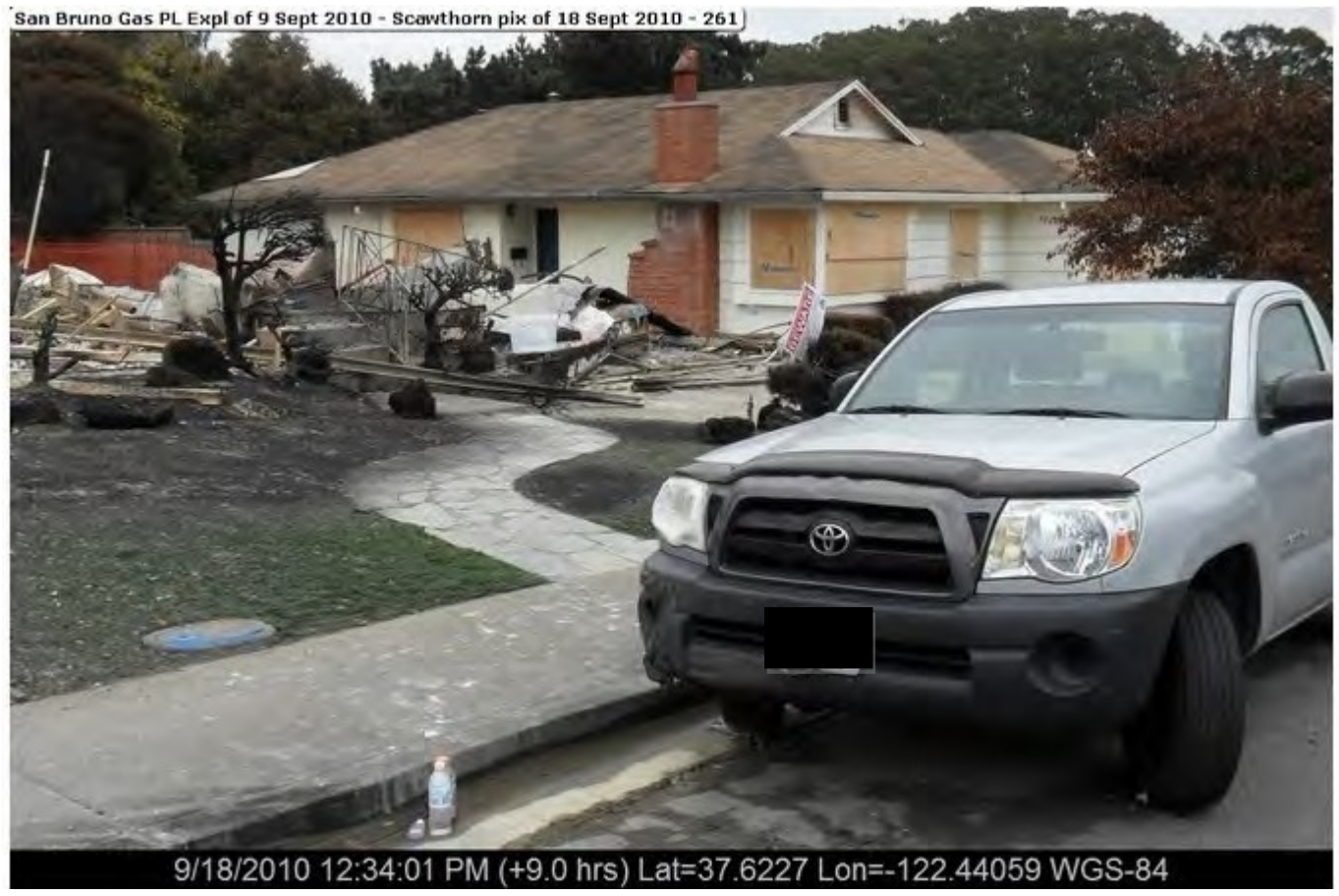

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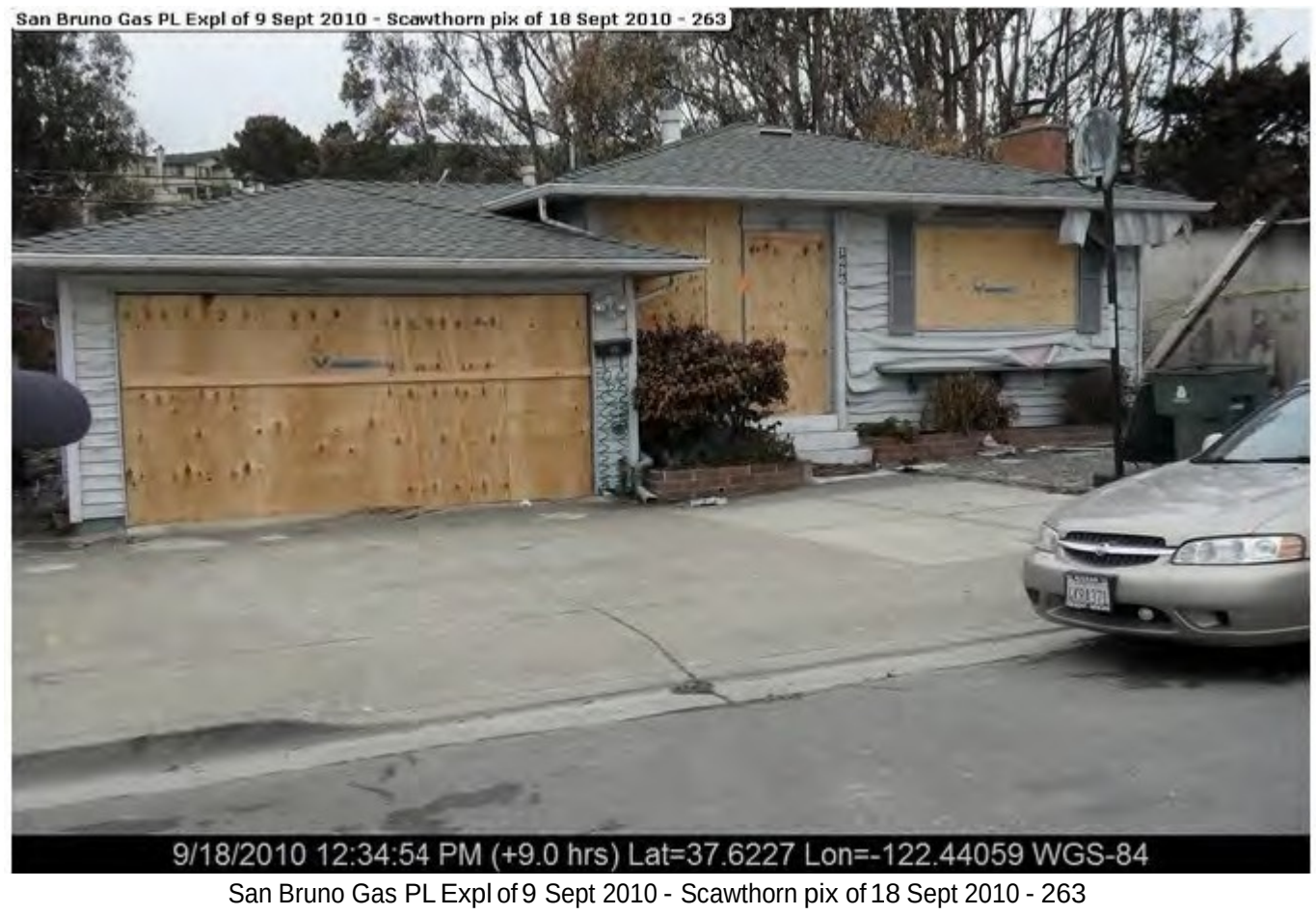
San Bruno Gas PL Expl of 9 Sept 2010 - Scawthorn pix of 18 Sept 2010 - 262



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San Bruno Gas PL Expl of 9 Sept 2010 - Scawthorn pix of 18 Sept 2010 - 283

Site Map - San Bruno Gas PL Expl of 9 Sept 2010 - Scawthorn pix of 18 Sept 2010

APPENDIX D. Sites of Photographs September 18, 2010

This Appendix contains 285 georeferenced photographs of the site taken on Sept. 18, 2010. All photos are *.jpg files and were taken on September 18, 2010 (i.e., 9 days following the incident). The locations of the photos are shown on Figure 36, and the location and shutter time of each photo is marked on each photo and also listed in Table 11. All photos are named **San Bruno Gas PL Expl of 9 Sept 2010 - Scawthorn pix of 18 Sept 2010 – xxx.jpg** where xxx indicates a 3 digit sequential number (1~285) – for brevity, all but the number and extension have been omitted from Table 1.

Figure 36 Locations at which photos were taken

Table 11 Location and time of each photo

Photo Name	Time taken	Lat	Long
001.jpg	11:38:47	37.6231	-122.4425
002.jpg	11:39:07	37.6230	-122.4418
003.jpg	11:39:17	37.6230	-122.4418
005.jpg	11:44:29	37.6228	-122.4418
006.jpg	11:48:03	37.6226	-122.4419
007.jpg	11:48:11	37.6226	-122.4419
008.jpg	11:48:22	37.6227	-122.4419
009.jpg	11:48:35	37.6227	-122.4419
010.jpg	11:48:38	37.6227	-122.4419
011.jpg	11:48:41	37.6227	-122.4419
012.jpg	11:48:48	37.6227	-122.4419
013.jpg	11:49:02	37.6227	-122.4419
014.jpg	11:49:12	37.6227	-122.4419
015.jpg	11:49:25	37.6227	-122.4419
016.jpg	11:49:31	37.6227	-122.4419
017.jpg	11:49:40	37.6227	-122.4419
018.jpg	11:49:42	37.6227	-122.4419
019.jpg	11:49:46	37.6227	-122.4419
020.jpg	11:49:56	37.6227	-122.4419
021.jpg	11:50:03	37.6227	-122.4419
022.jpg	11:50:18	37.6227	-122.4419
023.jpg	11:50:25	37.6227	-122.4419
024.jpg	11:51:10	37.6227	-122.4419
025.jpg	11:51:13	37.6227	-122.4419
026.jpg	11:51:16	37.6227	-122.4419
027.jpg	11:51:19	37.6227	-122.4419
028.jpg	11:51:22	37.6227	-122.4419
029.jpg	11:51:25	37.6227	-122.4419
030.jpg	11:53:51	37.6223	-122.4419
031.jpg	11:56:12	37.6219	-122.4418
032.jpg	11:56:14	37.6219	-122.4418
033.jpg	11:56:17	37.6219	-122.4418

Photo Name	Time taken	Lat	Long
034.jpg	11:56:19	37.6219	-122.4418
035.jpg	11:56:22	37.6219	-122.4418
036.jpg	11:56:30	37.6219	-122.4418
037.jpg	11:56:37	37.6219	-122.4418
038.jpg	11:56:41	37.6219	-122.4418
039.jpg	11:56:44	37.6219	-122.4418
040.jpg	11:56:46	37.6219	-122.4418
041.jpg	11:56:59	37.6219	-122.4418
042.jpg	11:57:15	37.6219	-122.4418
043.jpg	11:57:40	37.6219	-122.4418
044.jpg	11:58:04	37.6219	-122.4418
045.jpg	11:58:07	37.6219	-122.4418
046.jpg	11:58:10	37.6219	-122.4418
047.jpg	11:58:17	37.6219	-122.4418
048.jpg	11:58:20	37.6219	-122.4418
049.jpg	11:58:23	37.6219	-122.4418
050.jpg	11:58:26	37.6219	-122.4418
051.jpg	11:59:01	37.6219	-122.4418
052.jpg	11:59:06	37.6219	-122.4418
053.jpg	11:59:17	37.6219	-122.4418
054.jpg	11:59:36	37.6219	-122.4418
055.jpg	11:59:43	37.6219	-122.4418
056.jpg	12:00:20	37.6223	-122.4419
057.jpg	12:00:35	37.6223	-122.4419
058.jpg	12:00:49	37.6223	-122.4423
059.jpg	12:01:00	37.6223	-122.4423
060.jpg	12:01:03	37.6223	-122.4423
061.jpg	12:01:06	37.6223	-122.4423
062.jpg	12:01:09	37.6223	-122.4423
063.jpg	12:01:12	37.6223	-122.4423
064.jpg	12:01:25	37.6223	-122.4423
065.jpg	12:01:28	37.6223	-122.4423
066.jpg	12:01:31	37.6223	-122.4423

Photo Name	Time taken	Lat	Long
067.jpg	12:01:34	37.6223	-122.4423
068.jpg	12:01:37	37.6223	-122.4423
069.jpg	12:01:42	37.6223	-122.4423
070.jpg	12:01:45	37.6223	-122.4423
071.jpg	12:01:50	37.6223	-122.4423
072.jpg	12:01:52	37.6223	-122.4423
073.jpg	12:02:07	37.6223	-122.4423
074.jpg	12:02:13	37.6223	-122.4423
075.jpg	12:02:20	37.6223	-122.4423
076.jpg	12:02:26	37.6223	-122.4423
077.jpg	12:02:36	37.6223	-122.4423
078.jpg	12:02:39	37.6223	-122.4423
079.jpg	12:02:51	37.6223	-122.4423
080.jpg	12:03:59	37.6226	-122.4418
081.jpg	12:04:02	37.6226	-122.4418
082.jpg	12:04:05	37.6226	-122.4418
083.jpg	12:04:08	37.6230	-122.4419
084.jpg	12:04:10	37.6230	-122.4419
085.jpg	12:04:13	37.6230	-122.4419
086.jpg	12:04:16	37.6230	-122.4419
087.jpg	12:04:19	37.6230	-122.4419
088.jpg	12:04:22	37.6230	-122.4419
089.jpg	12:04:25	37.6230	-122.4419
090.jpg	12:04:28	37.6230	-122.4419
091.jpg	12:04:31	37.6230	-122.4419
092.jpg	12:04:33	37.6230	-122.4419
093.jpg	12:04:36	37.6230	-122.4419
094.jpg	12:04:39	37.6230	-122.4419
095.jpg	12:04:42	37.6230	-122.4419
096.jpg	12:04:55	37.6230	-122.4419
097.jpg	12:05:18	37.6230	-122.4419
098.jpg	12:05:21	37.6230	-122.4419
099.jpg	12:05:46	37.6230	-122.4419

Photo Name	Time taken	Lat	Long
100.jpg	12:05:59	37.6232	-122.4422
101.jpg	12:06:10	37.6232	-122.4422
102.jpg	12:06:12	37.6232	-122.4422
103.jpg	12:06:15	37.6232	-122.4422
104.jpg	12:06:18	37.6232	-122.4422
105.jpg	12:06:39	37.6230	-122.4424
106.jpg	12:06:41	37.6230	-122.4424
107.jpg	12:06:44	37.6230	-122.4424
108.jpg	12:07:31	37.6230	-122.4424
109.jpg	12:07:43	37.6230	-122.4424
110.jpg	12:08:46	37.6230	-122.4424
111.jpg	12:08:49	37.6230	-122.4424
112.jpg	12:08:52	37.6230	-122.4424
113.jpg	12:08:55	37.6230	-122.4424
114.jpg	12:08:58	37.6230	-122.4424
115.jpg	12:09:01	37.6230	-122.4424
116.jpg	12:09:04	37.6230	-122.4424
117.jpg	12:09:53	37.6229	-122.4429
118.jpg	12:10:03	37.6229	-122.4429
119.jpg	12:10:06	37.6229	-122.4429
120.jpg	12:10:08	37.6229	-122.4429
121.jpg	12:10:12	37.6229	-122.4429
122.jpg	12:10:15	37.6229	-122.4429
123.jpg	12:11:17	37.6231	-122.4424
124.jpg	12:11:20	37.6231	-122.4424
125.jpg	12:11:23	37.6231	-122.4424
126.jpg	12:11:26	37.6231	-122.4424
127.jpg	12:11:29	37.6231	-122.4424
128.jpg	12:11:41	37.6231	-122.4424
129.jpg	12:11:52	37.6231	-122.4424
130.jpg	12:12:15	37.6233	-122.4421
131.jpg	12:12:17	37.6233	-122.4421
132.jpg	12:12:20	37.6233	-122.4421

Photo Name	Time taken	Lat	Long
133.jpg	12:12:23	37.6233	-122.4421
134.jpg	12:12:25	37.6233	-122.4421
135.jpg	12:12:29	37.6233	-122.4421
136.jpg	12:12:39	37.6233	-122.4421
137.jpg	12:12:43	37.6233	-122.4421
138.jpg	12:12:47	37.6233	-122.4421
139.jpg	12:12:49	37.6233	-122.4421
140.jpg	12:12:52	37.6233	-122.4421
141.jpg	12:12:55	37.6233	-122.4421
142.jpg	12:12:58	37.6233	-122.4421
143.jpg	12:13:00	37.6233	-122.4421
144.jpg	12:13:03	37.6233	-122.4421
145.jpg	12:13:06	37.6233	-122.4421
146.jpg	12:13:09	37.6233	-122.4421
147.jpg	12:13:11	37.6233	-122.4421
148.jpg	12:13:14	37.6233	-122.4421
149.jpg	12:13:17	37.6233	-122.4421
150.jpg	12:13:35	37.6233	-122.4421
151.jpg	12:13:44	37.6233	-122.4421
152.jpg	12:14:07	37.6233	-122.4421
153.jpg	12:14:34	37.6233	-122.4421
154.jpg	12:14:40	37.6233	-122.4421
155.jpg	12:15:21	37.6237	-122.4421
156.jpg	12:15:24	37.6237	-122.4421
157.jpg	12:15:27	37.6237	-122.4421
158.jpg	12:15:50	37.6237	-122.4421
159.jpg	12:15:52	37.6237	-122.4421
160.jpg	12:15:55	37.6237	-122.4421
161.jpg	12:16:12	37.6237	-122.4421
162.jpg	12:16:15	37.6237	-122.4421
163.jpg	12:16:17	37.6237	-122.4421
164.jpg	12:16:20	37.6237	-122.4421
165.jpg	12:16:36	37.6237	-122.4421

Photo Name	Time taken	Lat	Long
166.jpg	12:16:51	37.6237	-122.4421
167.jpg	12:16:54	37.6237	-122.4421
168.jpg	12:16:57	37.6237	-122.4421
169.jpg	12:17:00	37.6237	-122.4421
170.jpg	12:17:02	37.6237	-122.4421
171.jpg	12:17:06	37.6237	-122.4421
172.jpg	12:17:36	37.6237	-122.4421
173.jpg	12:18:17	37.6237	-122.4421
174.jpg	12:18:36	37.6237	-122.4421
175.jpg	12:19:03	37.6233	-122.4419
176.jpg	12:19:08	37.6233	-122.4419
177.jpg	12:19:11	37.6233	-122.4419
178.jpg	12:20:38	37.6233	-122.4415
179.jpg	12:20:41	37.6233	-122.4415
180.jpg	12:20:44	37.6233	-122.4415
181.jpg	12:20:47	37.6233	-122.4415
182.jpg	12:21:31	37.6233	-122.4415
183.jpg	12:21:39	37.6233	-122.4415
184.jpg	12:23:17	37.6236	-122.4412
185.jpg	12:23:20	37.6236	-122.4412
186.jpg	12:23:23	37.6236	-122.4412
187.jpg	12:23:25	37.6236	-122.4412
188.jpg	12:23:28	37.6236	-122.4412
189.jpg	12:24:10	37.6236	-122.4412
190.jpg	12:24:13	37.6236	-122.4412
191.jpg	12:24:16	37.6236	-122.4412
192.jpg	12:24:19	37.6236	-122.4412
193.jpg	12:24:22	37.6236	-122.4412
194.jpg	12:24:25	37.6236	-122.4412
195.jpg	12:24:28	37.6236	-122.4412
196.jpg	12:24:31	37.6236	-122.4412
197.jpg	12:24:34	37.6236	-122.4412
198.jpg	12:24:37	37.6236	-122.4412

Photo Name	Time taken	Lat	Long
199.jpg	12:24:40	37.6236	-122.4412
200.jpg	12:24:46	37.6236	-122.4412
201.jpg	12:24:49	37.6236	-122.4412
202.jpg	12:24:51	37.6236	-122.4412
203.jpg	12:24:53	37.6236	-122.4412
204.jpg	12:24:56	37.6236	-122.4412
205.jpg	12:24:58	37.6236	-122.4412
206.jpg	12:25:33	37.6236	-122.4412
207.jpg	12:25:41	37.6236	-122.4412
208.jpg	12:26:03	37.6236	-122.4412
209.jpg	12:26:13	37.6236	-122.4412
210.jpg	12:26:23	37.6236	-122.4412
211.jpg	12:26:26	37.6236	-122.4412
212.jpg	12:26:29	37.6236	-122.4412
213.jpg	12:26:55	37.6236	-122.4412
214.jpg	12:26:58	37.6236	-122.4412
215.jpg	12:27:15	37.6239	-122.4413
216.jpg	12:27:19	37.6239	-122.4413
217.jpg	12:28:07	37.6240	-122.4413
218.jpg	12:28:10	37.6240	-122.4413
219.jpg	12:28:13	37.6240	-122.4413
220.jpg	12:28:15	37.6240	-122.4413
221.jpg	12:28:18	37.6240	-122.4413
222.jpg	12:28:38	37.6240	-122.4413
223.jpg	12:28:56	37.6236	-122.4412
224.jpg	12:28:59	37.6236	-122.4412
225.jpg	12:29:02	37.6236	-122.4412
226.jpg	12:29:28	37.6236	-122.4412
227.jpg	12:29:33	37.6236	-122.4412
228.jpg	12:29:38	37.6236	-122.4412
229.jpg	12:30:18	37.6232	-122.4413
230.jpg	12:30:21	37.6232	-122.4413
231.jpg	12:30:24	37.6232	-122.4413

Photo Name	Time taken	Lat	Long
232.jpg	12:30:31	37.6232	-122.4413
233.jpg	12:30:34	37.6232	-122.4413
234.jpg	12:30:37	37.6232	-122.4413
235.jpg	12:30:51	37.6232	-122.4413
236.jpg	12:30:54	37.6232	-122.4413
237.jpg	12:30:58	37.6232	-122.4413
238.jpg	12:31:00	37.6232	-122.4413
239.jpg	12:31:03	37.6232	-122.4413
240.jpg	12:31:06	37.6232	-122.4413
241.jpg	12:31:09	37.6232	-122.4413
242.jpg	12:31:12	37.6232	-122.4413
243.jpg	12:31:14	37.6232	-122.4413
244.jpg	12:31:17	37.6232	-122.4413
245.jpg	12:31:20	37.6232	-122.4413
246.jpg	12:31:22	37.6232	-122.4413
247.jpg	12:31:27	37.6232	-122.4413
248.jpg	12:31:37	37.6232	-122.4413
249.jpg	12:32:45	37.6229	-122.4410
250.jpg	12:32:48	37.6229	-122.4410
251.jpg	12:32:51	37.6229	-122.4410
252.jpg	12:32:53	37.6229	-122.4410
253.jpg	12:33:06	37.6229	-122.4410
254.jpg	12:33:21	37.6229	-122.4410
255.jpg	12:33:24	37.6229	-122.4410
256.jpg	12:33:26	37.6229	-122.4410
257.jpg	12:33:29	37.6229	-122.4410
258.jpg	12:33:31	37.6229	-122.4410
259.jpg	12:33:34	37.6229	-122.4410
260.jpg	12:33:37	37.6229	-122.4410
261.jpg	12:34:01	37.6227	-122.4406
262.jpg	12:34:15	37.6227	-122.4406
263.jpg	12:34:54	37.6227	-122.4406
264.jpg	12:35:46	37.6227	-122.4406

Photo Name	Time taken	Lat	Long
265.jpg	12:35:49	37.6227	-122.4406
266.jpg	12:35:52	37.6227	-122.4406
267.jpg	12:36:04	37.6227	-122.4406
268.jpg	12:36:09	37.6227	-122.4406
269.jpg	12:36:22	37.6227	-122.4406
270.jpg	12:36:46	37.6227	-122.4406
271.jpg	12:37:23	37.6227	-122.4406
272.jpg	12:37:52	37.6227	-122.4406
273.jpg	12:40:17	37.6227	-122.4406
274.jpg	12:41:27	37.6229	-122.4410
275.jpg	12:41:30	37.6229	-122.4410
276.jpg	12:41:32	37.6229	-122.4410
277.jpg	12:41:35	37.6229	-122.4410
278.jpg	12:41:38	37.6229	-122.4410
279.jpg	12:41:40	37.6229	-122.4410
280.jpg	12:41:44	37.6229	-122.4410
281.jpg	12:41:47	37.6229	-122.4410
282.jpg	12:41:50	37.6229	-122.4410
283.jpg	12:42:04	37.6229	-122.4410
284.jpg	12:58:30	37.6233	-122.4419
285.jpg	12:58:37	37.6233	-122.4419