PACIFIC GAS AND ELECTRIC COMPANY

ASSET MANAGEMENT & ELECTRIC TRANSMISSION
ASSET INVESTMENT PLANNING
GAS ASSET STRATEGY
GAS SYSTEM INTEGRITY

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Gas Transmission Earthquake Plan And Response Procedure

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TABLE OF CONTENTS

1. Introduction 1
2. Purposes 1
3. Major Bay Area Earthquake Scenarios 2
4. Gas Transmission Pipeline System Earthquake Risk Values 2
5. Earthquake Emergency Response Procedure 4
6. Post Earthquake Damage Evaluation (IDE) Guidelines 5
7. Distributions and Geosciences Contacts 7

TABLES

Table 1 Factors for A.) Liquefaction-Lateral Spreading and Landsliding as a function of Peak Ground Acceleration (PGA) for various susceptibility classes, and B.) Fault crossings as a function of earthquake magnitude 3

Table 2 Initial Damage Evaluation Criteria 7

FIGURES

Figure 1 Fault crossing. Pipeline damage from the 1906 earthquake. caused by right lateral offset of San Andreas fault. 10

Figure 2 Sand volcanoes at the Oakland Airport runway, caused by liquefaction from the 1989 Loma Prieta earthquake. 10

Figure 3 Lateral spreading caused by ground shaking. 11

Figure 4 Lateral spreading caused by landsliding. 11

Figure 5 Landsliding. 12

ATTACHMENTS

I. Earthquake Scenarios and Maintenance Organization Matrix 8

II. Earthquake Response Procedure Flowchart 9

III. Major Bay Area Earthquake Scenarios Maps and High Risk Facilities Spreadsheets (See Tabs)
1. Map Scenario Index
2. Northern Calaveras (M 6.8), with Detail A map
3. Southern and Central Calaveras (M 6.4)
4. Northern Hayward (M 6.5)
5. Northern and Southern Hayward (M 6.9), with Detail A and Detail B maps
6. Southern Hayward (M 6.7) 1868, with Detail A map
7. Rodgers Creek (M 7.0)
8. San Andreas (M 7.2) 1838
9. San Andreas (M 7.9) 1906, with Detail A and Detail B maps

1. Introduction:

This plan describes PG&E's use of Geographic Information System (GIS)-based products to enhance emergency response following a significant earthquake in the San Francisco Bay Area. This is being developed as part of PG&E's Pipeline Integrity Management Program.

Computer models utilizing new internet-based technologies (i.e., USGS ShakeMap, PG&E's Map Server) and improved digital geohazards maps for the San Francisco Bay Area have enabled the development of decision support tools to prioritize emergency response activities. Used as a screening tool, this information helps to rapidly identify potential gas transmission problem areas, prior to receipt of initial damage reports from the field. The ShakeMaps are real-time maps based on empirical (actual instrumental) observations and earthquake information (location and magnitude), and are corrected for local site amplification effects. The earthquake location and magnitude information is available from the US Geological Survey (USGS) immediately following a significant earthquake; ShakeMaps are available within about 15 minutes. These products are processed and posted on the PG&E MapServer at http://gisweb/GIS/maps/map_frames.asp?map=geosci_1.

The USGS also provides scenario ShakeMaps of likely Bay Area earthquakes. This plan contains ShakeMaps of these scenarios and spreadsheets of potential damage estimates to PG&E's gas transmission system (pipelines and gas-handling facilities). In the event that a large earthquake causes the Internet to be temporarily out of service, these scenarios can be used to prioritize damage assessment until the actual ShakeMaps are available.

2. Purposes:

The purposes of the Gas Transmission Earthquake plan are to:

1) Describe the eight Bay Area earthquake scenarios. (Section 3.)

2) Describe the Gas transmission pipeline Earthquake Risk Value (ER_VALUE), including the ground failure and pipeline factors used to calculate the ER_VALUE, and provide Gas Transmission Operation and Maintenance organizations with lists of the most vulnerable pipeline segments and gas-handing facilities (stations) and maps of their locations for each major Bay Area earthquake. (Section 4.)

3) Describe the earthquake response procedure. (Section 5.)

4) Describe the post-earthquake initial damage evaluation guidelines. (Section 6.)

In the absence of an actual ShakeMap following a significant Bay Area earthquake, the maps and spreadsheets of eight scenario earthquakes for the major faults in the San Francisco Bay Area can be used for an initial estimate of earthquake impact to the gas transmission pipeline system. These maps will be superseded by the actual ShakeMaps once they become available in the hours following the earthquake. In addition to emergency response, these scenarios can also be used for pre-event planning and mitigation activities.

3. Major Bay Area Earthquake Scenarios

Eight Bay Area earthquake scenarios for the faults having the highest likelihood of causing significant damage are listed below. They are based on both historic events and USGS computer simulations of likely future earthquakes. The scenario earthquakes are:

Peninsula
1838 San Andreas Peninsula section (M 7.2) 1838, Historic
1906 San Andreas (M 7.9) 1906, Historic
East Bay
Northern Calaveras (M 6.8)
Southern and Central Calaveras (M 6.4)
Northern Hayward (M 6.5)
Southern Hayward (M 6.7) 1868, Historic
Northern and Southern Hayward (M 6.9)
North Bay
Rodgers Creek (M 7.0)

4. Gas transmission pipeline system Earthquake Risk Values

4.1 Pipelines:
The Gas transmission pipeline system Earthquake Risk Values are based on combining information about the earthquake, with regional scale (1:24,000 to 1:250,000) digital geologic maps used to evaluate liquefaction and slope failure hazards associated with large earthquakes. These maps incorporate topographic, geologic, hydrologic, and geotechnical data to develop the liquefaction and landslide hazard GIS data layers. See Figures 1 through 6 for examples of these site effects.

The Earthquake Risk Value (ER_VALUE) is calculated according to the factors that influence pipeline integrity and failure consequence:

- Fault Crossing (FAULT_VAL) [Figure 1],
- Liquefaction and Ground Failure susceptibility (LIQUIF_VAL) [Figures 2-4],
- Landslide susceptibility (SLOPE_VAL) [Figure 5],
- Pipeline Age (YRINS_VAL) and
- High Consequence Areas (as defined in CFR 49 part 192 subpart O) (HCA_VAL).

ER Value = (FAULT_VAL+LIQUIF_VAL+SLOPE_VAL)*YRINS_VAL*HCA_VAL

The ER_VALUE can range from 0 to 432. Table 1 shows the factor values. For ease of identification, the pipeline segments shown on the maps and listed in the spreadsheets in the scenario book are color-highlighted as shown below.

- RED = High; ER_VALUE greater than or equal to 200.
- BLUE = Medium High; ER_VALUE 140 to 199.
- YELLOW = Medium; ER_VALUE 100 to 139. Listed on spreadsheets but not color highlighted.
- GREEN = Low; ER_VALUE 1 to 99. Listed on spreadsheets but not color highlighted.
- GREY = ER_VALUE equal to 0 or not analyzed (pipe segments are OD≤ 4.5", DF or STUB). Not listed on spreadsheets.

The pipeline spreadsheets are sorted according to Maintenance Organization (Maint_Org), Route Join and ER Value. Two types of spreadsheets are provided; one for the RED and BLUE pipe segments and the other for YELLOW segments.

The maintenance organizations that are potentially affected by the earthquake scenarios are summarized in Attachment I: Earthquake Scenarios and Maintenance Organization Matrix.

**** Pipeline segments having ER_VALUE ≥ than 140 (RED or BLUE) are recommended for immediate post earthquake inspection.**

Table 1. Factors for A.) Liquefaction-Lateral Spreading and Landsliding as a function of Peak Ground Acceleration (PGA) for various susceptibility classes, and B.) Fault crossings as a function of earthquake magnitude.

A.)

PGA (g)	Liquefaction -Lateral Spreading			Landsliding		
	Moderate to High	Low to Moderate	Low	Moderate to High & Known	Moderate	Low to Moderate
0.05	0	0	0	0	0	0
0.10	0	0	0	20	0	0
0.15	10	0	0	40	0	0
0.20	20	0	0	60	0	0
0.25	30	10	0	80	0	0
0.30	40	20	10	100	10	0
0.35	60	25	15	100	20	0
0.40	80	33	20	100	40	0
0.45	100	40	25	100	60	0
0.50	100	50	30	100	80	0
0.55	100	60	35	100	90	0
0.60	100	80	40	100	100	10
0.65	100	100	47	100	100	20
0.70	100	100	53	100	100	40
0.75	100	100	60	100	100	60
0.80	100	100	70	100	100	80
0.85	100	100	80	100	100	90
0.90	100	100	100	100	100	100
0.95	100	100	100	100	100	100
1.00	100	100	100	100	100	100

B.)

Fault Crossing	
Earthquake Magnitude	
4.0	0
4.5	0
5.0	0
5.5	10
6.0	20
6.5	40
7.0	60
7.5	80
8.0	100
8.5	100

4.2 Stations:
Gas-handling facilities (stations) in the gas transmission system have substantial inherent resistance to earthquake damage. Although such facilities have rarely been damaged by historical earthquakes, the potential occurrence of strong ground shaking and significant ground displacements in large earthquakes must be expected, and the gas-handling facilities may experience damage that could impede gas deliveries. Major above ground stations within a 0.2g contour or higher are listed on a spreadsheet and shown on the map. The spreadsheets are sorted by Maintenance Organization and ground acceleration in descending order.

****Immediate inspections of stations experiencing ground acceleration greater than or equal to 0.5 g are recommended. These stations are highlighted in red on the spreadsheets.**

5. Earthquake Emergency Response Procedure

After a major Bay Area earthquake (Magnitude 6.0 or greater), the following sequence of events will likely occur. Attachment II is a flowchart of the earthquake response procedure.

5.1 If the internet is available, E-page notification (via pager or email) of earthquake location and magnitude will be sent out by Geosciences to Emergency Response Personnel (ERP). (For initial warning a magnitude of 5.0 or stronger earthquake will trigger the e-mail). The E-page notification will include earthquake magnitude and depth, time of the event, and location of the epicenter in terms of lat/long coordinates and nearest city and nearest PG&E facility.

5.2 If the Internet is not available, ERP will need to get information from other sources, such as the Radio or TV.

5.3 If the Internet is now available the ERP shall receive another Epage as soon as PG&E has received the first USGS ShakeMap.

5.4 In the meantime, the Pipeline Restoration Center (PRC) will be activated.

5.5 Upon receiving a ShakeMap, the Gas Transmission/GIS system will automatically calculate the ER values and generate the maps showing the ShakeMap with affected pipelines and major gas stations, and spreadsheets of the affected pipeline segments and the major stations. The post-earthquake ER value spreadsheets and maps will automatically be sent in PDF format via email to PRC Staff, and the GSO Gas Control.

5.6 If the Internet is not available and no ShakeMap has been sent to the Gas Transmission/GIS system, the ERP shall use the earthquake magnitude and location information from the E-page (or other sources) to determine the closest earthquake scenario in this plan. The Geosciences Department may assist in this decision (see section 7. for contact). ERP will review the ER Pipelines (colored in red and blue) list and the list of stations with ground motions ≥ 0.2g of the chosen earthquake scenario and prepare a preliminary post earthquake inspection plan. The ERP shall receive analysis from the actual ShakeMap as soon as the Internet becomes available.

5.7 The PRC/Gas Control will review this information and information from other sources and communicate with the maintenance organizations on specific facilities to be inspected. The PRC/Gas Control will continue the process of reviewing and updating the response plan until the condition is stabilized.

5.8 ERP shall replace the preliminary post-earthquake inspection plan with the most current instructions from the PRC/Gas Control. The ERP shall proceed with the field inspections and report back to the PRC/Gas Control.

6. Post Earthquake Initial Damage Evaluation (IDE) Guidelines

6.1 Scope and Purpose

Immediately after a significant earthquake (magnitude 6.0 or greater), Gas Operations and Maintenance personnel will be responsible for performing an Initial Damage Evaluation (IDE) on gas transmission pipelines. The IDE is the first inspection a buried gas pipeline will receive immediately after the event. The IDE inspection is not a substitute for a detailed inspection performed by either PG&E pipeline engineers or consultants hired by PG&E. For that reason, the IDE inspectors should, where possible, take digital photos of all damage the inspector finds that he/she considers significant or questionable. If the inspector believes the situation to be urgent, these photos should be sent immediately to the PRC/Gas Control for information and evaluation. If the inspector believes the situation to be less urgent, the photos can be sent as time permits.

The objectives of the IDE are to determine the extent of nearby ground movement; i.e. surface fault rupture, liquefaction and slope failure and visible gas pipeline damage, and report such information to the PRC/Gas Control.

6.2 Responsibility and Authority of Inspectors

The responsibility of the IDE Inspectors is to inspect the assigned gas pipeline and report the results to the Gas Maintenance Supervisor, the PRC and the Operations Control Center (OCC). The Gas Maintenance Supervisor will verify that report results have been sent to the PRC/Gas Control and the OCC and authorize required mitigating actions.

Authority to order evacuation of an earthquake-damaged gas pipeline area is generally with the Gas Maintenance Supervisor. However, in the event of an extremely dangerous situation is encountered that requires immediate action, IDE Inspectors shall order evacuation of the area and work with other emergency responders including the local police and fire departments.

6.3 Evaluation Criteria

In an IDE, gas pipelines shall be evaluated using the criteria listed in Table 2. These criteria specify that the gas pipeline should be mitigated if: (a) a visual inspection indicates there is significant damage to the gas pipeline or (b) there are other hazards present which would make the gas pipeline unsafe, e.g. significant areas of ground movement. Generally, minimal amounts of ground deformation are not sufficient cause to shutdown a gas pipeline.

6.4 Step-by-Step Inspection Procedure

The following is a step-by-step procedure to be used in performing an IDE.

6.4.1. Report any Gas Leaks: In case of pipeline rupture or gas leaks, the inspector shall report to the PRC/Gas Control, request immediate engineering evaluation, and follow UO Standard S4110 to mitigate the leak.

6.4.2. Examine the Site for Ground Movements: If there are no gas leaks that require immediate action, inspect the ground for signs of settlement (vertical movement) and cracked or buckled ground or pavement (lateral movement). If any new, significant ground movements are observed, the inspector shall request immediate follow-up engineering review, whether these have damaged the pipeline or not. Be sure to distinguish between new cracks or movement and existing conditions. The followings are three types of ground movements:

- Surface Fault Rupture: Likely surface fault rupture can be estimated from combining Map Server layers of the ShakeMaps and active faults. Magnitude 6.5 (or less) earthquakes generally do not produce significant fault rupture to break modern (ductile steel or polyethylene) pipe in soil. (See Figure 1 for pipeline damage due to fault rupture)

- Liquefaction-Ground Failure: Liquefaction is the loss of soil strength as a consequence of increased pore-water pressures during earthquake ground shaking. Peak ground accelerations greater than 0.10 g can produce liquefaction in soils which are susceptible to liquefaction. Liquefaction can damage buried pipe either by land subsidence through the ejection of liquefied soil (evidenced by sand boils) or permanent ground displacements through lateral spreading and ground failure. (See Figures 2-4 for examples of liquefaction and lateral spreading)

- Slope Failure: Slope failures, or landslides, are masses of rock and soil that move down slope, under the influence of gravity, by sliding, falling, or flowing. Peak ground accelerations greater than 0.05 g can produce slope failure, especially if soil conditions are wet. Slope failure can produce permanent ground displacements through down slope movement. (See Figure5 for example of landsliding)

6.4.3 Deal with Unsafe Areas: If suspected hazards are encountered in the area of the gas pipeline segment, the hazardous area shall be closed to public access using barricades, tape, or other means to prevent public exposure.

6.4.4 Communicate Results: After completing the IDE, the Inspector shall communicate results to the Gas Maintenance Supervisor, the PRC/Gas Control and OCC. The gas pipeline Maintenance Supervisor shall be responsible for reporting items that require further action.

6.5 Personal Safety: The following tips shall be followed to ensure safety while making an IDE.

- Wear a hardhat and eye protection.
- Never take unnecessary risks.
- Be alert for overhead falling hazards.
- Do not smoke, light matches, or cause sparks.
- Avoid all areas where a hazardous material release is suspected or confirmed.
- Treat any spill of an unknown substance as a potential hazardous material spill.

6.6 Field Equipment: The following is a list of equipment that each IDE inspection team should have during an inspection.

1. IDE Procedures
2. Phone Numbers of PRC/Gas Control and OCC
3. ER_Pipeline Lists, ShakeMaps
4. Site Maps
5. Communication Equipment – Cell Phone, PG&E 2-way radio, etc.
6. Hard hat
7. Eye protection
8. Flashlight
9. Caution tape
10. Clipboard, paper, pen
11. Digital camera
12. Tape measure

Table 2. Initial Damage Evaluation Criteria

Condition	Action
1. There is smell of gas	Follow UO Standard S4110 to mitigate the leak and request immediate engineering evaluation
2. The gas pipeline is exposed and there is significant deformation to the pipeline.	Request immediate engineering evaluation
3. There is new ground cracking or movement (vertical or horizontal) of several inches or more in the vicinity of the gas pipeline.	Request immediate engineering evaluation
4. There is slope failure where large amounts of soil, rocks, etc. have deposited on top of the pipeline segment.	Request immediate engineering evaluation

7. Distributions and Geosciences Contacts

The Gas Transmission Emergency Plan and Response Procedure will be distributed to Gas Control, PRC, OM&C, District, Division, GAS-GSI, GAS GIS Website and will be incorporated in the Distribution Emergency Response Manual (by link to the GIS Website).

Geosciences Contacts:

[redacted] (Civil Engineer)
[redacted] (Geotechnical Engineer)
[redacted] (Seismologist)
[redacted]

Attachment I: Earthquake Scenarios and Maintenance Organization Matrix:

Maintenance organization	Northern Calaveras	Southern and Central Calaveras	Hayward 1868	Northern Hayward	Northern and Southern Hayward	Rogers Creek	San Andreas 1838	San Andreas 1906
DCCO								X
DDAZ								O
DDIA	O		O	O	O		O	X
DEBY			O	O	X			O
DMIS	O							
DNBY				X	X	X	O	X
DNCO					O	X		O
DPEN					O		X	X
DSFO			O		O		X	X
DSTK							O	X
GHOL		O						X
GMIL	X	X	X		X		O	X
GTRA	X		O		O			O

X : Maintenance Organizations with ER values > 200
O : Maintenance Organizations with ER values > 140

Attachment II: Earthquake Response Procedure Flowchart

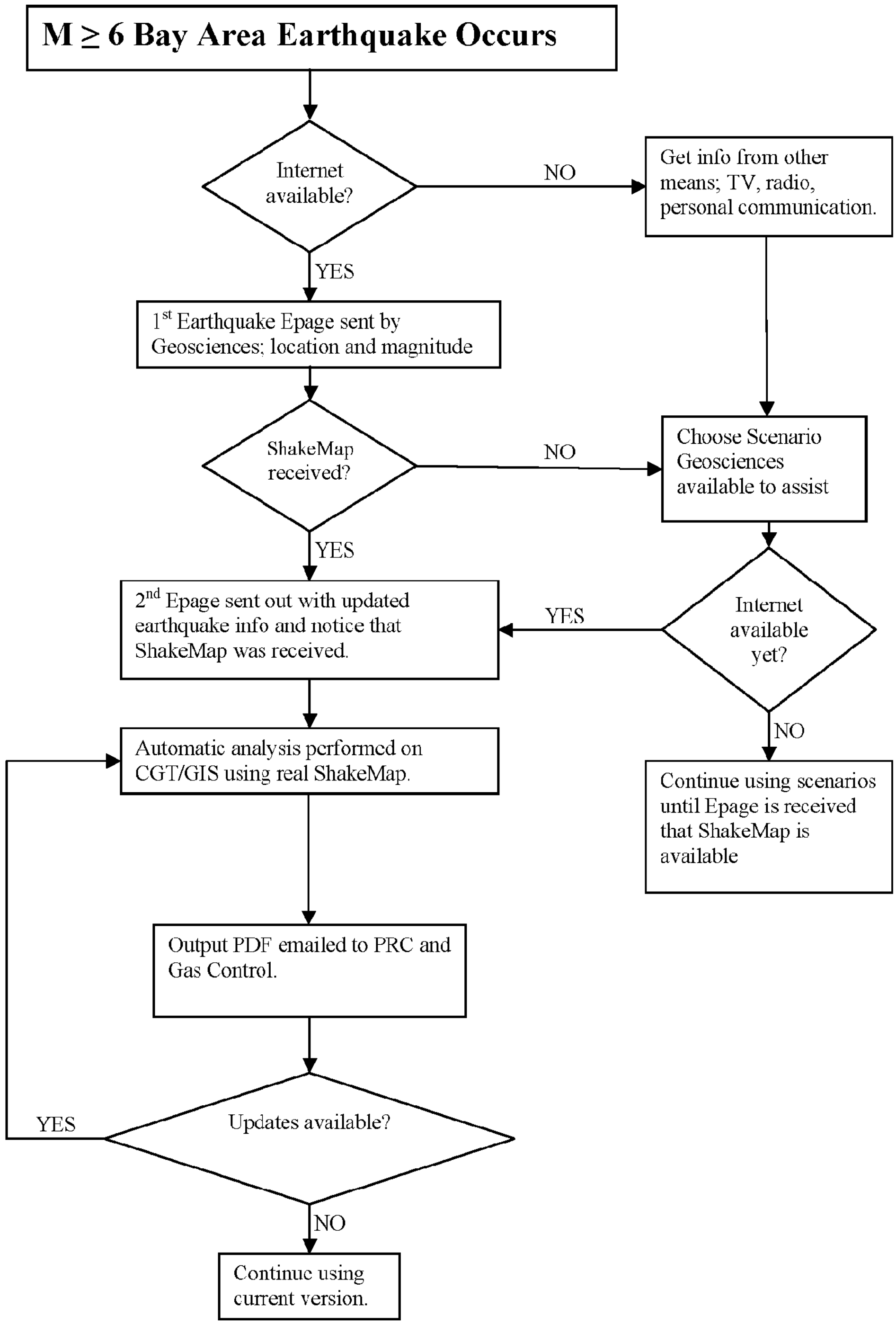

Figure 1. Fault crossing. Pipeline damage from the 1906 earthquake caused by right lateral offset of San Andreas fault. Red line is approximate location of fault; arrows are direction of fault motion.

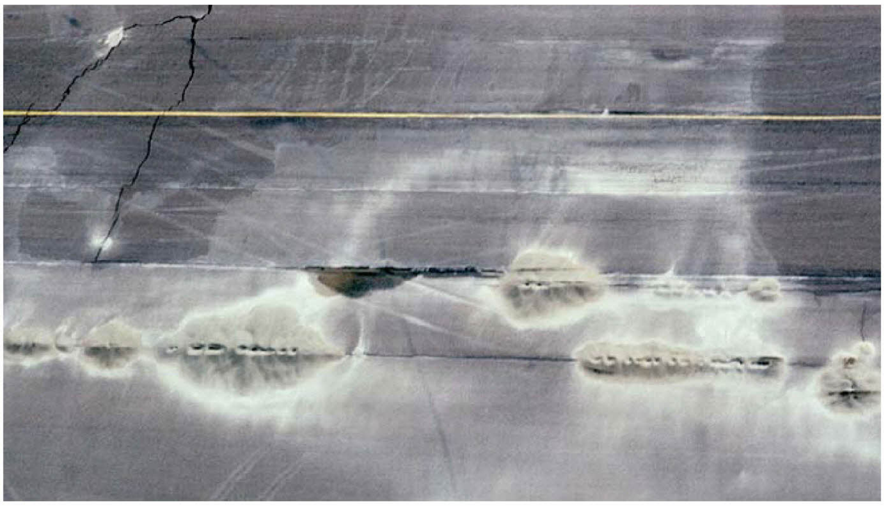

Figure 2. Sand volcanoes at the Oakland Airport runway, caused by liquefaction from the 1989 Loma Prieta earthquake.

Figure 3. Lateral spreading caused by ground shaking.

Figure 4. Lateral spreading caused by landsliding.

Figure 5. Landsliding