WEIDLINGER ASSOCIATES, CONSULTING ENGINEERS
110 EAST 59TH STREET
NEW YORK, NEW YORK 10022

and

SUITE 245, BUILDING 4
3000 SAND HILL ROAD
MENLO PARK, CALIFORNIA 94025

SURVEY OF EXISTING UNDERGROUND WATER PIPELINES WITH EMPHASIS ON THEIR SEISMIC RESISTANCE

By

J. Isenberg
J. P. Wright

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Washington, D.C. 20550

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TABLE OF CONTENTS

LIST OF TABLES

SECTION I

INTRODUCTION

A survey of the characteristics of underground water pipeline systems which may affect their seismic performance was conducted as part of an ongoing project sponsored by NSF/RANN. The main objectives of the survey were as follows:

a. To establish a data base on the types of water pipelines that are in current use, including materials, sizes, types of joints, depths of burial and backfill conditions.

b. To determine perceptions of seismic risk among water utilities.

c. To collect data on seismic performance of water pipelines.

The survey was conducted by questionnaire, which was mailed to 516 water utilities, including wholesalers and retialers, in the United States. Table 1 shows the number of questionnaires sent to various states and the number of responses from each as of July 1, 1977. The group selected reflects relative state populations, but is biased somewhat toward cities with larger populations and toward western states which are seismically more active. The questionnaire was mailed on March 31, 1977, and addressees were encouraged to respond within a few weeks.

A copy of the questionnaire and cover letter are attached as Appendix I.

SECTION 2

DESCRIPTION OF EXISTING SYSTEMS

Pipeline systems were categorized by pipe diameters and materials. Tables 2a through 2c contain cumulative totals of length of existing types of pipes and joints. The tabulation includes contributions from systems which vary widely in size, purpose, geology and other factors. As a result 8-10 large utilities dominate these data. In compiling most other statistics, however, the response of each utility is recorded regardless of size, so that each utility carries equal weight. Table 2a shows that for transmission lines (arbitrarily defined to be pipes 20 inches diameter and larger), the most common material is steel for which the most common type of joint is welding. Table 2b shows that, for distribution lines (4-20 inches diameter), the most common material and joint types are cast iron and various caulking compounds, including cement and lead. For service lines greater than 1 inch diameter the most common materials are cast and galvanized iron. Smaller service lines were most commonly steel and copper in ratio about 3 to 1, respectively.

Ninety-eight percent of the respondents use rubber gasket-type joints for new distribution lines. Tables 3a and 3b summarize the pipe materials and joint types which were used in distribution systems before the rubber gasket-type became available (early 1950's) and the percentage of pipe in use in the systems are not of the rubber gasket-type. The dominance of cast iron pipe, especially for other lines, and of lead caulking is apparent. With regard to methods of restraining tees, crosses, intersections and bends, the most frequently used method is a poured-in-place concrete thurst block; frequently bonding of pipes to the soil is enhanced by tie rods. The effect of attaching a large mass to the pipes is being studied as a separate task under the present project.

Another important physical parameter of existing systems is the depth of burial. About 90 percent of those replying use between 2-1/2 and 4-1/2 feet of backfill measured from the pipe crown and about 64 percent use between 2-1/2 feet and 3-1/2 feet. (Earth cover recommended to avoid freezing of underground fire-protection water mains varies according to climate. The National Fire Protection Association recommends earth cover of 2-1/2 to 4 feet in temperate areas and as much as 7 to 8 feet in the upper north. Survey results reflect predominance of temperate areas in mailing sample.) Backfill materials and methods of placing them are indicated in Table II. Most respondents appear to prefer native material for backfill. Regardless of whether backfill is native or imported material, backfill placement methods appear to be aimed at producing at least 90 percent compaction in backfill material. This is reflected in specifications for lift height, most of which are 1 foot or less. One large utility has, as a result of recent experience of a damaging earthquake, changed its backfill material to a soil-cement slurry. Two other utilities with recent experience of earthquakes use either imported or native material which is water jetted or tamped into place in lifts.

SECTION 3

PERCEPTIONS OF SEISMIC RISK

By augmenting actual data on seismic performance of pipelines with the intuition of experienced engineers, research can be directed toward the problems which utilities consider most important. Such information also indicates the priority that utilities give to seismic risk in relation to other problems. This will help in future planning to influence policy toward seismic risk.

About one-third of the respondents said that there is a policy-making body with respect to seismic hazard to the utility. The composition of the body most frequently included superintendent or general manager and chief or division engineer. About 30 percent of the respondents said that seismic risk is specifically addressed in fiscal and/or operational planning for transmission or distribution piping systems. Those 30 percent ranked on a scale of 1 to 5 (highest priority) the priority given to seismic risk with respect to other planning considerations. About 50 percent of those responding to this question (15 percent of the total respondents to the survey) gave seismic risk a priority of 3. Practically all of the other respondents ranked seismic risk near the bottom of the priority scale.

There appeared to be a moderate degree of awareness of earthquake threats. We chose as a measure of seismic activity the seismic zone number used in the lateral force provisions of the Uniform Building Code

(1971 Version). About one-third of the respondents answered the question, "What seismic zone number (3-zone system) is the utility in?" Another one-third of the respondents answered by "have no idea" or similar indication. The remainder were left blank. In contrast, in response to a question about whether there are known active faults within or near the system capable of producing strong ground shaking, about 80 percent indicated that they knew; slighly less than half of these replied yes. However, only 5 responses out of the 44 who said that there are active faults near their system included some description of the causative fault system. The replies which suggested that detailed earthquake engineering data were known to the utility were from areas where an earthquake had produced damage to water systems within the last 15 years or areas with the memory of a devastating earthquake. Sixty percent of the responses included some description of local geology, and many of these appeared to be well informed.

Parts of water pipeline systems were ranked according to highest probability of damage in an earthquake. In order of decreasing probability, respondents ranked the most likely damage locations as follows:

a. Transmission lines

b. Distribution lines

c. Connections in transmission lines

d. Connections in distribution lines.

Respondents related damage to pressure control stations and valves as low risk.

About 10 percent of the respondents said they had conducted a study to determine the seismic risk to their systems. Of these, 5 (out of a total of 115 respondents) said there had been changes in planning, design or operating procedures as a result of the study. Twelve percent said that their decision to use rubber gasket joints was motivated in part by seismic considerations (i.e., its presumed superior performance in earthquakes).

Insurance against earthquake damage is an indirect indication of perceived risk. To an extent, the willingness to buy coverage indicates a level of concern. There are many other factors which influence the decision to insure, however. About one-third of the respondents stated that they carry liability insurance for water damage following an earthquake. About 15 percent of the respondents stated that they carry insurance for other types of damage caused by earthquakes. It is presumed on the basis of interviews and a few written comments accompanying the completed questionnaires that this primarily covers seismic damage to above-ground structures, such as pumping plants. There is no evidence that utilities carry significant amounts of insurance covering seismic damage to buried pipelines.

It might be expected that there would be a trend toward insuring against earthquake related damage in areas which are seismically more active. Correlation between seismic zone number and insurance coverage for water damage is shown in Table 5a. About one-third of the respondents from seismic zone 3 and about 20 percent of those from seismic zone 2 carry liability insurance for water damage following an earthquake. The statistical basis is too narrow to draw conclusions about seismic zone 1. Correlation between seismic zone number and insurance coverage for other types of damage is shown in Table 5b. As is shown in Table 6, 11 respondents who have conducted a seismic risk study of their systems have not overwhelmingly decided to use rubber gasket joints to try to improve seismic performance. Neither are they the most frequent insurers against water damage following an earthquake. Only two of these utilities, one with recent experience of a damaging earthquake and the other in an area with a history of strong earthquakes, modify their backfill procedures and pipe replacement schedules to upgrade for earthquakes. Table 6 also shows that seismic risk surveys have been made by large and small utilities whose chief common feature is that they are all in seismic zone 3.

SECTION 4

EXPERIENCE OF DAMAGE IN PIPELINES

There were 13 respondents to a question asking whether parts of the system were known to have performed well or badly during earthquakes, landslides or other ground movements. The replies are summarized in Table 7. Although the statistical basis is too narrow to draw definite conclusions, it appears that rubber gasket joints may perform well in earthquakes. Three of the 8 who said that rubber gaskets performed well also said that the decision to use them was prompted at least partially by seismic considerations. The replies also show that 4 utilities had some experience in which asbestos-cement pipes performed badly and none reported that pipe made of this material performed well under conditions of earthquake, landslides or ground movement.

The results reported in the questionnaire were expanded by interviews with 7 major water wholesalers and retailers in the states of California and Washington. One observation in the 1971 San Fernando earthquake, which apparently was also made in the 1969 Santa Rosa earthquake (Reference 1), is that ground shaking damaged steel water mains at points which had already been weakened by corrosion. The damage appeared in the form of small holes which occurred in the pipes. In the 1965 Seattle earthquake, ground shaking may have hastened the deterioration of lead-caulked joints, which developed leaks due to pressure and traffic vibration sooner than would otherwise have happened. The most common mode of damage to pipelines in that earthquake, however, was tension failure at threaded joints in steel pipes. The interviews conducted as part of this project indicated that, where a fault break in the 1971 San Fernando earthquake intersected cast iron or steel pipe, the pipe was broken. Broken bells in bell and spigot cast iron pipe were also observed. These findings essentially confirm the damage description given in Reference 2.

Respondents to the questionnaire were also asked to state the most common causes of failure in buried pipelines under normal conditions (excluding earthquakes). It was indicated that failures occur in pipes nearly 3 times as often as in joints. Failures are reported most frequently in cast iron pipe, followed by steel and asbestos-cement, in ratio of 5:3:3, respectively. The most frequent cause of failure was age or corrosion, followed by ground settlement and then laying condition in ratio of 4:2:1. Tables 2 and 3a indicate that there is more cast iron pipe in service, especially in distribution lines, than other types of pipe; the tables also indicate that a substantial portion of it is old. Therefore it is not surprising to hear that cast iron pipe experiences leaks and failures. The most frequent joint failures were reported in lead-caulked joints. Failure in these and other joints were ascribed chiefly to age or corrosion and to ground settlement. The causes of failure under normal conditions apparently are uncorrelated with the normal and surge pressures.

SECTION 5

SUMMARY AND CONCLUSIONS

1. Summary

a. A survey of 525 water utilities resulted in 115 responses, or about 22 percent.

b. Results showed that welded steel is the most common type of transmission pipeline and that cast iron with lead or cement caulking is the most common type of distribution line. Almost all utilities use rubber gasket joints in new or replacement pipelines. Eight respondents said that they had favorable experience with rubber gasket joints during earthquakes or other ground movements.

c. Respondents believe that transmission lines followed by distribution lines are the most vulnerable parts of a pipeline system. Joints in these lines are considered to be the next most vulnerable part.

d. About one-third of the respondents carry insurance covering water damage associated with earthquakes.

e. Twelve respondents (about 10 percent of the total respondents) reported having experience of earthquake damage to their pipeline systems. Ground shaking is reported to hasten leaking and failure of corroded steel pipes and of lead-caulked joints. Tension failure of threaded steel joints and broken bells in bell-and-spigot cast iron were also reported.

f. About 10 percent of the respondents, including both large and small utilities, have conducted seismic risk surveys of their systems. These surveys have apparently not resulted in a common course of action by the utilities to upgrade their systems for earthquakes.

g. Under normal conditions (excluding earthquakes), failures are reported to occur nearly three times more often in pipes than in joints. The most frequent cause of failure was age and corrosion; the next most frequent cause was ground settlement.

2. Conclusions

a. Responses to this survey and interviews with selected utilities indicate that damage to underground pipelines has not yet been correlated with intensity and frequency content of earthquakes or any other practically useful measure of ground shaking.

b. One type of earthquake damage occurs in pipes and joints which are weakened by corrosion. Earthquakes also accelerate the process of deterioration. In order to evaluate the seismic performance of a system, the in situ condition of the pipes must be considered.

c. A few utilities in the western United States perceive that seismic risk is important enough to justify changes in backfill procedure, to change to rubber gaskets, renew old pipe, pay insurance premiums for possible water damage or evaluate seismic risk to their systems. The cost effectiveness of these steps is not known and there is no common course of action for upgrading the seismic performance of systems.

d. In spite of the wide range of pipe and joint materials, pressures, backfill conditions, methods of anchoring intersections and bends and other factors, there is enough common practice that a series of representative pipeline situations can be defined for analysis purposes. This would include welded steel transmission lines and cement or lead caulked cast iron distribution lines covered by 3 to 4 feet of tamped, native backfill.

SECTION 6

REFERENCES

1. Steinbrugge, K. V., Cloud, W. K., and Sestl, N. H., "The Santa Rosa, California, Earthquakes of October 1, 1969. U. S. Department of Commerce, Environmental Science Services Administration, Coast and Geodatic Survey, Rockville, Maryland, 1970.

2. Murphy, L. M., "San Fernando, California, Earthquake of February 9, 1971," Volume II. Utilities, Transportation and Socialogical Aspects, NOAA, 1973, p. 185.

TABLE 1

GEOGRAPHICAL DISTRIBUTION OF QUESTIONNAIRES SENT AND RECEIVED

State	Sent	Received
California	274	63
Alaska	7	3
Hawaii	8	3
Nevada	7	3
Washington	35	7
Utah	12	2
Montana	6	1
Missouri	17	4
Illinois	36	5
Tennessee	18	2
South Carolina	2	2
Georgia	16	0
New York	52	9
Massachusetts	14	3
Connecticut	12	3
Anonymous	___	5
	516	115

Responses are 22 percent of questionnaires sent.

TABLE 2

TYPES OF PIPE MATERIAL IN COMMON USE

TOTAL LENGTH (IN MILES) REPORTED BY ALL RESPONDENTS

Table 2a
TRANSMISSION

Material	20-23	24-29	30-41	42-49	60 and above	Common Joint Type
Steel	222	399	534	258	442	welded
Concrete	52	111	154	141	147	rubber gasket
Asbestos-Cement	72	36	20			rubber gasket
Cast Iron	364	315	147	14		lead caulking
Ductile Iron	67	74	147	1		rubber gasket
Cement and Steel	2	4	22	14	15	
Concrete Cylinder		8				

Table 2b
DISTRIBUTION

Material	4-5	6-7	8-11	12-15	16-19	Common Joint Type
Steel	456	1,130	1,623	722	753	welded, rubber gasket
Concrete	21	13	28	20	31	rubber gasket
Asbestos-Cement	502	3,218	2,621	623	178	rubber gasket
Cast Iron	1,882	9,165	5,093	1,735	484	lead caulking
Ductile Iron	129	409	357	316	200	rubber gasket
Other	2					
Wood	1	1				
PVC	13	78	52			
Plastic	1	11				
Steel-Cement	21	55	37	26	1	
Cast Iron and Concrete	42	172	636	210	85	

Table 2c
SERVICE

Material	Less than 1	1-2	Greater than 2	Common Joint Type
Steel	4,066	950	157	threaded
Asbestos-Cement			87	
Cast Iron	4	59	5,363	threaded, lead
Ductile Iron	2		5	rubber gasket
Copper	2,640	1,160	26	flared, soldered
Plastic	559	250	2	
PE	40	41		
Calvilron	5	3,751	154	
CV		45	3	

TABLE 3

TYPES OF JOINTS IN COMMON USE

TABLE 3a

INSTALLATION DATES FOR PIPES WITHOUT RUBBER GASKET JOINTS

	Before 1900-1920	1921-1940	1941-1950	After 1950	N.S.
Steel	2e 3s	3e 8s	6e 6s	2e 4s	3e 6s
Concrete	-	1e 1s	2s	1s	2s
Cast Iron	7e 19s	3e 25s	4e 20s	4e 8s	10e 8s

TABLE 3b

PERCENTAGES OF JOINT TYPE CURRENTLY IN USE EXCLUDING RUBBER GASKETS

Type	<10%	10-25%	25-50%	>50%
Lead	5e 1s	7e 3s	5e 1s	15e 10s
Cement	1e	3s	1e	3e 6s
Thread	1e 1s	2s	1e	1e 2s
Weld	4e 1s	1e 2s	2e 1s	7e 3s
Bolt		1e		
Rivet				1s
Glue			2e	
Other or Not Specified			2e 1s	3e 2s

LEGEND e = one material or type reported exclusively

s = several materials reported by one respondent

TABLE 3. TYPES OF PIPE AND JOINTS IN PIPES WHERE RUBBER GASKETS ARE NOT USED

TABLE 4

BACKFILLING METHODS IN COMMON USE

Table 4a
BACKFILL USED IN BURIED PIPES

Placement Method

Flooding--17

- Without Compaction--8
- With Compaction--9

Water Jetting--21

Tamping--40

Loose Fill--8

- Without Compaction--5
- With Compaction--3

Vibration--1

Table 4b
Backfill Material

Native material is used by about 80 percent of the respondents.

The most frequently imported material is sand or gravel, which is frequently placed by flooding and used as a bedding material.

Height of lifts predominantly in the range of 6-12 inches.

TABLE 5

INSURANCE

TABLE 5a

INSURANCE COVERAGE

LIABILITY INSURANCE COVERING WATER DAMAGE

FOLLOWING AN EARTHQUAKE

	Seismic Zone Number		
	1	2	3
Have Insurance	3	14	24
Do Not Have Insurance	4	16	43

TABLE 5b

OTHER INSURANCE COVERAGE

FOR EARTHQUAKE DAMAGE

	Seismic Zone Number		
	1	2	3
Have Insurance	3	3	4
Do Not Have Insurance	5	17	54

TABLE 6

UTILITIES CONDUCTING A SEISMIC RISK STUDY OF THEIR TRANSMISSION OR DISTRIBUTION SYSTEMS (11 of 115 Respondents; all 11 in Seismic Zone 3)

Seismic Risk Study Resulted in Policy Change	Decision to Use Rubber Gaskets Influenced by Seismic Conditions	Insurance for Water Damage or Other Earthquake-Related Damage	Modified Backfill to Improve Seismic Performance	Renew Pipes to Improve Seismic Performance	Size of System
y	n	y	n	y	c
n	y	n	n	n	c
y	n	y	y	n	c
n	n	n	n	n	b
n	n	n	n	n	a
n	n	n	n	n	a
n	n	n	n	n	b
y	n	n	n	n	c
n	y	n	n	n	a
y	n	y	n	n	c
y	n	n	n	n	b

Size of System

Length (L) of Transmission and Distribution Lines (in miles)

a -- $L < 100$

b -- $100 < L < 1,000$

c -- $L > 1,000$

y = yes

n = no

TABLE 7

EXPERIENCE OF DAMAGE TO PIPELINES FROM EARTHQUAKES, LANDSLIDES AND GROUND MOVEMENTS

Performed Well

Joints		Pipe Material	
Rubber Gasket	8	Cast Iron	4
Lead Caulked	1	Ductile Iron	4
Welded	2	Wood	1
		Steel	3
		Transite	2

Performed Badly

Joints		Pipe Material	
Rubber Gasket	2	Asbestos-Cement	4
Lead Caulked	2	Cast Iron	3
Cement Caulked	1	Ductile Iron	1

APPENDIX I

Copy of questionnaire and cover letter

Weidlinger Associates Consulting Engineers 110 East 59th Street, New York, N.Y. 10022

Sir:

We are conducting a survey of water transmission and distribution systems as part of a National Science Foundation project on earthquake engineering. The survey is one step in evaluating the performance of these systems in earthquakes. The results will be published in the middle of this year and we would greatly appreciate your assistance in this matter.

We anticipate that the results of this study will be of interest to people other than those in the earthquake engineering field and hope, therefore, that you or someone in your organization can spend an hour or more filling out the enclosed questionnaire. For our convenience, we request that you place the questionnaire in the mail no later than April 29. A stamped, addressed envelope is included for this purpose.

If you wish to receive the results of this survey please check the box at the beginning of the questionnaire.

Sincerely yours

Joseph P. Wright

JOSEPH P. WRIGHT
Associate

March 31, 1977

Tel: (212) 838-2830 Telex: 620594 WEID

SURVEY OF UNDERGROUND WATER PIPELINE SYSTEMS*

ORGANIZATION NAME (Optional) ______________________

LOCATION (State): ______________________

Please check the box at right and fill in above address if you wish to receive the results ☐ of this survey.

1. Organization, priorities, fiscal constraints

1.1 Who is the owner of the water utility?

City ________ Independent public utility district ________

State ________ Private or public corporation ________

Federal ________ Other (Specify) ________

1.2 Is there a policy-making body with respect to earthquake hazard to the utility?

YES ________ NO ________

If YES, policy is made by

Utility Board of Directors ________ Superintendent/General Manager ________

(elected ______ or appointed ______) Chief or Division Engineer ________

Legislative Authority ________ Other (Specify) ________

1.3 In fiscal and/or operational planning, is seismic risk to the distribution and/or transmission system piping specifically addressed?

YES ________ NO ________

If YES, estimate priority given to seismic risk on a scale of 5 (highest) to 1 with respect to other planning considerations

____

1.4 Has a seismic risk study been conducted for the water transmission or distribution systems

YES ________ NO ________ Year Conducted? ________

Was there a change of policy as a result of the study?

YES ________ NO ________

2. Description of the System

2.1 Pipeline systems have been categorized by pipe diameters (given in inches) as Transmission pipelines (20 inches and larger), Distribution pipelines (4-19 inches) and Service pipelines (3 inches and smaller). Please indicate the length in miles of pipe of each material in your system; for example, how many miles of steel transmission pipe in the range 20-23 inch diameter? Please indicate also what is the most common joint for each pipe material; for example, what type of joint is most common in steel transmission pipelines in your system?

TRANSMISSION
Diameter

Material	20-23	24-29	30-41	42-49	60 and above	Common Joint Type
Steel						
Concrete						
Asbestos-Cement						
Cast Iron						
Ductile Iron						
Other ________						

* Attach extra sheets if more space is needed to answer any question. Please indicate the question number on any such attachments.

2.1 (Continued)

DISTRIBUTION
Diameter

Material	4-5	6-7	8-11	12-15	16-19	Common Joint Type
Steel						
Concrete						
Asbestos-Cement						
Cast Iron						
Ductile Iron						
Other _______						

SERVICE
Diameter

Material	less than 1	1-2	greater than 2	Common Joint Type
Steel				
Concrete				
Asbestos-Cement				
Cast Iron				
Ductile Iron				
Other _______				

2.2 Does your utility use rubber gasket-type joints for new distribution pipelines?

YES _______________ NO _______________

What pipe material and type of joint or joint material was used in your distribution pipelines before rubber gasket-type joints became available (early 1950's)?

Material	Approximate Date of Installation	Joint or Joint Material

2.3 What percentage of pipe in use in the distribution system is not of the rubber gasket-type?

____

2.4 Is the decision to use rubber gasket-type joints specifically influenced by seismic considerations?

____

2.5 What is the method of restraining tees, crosses, intersections and bends?

____

2.6 Is separation or other relative movement between the restraints and pipe a significant problem?

____

2.7 Are there any structures, such as pressure control stations or pumping stations, which are massive and which may interact dynamically with the pipes during earthquakes?

____

2.8 Are special pipe jointing procedures used where pipe enters massive structures?

____

3. Experience with respect to failure, leaks, earthquakes, displacements (settlement, uplift, etc.)

3.1 Under normal operations, is failure of buried pipelines most commonly associated with

a) joints ____________________ or pipes ____________________?

b) a particular type of pipe ____________________?

c) a particular type of joint ____________________?

d) a particular laying condition ____________________?

e) age or corrosion ____________________?

f) ground settlement ____________________?

g) soil erosion ____________________?

3.2 Rank in order of seriousness the damage expected in an earthquake (6--most serious, 5--etc.) to the following:

Distribution lines	________	Connections in these lines	________
Transmission lines	________	Connections in these lines	________
Valves	________	Pressure control stations	________

3.3 Does the utility have experience of ground movement or earthquakes which prompts it to use or avoid a particular pipe size, pipe material or joint or joint material?

YES ____________ NO ____________

3.4 If answer to 3.3 is YES, what size, materials, etc., have been performed well or badly?

	WELL	**BADLY**
Size		
Material		
Joint or Joint Material		

3.5 What seismic zone number (3-zone system) is the utility in?

____

3.6 Brief geologic description of utility district.

____

____

____

____

____

3.7 Are there known active faults within or near the system which are capable of producing strong ground shaking (Richter magnitude greater than 6)?

YES ____________ NO ____________

If YES, what are the Richter magnitudes and epicentral distances for the most significant of these faults?

(1) ____

(2) ____

(3) ____

When were they last active?

(1) ____

(2) ____

Have potential fault movements been estimated at points where the system crosses such faults?

YES ______________ NO ______________

If YES, what are the estimated maximum and minimum displacements?

Maximum	Minimum
__________________	__________________

3.8 What is the Insurance Services Organization (ISO) rating for the utility district?

____

3.9 Does the utility carry liability insurance covering water damage following an earthquake?

YES ______________ NO ______________

Other insurance coverage for earthquake damage?

____

3.10 What is the basis for estimating such liability?

____

4. Operational procedures

4.1 What is the normal range of pressure in the system?

OPERATIONAL ______________________ SURGE ______________________

4.2 What is usual depth of burial of pipe?

____

4.3 How is backfill placed during construction?

____

4.4 What percentage of the new and replacement pipe installation is accomplished with the utility's own work force at present?

____

4.5 What is the usual type of pipe laying condition used in your district?

Current design ______________________ Past practice ______________________

5. Additional comments may be made below or on the back of this page.