2.0 DEFINING THE WATER SYSTEM AT RISK

2.1 Introduction

In this chapter, one of the basic steps is presented in an evaluation of water systems subjected to natural hazards: the inventory procedure. This chapter clarifies the basic decision procedure in Figure 1 with respect to the shaded box “Define System to be Evaluated (Input Parameters).”

Section 2.2 reminds the reader that there are multiple levels of evaluation possible so that only in special cases is there a requirement to inventory the water system comprehensively. Section 2.3 provides guidance on developing replacement cost information—should a financial evaluation be desirable. Section 2.4 outlines a comprehensive view of basic components of interest. These basic components of interest may cover more than is of interest to a decision-maker on a specific decision. Also included in Section 2.4 are sample data requirements for a comprehensive financial and/or operational evaluation of the water utility system. For decisions which do not require a comprehensive financial and/or operational evaluation of the water utility system, section 2.4 can assist in excluding components and considerations not pertinent to the decision at hand.

Appendix B contains an elaboration of this Chapter. Discussed in Appendix B are lists of the basic components along with selected photographs of these components, a discussion of the usefulness of various information and display technologies (not necessarily required) and a hypothetical system that contains virtually all pertinent components and natural hazards.

2.2 Multiple Levels of Evaluation Limiting Inventory Needs

As section 1.4 suggests, potential multiple levels of evaluation may limit inventory needs. The scope of work required to assess the impacts of natural hazards on a water system will vary with the risk management objectives and resources of the water utility, the hazards present, the vulnerability or lack of vulnerability of components to the hazards present, the system architecture (e.g., which portions of the systems are series or linear systems and which are parallel or redundant systems) and flow characteristics (gravity-flow versus pressurized) of the system, and available system and stakeholder information (inventory).

Screening or scoping studies are generally undertaken by the water utility staff itself. (See section 1.5) These provide a preliminary overview of the system-wide risk or else narrow the scope of study for further investigation. Specific inventories will not be required for such a scoping study by itself. These guidelines are designed to assist such scoping studies. Financial risk studies and operational impairment investigations are often conducted by consultants or other outside agencies. Moreover, higher level studies may include most or all of the tasks involved in the simpler studies, so that risk screening and financial risk analysis are viewed as phases within a larger study.

Within the context of such a scoping study, it may be determined that only a sub-system should be inventoried. This, for instance, would be the case if the decision in question pertains to the design levels desirable for a specific new steel water distribution reservoir. Such a decision may require an inventory only on the sub-system in which this reservoir is to become a part. This sub-system may consist of a booster pumping station, its equipment, distribution piping supplied by the new reservoir, and alternative design concepts for the new reservoir. For instance, for a proposed, new water distribution reservoir, the level of site investigations and reservoir evaluation may be far higher than that required for other components that are associated with the general decision. Higher level of site and mechanical, electrical, and structural evaluations typically require greater inventory details.

Similarly, the specific decision in question may pertain to an upgrade of a water treatment plant that serves only a portion of the water utility system. Again, such a decision may require an inventory of only the water treatment plant and the sub-system that it serves. Focus of the inventory procedure may be on details of the water treatment plant.

Such a scoping study may also indicate that various natural hazards are not significant to the decision at hand. For instance, the decision at hand may pertain to the installation of a flood wall to protect a water treatment plant. This decision may require only an inventory of the water treatment plant and components in the sub-system that it serves and that are vulnerable to potential flood effects in the absence of a flood wall.

The decision itself may pertain either to operational or to financial system metrics and not to both, and thus the inventory needs may be reduced. Financial system risk analyses use estimates of component damage levels and costs to repair damage from natural hazards; along with revenue losses and stakeholder losses (and gains—such as for utility contractors). Financial systems risk analysis studies may range from simple tabulation of aggregate direct damage and repair cost to individual components or subsystems to more complete analysis of primary, secondary and higher-order impacts to the many water system stakeholders. Information on repair and replacement costs, water utility revenues, and prospective dollar losses to other stakeholders thus may be of significant interest in financial risks evaluations.

In contrast, if only operational evaluations are desired, then many of these financial inventory concerns vanish. Operational impairment studies assess the degree of impairment of the water system from natural hazards. Operational impairment studies may be restricted to the estimation of service interruption areas for particular natural hazard events, or may address the complex questions relating to the time required for restoration of service.

In chapter 3, natural hazards will be discussed within the scope of this investigation. In chapter 4, component vulnerabilities will be discussed. If the proposed systems risk evaluation covers only some of these natural hazards, then some water system components may not need to be inventoried. For instance, elevated components may be impervious to various forms of water damage—save for collateral damage from debris. For another instance, buried facilities are impervious to wind damage. For a third instance, the topography of a given system may rule out prospective landslides. Thus, in a scoping study, ruling out natural hazards for the specific region and components invulnerable to damage from natural hazards studied will simplify inventory needs.

Chapter 5 will discuss systems evaluations. For very linear portions of a system (e.g., a sole water treatment plant), very linear systems (a wholesaler's system consisting of a water treatment plant and an aqueduct feeding various distribution systems), and gravity-flow systems or subsystems, simplified systems evaluations may be undertaken. Inventory needs for developing hydraulic analyses will thus not always be needed.

In weighing how much effort to devote to assembling the inventory of a water utility system, decision-makers should further consider multiple benefits of such an inventory. Benefits beyond those of assisting in natural hazards risk reduction decisions could include: a superior inventory of the existing system for purposes of routine repairs, maintenance, upgrades, training, personnel safety, inspection, budgeting, and monitoring and supervisory control. Recent revisions to the rules of accounting for public agencies [Governmental Accounting Standards Board Statement No. 34] may require more extensive inventories, as well as close monitoring of system condition and maintenance costs, in order for water utilities to receive positive municipal ratings for bond debt.

2.3 Costs of Decision Alternatives and Other Costs

In decision-making, costs of decision alternatives (initial outlays) are always important. Low-cost risk reduction measures, such as using chains to anchor chlorine cylinders, often lie beneath the thresh-hold of consideration for a formal risk evaluation. Higher cost alternatives (e.g., retrofit of a steel distribution reservoir), however, need to be evaluated in order to compare system performance against costs and budgetary limitations.

Principal sources of cost data are: Means Cost Data, water system piping and valve vendors, and past project history where similar projects were constructed under similar conditions. Current vendor data has become much more readily available through the Internet (see Figure 2).

The evaluation of decision alternatives may proceed through conceptual design, using qualitative assessments of cost effectiveness, and into preliminary design, so that costs (and performance) of each option can be adequately quantified. The evaluation of costs for decision alternatives may be done in-house, especially in larger water agencies, and especially at earlier stages of the evaluation process. Final evaluation of the benefits and costs for large projects often requires outside assistance, in the form of studies using engineering consultants and cost estimators.

Replacement and/or repair cost information for existing facilities will be needed if it is desirable to assess aggregate system dollar losses for various scenario events and/or for a representative suite of natural hazards scenarios. This will apply only if financial criteria are used in the decision process—beyond the consideration of initial outlays.

2.4 Components and Considerations for a Comprehensive Evaluation

2.4.1 Overview

This section includes basic inventory and data needs for potable water conveyance facilities (2.4.2), distribution storage reservoirs (2.4.3), booster pumping stations and wells (2.4.4), building structures (2.4.5), selected non-building components (2.4.6), water treatment, chlorination, and fluoridation facilities (2.4.7), hydraulic evaluations (2.4.8), and stakeholder evaluations (2.4.9). As section 2.2 implies, not all components and data requirements listed in this section need to be undertaken for the decision at hand.

2.4.2 Potable Water Conveyance Facilities

The potable water system can be comprised of various water conveyance facilities. These typically reflect the geographic area of the system and its ability to provide potable water demand as well as to meet local fire-flow requirements. Potable water conveyance facilities include (but are not limited to):

- Above-ground piping structures: pipe bridges, pipe supported by saddles or ring girders
- Pumping station and associated inlet and discharge lines
- Pen-stocks
- Aqueducts consisting of canals, tunnels, pipelines, conduits, and sometimes flumes
- Intake piping (at lakes or rivers)
- Transmission piping
- Distribution piping
- Service and fire hydrant connections
- Valves and valve operators

Information collected during a survey of the water delivery and distribution system should satisfy input requirements for hydraulic modeling as further discussed in Chapter 5 and as elaborated in American Water Works Association (AWWA) M32 on distribution network analysis for water utilities. As a general rule, in very large systems and for most decisions, pipelines representing the water system “backbone” typically are of a larger diameter (say 12 to 16 inches; 300 to 400 mm; and even larger for the largest water systems) and may reflect the minimum size of pipelines considered in a natural hazards evaluation. For smaller systems, pipelines down to 4 inches (10 cm) in diameter may be considered.

The basic information on pipelines surveyed includes:

- section number
- location (with reference to various nodal points)—implying lengths of pipe
- pipe material(s)
- year installed (implying age)
- diameter
- pipe joint type
- lining and coating
- buried or above-ground (depth?)
- directionality of flows

- pressure-reducing valve locations
- elevations
- special local hazards (e.g., corrosive soils, fault crossings, slope or slide areas and other ground failure potential areas—see Chapter 3)
- previous damages, leaks, and methods of repair
- maintenance history
- street rehabilitation schedule
- customer type (e.g., hospitals)
- vulnerability evaluation method(s) used (see Chapter 4)

2.4.3 Distribution Storage Reservoirs

Distribution storage reservoirs can include:

- Steel and concrete reservoirs--elevated, surface, or buried
- Open or covered surface water reservoirs
- Sumps

For distribution storage reservoirs, the following information is fundamental:

- construction date(s)
- materials (e.g., steel, concrete)
- shape and dimensions
- basic design/redesign considerations used in construction (AWWA Code, year, seismic zone, wind velocity)
- maximum storage capacity (assumed to be full unless otherwise specified)
- type of roof
- minimum freeboard (height above maximum water level to top of tank wall)
- footing type (ring wall, mat, etc.)
- anchorage to footing (if any)
- type of inlet/outlet connections (e.g., flexible couplings)
- local hazards—including geotechnical analysis of foundation (Chapter 3)
- basic usage (potable versus emergency fire-flow protection)
- previous damages, if any, and methods of repair

- method of vulnerability evaluation (Chapter 4)

2.4.4 Booster Pumping Stations and Wells

This category includes

- booster pumping stations
- hydro-pneumatic pumping stations
- groundwater wells
- pressure vessels and surge tanks
- electric substations

For these facilities the following information is fundamental:

- construction date(s)
- as-constructed drawings
- basic design/redesign considerations used in construction (e.g., AWWA code and year)
- maximum and operating flow capacity and head (e.g., pump curves)
- local hazards—including geotechnical analysis of site
- type of mechanical and electrical equipment
- type of piping connections (suction and discharge)
- basic usage (potable versus emergency fire flow protection)
- well drilling method (e.g., cable tool, rotary)
- type of well casing
- previous damage, if any, and repairs
- power supply backup
- hazardous materials on site
- method of vulnerability evaluation (chapter 4)

2.4.5 Building Structures (“Housing”)

Basic building structures that have significant occupancy tend to be covered under building codes. Nonetheless, for assessing the response of a water utility system to natural hazards, the functionality of building structures (often, housing) may be essential. Such “housing” may be found in

- Water treatment, chlorination, and/or fluoridation facilities

- Booster pumping stations
- Groundwater pumping wells
- Utility buildings, including administrative headquarters, including buildings that house record-drawing vaults, computers and financial information; an emergency and normal operating center, maintenance facilities, spare parts and material storage

For buildings that are included in the water systems evaluation, the following information can be fundamental (see also Figure 3):

- As-constructed drawings
- Facility usage/function
- Location
- Base elevation (for specific flood-related hazards and for hydraulic evaluations)
- Previous damage, if any, and causes
- Previous damage repairs, if any
- Construction date(s)
- Building code(s) used in construction
- Gravity load-carrying system
- Lateral force-resisting system
- Materials used in roof and floor diaphragms, structural columns and walls
- Number of stories below ground
- Number of stories above ground
- Local hazards (see Chapter 3)
- Previous damage, if any, and repairs
- Vulnerability evaluation method(s) used (see Chapter 4)

2.4.6 Selected Non-Building Components

Selected non-building components can include:

- Electric equipment: control equipment, electrical raceways
- Mechanical equipment, pumps
- (SCADA) Instrumentation, chlorination control, surveillance
- Equipment for chemical storage and usage; chemical piping

- Sumps
- Fire hydrants
- Mass and center of gravity for components with significant overturning potential

For the variety of other non-building components, the following information is useful:

- anchorage or bracing
- base elevation (for such hazards as floods and for hydraulic evaluations)
- location (including story number in a building)
- submergence-rating (if any)
- part of which sub-system (node or link)
- previous damage, if any, and repairs
- evaluation method(s) used

2.4.7 Water Treatment, Chlorination, and Fluoridation Facilities

As shown in Chapter 5, major or highly redundant water treatment facilities may be considered as major sub-systems, consisting potentially of a diversion structure, inlet control building, screen house, chemical building, mixing and sedimentation basins, filter basin, outlet building, wash-water tank, chlorine tank, clearwater tank, and pipe gallery. Information developed on each of these components will be similar to information gathered under building structures and other non-building components, above. Consideration of a major water treatment plant as a major sub-system is especially important if portions of the water treatment plant can continue to provide potable water even if portions of the treatment plant are damaged.

For less redundant water treatment facilities or special chlorination and/or fluoridation facilities, the presence of disinfection capabilities along with a diversion structure are necessary to maintain service should the water treatment facility become inoperable.

2.4.8 Special Data Needs for Hydraulic Evaluations

Larger systems may already have a hydraulic model in place. These models can be extremely important in assessing post-disaster response and recovery activities, and in modeling generally the systemic consequences of natural disasters.

Smaller system purveyors may not have a hydraulic model in place but may be required to create one to accurately assess potential risks caused by a disaster. A hydraulic model of a system or parts of a system can be readily developed with minimum information. AWWA M32, on distribution network analysis for water utilities, provides a further discussion on the development of water distribution models. The following is a list of data requirements and potential sources to obtain the needed data:

Minimum Required Data are:

- Pipe lengths/diameters
- Node elevations
- Node demands (domestic and fire flow)
- Supply pumps and booster pumps
- Control valves
- Reservoirs (storage facilities)
- Pressure regulating valves
- Location of pipes in special hazards zones (e.g., flood zones, liquefiable soils, steep slopes)

Other Operational Data Needs include:

- Water Treatment Plant Clearwell Overflow (High Water) Elevation
- Pumping station firm capacity and design head (i.e. pump curves)
- Reservoirs/Storage Tank Overflow (High Water) Elevations
- Water quality parameters (Chlorine residuals, hardness, Total Dissolved Solids)
- Junction pressure data (i.e. Pressure Relief/Sustaining Valve Station)
- Unit flow demands - Max Day, Max Hour, and Fire Flow

Potential Data Sources for the above include:

- Water Utility Maps (Pipe diameters, lengths, control valve locations, pressure zones)
- Water Utility Facilities Design Reports and As Built Drawings
- Operation and Maintenance Personnel (Institutional/Operational knowledge)
- Supervisory Control and Data Acquisition (SCADA) Information (Flow Rates/Demands)
- United States Geological Survey (USGS) Maps (Planimetrics, Topography)
- Geographical Information systems (GIS) Databases/Coverage (Planimetrics, Contour Elevation, Population, Zoning, etc.)
- Local Fire Department and National Fire Protection Association (NFPA) Fire Flow Data

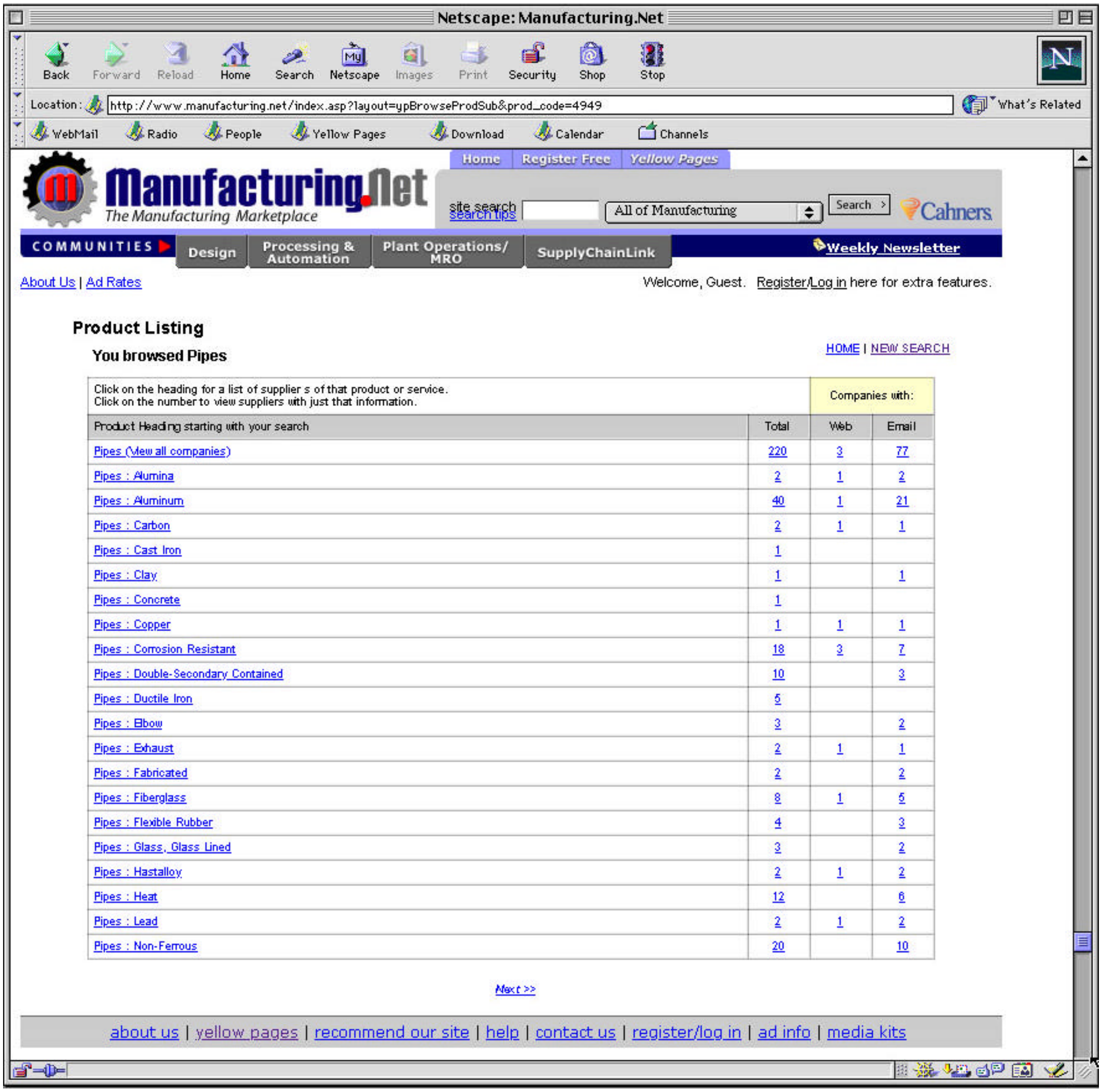
Appendix B and Chapter 4 discuss in greater detail circumstances under which these data would be required, and the current ease with which these data can be gathered.

2.4.9 Minimum Stakeholder Data

Section 1.3.4 discusses basic stakeholders in water utility system responses to natural hazards. Under some circumstances, a quantifiable stakeholder evaluation may be desirable in order to sort out how much various stakeholders lose (and gain—for such sectors as utility contracting) from various decision alternatives pertaining to natural hazards.

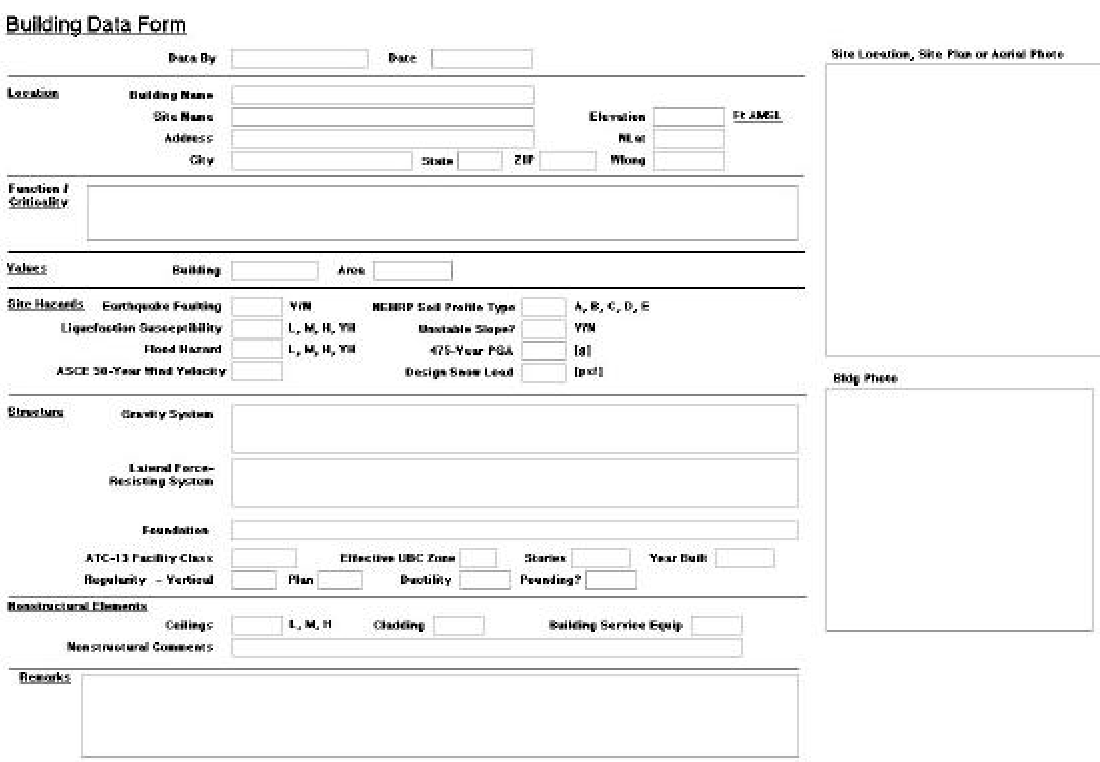
As sections 1.3 and 2.2 imply, definition of stakeholders will generally be part of the scoping for the decision or decisions for which the water system evaluation is to be made. Identification of pertinent service zones and customers as well as classes of customers will be required. Operational evaluations may focus on key service areas and/or customers for which fire-fighting capability, patient care, and potential contamination are possible effects of natural hazard events. Financial evaluations may focus on lost revenues to the utility—considering as well how rates may need to be raised to restore lost revenues. Insurers, lenders, and bond-holders may be implicated from a financial standpoint in various decisions, as will be local, state, and federal governments expected to provide disaster assistance. Detailed evaluation of natural hazard impacts on customers will generally require business surveys to estimate prospective business interruption losses (lost revenues minus reduced expenditures) .

Estimates of higher-order economic losses from natural disasters require still further data. Estimates of these higher-order economic losses generally start from estimates of “primary” losses, namely, repair costs and business interruption losses. Estimates of higher-order economic losses are not discussed in any detail in this document, and require special work by macro-economists.



Product Heading starting with your search	Total	Web	Email
Pipes (View all companies)	220	3	77
Pipes : Alumina	2	1	2
Pipes : Aluminum	40	1	21
Pipes : Carbon	2	1	1
Pipes : Cast Iron	1		
Pipes : Clay	1		1
Pipes : Concrete	1		
Pipes : Copper	1	1	1
Pipes : Corrosion Resistant	18	3	7
Pipes : Double-Secondary Contained	10		3
Pipes : Ductile Iron	5		
Pipes : Elbow	3		2
Pipes : Exhaust	2	1	1
Pipes : Fabricated	2		2
Pipes : Fiberglass	8	1	5
Pipes : Flexible Rubber	4		3
Pipes : Glass, Glass Lined	3		2
Pipes : Hastalloy	2	1	2
Pipes : Heat	12		6
Pipes : Lead	2	1	2
Pipes : Non-Ferrous	20		10

Figure 2: Sample Vendor Data Sheet



Building Data Form

Data By | Date | Site Location, Site Plan or Aerial Photo

Location — Building Name; Site Name; Elevation Ft AMSL; Address; NLat; City; State; ZIP; Wlong

Function / Criticality

Values — Building; Area

Site Hazards — Earthquake Faulting Y/N; NEHRP Soil Profile Type A, B, C, D, E; Liquefaction Susceptibility L, M, H, VH; Unstable Slope? Y/N; Flood Hazard L, M, H, VH; 475-Year PGA [g]; ASCE 50-Year Wind Velocity; Design Snow Load [psf]

Bldg Photo

Structure — Gravity System; Lateral Force-Resisting System; Foundation; ATC-13 Facility Class; Effective UBC Zone; Stories; Year Built; Regularity - Vertical; Plan; Ductility; Pounding?

Nonstructural Elements — Ceilings L, M, H; Cladding; Building Service Equip; Nonstructural Comments

Remarks

Figure 3: Sample Building Data Form