Appendix C. Description of Lifeline Componenets

C.1 Highway Transportation System

Below is a list of highway components which have been defined for the methodology. The list indicates the 3 basic components of the transportation system. Some of these components are subdivided further.

- Highway Roads
- Highway Bridges
- Highway Tunnels

C.1.1 Highway Roads

Highway roads are classified as major roads and urban roads. Major roads include interstate and state highways and other roads with four lanes or more. Parkways are also classified as major roads. Urban roads include inter-city roads and other roads with two lanes.

C.1.2 Bridges

Bridges are classified based on the following structural characteristics:

- Seismic Design
- Number of spans: single vs. multiple span bridges
- Structure type: concrete, steel, others
- Pier type: multiple column bents, single column bents and pier walls
- Abutment type and bearing type: monolithic vs. non-monolithic; high rocker bearings, low steel bearings and neoprene rubber bearings
- Span continuity: continuous, discontinuous (in-span hinges), simply supported.
- The seismic design of a bridge is taken into account in terms of the (*i*) spectrum modification factor, (*ii*) strength reduction factor due to cyclic motion, (*iii*) drift limits, and (*iv*) the longitudinal reinforcement ratio.

This classification scheme incorporates various parameters that affect damage into fragility analysis and provides a means to obtain better fragility curves when data become available.

C.1.3 Tunnels

Tunnels are classified as:

- Bored/Drilled
- Cut & Cover

C.2 Railway Transportation System

Below is a list of railway components which have been defined for the methodology. By reviewing the list it can be seen that there are 7 basic components (shown in bold) with some being subdivided. Each component is defined by a short description below.

- Railway Tracks
- Railway Bridges
- Railway Tunnels
- Railway Urban Station
- Railway Fuel Facility
- Railway Dispatch Facility
- Railway Maintenance Facility

C.2.1 Tracks

The class Railway Tracks refers to the assembly of rails, ties, and fastenings, and the ground on which they rest. Only one classification is adopted for these components.

C.2.2 Bridges

The classes of railway bridges are considered analogous to those of major bridges in highway systems. That is they are considered to have at least one span greater than 500 feet. Railway bridges are classified based on the design criteria adopted in the design of these bridges.

- • Seismically designed/retrofitted bridges
- These bridges are either designed with seismic considerations or were retrofitted to comply with the seismic provisions.
- • Conventionally designed bridges
- These bridges are designed without taking seismic considerations into account.

C.2.3 Tunnels

Tunnels are classified as

- Bored/Drilled
- Cut & Cover

C.2.4 Railway System Facilities

- Railway system facilities include urban and suburban stations, maintenance facilities, fuel facilities, and dispatch facilities.
- **Urban and Suburban stations** are generally key connecting hubs that are important for system functionality. In the western U.S., these buildings are mostly made of reinforced concrete shear walls or moment resisting steel frames, while in

the eastern U.S., the small stations are mostly wood and the large ones are mostly masonry or braced steel frames.

- **Fuel facilities** include buildings, tanks (anchored, unanchored, or buried), backup power systems (if available, anchored or unanchored diesel generators), pumps, and other equipment (anchored or unanchored). It should be mentioned that anchored equipment in general refers to equipment designed with special seismic tiedowns or tiebacks, while unanchored equipment refers to equipment designed with no special considerations other than the manufacturer's normal requirements. Above ground tanks are typically made of steel with roofs also made of steel. Buried tanks are typically concrete wall construction with concrete roofs. In total, five types of fuel facilities are considered. These are: fuel facilities with or without anchored equipment and with or without backup power (all combinations), and fuel facilities with buried tanks.
- **Dispatch facilities** consist of buildings, backup power supplies (if available, anchored or unanchored diesel generators), and electrical equipment (anchored or unanchored). In total, four types of dispatch facilities are considered. These are dispatch facilities with or without anchored equipment and with or without backup power (all combinations).
- **Maintenance facilities** are housed in large structures that are not usually critical for system functionality as maintenance activities can be delayed or performed elsewhere. These building structures are often low-rise steel braced frames.

C.3 Light Railway Transportation System

A light rail system consists mainly of six components: tracks, bridges, tunnels, maintenance facilities, dispatch facilities, and DC power substations. These components are listed below.

- Light Rail Tracks
- Light Rail Bridges
- Light Rail Tunnels
- DC Substation
- Dispatch Facility
- Maintenance Facility

C.3.1 Tracks

The class Light Rail Tracks refers to the assembly of rails, ties, and fastenings, and the ground on which they rest. Only one classification is adopted for these components.

C.3.2 Bridges

The classes of light rail bridges are considered analogous to those of bridges in highway systems. Light rail bridges are classified based on the design criteria adopted in the design of these bridges.

- Seismically designed/retrofitted bridges

These bridges are either designed with seismic considerations or were retrofitted to comply with the seismic provisions.

- Conventionally designed bridges

These bridges are designed without taking seismic considerations into account.

C.3.3 Tunnels

Tunnels are classified as

- Bored/Drilled
- Cut & Cover

C.3.4 Railway System Facilities

Railway system facilities include DC power substations, dispatch facilities, and maintenance facilities.

- **DC Power Substations** provide DC power used by the light rail electrical distribution system. Light rail systems have low voltage DC power which consists of electrical equipment that converts the local electric utility AC power to DC power. Two types of DC power stations are considered. These are DC power stations with anchored components and DC power stations with unanchored components.
- **Dispatch facilities** consist of buildings, backup power supplies (if available, anchored or unanchored diesel generators), and electrical equipment (anchored or unanchored). In total, four types of dispatch facilities are considered. These are dispatch facilities with or without anchored equipment and with or without backup power (all combinations).
- **Maintenance facilities** are housed in large structures that are not usually critical for system functionality as maintenance activities can be delayed or performed elsewhere. These building structures are often low-rise steel braced frames.

C.4 Bus Transportation System

A bus system consists mainly of four basic components: urban stations, fuel facilities, dispatch facilities, and maintenance facilities. These components are listed below.

- Bus Urban Station
- Bus Fuel Facility
- Bus Dispatch Facility
- Bus Maintenance Facility

C.4.1 Urban and Suburban Stations

Urban and suburban stations are generally key connecting hubs that are important for system functionality. In the western U.S., these buildings are mostly made of reinforced

concrete shear walls or moment resisting steel frames, while in the eastern U.S., the small stations are mostly wood and the large ones are mostly masonry or braced steel frames.

C.4.2 Bus System Fuel Facilities

A fuel facility includes buildings, tanks (anchored, unanchored, or buried), backup power systems (if available, anchored or unanchored diesel generators), pumps, and other equipment (anchored or unanchored). It should be mentioned that anchored equipment in general refers to equipment designed with special seismic tiedowns or tiebacks, while unanchored equipment refers to equipment designed with no special considerations other than the manufacturer's normal requirements. Above ground tanks are typically made of steel with roofs also made of steel. Buried tanks are typically concrete wall construction with concrete roofs. In total, five types of fuel facilities are considered. These are: fuel facilities with or without anchored equipment and with or without backup power (all combinations), and fuel facilities with buried tanks.

C.4.3 Bus System Dispatch Facilities

Dispatch facilities consist of buildings, backup power supplies (if available, anchored or unanchored diesel generators), and electrical equipment (anchored or unanchored). In total, four types of dispatch facilities are considered. These are dispatch facilities with or without anchored equipment and with or without backup power (all combinations).

C.4.4 Bus System Maintenance Facilities

Maintenance facilities for bus systems are housed in large structures that are not usually critical for system functionality as maintenance activities can be delayed or performed elsewhere. These building structures are mostly low-rise steel braced frames.

C.5 Port Transportation Systems

A port system consists of four basic components: waterfront structures, cranes/cargo handling equipment, warehouses and fuel facilities as listed below. This section provides a brief description of each.

- Waterfront Structures
- Cranes/Cargo Handling Equipment
- Warehouses
- Fuel Facility

C.5.1 Waterfront Structures

This component includes the wharf, seawalls, and piers that exist in the port system. Waterfront structures typically are supported by wood, steel or concrete piles. Many also have batter piles to resist lateral loads from wave action and impact of vessels. Seawalls are caisson walls retaining earth fill material.

C.5.2 Cranes and Cargo Handling Equipment

These are large equipment items used to load and unload freight from vessels. These can be stationary or mounted on rails.

C.5.3 Port Fuel Facilities

Fuel facilities include buildings, tanks (anchored, unanchored, or buried), backup power systems (if available, anchored or unanchored diesel generators), pumps, and other equipment (anchored or unanchored). It should be mentioned that anchored equipment in general refers to equipment designed with special seismic tiedowns or tiebacks, while unanchored equipment refers to equipment designed with no special considerations other than the manufacturer's normal requirements. Above ground tanks are typically made of steel with roofs also made of steel. Buried tanks are typically concrete wall construction with concrete roofs. In total, five types of fuel facilities are considered. These are: fuel facilities with or without anchored equipment and with or without backup power (all combinations), and fuel facilities with buried tanks.

C.5.4 Warehouses

Warehouses are large buildings usually constructed of structural steel. In some cases, warehouses may be several hundred feet from the shoreline, while in other instances, they may be located on the wharf itself.

C.6 Ferry Transportation System

A ferry system consists of five components: waterfront structures, passenger terminals, fuel facilities, dispatch facilities, and maintenance facilities. This section provides a brief description of each.

- Water Front Structures
- Ferry Passenger Terminals
- Ferry Fuel Facility
- Ferry Dispatch Facility
- Ferry Maintenance Facility

C.6.1 Waterfront Structures

The waterfront structures are located at the points of disembarkation, and they are similar to, although not as extensive as, those of the port transportation system. In some cases the ferry system may be located within the boundary of the port transportation system. The points of disembarkation are located some distance apart from one another, usually on opposite shorelines. The waterfront structures include hydraulic sandfill placement poles and/or piled dock structures.

C.6.2 Passenger Terminals

C.6.3 Fuel and Maintenance Facilities

Fuel and maintenance facilities are usually located at one of the two points of disembarkation. The size of the fuel facility is smaller than that of the port facility. Maintenance facilities are mainly steel braced frame structures.

C.6.4 Dispatch Facilities

In many cases, the dispatch facility is located in the maintenance facility or one of the passenger terminals.

C.7 Airport Transportation System

An airport system consists of six components: control tower, runways, terminal buildings, parking structures, fuel facilities, and maintenance facilities. This section provides a brief description of each.

- Airport Control Towers
- Airport Runways
- Airport Terminal Buildings
- Airport Parking Structures
- Fuel Facilities
- Airport Maintenance & Hangar Facility

C.7.1 Control Tower

The control tower consists of a building and the necessary equipment for air control and monitoring.

C.7.2 Runways

This component consists of well paved "flat and wide surfaces".

C.7.3 Terminal Buildings

These are similar to railway urban stations in that many of the functions performed and services provided to passengers are similar. These are usually constructed of structural steel or reinforced concrete.

C.7.4 Fuel Facilities

A fuel facility includes buildings, tanks (anchored, unanchored, or buried), backup power systems (if available, anchored or unanchored diesel generators), pumps, and other equipment (anchored or unanchored). It should be mentioned that anchored equipment in general refers to equipment designed with special seismic tiedowns or tiebacks, while unanchored equipment refers to equipment designed with no special considerations other than the manufacturer's normal requirements. Above ground tanks are typically made of

steel with roofs also made of steel. Buried tanks are typically concrete wall construction with concrete roofs. In total, five types of fuel facilities are considered. These are: fuel facilities with or without anchored equipment and with or without backup power (all combinations), and fuel facilities with buried tanks.

C.7.5 Maintenance Facilities, Hangar Facilities, and Parking Structures

Maintenance facilities are housed in large structures that are not usually critical for system functionality as maintenance activities can be delayed or performed elsewhere. These building structures are mostly low-rise steel braced frames. Hangar facilities and parking structures are usually constructed of structural steel or reinforced concrete.

C.8 Potable Water System

A potable water system typically consists of transmission and distribution pipelines, water treatment plants, wells, storage tanks pumping plants, as listed below. In addition the system consists of terminal reservoirs. In this subsection, a brief description of each of these components is presented.

- Pipelines
- Water Treatment Plants
- Wells
- Water Storage Tanks (Typically, 0.5 MGD to 2 MGD)
- Pumping Plants

C.8.1 Pipelines

- **Transmission Aqueducts:** These transmission conduits are typically large size pipes more than 20 inches in diameter or channels (canals) that convey water from the source such as a reservoir, lake, river to the treatment plant. Transmission pipelines are commonly made of concrete, ductile iron, cast iron, or steel. These could be elevated, at-grade or buried. Elevated or at-grade pipes are typically made of steel (welded or riveted), and they can run in single or multiple lines. Canals are typically lined with concrete, mainly to avoid excessive loss of water by seepage and to control erosion. In addition to concrete lining, expansion joints are usually used to account for swelling and shrinkage under varying temperature and moisture conditions. Damageability of channels is not considered in the loss estimation methodology.
- **Distribution Facilities and Distribution Pipes:** Distribution of water can be accomplished by gravity, or by pumps in conjunction with on-line storage. Except for storage reservoirs located at a much higher elevation than the area being served, distribution of water would necessitate, at least, some pumping along the way. Typically, water is pumped at a relatively constant rate, with flow in excess of consumption being stored in elevated storage tanks. The stored water provides a reserve for fire flow and may be used for general-purpose flow should the electric power fail, or in case of pumping capacity loss.

Distribution pipelines are commonly made of concrete (prestressed or reinforced), asbestos cement, ductile iron, cast iron, steel, or plastic. The selection of material type and pipe size are based on the desired carrying capacity, availability of material, durability, and cost. Distribution pipes represent the network that delivers water to consumption areas. Distribution pipes may be further subdivided into primary lines, secondary lines, and small distribution mains. The primary or arterial mains carry flow from the pumping station to and from elevated storage tanks, and to the consumption areas, whether residential, industrial, commercial, or public. These lines are typically laid out in interlocking loops, and all smaller lines connecting to them are typically valved so that failure in smaller lines does not require shutting off the larger. Primary lines can be up to 36 inches in diameter. Secondary lines are smaller loops within the primary mains and run from one primary line to another. They serve to provide a large amount of water for fire fighting without excessive pressure loss. Small distribution lines represent the mains that supply water to the user and to the fire hydrants.

In this earthquake loss estimation study, the simplified method for water system network performance evaluation applies to a distribution pipe network digitized at the primary level.

C.8.2 Supply Facilities- Water Treatment Plants (WTP)

Water treatment plants are generally composed of a number of physical and chemical unit processes connected in series, for the purpose of improving the water quality. A conventional WTP consists of a coagulation process, followed by a sedimentation process, and finally a filtration process. Alternately, a WTP can be regarded as a system of interconnected pipes, basins, and channels through which the water moves, and where the flow is governed by hydraulic principles. WTP are categorized as follows:

- ***Small water treatment plants***, with capacity ranging from 10 mgd to 50 mgd, are assumed to consist of a filter gallery with flocculation tanks (composed of paddles and baffles) and settling (or sedimentation) basins as main components, chemical tanks (needed in the coagulation and other destabilization processes), a chlorination tank, electrical and mechanical equipment, and elevated pipes.
- ***Medium water treatment plants***, with capacity ranging from 50 mgd to 200 mgd, are also assumed to consist of a filter gallery with flocculation tanks (composed of paddles and baffles) and settling (or sedimentation) basins as main components, chemical tanks (needed in the coagulation and other destabilization processes), a chlorination tank, electrical and mechanical equipment, and elevated pipes.
- ***Large water treatment plants***, with capacity above 200 mgd, are simulated by adding even more redundancy to small treatment plants (i.e., three times as many flocculation, sedimentation, chemical and chlorination tanks/basins).

Water treatment plants are also classified based on whether the subcomponents (equipment and backup power) are anchored or not.

C.8.3 Wells (WE)

Wells typically have a capacity between 1 and 5 mgd. Wells are used in many cities as a primary or supplementary source of water supply. Wells include a shaft from the surface down to the aquifer, a pump to bring the water up to the surface, equipment used to treat the water, and sometimes a building which encloses the well and equipment.

C.8.4 Water Storage Tanks (ST)

Water storage tanks can be elevated steel, on-ground steel (anchored/unanchored), on-ground concrete (anchored/unanchored), buried concrete, or on-ground wood tanks. Typical capacity of storage tanks is in the range of 0.5 mgd to 2 mgd.

C.8.5 Pumping Plants (PP)

Pumping plants are usually composed of a building, one or more pumps, electrical equipment, and in some cases, backup power systems. Pumping plants are classified as either small PP with less than 10 mgd capacity or medium/large PP with more than 10 mgd capacity. Pumping plants are also classified with respect to whether or not the subcomponents (equipment and backup power) are anchored.

C.8.6 Terminal Reservoirs

Terminal reservoirs are typically lakes (man made or natural) and are usually located nearby and upstream of the water treatment plant. Vulnerability of terminal reservoirs and associated dams is marginally assessed in the loss estimation methodology. Therefore, even though reservoirs are an essential part of a potable water system, it is assumed in the analysis of water systems that the amount of water flowing into water treatment plants from reservoirs right after an earthquake is essentially the same as before the earthquake.

C.9 Waste Water System

A waste water system typically consists of collection sewers, interceptors, waste water treatment plants and lift stations as listed below. In this section, a brief description of each of these components is given.

- Buried Pipelines
- Waste Water Treatment Plants
- Lift Stations

C.9.1 Collection Sewers

Collection sewers are generally closed conduits that carry sewage normally with a partial flow. Collection sewers could be sanitary sewers, storm sewers, or combined sewers. Pipe materials that are used for potable water transportation may also be used for wastewater collection. The most commonly used sewer material is clay pipe manufactured with integral bell and spigot ends. These pipes range in size from 4 to 42 inch in diameter. Concrete pipes are mostly used for storm drains and for sanitary sewers

carrying noncorrosive sewage (i.e. with organic materials). For the smaller diameter range, plastic pipes are also used.

C.9.2 Interceptors

Interceptors are large diameter sewer mains. They are usually located at the lowest elevation areas. Pipe materials that are used for interceptor sewers are similar to those used for collection sewers.

C.9.3 Lift Stations (LS)

Lift stations are important parts of the waste water system. Lift stations serve to raise sewage over topographical rises. If the lift station is out of service for more than a short time, untreated sewage will either spill out near the lift station, or back up into the collection sewer system.

In this study, lift stations are classified as either small LS (capacity less than 10 mgd) or medium/large LS (capacity greater than 10 mgd). Cases of lift stations with anchored versus unanchored subcomponents are also investigated.

C.9.4 Waste Water Treatment Plants (WWTP)

Three sizes of waste water treatment plants are considered: small (capacity less than 50 mgd), medium (capacity between 50 and 200 mgd), and large (capacity greater than 200 mgd). A WWTP has the same processes existing in a WTP with the addition of secondary treatment subcomponents.

C.10 Oil System

An oil system typically consists of refineries, pumping plants, tank farms, and pipelines as listed below. In this section, a brief description of each of these components is given.

- Pipelines
- Refineries
- Pumping Plants
- Tank Farms

C.10.1 Refineries (RF)

Refineries are an important part of an oil system. They are used for processing crude oil before it can be used. Two sizes of refineries are considered: small, and medium/large.

- ***Small refineries*** have a capacity of less than 100,000 barrels per day. These usually consist of steel tanks on grade, stacks, other electrical and mechanical equipment, and elevated pipes. Stacks are essentially tall cylindrical chimneys.
- ***Medium/Large refineries*** have a capacity of more than 100,000 barrels per day. These also consist of steel tanks on grade, stacks, other electrical and mechanical equipment, and elevated pipes.

C.10.2 Oil Pipelines

Oil pipelines are used for the transportation of oil over long distances. About seventy-five percent of the crude oil is transported throughout the United States by pipelines. A large segment of industry and millions of people could be severely affected by disruption of crude oil supplies. Rupture of crude oil pipelines could lead to a large scale environmental disaster due to pollution of land and rivers. Pipelines are typically made of mild steel with submerged arc welded joints, although older gas welded steel pipe may be present in some systems.

C.10.3 Pumping Plants (PP)

Pumping plants serve to maintain the flow of oil in cross country pipelines. Pumping plants usually use two or more pumps. Pumps can be of either centrifugal or reciprocating type. However, no differentiation is made between these two types of pumps in the analysis of oil systems. There are pumping plants with anchored as well as unanchored subcomponents.

C.10.4 Tank Farms (TF)

Tank farms are facilities which store fuel products. They include tanks, pipes and electric components. There are tank farms with anchored as well as unanchored subcomponents.

C.11 Natural Gas System

A natural gas system typically consists of compressor stations and pipelines as listed below. In this section, a brief description of each of these components is given.

- Buried Pipelines
- Compressor Stations

C.11.1 Compressor Stations

Compressor stations serve to maintain the flow of gas in cross country pipelines. Compressor stations consist of either centrifugal or reciprocating compressors. However, no differentiation is made between these two types of compressors in the analysis of natural gas systems. Cases of compressor stations with anchored versus unanchored subcomponents are also investigated.

C.11.2 Natural Gas Pipelines

Pipelines are typically made of mild steel with submerged arc welded joints, although older lines may have gas welded joints. These are used for the transportation of natural gas over long distances. Many industries and millions of people could be severely affected should disruption of natural gas supplies occur.

C.12 Electric Power System

The only components of an electric power system considered in the loss estimation methodology are substations, distribution circuits, and generation plantsm as listed below. In this section a brief description of each of these components is presented.

- Transmission Substations
- Distribution Circuits
- Generation Plants

C.12.1 Substations

An electric substation is a facility that serves as a source of energy supply for the local distribution area in which it is located, and has the following main functions:

- - Change or switch voltage from one level to another.
- - Provide points where safety devices such as disconnect switches, circuit breakers, and other equipment can be installed.
- - Regulate voltage to compensate for system voltage changes.
- - Eliminate lightning and switching surges from the system.
- - Convert AC to DC and DC to AC, as needed.
- - Change frequency, as needed.

Substations can be entirely enclosed in buildings where all the equipment is assembled into one metal clad unit. Other substations have step-down transformers, high voltage switches, oil circuit breakers, and lightning arrestors located outside the substation building. In the current loss estimation methodology, only transmission (138 kV to 765 kV or higher) and subtransmission (34.5 kV to 161 kV) substations are considered. Substations are also classified based on whether they have anchored or unanchored subcomponents. The substations are classified as:

- High Voltage: he line voltage at these substations is 350 kV or more. These are referred to as 500 kV substations.
- Medium Voltage: The line voltage at these substations is between 150 kV and 350 kV. These are referred to as 230 kV substations.
- Low Voltage: The line voltage at these substations is between 34.5 kV and 150 kV. These are referred to as 115 kV substations.

C.12.2 Distribution Circuits

The distribution system is divided into a number of circuits. A distribution circuit includes poles, wires, in-line equipment and utility-owned equipment at customer sites. A distribution circuit also includes above ground and underground conductors. Distribution circuits either consist of seismically designed components or standard components.

C.12.3 Generation Plants

Power generation plants are facilities where the coal, oil, natural gas, or atom are transformed into electrical energy. These plants produce alternating current (AC) and may be any of the following types:

- - Hydroelectric
- - Steam turbine (fossil fired or nuclear)
- - Combustion turbine
- - Geothermal
- - Solar
- - Wind
- - Compressed air

Generation plant subcomponents include diesel generators, turbines, racks and panels, boilers and pressure vessels, and the building in which these are housed. The size of the generation plant is determined from the number of Megawatts of electric power that the plant can produce under normal operations. Small generation plants have a generation capacity of less than 200 Megawatts. Medium/Large generation plants have a capacity greater than 200 Megawatts. Fragility curves for generation plants with anchored versus unanchored subcomponents are presented.

C.13 Communication System

Only central offices are considered for the loss estimation of the communication systems as listed below. A central office consists of a building, central switching equipment (i.e., digital switches, anchored or unanchored), and back-up power supply (i.e. diesel generators or battery generators, anchored or unanchored) that may be needed to supply the requisite power to the center in case of loss of off-site power.

- Central Offices